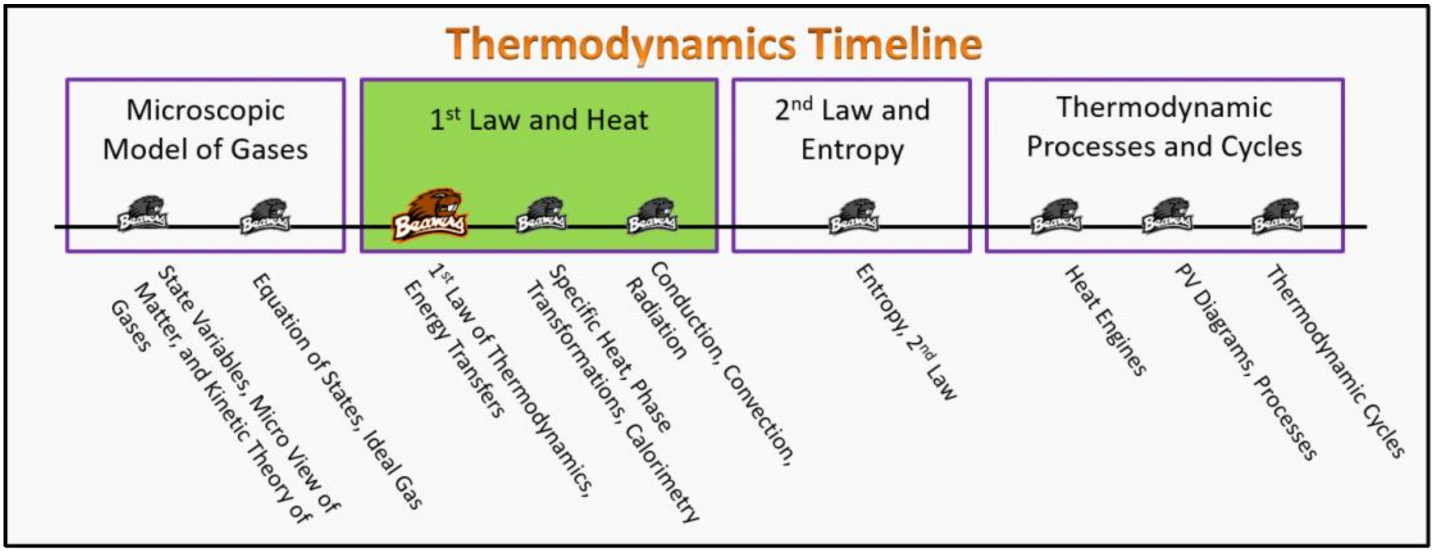
(1H.2.L1) Ryan's Space

Monday, January 22, 2018 5:44 PM

1^{st} Law and Heat
Foundation Stage (1H.2.L1)

Lecture 1
1^{st} Law of Thermodynamics, Energy Transfers



Textbook Chapters (* Calculus version)

- **BoxSand** :: KC videos (First Law of Thermodynamics)
- **Knight** (College Physics : A strategic approach 3^{rd}) :: 10.8 ; 11.1 ; 11.2 ; 11.3 ; 11.4
- ***Knight** (Physics for Scientists and Engineers 4^{th}) :: 19.1 ; 19.3 ; 19.4 ;
- **Giancoli** (Physics Principles with Applications 7^{th}) :: 14-1 ; 14-2 ; 15-1

Warm up

1H.2.L1-1:

Description: Explain the work-energy principle.

Learning Objectives: [?] - Can you identify the objectives from the previous lecture, and this lecture, that this question is relevant to?

Problem Statement: Recall the work-energy principle shown below in the mathematical representation. With your neighbor, discuss everything you about this work-energy principle. For example, what are each term called, conceptually what do the terms represent, what are the functional forms of any of the terms, etc..

$$\Sigma E_i + W_{ext} = \Sigma E_f$$

Selected Learning Objectives

1. Coming soon to a lecture template near you.

Key Terms

- Heat
- 1st Law of Thermodynamics

Key Equations

E_th = W + Q

Key Concepts

- Coming soon to a lecture template near you

Questions

Act I: Heat

1H.2.L1-2:

Description: Conceptual question about heat. (3 minutes)

Learning Objectives: [?]

