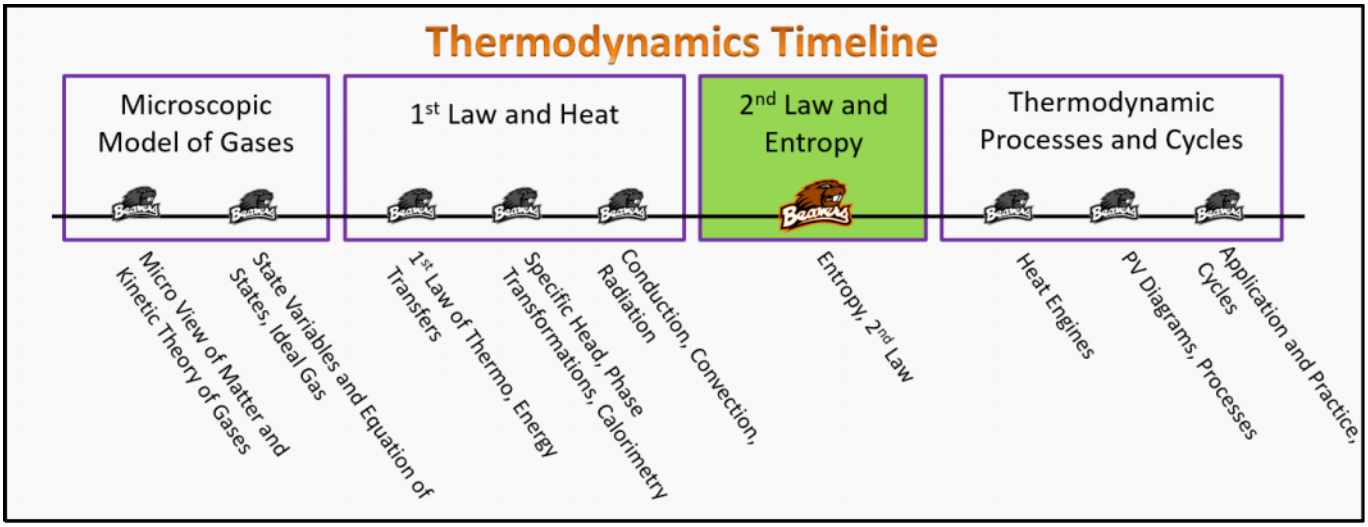
2E.2.L1 - Solutions

Monday, February 4, 2019 7:05 AM

Thermodynamics

Foundation Stage (2E.2.L1)

Lecture 1
Entropy, 2nd Law



Textbook Chapters (* Calculus version)

- **BoxSand** :: KC videos (Entropy and 2nd Law of Thermodynamics)
- **Knight** (College Physics : A strategic approach 3rd) :: 11.7 ; 11.8
- ***Knight** (Physics for Scientists and Engineers 4th) :: 20.6
- **Giancoli** (Physics Principles with Applications 7th) :: 15-4 ; 15-7 ; 15-8 ; 15-9 ; 15-10

Warm up

2E.2.L1-1:

Description: Describe what you have heard about entropy from other classes or sources.

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

Problem Statement: Have you heard of the word entropy before? If so, list everything you can remember about what you know about entropy.

S

measure of disorder in a system
↳ unusable heat in a sys.

increases

must pay entropy tax → eventually all E → S ⇒ heat death of Universe

Selected Learning Objectives

1. Coming soon to a lecture template near you.

Key Terms

- Macroscopic state
- Microscopic state
- Multiplicity
- Probability
- Entropy

Key Equations

Key Concepts

- Coming soon to a lecture template near you.

Questions

Act I: Equilibrium

2E.2.L1-2:

Description: Conceptual question about equilibrium. (2 minutes + 3 minutes + 2 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: A box partitioned into two sides via a divider contains 75 L of oxygen on the right hand side and 25 L of oxygen on the left hand side. Both sides are at the same temperature. When the middle divider is removed, the gasses mix.

(a) Are the gases in equilibrium the instant after the divider is removed?

(1) Yes
(2) No

(b) What caused the gasses to mix, changing the state of the system?

(1) Energy gradients
(2) Entropy gradients
(3) Configurational drive to equilibrium
(4) Temperature gradients
(5) Average momentum gradients

(c) What is the probability that the system will find itself back in the original state with the gasses separated at a later date ?

(1) 75%
(2) 42%
(3) 1.2 %
(4) 0.000001%
(5) Not zero but close enough to zero to be zero.

2E.2.L1-3:

Description: Identify the most probable macro state. (4 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: Two coins are tossed at the same time. The table below represents common features of a system. Which is the most probable macroscopic state?

