ESO 201A: Thermodynamics

2016-2017-I semester

Energy and Energy Transfer-part 3

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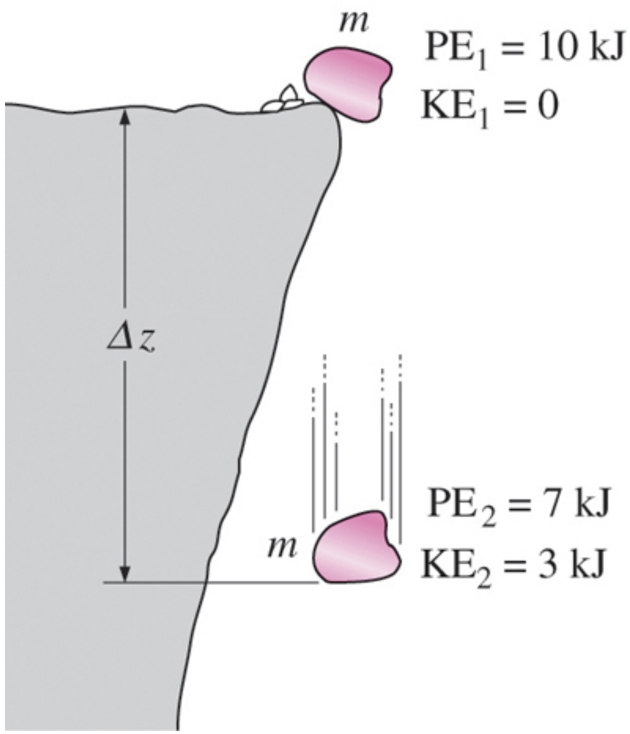
Learning objectives

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

The first law of thermodynamics

- **The *first law of thermodynamics* (*the conservation of energy principle*)** provides a sound basis for studying the relationships among the various forms of energy and energy interactions.
- The first law states that ***energy can be neither created nor destroyed during a process; it can only change forms.***
- **The *first Law*** *Change in total energy during an adiabatic process must be equal to the net work done*



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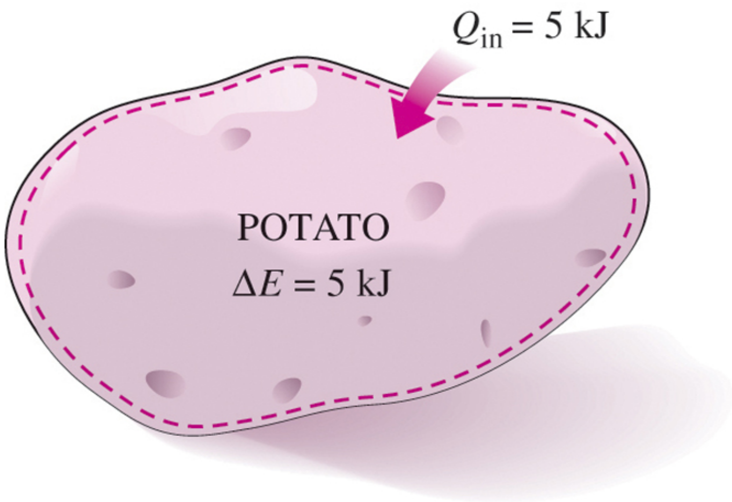
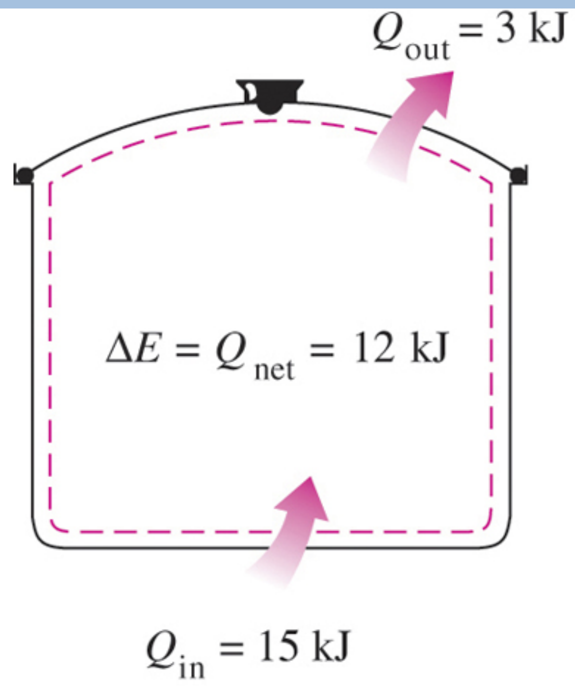
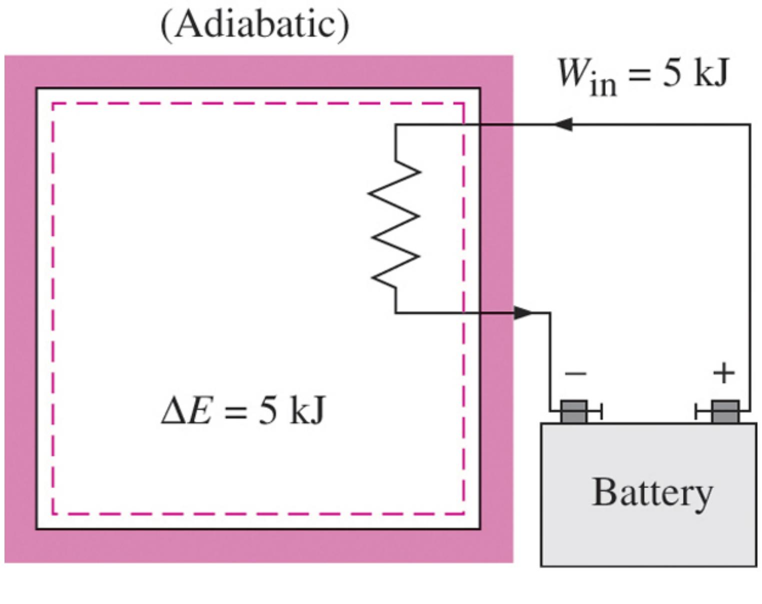


