

ELEMENTS OF MECHANICAL ENGINEERING (BMEC-1201)

Course Name: ELEMENTS OF THE MECHANICAL ENGG(EME)

Semester: 2ND

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Introduction to Thermodynamics

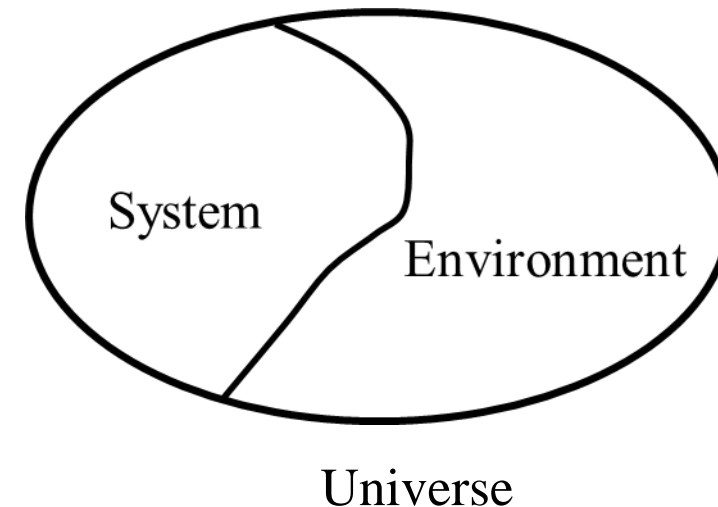
- Introduction to the thermodynamics
- First Law of Thermodynamics
- Second Law of Thermodynamics
- Third Law of Thermodynamics

Thermodynamics

Thermodynamics is the study of the inter-relation between heat, work and internal energy of a system and its interaction with its environment..

Example systems

- Gas in a container
- Magnetization and demagnetization
- Charging & discharging a battery
- Chemical reactions
- Thermocouple operation



Thermodynamics States

- A **state variable** describes the state of a system at time t , but it does not reveal how the system was put into that state.

Examples of state variables:

- P = pressure (Pa or N/m^2),
- T = temperature (K),
- V = volume (m^3),
- n = number of moles, and
- U = internal energy (J).

The First Law of Thermodynamics

The first law of thermodynamics says the change in internal energy of a system is equal to the heat flow into the system plus the work done on the system (conservation of energy).

$$\Delta U = Q + W$$

Sign Conventions

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Table 15.1 Sign Conventions for the First Law of Thermodynamics

Quantity	Definition	Meaning of + Sign	Meaning of – Sign
Q	Heat flow into the system	Heat flows <i>into</i> the system	Heat flows <i>out of</i> the system
W	Work done <i>on</i> the system	Surroundings do <i>positive</i> work on the system	Surroundings do <i>negative</i> work on the system (system does positive work on the surroundings)
ΔU	Internal energy change	Internal energy <i>increases</i>	Internal energy <i>decreases</i>

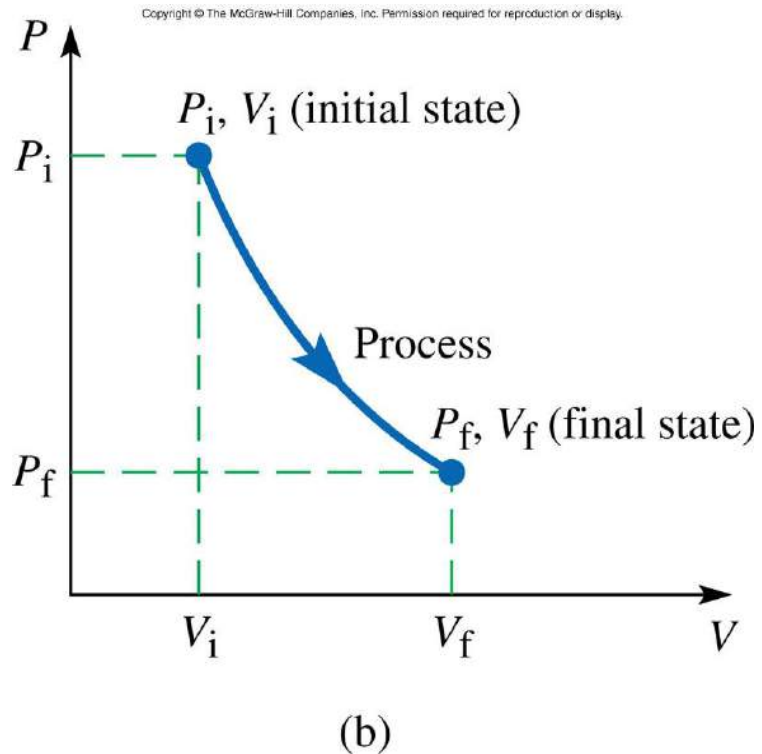
Sign Conventions



- Our book uses $\Delta U = Q + W'$ (a rearrangement of the previous slide)
- $W' < 0$ for the system doing work on the environment.
- $W' > 0$ for the environment doing work on the system.
- Q is the input energy. If W' is negative then that amount of energy is not available to raise the internal energy of the system.
- *Our focus is the energy in the ideal gas system. Doing work on the environment removes energy from our system.*

Thermodynamic Processes

A thermodynamic process is represented by a change in one or more of the thermodynamic variables describing the system.



