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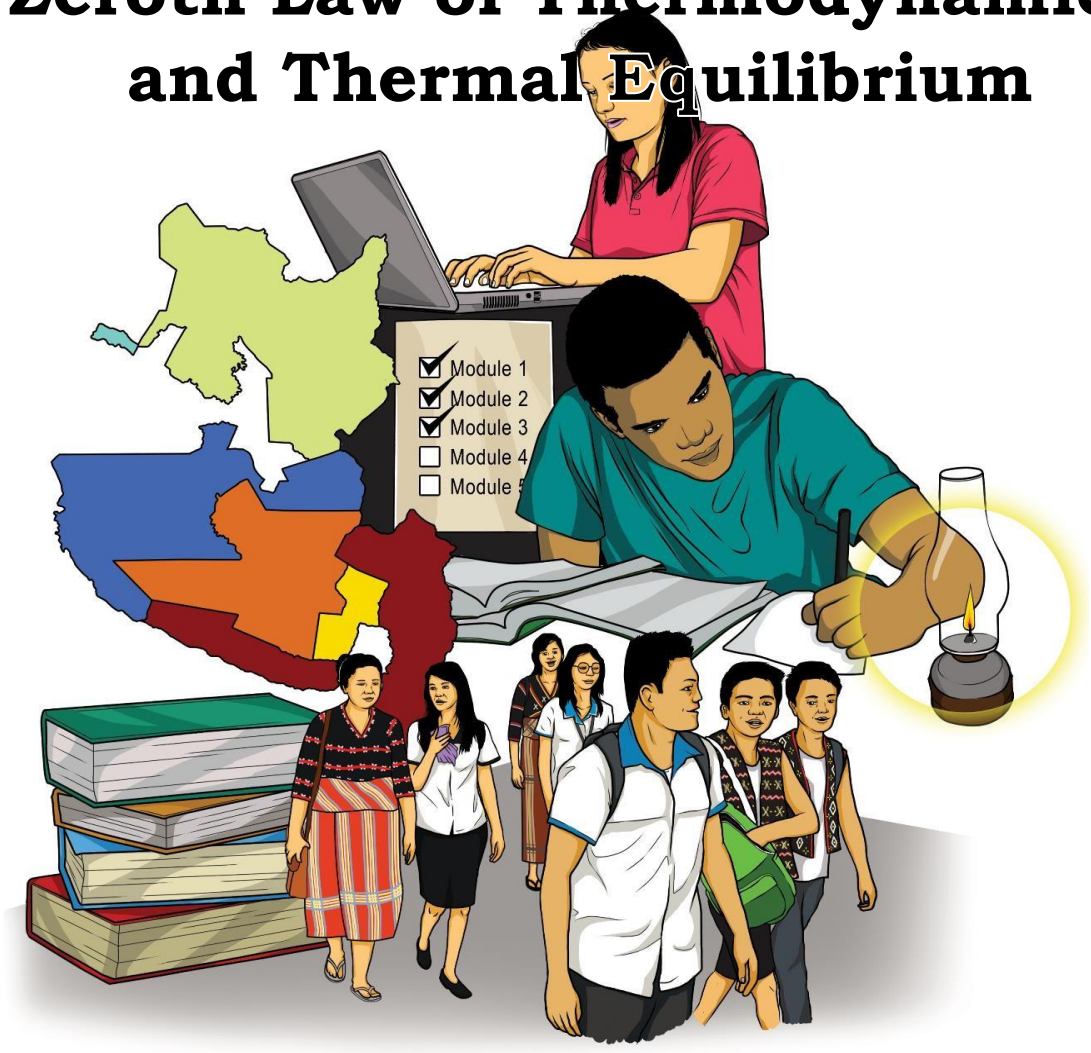
DEPARTMENT OF EDUCATION

General Physics 1

Quarter 2 – Module 8

Zeroth Law of Thermodynamics and Thermal Equilibrium



SELF-LEARNING MODULE

DEPARTMENT OF EDUCATION - SOCCSKSARGEN

Physics- Grade 12
Self-Learning Module (SLM)
Quarter 2 – Module 8: Zeroth Law of Thermodynamics and Thermal Equilibrium First Edition, 2020

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Introductory Message

For the facilitator:

Welcome to the **General Physics - 12** Self-Learning Module (SLM) on **Zeroth Law of Thermodynamics and Thermal Equilibrium!**

This module was collaboratively designed, developed and reviewed by educators both from public and private institutions to assist you, the teacher or facilitator in helping the learners meet the standards set by the K to 12 Curriculum while overcoming their personal, social, and economic constraints in schooling.