The increase in the energy of a potato in an oven is equal to the amount of heat transferred to it.

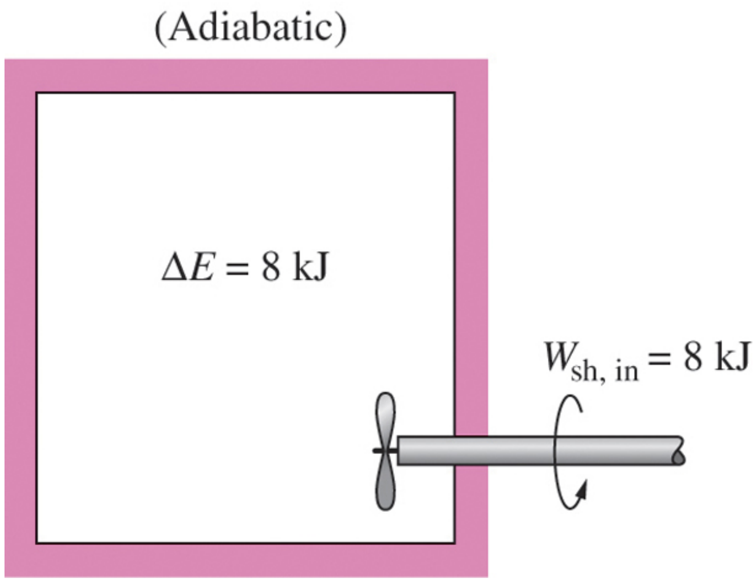
The first law of thermodynamics



In the absence of any work interactions, the energy change of a system is equal to the net heat transfer.



The work (electrical) done on an adiabatic system is equal to the increase in the energy of the system.



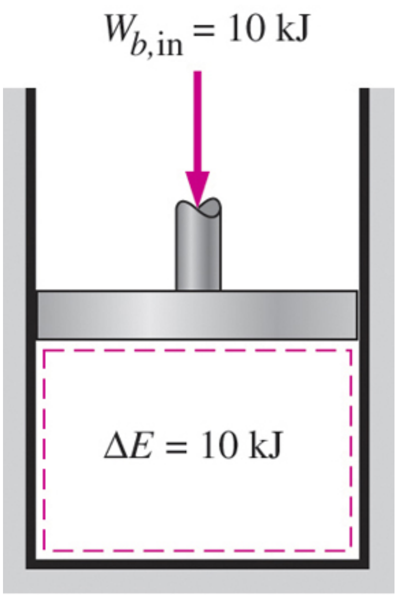
The work (shaft) done on an adiabatic system is equal to the increase in the energy of the system.

