Preview of Period 7: Applications of the Laws of Thermodynamics

7.1 Conservation of Energy and the 1st Law of Thermodynamics

How does conservation of energy relate to molecular motion?

What is the 1st Law of Thermodynamics?

7.2 Ideal Gas Law

How are pressure, volume, temperature, and the number of gas molecules related?

7.3 Work from Thermodynamic Systems

How is work related to equilibrium?

7.4 Engines and Work

How do internal and external combustion engines work?

7.5 Air Conditioners, Refrigerators, and Heat Pumps

How do they work? How efficient are they?

The Entropy Story so far ...

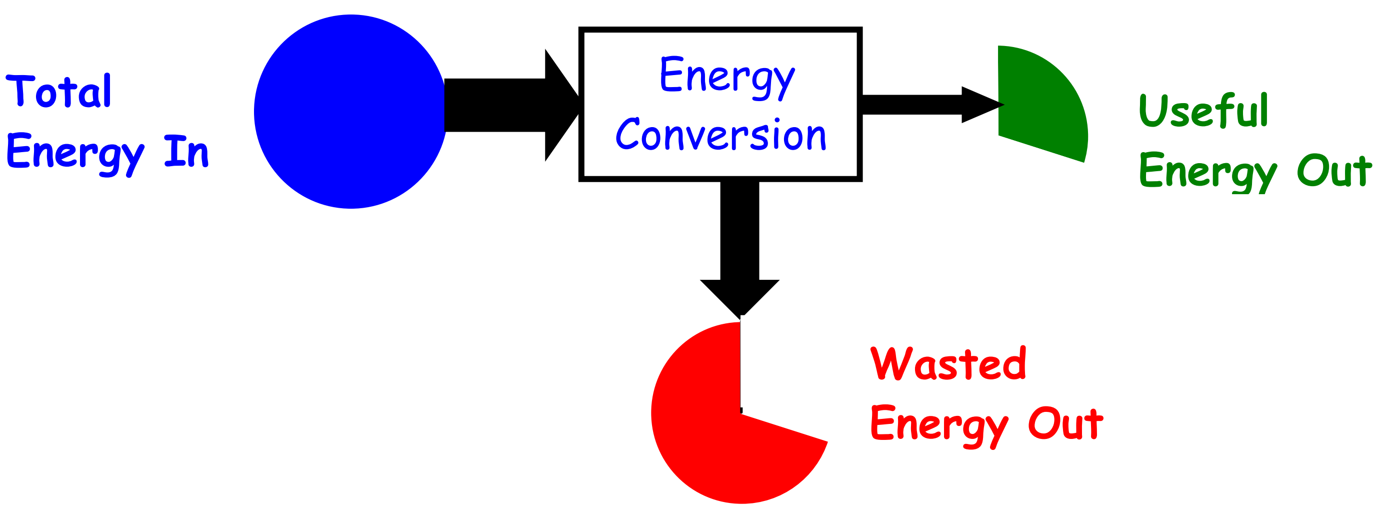
- **Entropy** is a measure of the degree of disorder of a system.
- The greater the disorder, the greater the amount of entropy.
- In nature, disordered systems are more common than ordered systems because there are many more disorderly arrangements than orderly arrangements.
- Entropy tends to increase with time.

  If the temperature is constant, the change in entropy is given by

$$\Delta S = \Delta Q / T$$

The law of conservation of energy:

- Energy can be neither created nor destroyed. All the energy that goes into a conversion process must come out.
- In every energy conversion, some energy is wasted, often in the form of thermal energy.
- Total internal energy of an object is the kinetic energy of the molecules plus the potential energy stored in molecular attractions.
- When applied to thermodynamic systems, the law of conservation of energy is called the first law of thermodynamics.



The Relationship among Pressure, Temperature, and Volume:

The Ideal Gas Law

$$P\,V = N\,k\,T$$

P **= pressure the gas exerts (newtons/meters^2)**

V **= the volume of the gas (meters^3)**

N **= the number of gas molecules**

k **= Boltzmann's constant (1.38 x 10^{-23} J/K)**

T **= temperature (Kelvin)**

Work and Internal Energy:

The First Law of Thermodynamics states..

The change in internal energy of a system ΔU equals the heat Q added to or subtracted from the system minus the work W done by the system.

$$\Delta U = Q - W$$

U = total internal energy (joules)

ΔU = the change in internal energy (joules)

Q = heat added to or subtracted from the system (joules)

W = work done by the system (joules)

It is not possible to get more energy out of a system than has been put into the system!