Problem Statement: Heat is

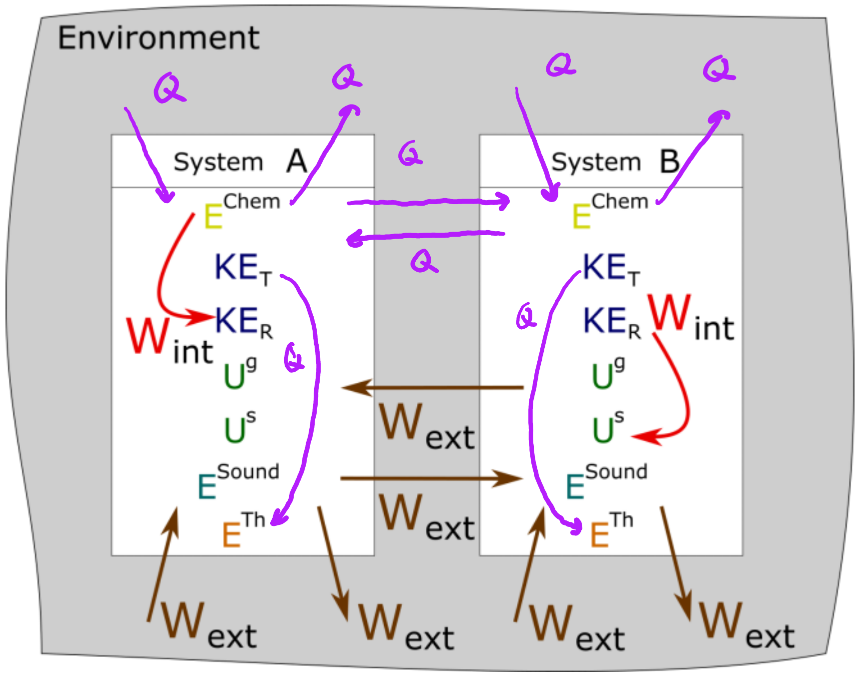
(1) a physical property objects with **T** > 0 K possess.
(2) the amount of thermal energy in an object.
(3) the energy that moves (typically) from a hotter object to a colder object.
(4) a measure of how hot an object it.
(5) one of the two ways to account for energy transfers or transformations.
(6) measured in J.
(7) a term used to represent three new mechanisms of energy transfer.

1H.2.L1-3:

Description: Conceptual question about heat and energy model. (4 minutes)

Learning Objectives: [?]

Problem Statement: Consider the blank energy flow diagram below. In general we can define more than one system, here we have two systems **A** and **B**. Anything not included in **A** and **B** is the environment. Our current energy model says that external work is a mechanism to transfer energy into or out of a system. This energy can come from the environment or a different system. Internal work transforms energy from one from of energy to another form of energy within a system. Update this energy model to represent our new knowledge of what heat is.



1H.2.L1-4:

Description: Conceptual question about energy transfer mechanisms; heat vs work. (3 minutes)

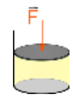
Learning Objectives: [?]

Problem Statement: Which of the following processes explicitly involves *heat* as the only mechanism for energy transfer?

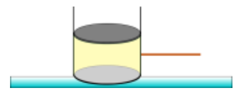
(1) The brakes on your car get hot when you stop.

(2) A steel block is placed over a candle.

(3) Ice melting in a glass of water.

(4) A piston pushed into a cylinder of gas, increasing the temperature of the gas. 

(5) A rigid cylinder of gas being pulled across a frictionless surface.



1H.2.L1-5:

Description: Sketch energy flow diagram for system involving heat. Sketch energy flow diagram for system involving work. (3 minutes).

Learning Objectives: [?]

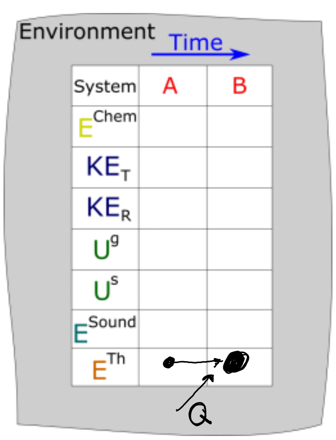
Problem Statement: Sketch the energy flow diagram that best represents the following scenarios.

(a) A steel block is placed over a candle.

Snapshots were taken of the block at the following times:

A: The moment the steel block is placed over the candle.
B: A few moments later when the candle has increased in temperature.

System: Steel block

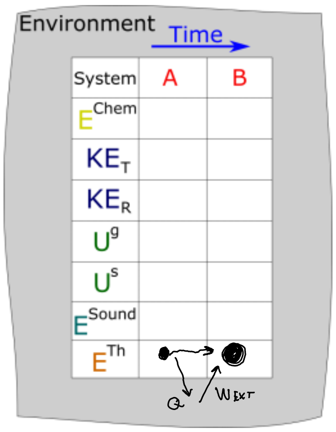


(b) A piston pushed into a cylinder of gas, increasing the temperature of the gas. The cylinder is metal and has been sitting in a bath of ice water for a long time.