(1) 2**H** 0**T**
(2) 1**H** 1**T**
(3) 0**H** 2**T**
(4) All equally probable

Macro State Label	Micro State Specification Coin 1 ; Coin 2	Multiplicity	Probability
2**H** 0**T**	**H** ; **H**	1	1/4
1**H** 1**T**	**H** ; **T** **T** ; **H**	2	1/2
0**H** 2**T**	**T** ; **T**	1	1/4

Act II: Entropy

2E.2.L1-4:

Description: Identify state of higher entropy. (3 minutes + 2 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: A box partitioned into two sides via a divider contains 75 L of oxygen on the right hand side and 25 L of oxygen on the left hand side. Both sides are at the same temperature. When the middle divider is removed, the gasses mix.

(a) Which state has the most entropy?

(1) The two gases separated in their respective sides.
(2) The two gases mixed together after divider is removed.
(3) Both states have equal entropy.

(b) Which state has the most microscopic configurations that yield the same macroscopic state?

(1) The two gases separated in their respective sides.
(2) The two gases mixed together after divider is removed.
(3) Both states have equal number of microscopic configurations that yield the same macroscopic state.

macro state:

micro states: 1,2,3,4 | - | - 1,2,3,4 | 1 2 3 4 / 2,3,4 1,3,4 1,2,4 1,2,3 | 1,2,3 1,2,4 1,3,4 2,3,4 / 4 3 2 1 | 1,2 1,3 1,4 2,3 2,4 3,4 / 3,4 2,4 2,3 1,4 1,3 1,2

multiplicity: 1 1 4 4 6

↑ highest multiplicity ⇒ highest entropy

2E.2.L1-5:

Description: Determine most probably macro state. Identify evolution of system. (4 minutes + 3 minutes + 2 minutes + 4 minutes).

Learning Objectives: [1, 12, 13]

Problem Statement: A very large number of six-sided die are all initially on a table, all with their 1 side showing. You decide to take two dice at a time and roll them until you have rolled all dice once.

(a) The table to the right shows an example of a possible outcome after rolling two dice. What is the most probable macro state when you roll two dice?

Macro State	Micro State Die 1 ; Die 2	Multiplicity
1 + 5 = **6**	1 ; 5	5

7

(b) What is the multiplicity of this most probable macro state?