Heat Engines

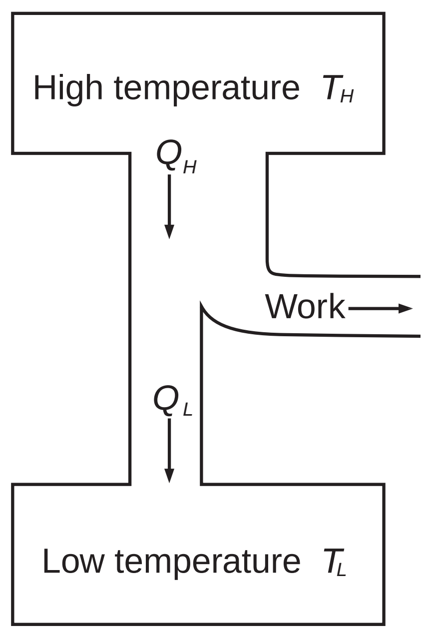
Heat engines do work by converting thermal energy into mechanical energy.

The efficiency of an ideal heat engine =

$$Eff = \frac{T_H - T_L}{T_H}$$

Note: the temperatures T are measured in Kelvin

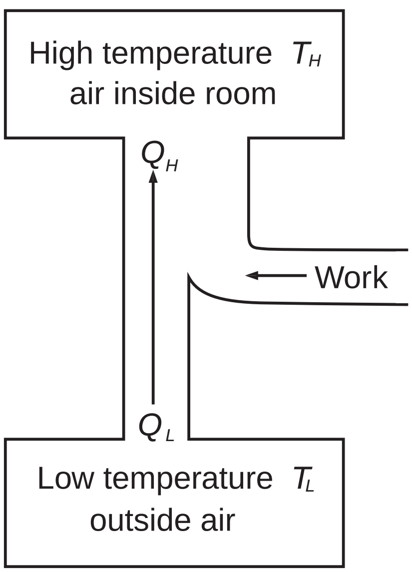
Diagram of a Heat Engine



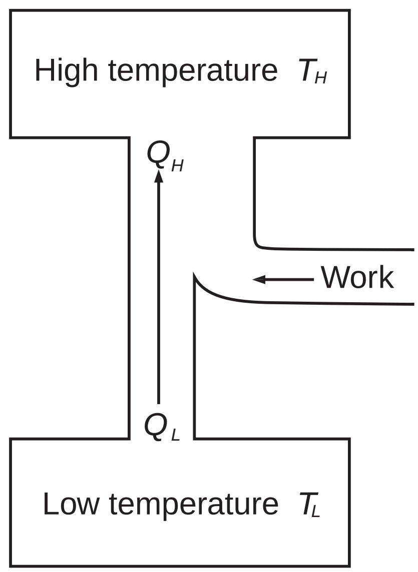
Heat Pumps, Air Conditioners, and Refrigerators

These devices use energy to move heat from cooler environments to warmer environments.

A Heat Pump



An Air Conditioner or Refrigerator



Coefficient of Performance of
Heat Pumps, Air Conditioners, and Refrigerators

The efficiency of the process of moving heat from cooler environments to warmer environments. is measured by the coefficient of performance, ***COP***

Heat pump COP = $$\frac{Q_H}{W} = \frac{T_H}{T_H - T_C}$$

where Q_H = heat transferred from a lower temperature environment to a higher temperature environment

Air Conditioner or refrigerator COP =

$$\frac{Q_L}{W} = \frac{T_C}{T_H - T_C}$$

where Q_L = heat transferred from a lower temperature environment to a higher temperature environment.

T is measured in Kelvin

Period 7 Summary

7.1: The first law of thermodynamics states the change in internal energy of a system equals the heat added to the system minus the work done by the system.

$$\Delta U = Q - W$$

7.2: The ideal gas law describes the relationship among the pressure, temperature, and volume of a gas and number of molecules in a gas: $P\,V = N\,k\,T$

7.3: Heat engines do work by converting thermal energy into mechanical energy.

The efficiency of an ideal heat engine =

$$Eff = \frac{T_H - T_L}{T_H}$$ **with T measured in Kelvin**

Heat pumps, refrigerators, and air conditioners use energy to move heat from cooler environments to warmer environments.

The efficiency of the process is measured by the coefficient of performance, *COP*

Heat pump: $COP = Q_H / W$

Air Conditioner or refrigerator:
$COP = Q_L / W$

Period 7 Review Questions

R.1 **How do you find the work done by a system in terms of the first law of thermodynamics?**

R.2 **Why does the label on some aerosol cans say, "Contents under pressure. Do not incinerate."?**

R.3 **What is the difference between a heat pump and a refrigerator?**

R.4 **What is the difference between a heat pump and a heat engine?**

R.5 **Do you want the coefficient of performance *COP* of a refrigerator to be small or large?**