Snapshots were taken of the gas as the following times:

A: The moment the cylinder full of room temperature gas is placed into the ice container.
B: A few moments later when the piston is being pushed into the cylinder and the temperature of the gas increased.

System: Gas



Act II: 1st Law of Thermodynamics

1H.2.L1-6:

Description: Apply first law of thermodynamics given work and heat. (2 minutes + 3 minutes + 2 minutes)

Learning Objectives: [?]

Problem Statement: In a certain process, 16 kJ of work is done on a system while 12 kJ of heat is extracted.

(a) The temperature of the system ____________.

(1) increases
(2) decreases
(3) stays the same

$\Delta E^{Th} = W + Q$

$= 16\text{ kJ} - 12\text{ kJ}$

$\Delta E^{Th} = 4\text{ kJ}$ ΔE^{Th} (+) so ΔT (+)

(b) If the system consists of 3 moles of an ideal monatomic gas, how much does the temperature rise? (**R** = 8.314 J/mol·K)

(1) 21 K
(2) 25 K
(3) 67 K
(4) 107 K
(5) 214 K
(6) 301 K

$\Delta E^{Th} = \frac{3}{2} n R \Delta T$

$4000\text{ J} = \frac{3}{2}(3)(8.314\text{ J/mol K})\Delta T$

$\Delta T \approx 107\text{ K}$

(c) What is the final temperate of the 3 moles of gas after the process is complete?

(1) 67 K
(2) 107 K
(3) 314 K
(4) Unable to determine, need more information.

(2) 107 K
(3) 314 K
(4) Unable to determine, need more information.

$\Delta T = 107\,K$

$T_f - T_i = 107$?

$T_f = 107 + T_i$

1H.2.L1-7:

Description: Calculate change in thermal energy of system that includes heat and gravitational energy. (2 minutes + 6 minutes)

Learning Objectives: [?]

Problem Statement: A paddle wheel frictionally adds thermal energy to 5.0 moles of an ideal monatomic gas in a sealed closed container. The paddle wheel is driven by a cord connected to a falling 2.0 kg mass falling shown in the figure.

(a) Refer to **MG.2.L1-4** where there was zero heat transfer because the system was isolated. The 2 kg mass fell about 32 meters and the temperature of the gas increased by 10 K. Here the system is closed so energy can be transferred into or out of the system. It is discovered that the temperature increased by 8 K doing the same 32 meter drop. Was the chamber next to ice or next to fire?

(1) Ice.
(2) Fire.

System mass + gas

$\Delta E^{th} = W + Q$
(+) (+) (?)

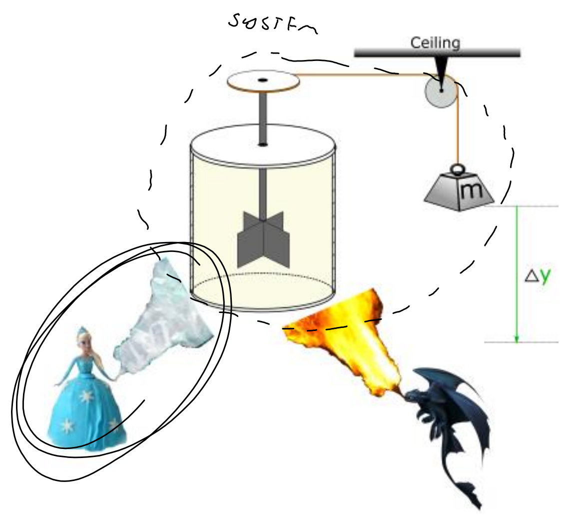
$Q = \Delta E^{th} - W$

$= \frac{3}{2} nR\Delta T - mg|\Delta y|$

$= 499\,J - 627\,J$

$Q = -128\,J$

↑ so energy removed from system



(b) A paddle wheel frictionally adds thermal energy to 5.0 moles of an ideal monatomic gas in a sealed closed container. The paddle wheel is driven by a cord connected to a falling 2.0 kg mass falling shown in the figure. It is discovered that the temperature increased by 8 K doing the same 32 meter drop. **Calculate the energy transferred via heat. Include the proper sign if the gas is the system.**

$Q = -128\,J$

1H.2.L1-8:

Description: Calculate how many moles are present given work, heat, and change in temperature. (2 minutes + 2 minutes + 4 minutes)

Learning Objectives: [?]

Problem Statement: In a certain process a monatomic gas does 3 kJ of work on the environment while 5 kJ of heat is added to the system. It is noticed that the temperature of the gas increases by 300 C°.

