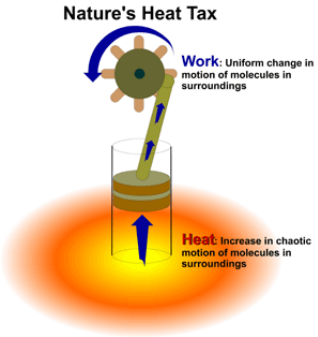
2.C.1 - First Law of Thermodynamics, Some Definitions

Side Button for Rabbit Holes



Thermodynamics

Science dealing with heat transfer in systems.

As non-renewable energy resources dwindle, this branch has been receiving more attention as far as making more efficient machines etc.

Zeroth Law of Thermodynamics: if two objects are in thermal contact, heat flows from the warmer object to the cooler one until they reach thermal equilibrium.

Definitions

System – Definite quantity of matter enclosed by boundaries.

Thermally Isolated – No heat transferred in or out of a system.
Note: work can be done on such a system, transferring energy to it.

Heat Reservoir – System with unlimited heat capacity.

Definitions

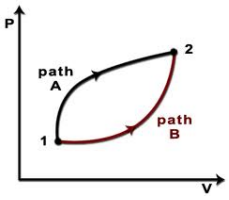
Equations of State – Express mathematical relationships between thermodynamic variables: pressure (Pa), volume (m^3), and T (K).

Ex: PV = nRT.

Processes

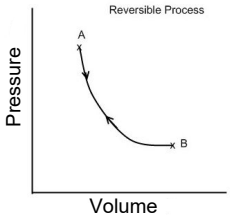
Any change in pressure, volume, and/or temperature of a system.

Irreversible Process – Changes of state are rapid and unpredictable: the process is unrepeatable.
Ex: Explosions.



Processes

Reversible Process – Changes that occur in a system are slow, so the entire process is known, and could be repeated (such as an internal combustion engine).



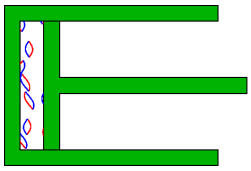
Heat and Work

Transfer of molecular kinetic energy (heat) is analogous to mechanical work.

This is seen in a sample of gas in a cylinder with a piston in it: when the gas is heated – it expands, causing the piston to move out.

Stirling Engine Demo.

http://www.animatedengines.com/otto.html
Four Stroke e-Demo



First Law of Thermodynamics

Review: you learned: gas in a system has internal energy that changes with temperature:

$\Delta U = \frac{3}{2} nR\Delta T$ (Ideal & Monatomic) $= \frac{5}{2} nR\Delta T$ (Diatomic)	ΔU = Change in internal energy (J) n = Amount of gas (moles) R = Universal Gas Constant: 8.31 J/mol*K T = Temperature (K)

In a changing system, work and heat are related to a system's internal energy:

AP Equation: 1st Law of Thermodynamics	
$\Delta U = Q + W$	ΔU = Change in internal energy (J) Q = Heat added to a system (J) W = Work done on a system (J)

First Law Reference Frame

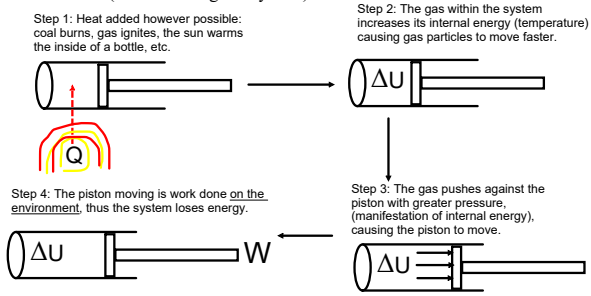
The AP Test considers energy transfers from the perspective of the system.

If a system is doing work on the environment (such as an outward moving piston (volume expansion)), it is NEGATIVE.

If work is being done on the system (piston compressing a gas), it is positive - indicating that energy was GAINED by the system.

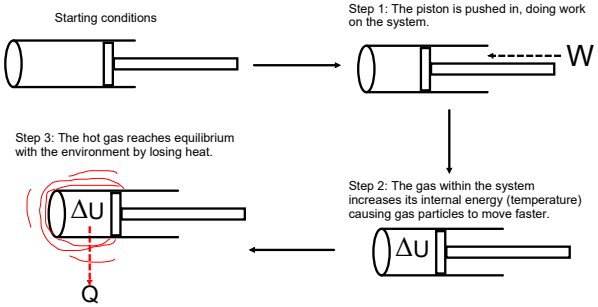
First Law: Conceptual View 1

A change in internal energy (temperature change) equals heat added combined with some energy change due to work (volume change of system).



First Law: Conceptual View 2

The reverse works from this perspective too:



Burn your skin with a bike pump to prove this!

1. Exercise Example

Usually, internal energy change involves a gas, but it could relate to metabolizing food, or burning gasoline, or anything that alters molecular structure.

If a worker shovels coal for 3 hours at an average rate of 20 W, and loses heat to the environment at a rate of 480 W, what's the change in his internal energy?
In other words, how many joules of food and stored energy did he lose?

1. Exercise Answer

He's losing heat, so Q must be negative:

$$Q = \frac{-480\,J}{s} \bullet \frac{3600\,s}{h} \bullet 3.0\,h = -5.18\,E\,6\,J$$

Work done is negative (work output):

$$W = Power \bullet Time = \frac{-20\,J}{s} \bullet \frac{3600\,s}{h} \bullet 3.0\,h = -2.16\,E\,5\,J$$

So:

$$\Delta U = Q + W$$
$$= -5.18\,E\,6\,J + (-2.16\,E\,5\,J)$$
$$= -5.40\,E\,6\,J$$

Homework

Preview 2.C.2

2.C.1 Booklet Problems
Due: Next Class.