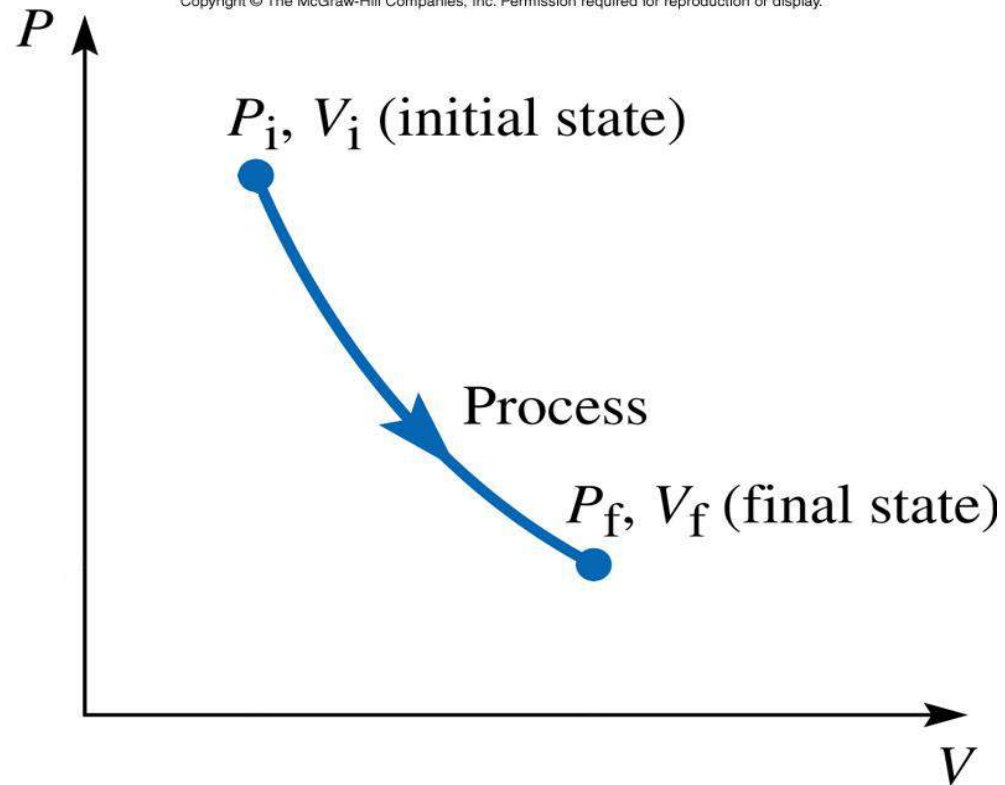
Each point on the curve represents an equilibrium state of the system.

Our equation of state, the ideal gas law ($PV = nRT$), only describes the system when it is in a state of thermal equilibrium.

Reversible Thermodynamic Process

For a process to be reversible each point on the curve must represent an equilibrium state of the system.

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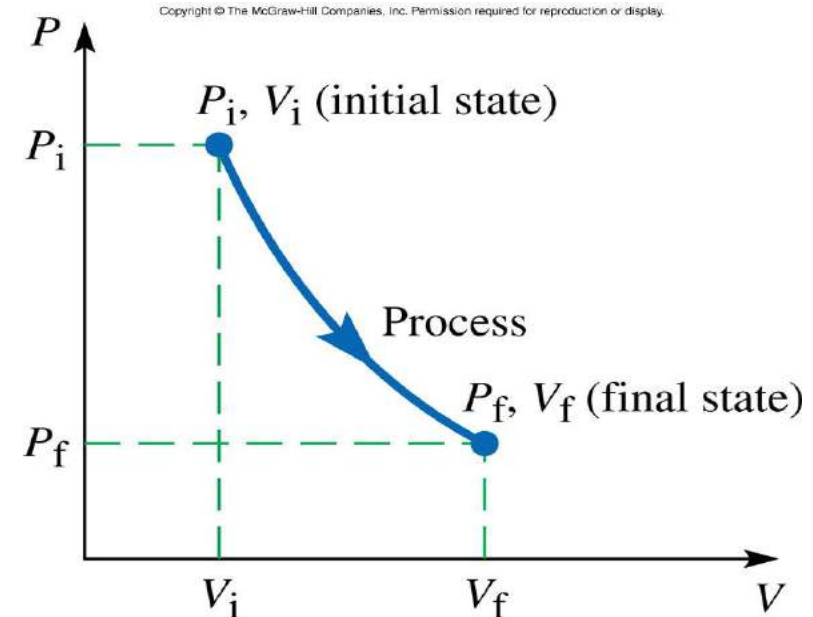


The ideal gas law ($PV = nRT$), does not describe the system when it is not in a state of thermal equilibrium.

Thermodynamic Processes

A PV diagram can be used to represent the state changes of a system, provided the system is always near equilibrium.

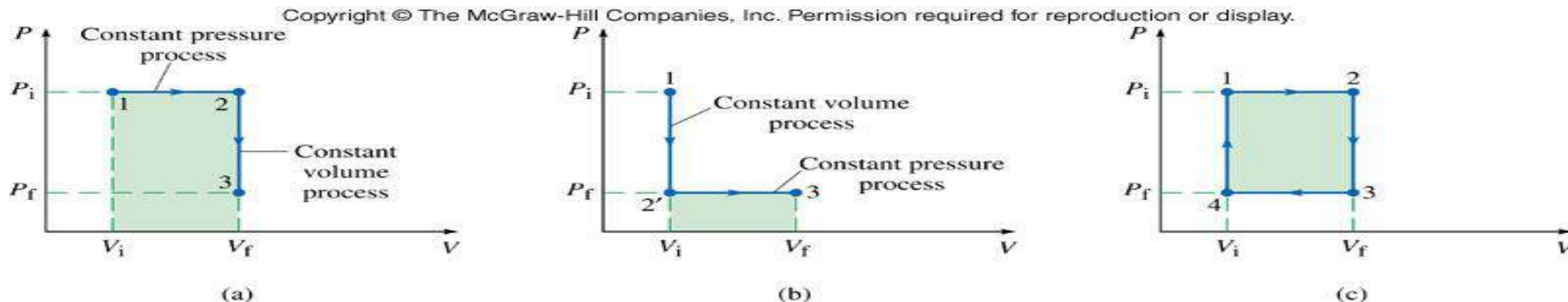
The area under a PV curve gives the magnitude of the work done on a system. $W > 0$ for compression and $W < 0$ for expansion.