This learning resource hopes to engage the learners into guided and independent learning activities at their own pace and time. Furthermore, this also aims to help learners acquire the needed 21st century skills while taking into consideration their needs and circumstances.

In addition to the material in the main text, you will also see this box in the body of the module:

Notes to the Teacher

This contains helpful tips or strategies that will help you in guiding the learners.

As a facilitator you are expected to orient the learners on how to use this module. You also need to keep track of the learners' progress while allowing them to manage their own learning. Furthermore, you are expected to encourage and assist the learners as they do the tasks included in the module.

For the learner:

Welcome to the **General Physics - 12** Self-Learning Module (SLM) on **Zeroth Law of Thermodynamics and Thermal Equilibrium!**

The hand is one of the most symbolized part of the human body. It is often used to depict skill, action and purpose. Through our hands we may learn, create and accomplish. Hence, the hand in this learning resource signifies that you as a learner is capable and empowered to successfully achieve the relevant competencies and skills at your own pace and time. Your academic success lies in your own hands!

This module was designed to provide you with fun and meaningful opportunities for guided and independent learning at your own pace and time. You will be enabled to process the contents of the learning resource while being an active learner.

This module has the following parts and corresponding icons:

 ***What I Need to Know***	This will give you an idea of the skills or competencies you are expected to learn in the module.
 ***What I Know***	This part includes an activity that aims to check what you already know about the lesson to take. If you get all the answers correct (100%), you may decide to skip this module.
 ***What's In***	This is a brief drill or review to help you link the current lesson with the previous one.
 ***What's New***	In this portion, the new lesson will be introduced to you in various ways such as a story, a song, a poem, a problem opener, an activity or a situation.
 ***What is It***	This section provides a brief discussion of the lesson. This aims to help you discover and understand new concepts and skills.
 ***What's More***	This comprises activities for independent practice to solidify your understanding and skills of the topic. You may check the answers to the exercises using the Answer Key at the end of the module.
 ***What I Have Learned***	This includes questions or blank sentence/paragraph to be filled in to process what you learned from the lesson.

 ***What I Can Do***	This section provides an activity which will help you transfer your new knowledge or skill into real life situations or concerns.
 ***Assessment***	This is a task which aims to evaluate your level of mastery in achieving the learning competency.
 ***Additional Activities***	In this portion, another activity will be given to you to enrich your knowledge or skill ofthe lesson learned. This also tends retention of learned concepts.
 ***Answer Key***	This contains answers to all activities in the module.

At the end of this module you will also find:

References	This is a list of all sources used in developing this module.

The following are some reminders in using this module:

1. Use the module with care. Do not put unnecessary mark/s on any part of the module. Use a separate sheet of paper in answering the exercises.
2. Don't forget to answer *What I Know* before moving on to the other activities included in the module.
3. Read the instruction carefully before doing each task.
4. Observe honesty and integrity in doing the tasks and checking your answers.
5. Finish the task at hand before proceeding to the next.
6. Return this module to your teacher/facilitator once you are through with it.

If you encounter any difficulty in answering the tasks in this module, do not hesitate to consult your teacher or facilitator. Always bear in mind that you are not alone.

We hope that through this material, you will experience meaningful learning and gain deep understanding of the relevant competencies. You can do it!

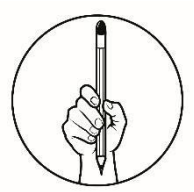
What I Need to Know

This module was designed and written with you in mind. It is here to help you master the nature of Physics. The scope of this module permits it to be used in many different situations, and lets you explore the vast concept of momentum and impulse. The lessons are arranged to follow the standard sequence of the course.

At the end of this module, you will be able to **explain the connection between the Zeroth Law of Thermodynamics, thermal equilibrium and temperature scales.**

After going through this module, you are expected to:

1. define Zeroth Law of Thermodynamics
2. state the relationship between Zeroth Law of Thermodynamics and Thermal equilibrium, and;
3. solve problems in Zeroth Law of Thermodynamics and Thermal equilibrium and temperature scales.