Energy balance

The net change (increase or decrease) in the total energy of the system during a process is equal to the difference between the total energy entering and the total energy leaving the system during that process.

$$\begin{pmatrix}\text{Total energy}\\ \text{entering the system}\end{pmatrix} - \begin{pmatrix}\text{Total energy}\\ \text{leaving the system}\end{pmatrix} = \begin{pmatrix}\text{Change in the total}\\ \text{energy of the system}\end{pmatrix}$$

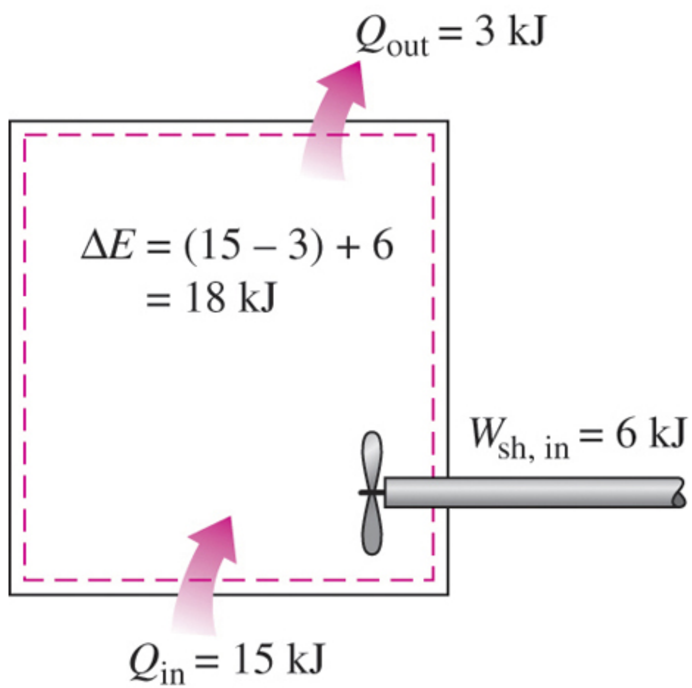
$$E_{in} - E_{out} = \Delta E_{system}$$



(Adiabatic)

The work (boundary) done on an adiabatic system is equal to the increase in the energy of the system.

The energy change of a system during a process is equal to the *net* work and heat transfer between the system and its surroundings.



Energy change of a system

Energy change = Energy at final state − Energy at initial state

$$\Delta E_{\text{system}} = E_{\text{final}} - E_{\text{initial}} = E_2 - E_1$$

$$\Delta E = \Delta U + \Delta \text{KE} + \Delta \text{PE}$$

Internal, kinetic, and
potential energy changes

$$\Delta U = m(u_2 - u_1)$$

$$\Delta \text{KE} = \tfrac{1}{2} m(V_2^2 - V_1^2)$$

$$\Delta \text{PE} = mg(z_2 - z_1)$$

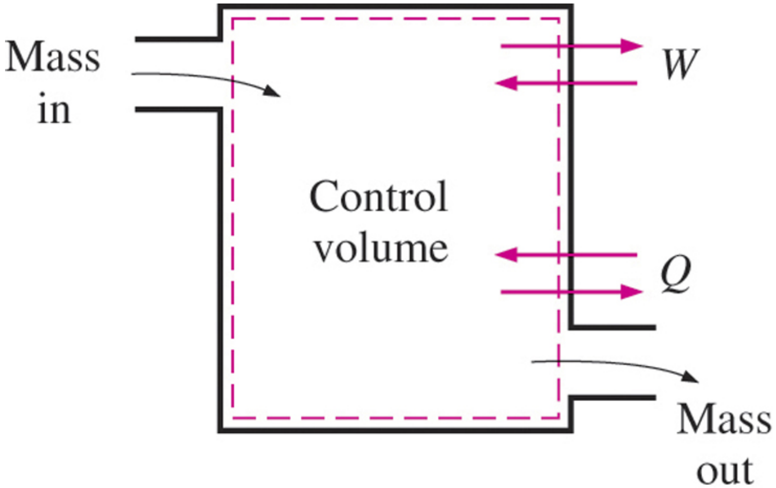
Stationary Systems

$$z_1 = z_2 \rightarrow \Delta \text{PE} = 0$$

$$V_1 = V_2 \rightarrow \Delta \text{KE} = 0$$

$$\Delta E = \Delta U$$

Mechanism of Energy change?