(b)

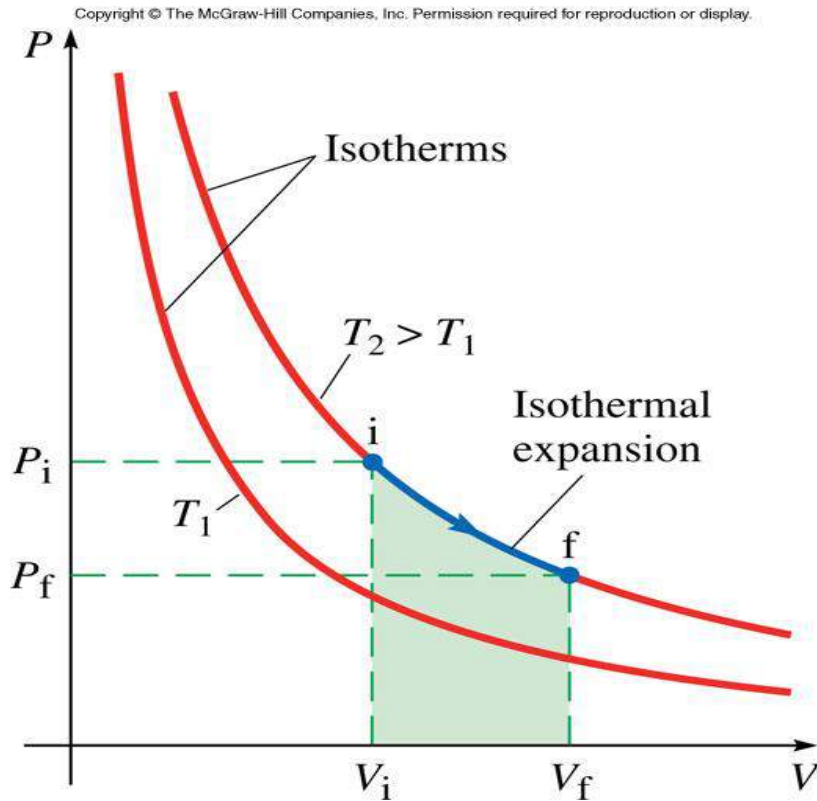
Thermodynamic Processes

To go from the state (V_i, P_i) by the path (a) to the state (V_f, P_f) requires a different amount of work than by path (b). To return to the initial point (1) requires the work to be nonzero.



The work done on a system depends on the path taken in the PV diagram. The work done on a system during a closed cycle can be nonzero.

ISOTHERMAL PROCESS



An isothermal process implies that both P and V of the gas change ($PV \propto T$).

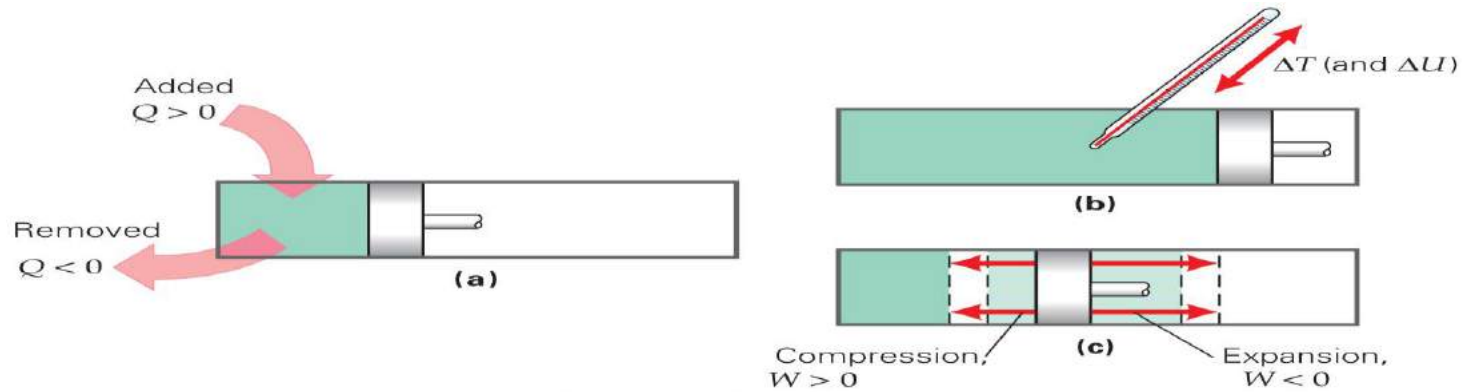
Summary of Thermodynamic Processes

Process	Name	Condition	Consequences
Constant temperature	Isothermal	$T = \text{constant}$	<i>(For an ideal gas, $\Delta U = 0$)</i>
Constant pressure	Isobaric	$P = \text{constant}$	$W = -P \Delta V$
Constant volume	Isochoric	$V = \text{constant}$	$W = 0; \Delta U = Q$
No heat flow	Adiabatic	$Q = 0$	$\Delta U = W$