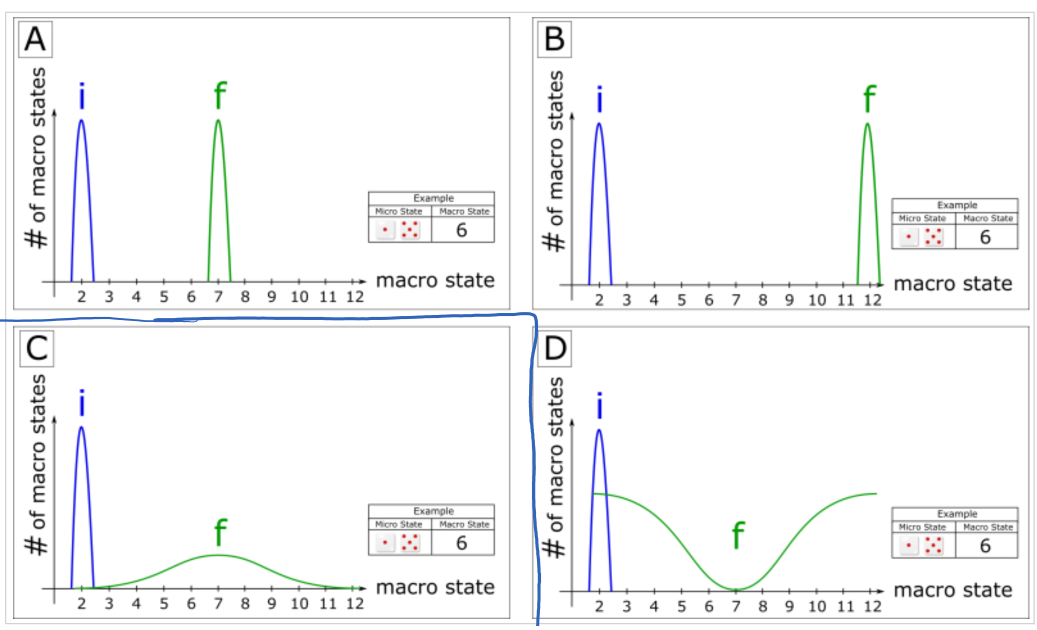
1 6
2 5
3 4
4 3
5 2
6 1

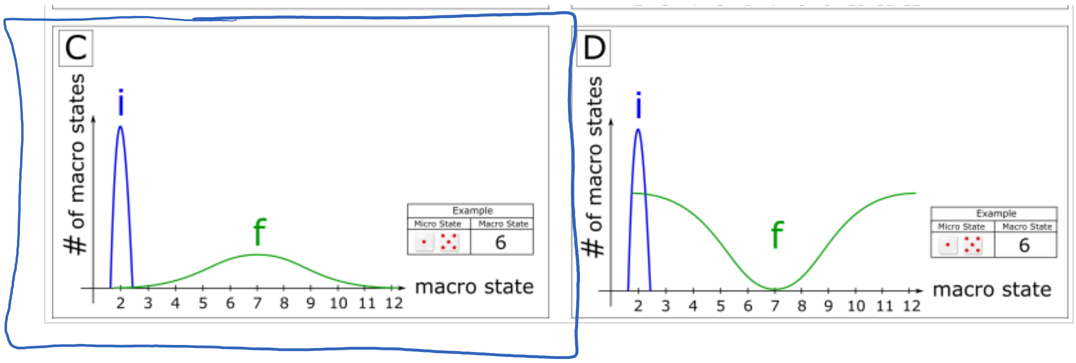
6 = multiplicity

(c) What is the least probable macro state?

2, 12

(d) Which of the following plots shows the correct evolution of the system as you go from the initial state of all dice showing 1, to the final state after you have rolled each die many times?





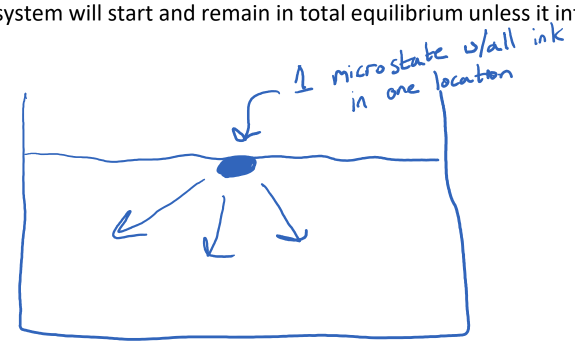
2E.2.L1-6:

Description: Identify entropy increases and/or decreases. (5 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: A drop of water soluble blue ink (**T** = 20 °C) falls into an isolated beaker of water (**T** = 20 °C). Which of the following statements are true regarding the time after the ink drops has landed in the water?

(1) The entropy of the water + ink system decreases.
(2) The entropy of the water + ink system increases.
(3) The entropy of the water + ink system will remain a constant.
(4) Thermal energy will flow between the ink and the water in accordance with the second law of thermodynamics.
(5) The system will start and remain in total equilibrium unless it interacts with the outside environment.



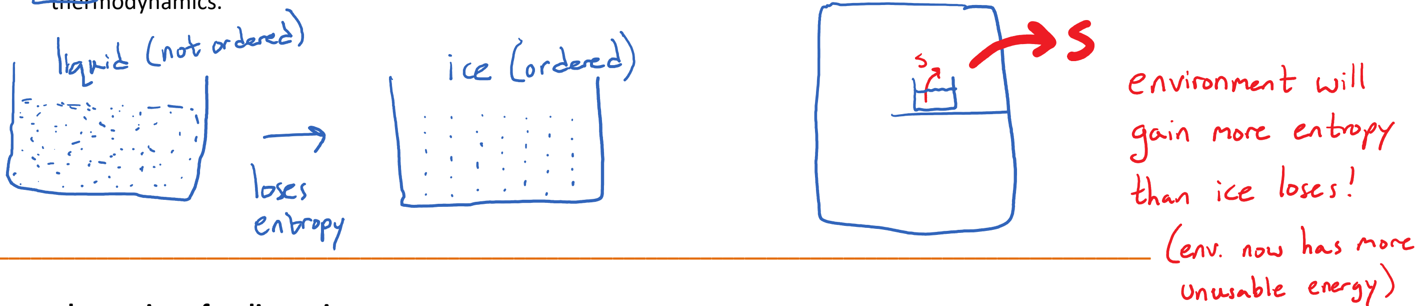
2E.2.L1-7:

Description: Identify entropy increases and/or decreases. (6 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: Water is placed in a freezer and as it comes into thermal equilibrium it freezes. Which of the following statements are true concerning this process?

(1) The water gains entropy in accordance with the second law of thermodynamics.
(2) The water loses entropy so the process violates the second law of thermodynamics.
(3) The water gains entropy, but the air outside the freezer loses entropy in accordance with the second law of thermodynamics.
(4) Both the water and the air outside the refrigerator lose entropy, but the universe gains entropy in accordance with the second law of thermodynamics.
(5) The water loses entropy, but the air outside the refrigerator gains entropy in accordance with the second law of thermodynamics.



Conceptual questions for discussion

1. Coming soon.

Hints

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

2E.2.L1-2: No hints.

2E.2.L1-3: No hints.

2E.2.L1-4: No hints.

2E.2.L1-5: No hints.

2E.2.L1-6: No hints.

2E.2.L1-7: No hints.