What I Know

Multiple Choice. Choose the letter of the correct answer. Encircle the letter of your choice.

1. Why is the sun and the Earth not in thermal equilibrium?
   A. The mass of the sun is much greater than the mass of the Earth.
   B. There is vast amount of empty space between the sun and Earth.
   C. The diameter of the sun is much greater than the diameter of the Earth.
   D. The sun is in thermal contact with Earth.

2. Which of the following systems only allows for the exchange of energy with the surroundings?
   A. Closed C. Open
   B. Isolated D. None of the above

3. Which temperature scale does NOT have negative values?
   A. Celsius C. Kelvin
   B. Fahrenheit D. All of these

4. Suppose you mix two identical blocks of metal, one having a temperature of 10°C and the other 20°C. Is it possible for the colder block to cool to 5°C and the warmer block to warm to 25°C?
   A. No, because it will violate the first law of thermodynamics.
   B. Yes, because it adheres to the Zeroth law of thermodynamics.
   C. No, because it will violate the Zeroth law of thermodynamics.
   D. No, because, it will violate the second law of thermodynamics.

5. What makes a rubbing alcohol effective in reducing fever?
   A. Warms the body C. Evaporates very quickly
   B. Irritates the skin D. Stimulates the nerve endings

6. What is the first law of Thermodynamics?
   A. Conservation of energy C. Newton's laws
   B. Conservation of mass D. Principle of energy

7. Which law of thermodynamics dictates that for objects to be in thermal equilibrium, they must have a common temperature?
   A. Zeroth law
   B. First law
   C. Second law
   D. Third law

8. Freezing point of ethyl alcohol is 156K, which is equal to
   A. 426°C
   B. 117°C
   C. -426°C
   D. -117°C

9. Why is the Zeroth law of thermodynamics important or necessary?
   A. Because you have to first define your terms, in particular: temperature.
   B. Because you have to first define your terms, in particular: volume.
   C. Because you have to first define your terms, in particular: pressure.
   D. Because you have to understand what thermal equilibrium is.

10. Steam point is equal to 100°C, which is equal to?
   A. -373 K
   B. -173 K
   C. 373 K
   D. 173 K

11. A solid X is in thermal equilibrium with a solid Y, which is at the same temperature as a third solid Z. The three bodies are different materials and masses. Which one of the following statements is certainly correct? Of 164.9 J/s, calculate the thermal conductivity of aluminum: A. X and Y have the same heat capacity.
   B. X and Y have the same internal energy.
   C. It is not necessary that Y should be in thermal equilibrium with Z.
   D. There is no net transfer of energy if X is placed in thermal contact with Z.

12. When thermodynamic equilibrium exists for a system, there exists _____ entropy.
   A. Maximum B. minimum C. zero D. undefined

13. To which mathematical property is Zeroth law of thermodynamics similar?
   A. Associative property
   B. Commutative property
   C. Distributive property
   D. Transitive property

14. What concept is applied when we feel no cold or hot?
   A. Temperature constancy
   B. Thermal constancy
   C. Thermal equilibrium
   D. Temperature equilibrium

15. Which of two temperature change are equivalent?
   A. 1K = 1°F
   B. 1°F =1°C
   c. 1 Re = 1 K
   d. 1°F = 1°F

Lesson 1

MOMENT IN TIME
(Momentum and Impulse)

Learning Objectives:

1. define Zeroth Law of Thermodynamics
2. state the relationship between Zeroth Law of and Thermal equilibrium
3. solve problems in Zeroth Law of and Thermal equilibrium and temperature scales.

What's In

Activity 1. Puzzle in Motion

Identify the jumbled words being presented below. Write the correct answers on the space provided.