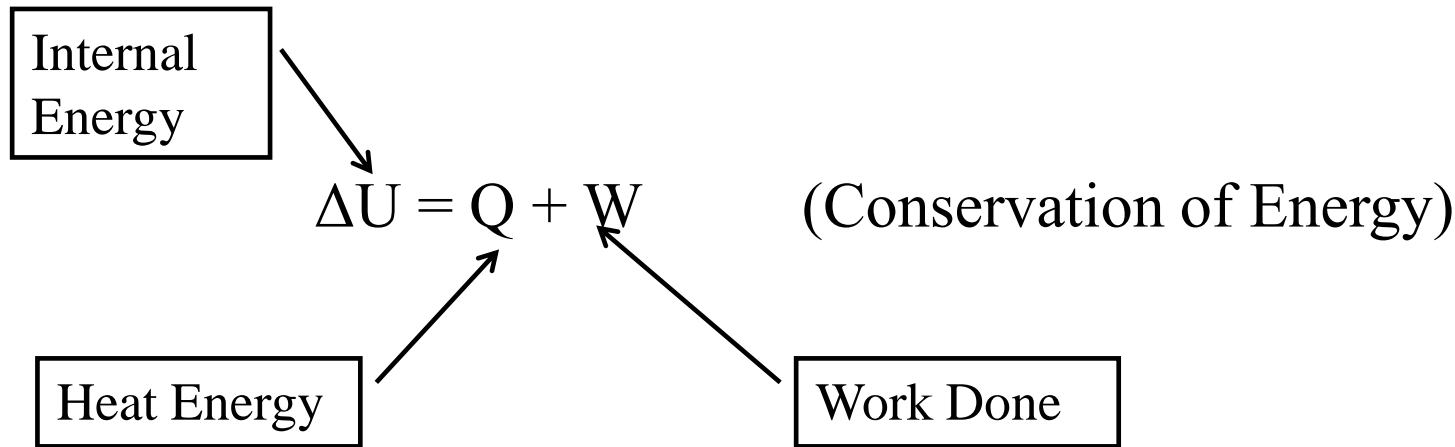
Summary of Thermodynamic Processes

Type of Thermal Process	Work Done	First Law of Thermodynamics ($\Delta U = Q - W$)
Isobaric (constant pressure)	$W = P(V_f - V_i)$	$\Delta U = Q - \underbrace{P(V_f - V_i)}_W$
Isochoric (constant volume)	$W = 0 \text{ J}$	$\Delta U = Q - \underbrace{0 \text{ J}}_W$
Isothermal (constant temperature)	$W = nRT \ln \left(\frac{V_f}{V_i} \right)$ (for an ideal gas)	$\underbrace{0 \text{ J}}_{\Delta U \text{ for an ideal gas}} = Q - \underbrace{nRT \ln \left(\frac{V_f}{V_i} \right)}_W$
Adiabatic (no heat flow)	$W = \frac{3}{2}nR(T_f - T_i)$ (for a monatomic ideal gas)	$\Delta U = \underbrace{0 \text{ J}}_Q - \underbrace{\frac{3}{2}nR(T_i - T_f)}_W$