(a) What is the change in temperature in Kelvin?

(1) Greater than 300 K
(2) Less than 300 K
(3) Equal to 300 K

$\Delta T(°C) = \Delta T(K)$

Ex

$T_f = 400°C \rightarrow T_f = 673 K$
$T_i = 100°C \rightarrow T_i = 373 K$
$\Delta T(°C) = 300°C$
$\Delta T(K) = 300 K$

(b) What is the change in temperature in Fahrenheit?

(1) Greater than 300 F°
(2) Less than 300 F°
(3) Equal to 300 F°

$\Delta T(°F) \neq \Delta T(°C)$ or $\Delta T(K)$

Ex

$T_f = 400°C \rightarrow T_f = 752°F$
$T_i = 100°C \rightarrow T_i = 212°F$
$\Delta T(°C) = 300°C$
$\Delta T(°F) = 540°F$

(c) Approximately how many moles are present in the gas?

$\Delta E^{th} = W + Q$

$\frac{3}{2} nR\Delta T = -3000 + 5000$

$n \approx 0.5$ moles

1H.2.L1-9:

Description: Apply 1st law of thermodynamics in the graphical representation. (3 minutes + 3 minutes + 2 minutes + 2 minutes)

Learning Objectives: [?]

Problem Statement: Power is defined as energy per time. The SI units are J/s which are often referred to as watts "W".

(a) Which of the following equations is a valid form for the 1st law of thermodynamics?

(1) $\Delta E^{TH} = W + Q$

(2) $\Delta E^{TH}/\Delta t = W + Q$

(3) $\Delta E^{TH} = W/\Delta t + Q/\Delta t$

(4) $\Delta E^{TH}/\Delta t = W/\Delta t + Q/\Delta t$

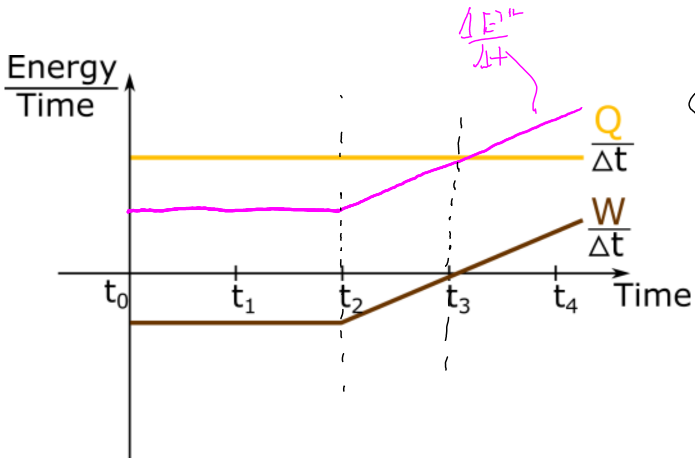
$\frac{1}{\Delta t}\left(\Delta E^{th} = W + Q\right)$

$\frac{\Delta E^{th}}{\Delta t} = \frac{W}{\Delta t} + \frac{Q}{\Delta t}$

(b) The plot below shows the amount of heat and work per time into or out of a system as a function of time. Sketch the change in thermal power as a function of time on the same plot?

ΔE^{th}

thermal power as a function of time on the same plot?



(c) During which time interval(s) is the system doing work on the environment?

W(-) (t_0, t_3)

(d) During which time interval(s) is the system in thermal equilibrium?

$\frac{\Delta E^{th}}{\Delta t} = 0$

NEVER IN EQ

Conceptual questions for discussion

1. With your neighbor, discuss why objects can not possess heat.
2. With your neighbor, discuss the differences between the 1st law of thermodynamics and the work-energy theorem.
3. Chemists and Engineers sometimes use the 1st law of thermodynamics in the form $\Delta \mathbf{E}^{th} = \mathbf{Q} - \mathbf{W}$. Explain the difference between the first law written as $\Delta \mathbf{E}^{th} = \mathbf{Q} + \mathbf{W}$.

Hints

1H.2.L1-1: Review the work-energy theorem.

1H.2.L1-2: No hints.

1H.2.L1-3: Recall that work is a mechanism for how energy can be transferred into or out of a system as well as a way to transform energy within a system. Compare this definition of work with that of the new quantity, heat.

1H.2.L1-4: Work involves forces acting over distances, heat does not involve this.

1H.2.L1-5: All objects with a temperature greater than 0 K have thermal energy.

1H.2.L1-6: Discuss with you neighbors what is the sign of the work and heat?

1H.2.L1-7: No hints.

1H.2.L1-8: No hints.

1H.2.L1-9: No hints.