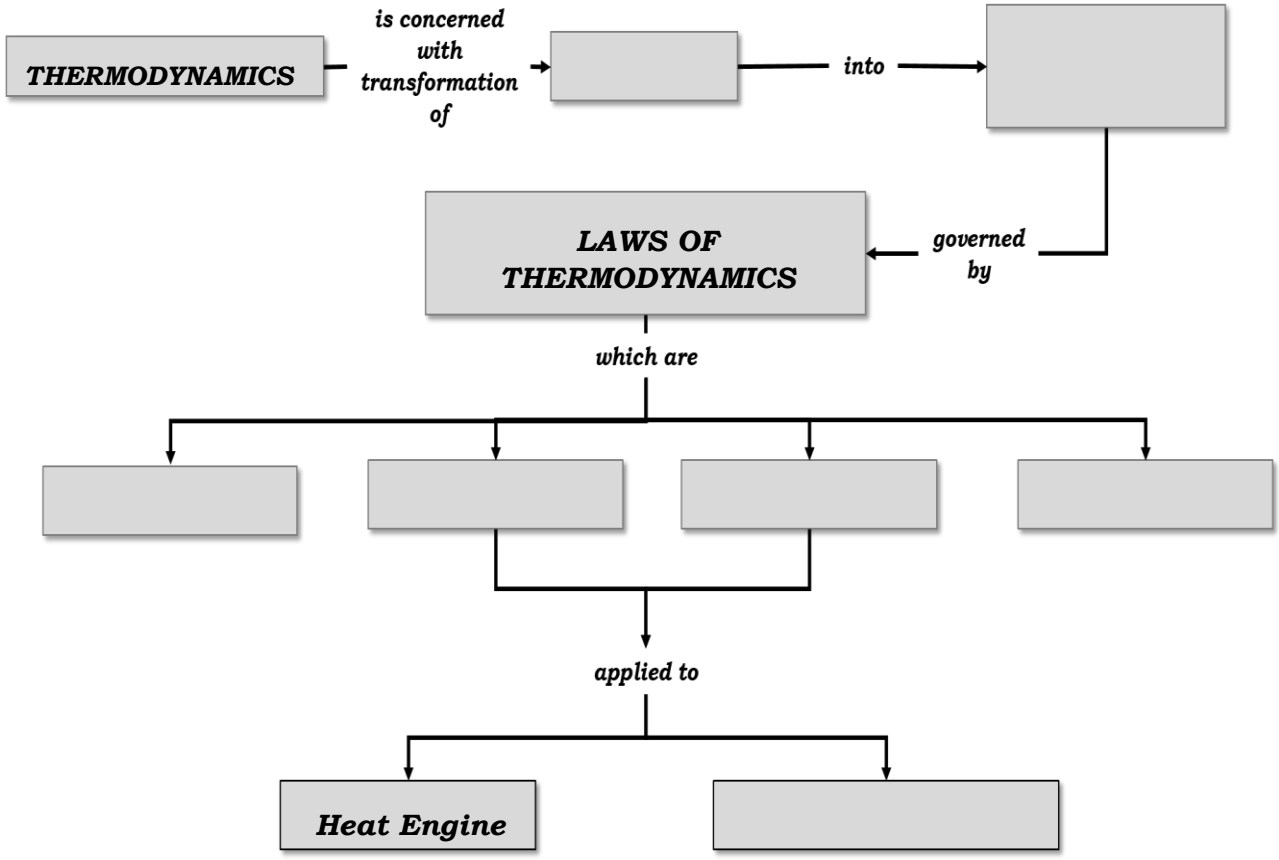
TZEHOR WLA **1.** ____ ____ ____ ____ ____ ____ ____ ____ ____
USPRESER **2.** ____ ____ ____ ____ ____ ____ ____ ____
RTAERMTEPEU **3.** ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
RHYTCOEMAMSDNI **4.** ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
APENNSOXI **5.** ____ ____ ____ ____ ____ ____ ____ ____ ____

What's New

Activity 2. Concept Box

Fill in the graphic organizer based on the given selection.

ZEROTH'S LAW	3RD LAW
HEAT	MECHANICAL ENERGY
2ND LAW	1ST LAW
REFRIGERATORS AND AIR CONDTIONERS	



Activity 3. Mix and Match

Answer the following problem below by matching the commonly used temperature constant to its specific qualitative value.