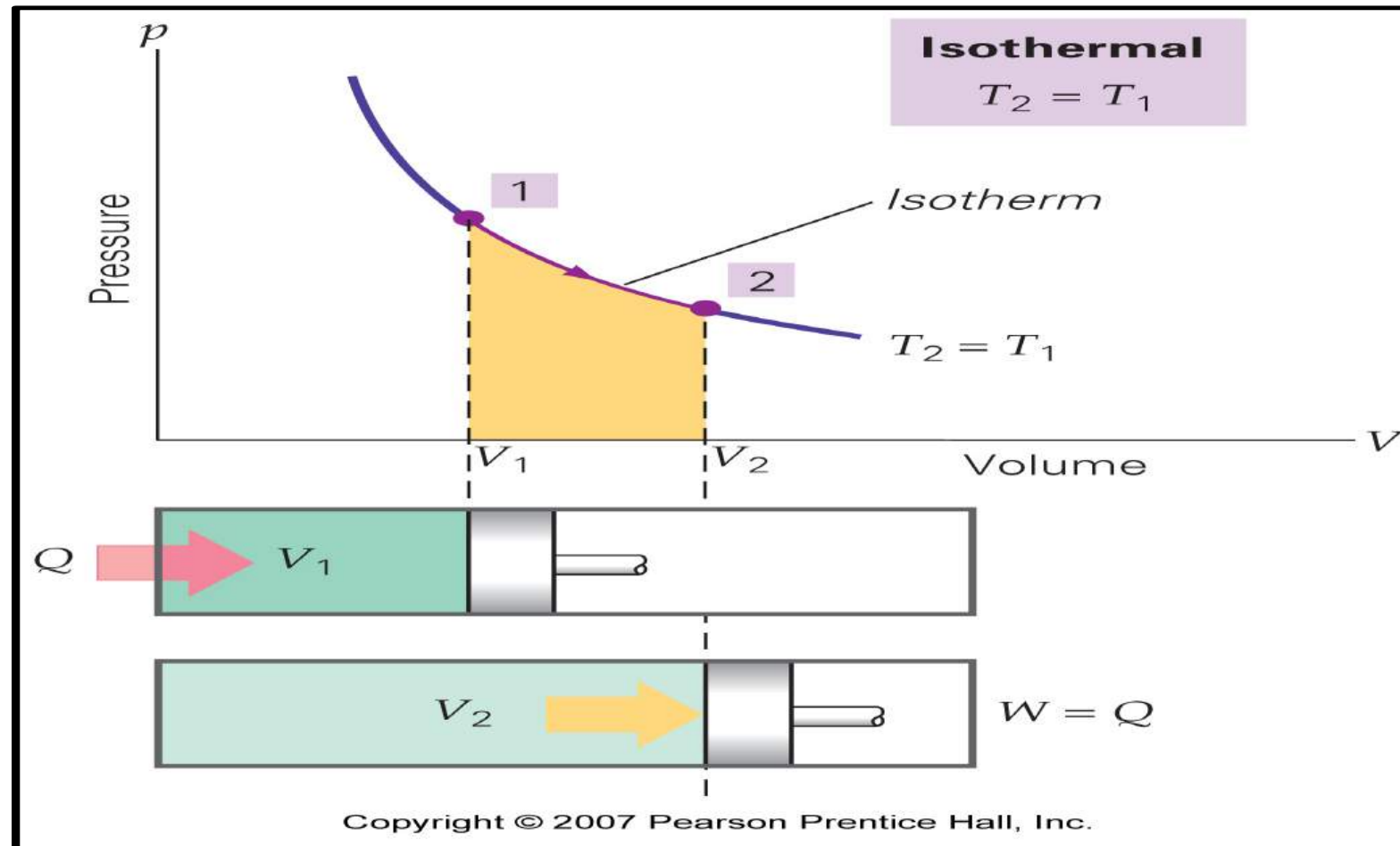
First Law of Thermodynamics



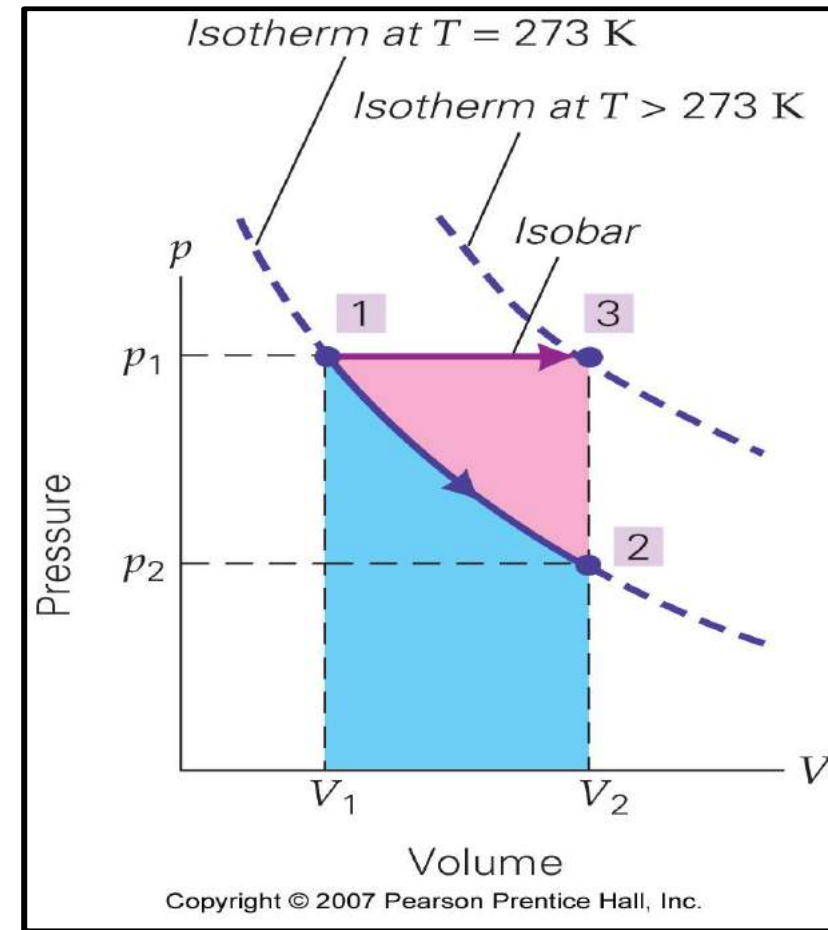
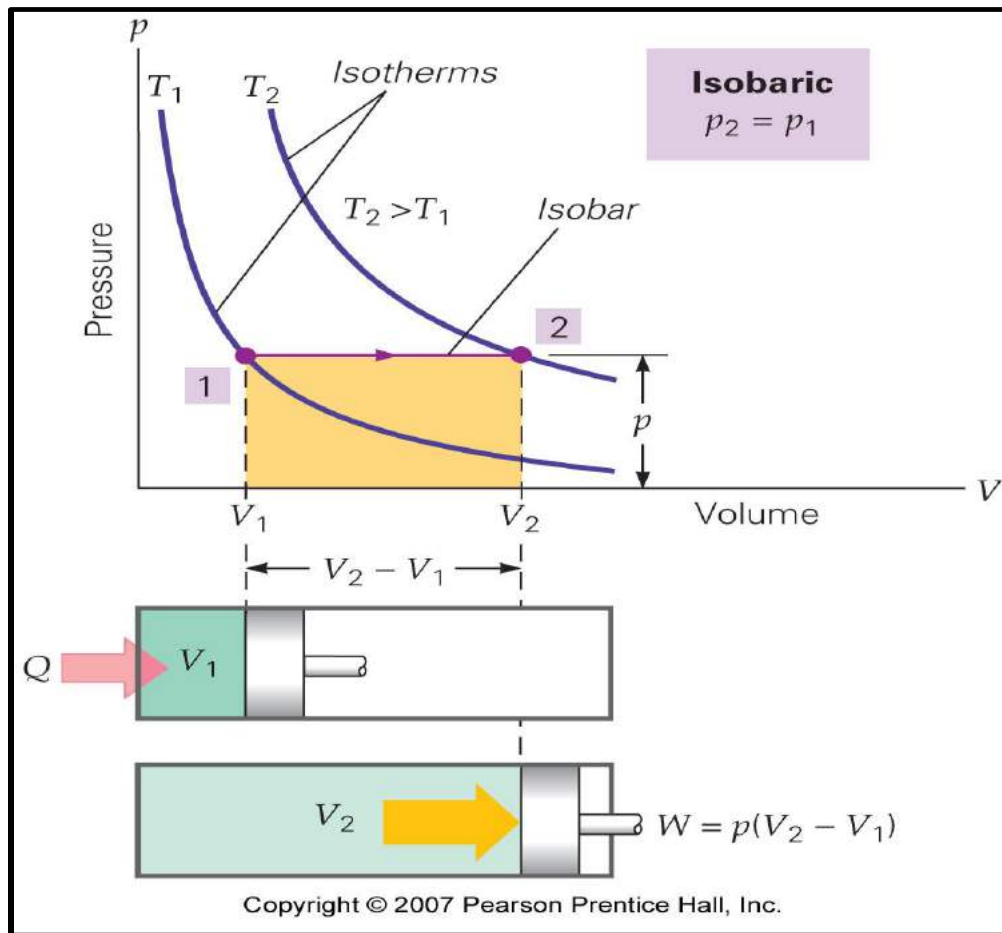