Energy can be transferred to or from a system in three forms

- Heat transfer
- Work transfer
- Mass flow

A closed mass involves only *heat transfer* and *work.*

Energy balance involving the three forms.

$$E_{in} - E_{out} = (Q_{in} - Q_{out}) + (W_{in} - W_{out}) + (E_{mass,in} - E_{mass,out}) = \Delta E_{system}$$

Energy balance in compact expression

$$\underbrace{E_{in} - E_{out}}_{\substack{\text{Net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{\Delta E_{system}}_{\substack{\text{Change in internal, kinetic,} \\ \text{potential, etc., energies}}} \quad \text{(kJ)}$$

Mechanism of Energy change?

Energy balance in rate form

$$\underbrace{\dot{E}_{in} - \dot{E}_{out}}_{\substack{\text{Rate of net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{dE_{system}/dt}_{\substack{\text{Rate of change in internal,} \\ \text{kinetic, potential, etc., energies}}} \quad \text{(kW)}$$

For constant rate: $\Delta E = (dE/dt)\,\Delta t \quad Q = \dot{Q}\,\Delta t \quad W = \dot{W}\,\Delta t \quad$ (kJ)

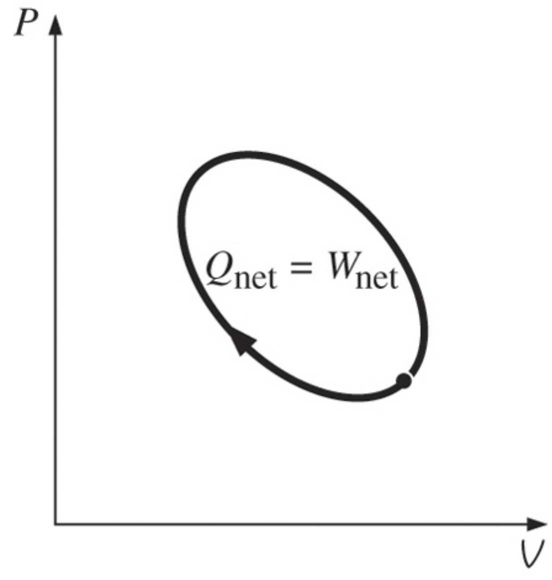
Energy balance per unit mass basis

$$e_{in} - e_{out} = \Delta e_{system} \quad \text{(kJ/kg)}$$

Energy balance in differential form

$$\delta E_{in} - \delta E_{out} = dE_{system}$$

$$\delta e_{in} - \delta e_{out} = de_{system}$$

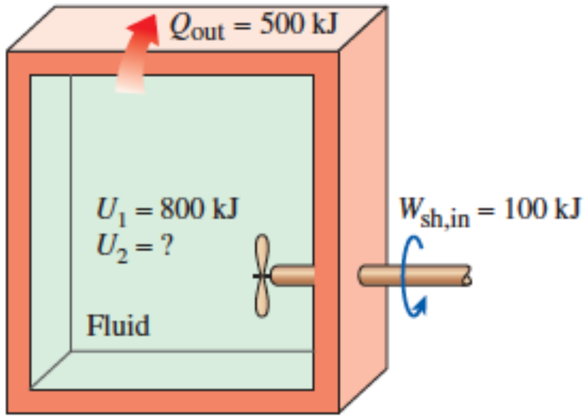


For a closed system undergoing a cycle:
$\Delta E = 0$, thus $Q = W$.

$$W_{net,out} = Q_{net,in} \quad \text{or} \quad \dot{W}_{net,out} = \dot{Q}_{net,in} \quad \text{(for a cycle)}$$

Mechanism of Energy change?

Fluid is cooled in a rigid tank while being stirred by a paddle wheel. During the cooling process, the fluid loses 500 kJ of heat, and the paddle wheel does 100 kJ of work. Find U_2



Next lecture

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