Physics 161
Lecture 16 Summ
Heat Engines
Second Law of Thermodynamics

October 26, 2017

Lecture 16: learning objectives

You will be able to analyse heat engines using the first law of thermodynamics.

You will be able to state both formulations of the second law of thermodynamics.

You will be able to define and calculate the Carnot engine efficiency.

You will be able to state the thermodynamic and statistical definitions of entropy.

Heat engines and pumps

Heat engine:
Takes in heat, Q_h, from a hot reservoir, does an amount of work W_{eng}, and releases heat Q_c into a cold reservoir.

$$W_{\text{eng}} = |Q_h| - |Q_c|$$

Thermal efficiency of a heat engine:
The ratio of the work done by a heat engine, W_{eng}, to the energy absorbed during one cycle, $|Q_h|$.

$$e = \frac{W_{\text{eng}}}{|Q_h|} = 1 - \frac{|Q_c|}{|Q_h|}$$

Heat pump:
Work is done on a heat pump to take heat, Q_c, from a cold reservoir, and deposit heat Q_h into a hot reservoir.

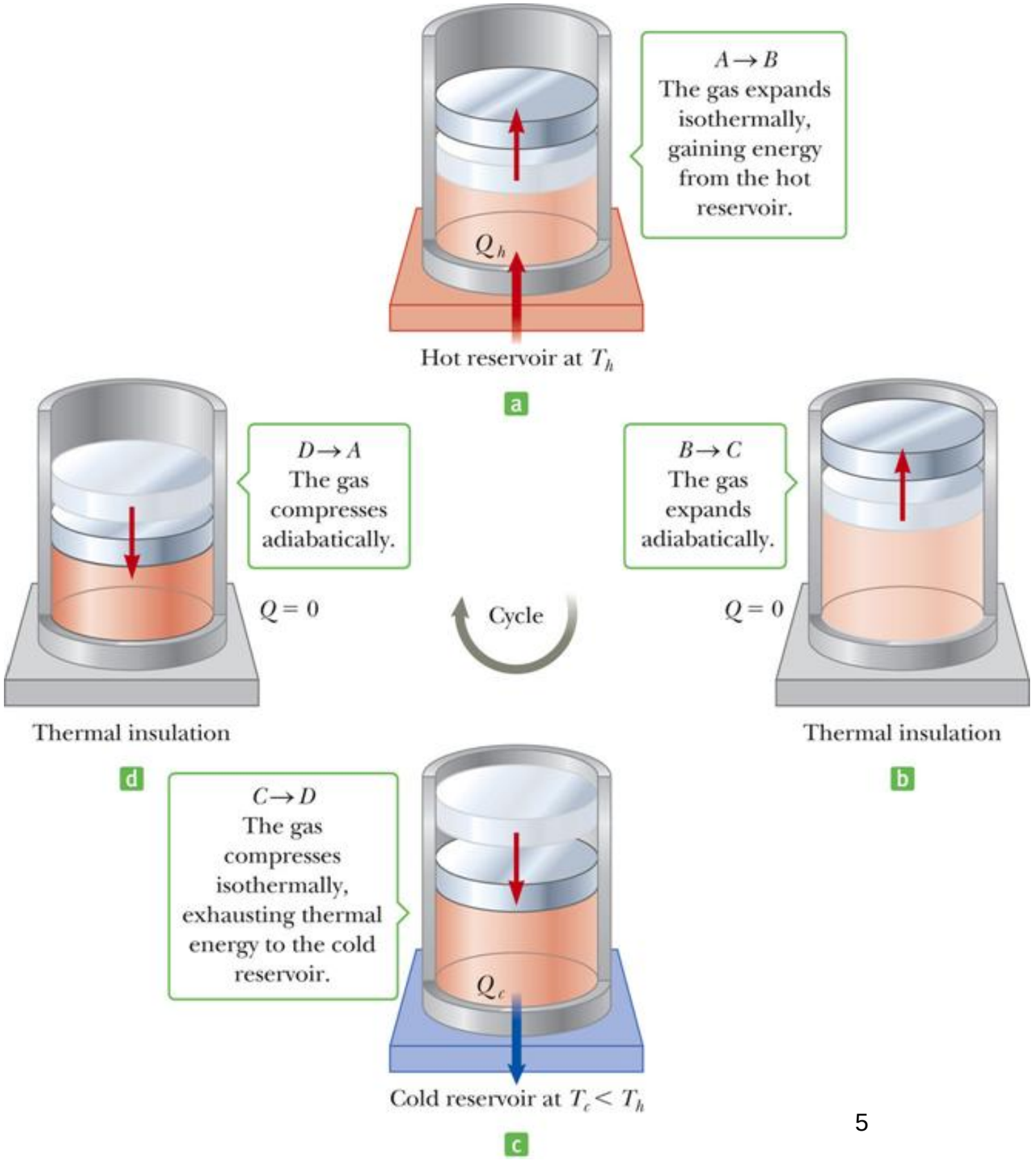
Reversible processes

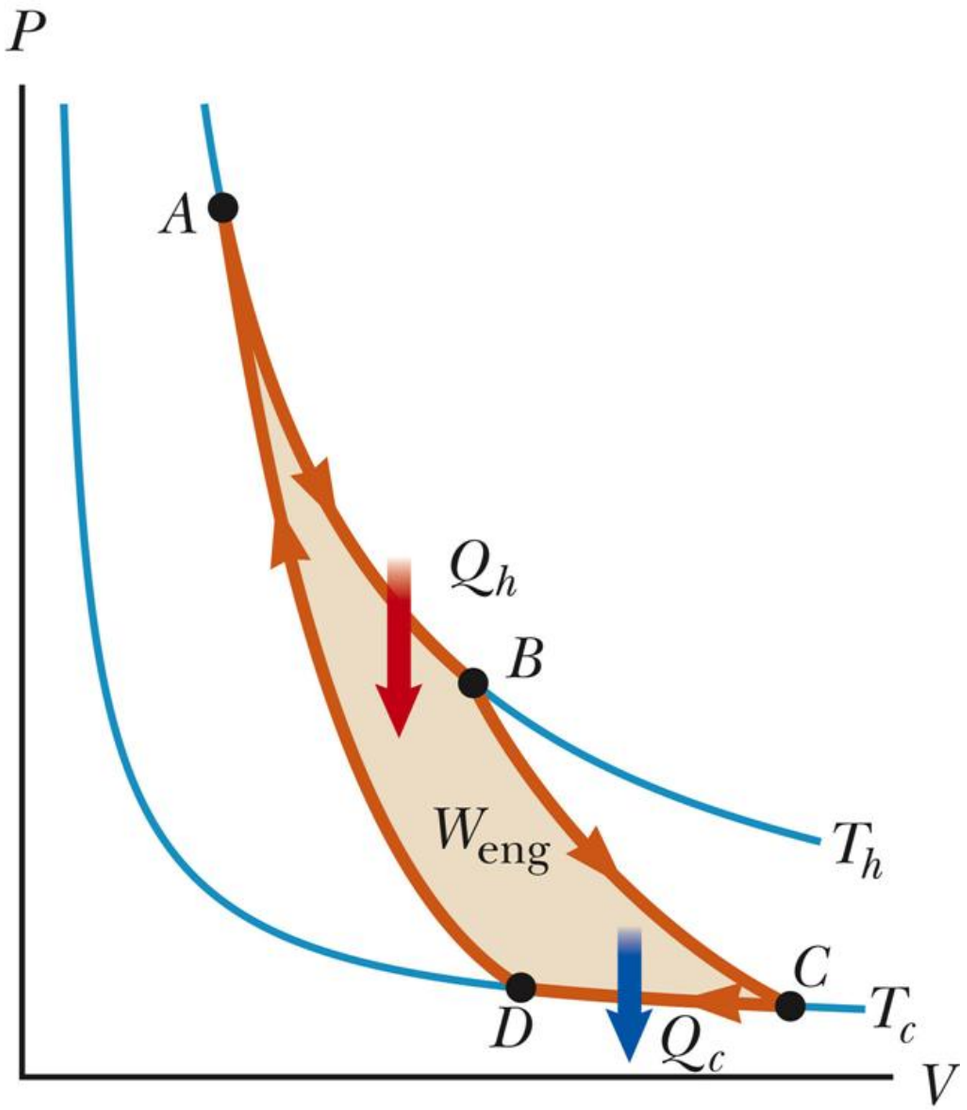
Reversible process:
Every state is an equilibrium state, so the system can return to its initial conditions by going along the same path in reverse.

Carnot's theorem:
A Carnot engine operating between two energy reservoirs is the most efficient possible engine.

$$e_{\text{Carnot}} = 1 - \frac{T_c}{T_h}$$

Carnot cycle





Entropy

Entropy:
Change in entropy of a system is equal to the heat added to a system during an isothermal process divided by the (constant) temperature of that system.

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

Entropy change is zero for a reversible process and greater than zero for an irreversible process.

The entropy of the Universe increases for all natural processes. That does not mean that the entropy of a subsystem of the Universe cannot decrease!

Second law of thermodynamics

Second law:
Heat cannot be entirely converted to work with all else remaining the same.

Second law:
Heat will not flow spontaneously from a cold object to a hot object.

Second law:
"There is no such thing as a free lunch."

Second law:
For any process the net change in entropy is greater than, or equal to, zero.

$$\Delta S \geq 0$$

Entropy and the third law

Entropy is a measure of the disorder of a system. The greater the disorder the greater the entropy. The second law of thermodynamics tells us that in any process the amount of disorder does not decrease.

In reversible processes the disorder remains the same.

In irreversible processes the disorder will always increase.

Third law:
As a system approaches absolute zero the entropy (disorder) approaches zero.