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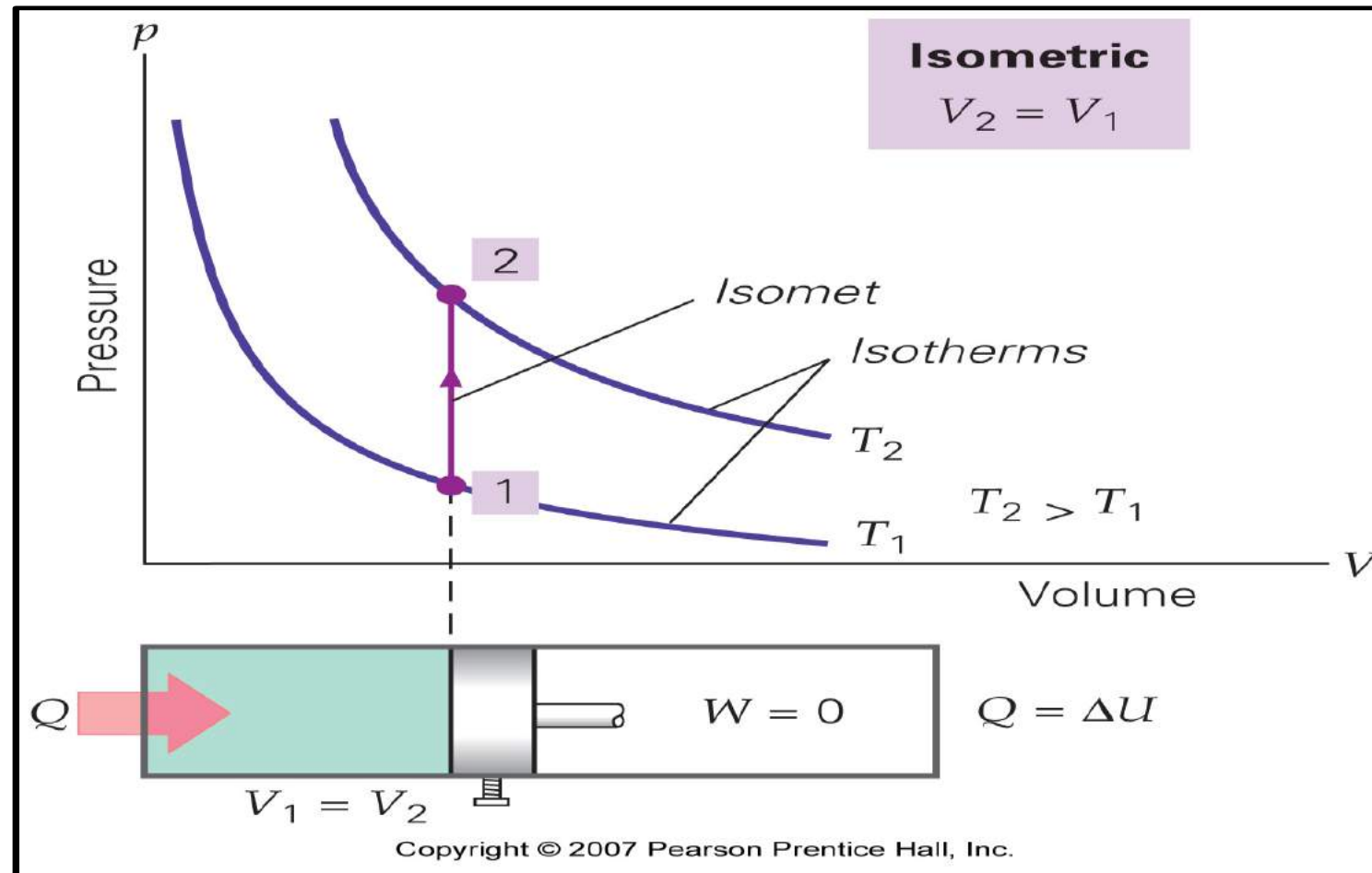
ISOTHERMAL PROCESS



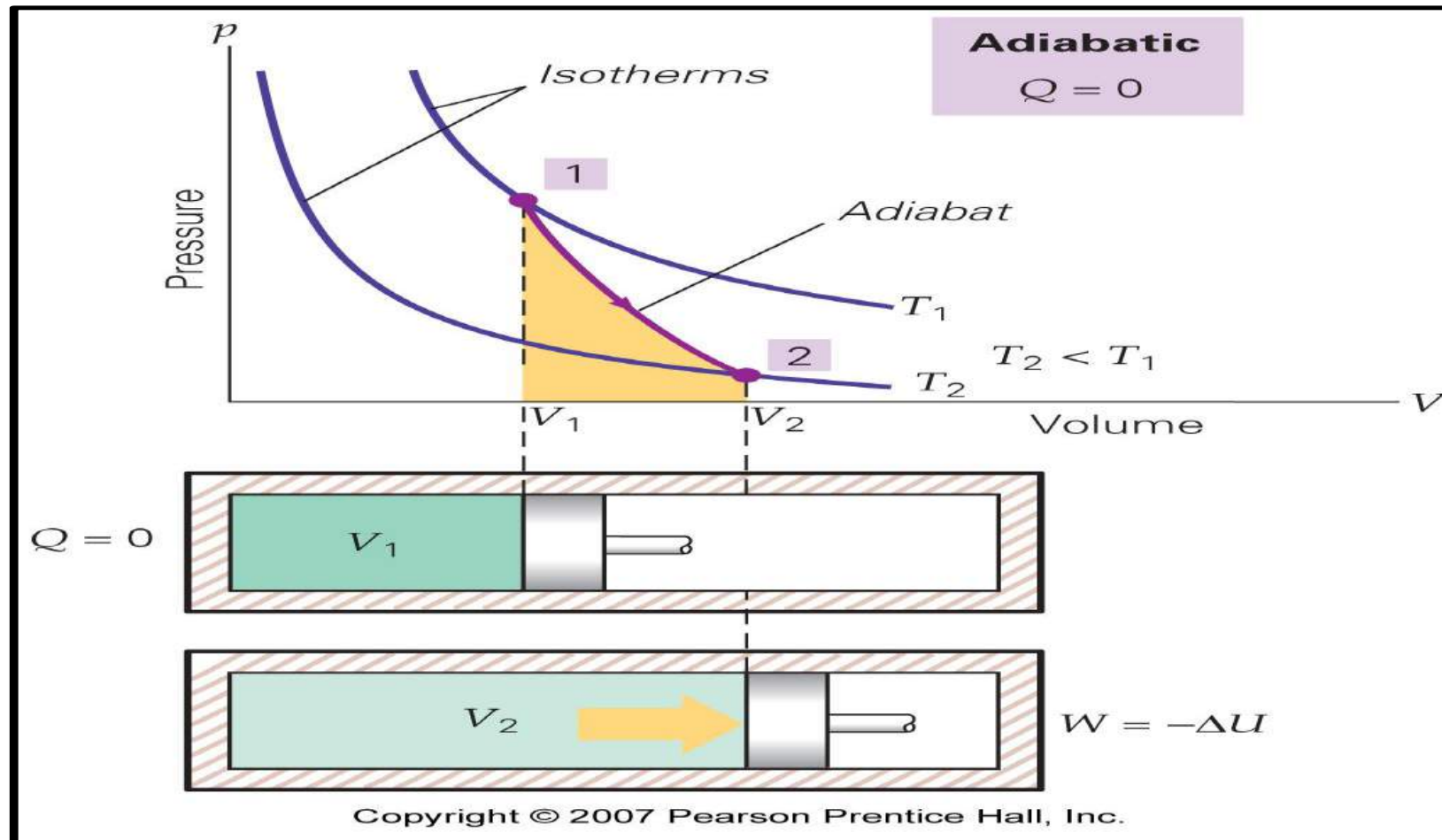
ISOTHERMAL AND ISOBARIC PROCESSES



ISOMETRIC or ISOCHORIC PROCESS



ADIABATIC PROCESS



Reversible and Irreversible Processes

- A process is **reversible** if it does not violate any law of physics when it is run backwards in time.
- For example an ice cube placed on a countertop in a warm room will melt.
- The reverse process cannot occur: an ice cube will not form out of the puddle of water on the countertop in a warm room.

Second law of thermodynamics

The second law of thermodynamics (Clausius Statement): Heat never flows spontaneously from a colder body to a hotter body.

Any process that involves dissipation of energy is not reversible.

Any process that involves heat transfer from a hotter object to a colder object is not reversible.

ENTROPY

Entropy is a state variable and is not a conserved quantity.

Entropy is a measure of a system's disorder.

Heat flows from objects of high temperature to objects at low temperature because this process increases the disorder of the system.

If an amount of heat Q flows into a system at constant temperature, then the change in entropy is

$$\Delta S = \frac{Q}{T}.$$

Every irreversible process increases the total entropy of the universe. Reversible processes do not increase the total entropy of the universe.

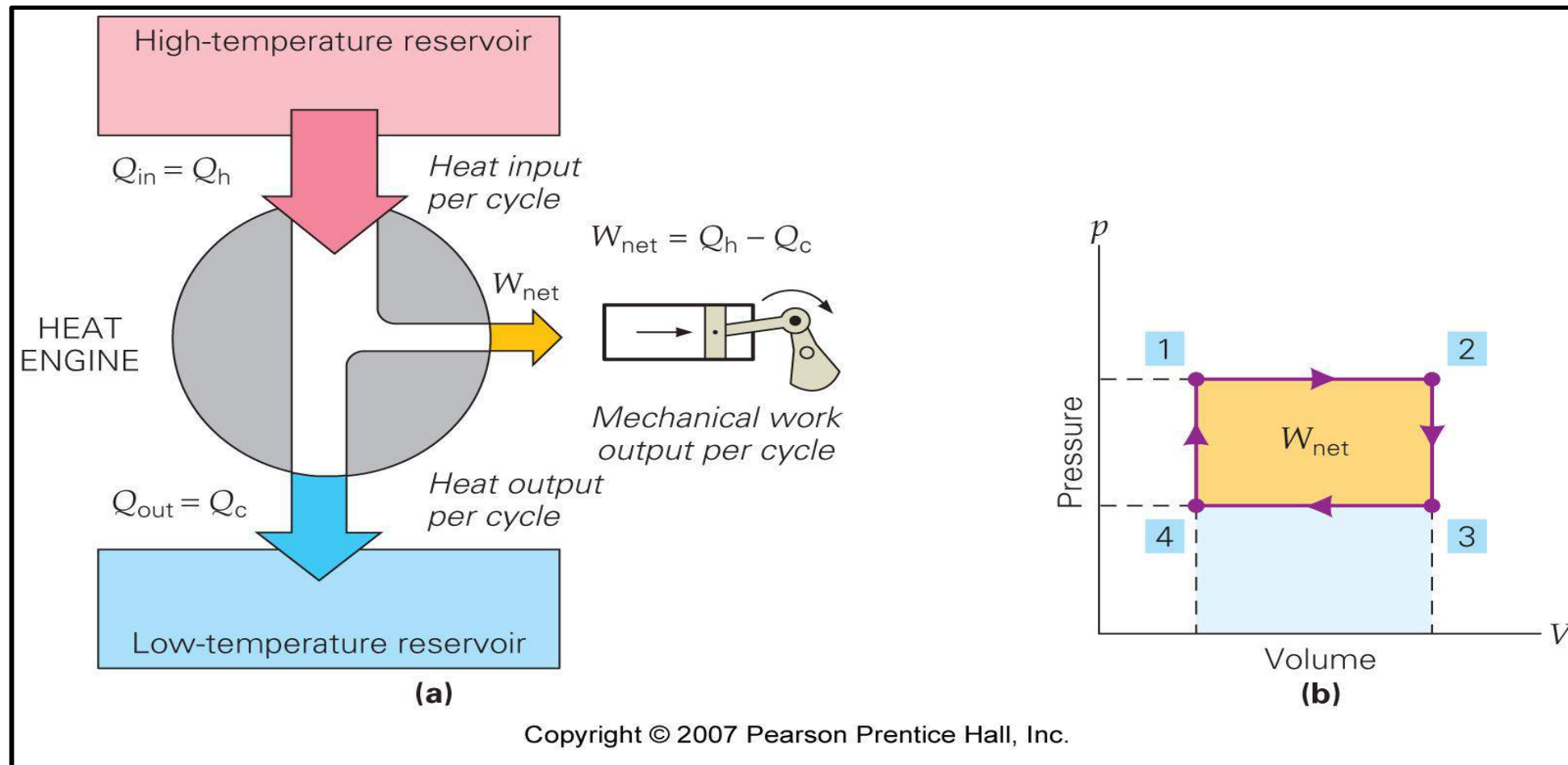
THIRD LAW OF THERMODYNAMICS

The third law of thermodynamics is a statistical law of nature regarding entropy and the impossibility of reaching absolute zero of temperature. The most common enunciation of third law of thermodynamics is:

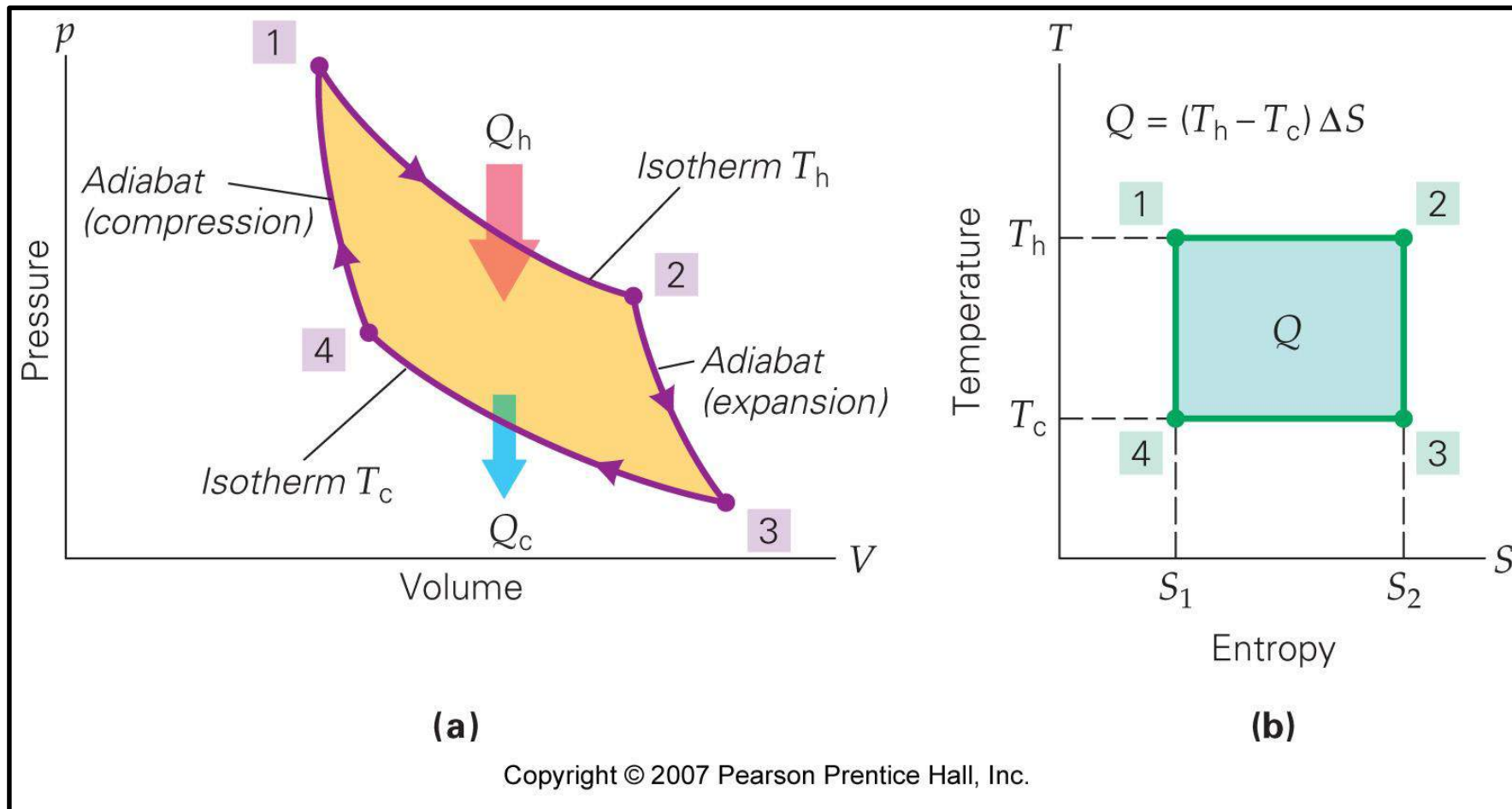
“As a system approaches absolute zero, all processes cease and the entropy of the system approaches a minimum value.”

It is impossible to cool a system to absolute zero by a process consisting of a finite number of steps.

HEAT ENGINE



CARNOT CYCLE



CARNOT CYCLE: IDEAL HEAT ENGINE

Process efficiency

$$\eta = 1 - \frac{T_L}{T_H}$$

No heat engine can run at 100% efficiency. Therefore T_L can never be zero. Hence absolute zero is unattainable.

Summary

- The first law of thermodynamics
- Thermodynamic processes
- Thermodynamic processes for an ideal gas
- Reversible and irreversible processes
- Entropy - the second law of thermodynamics
- Statistical interpretation of entropy
- The third law of thermodynamics

Topics to be Discussed in Next Lecture

- IC ENGINES
- CLASSIFICATION OF IC ENGINES
- DIFFERENTIATING BETWEEN PETROL AND DIESEL ENGINES
- CONSTRUCTIONAL FEATURES OF IC ENGINES
- COMPARISON BETWEEN PETROL AND DIESEL ENGINES