_____ 1. **100 ºC**	**a. Normal body temperature**
_____ 2. **37 ºC**	**b. Freezing Point**
_____ 3. **20 ºC**	**c. Absolute Zero**
_____ 4. **0 ºC**	**d. Boiling Point**
_____ 5. **-273.15 ºC**	**e. Normal room temperature**

What is It

This module was designed and written with you in mind. It is here to help you master the nature of Physics. The scope of this module permits it to be used in many different situations, and lets you explore the vast concept of momentum and impulse. The lessons are arranged to follow the standard sequence of the course.

The **Zeroth Law of Thermodynamics** was first formulated by Ralph H. Fowler in 1931. Its main concern is **Thermal equilibrium,** in which two bodies are said to be in thermal equilibrium if they have the same temperature. **Zeroth Law of Thermodynamics** states that if object A is in thermal equilibrium with object B and object A is in thermal with the third object C, then object B must be equilibrium with object C.

Let the temperatures of an objects A, B, and C be T_A, T_B, and T_C, respectively. Since $T_A = T_B$ **and** $T_A = T_C$, therefore $T_B = T_C$. **In effect the** zeroth law of thermodynamics **is very similar to the transitive property in elementary algebra.**

According to David McKee, a professor of physics at Missouri Southern State University, the Zeroth Law "tells us that no matter how much energy two systems have, knowing how much energy they have doesn't let me predict which direction heat will flow if I put them in contact with each other. The Zeroth Law says that this number, which is the temperature, defines the direction of heat flow, and it does not depend directly on the amount of energy that's involved."

He continued, "The temperature of two systems is the only thing you need to know in order to determine which direction heat will flow between them."

The Zeroth Law of Thermodynamics defines temperature and makes thermometers possible. For a thermometer to be useful, though, it must be first calibrated. All other basic units of measure, e.g., for length, mass, time, etc., are each defined according to a precise standard. In this case, we must not only define a unit of measure, but also the beginning point of the scale.

The Zeroth law of thermodynamics begins with a simple definition of **thermodynamic equilibrium.** It is observed that some property of an object, like the pressure in a volume of gas, the length of a metal rod, or the electrical conductivity of a wire, can change when the object is heated or cooled. If two of these objects are brought into physical contact there is initially a change in the property of both objects. But, eventually, the change in property stops and the objects are said to be in thermal, or thermodynamic, equilibrium. Thermodynamic equilibrium leads to the large scale definition of temperature. When two objects are in thermal

equilibrium they are said to have the same temperature. During the process of reaching thermal equilibrium, heat, which is a form of energy, is transferred between the objects. The details of the process of reaching thermal equilibrium are described in the first and second laws of thermodynamics.

Activity 4. Table Completion

Complete the table below by supplying information on the different temperature equivalent.

DEGREE CELSIUS (^oC)	**KELVIN (K)**	**DEGREE FARENHEIT (^oF)**
37 **^oC**	1.	2.
3.	0 **K**	4.
5.	6.	100 **^oF**
20 **^oC**	7.	8.
9.	546.30 **K**	10.

The **Thermal equilibrium** is a state that is achieved when the substances are in contact with each other and they are at the same temperature. The thermal equilibrium is achieved by the transfer of heat between the hotter and the colder objects.

Heat is the flow of energy from a high temperature to a low temperature. When these temperatures balance out, heat stops flowing, then the system (or set of systems) is said to be in **thermal equilibrium**. Thermal equilibrium also implies that there's no matter flowing into or out of the system.

The zeroth law of thermodynamics uses thermal equilibrium to define how two different systems can be said to be at the same temperature. For example, when molten rock comes up from a volcano, it will give off heat to the atmosphere until the rock and the atmosphere are at the same temperature. Even though the two systems (rock and air) are very different, thermal equilibrium allows a definition of temperature for both.

All systems tend towards thermal equilibrium over time—and some systems will take a lot longer than others. Knowing that interacting systems

will tend towards the same temperature allows for important applications in all areas of science.

For example, the specific heat capacity of a substance can be determined by placing it in water and measuring the temperature after a period of time.

Examples of thermal equilibrium

1. Measuring body temperature through a thermometer works that way. The long duration that the thermometer must have in contact with the body to be able to truly quantify the degrees of temperature is due precisely to the time it takes to reach thermal equilibrium.
2. When a person comes out of bathing, it is relatively cold because the body had entered into equilibrium with the hot water, and now it must balance with the environment.
3. When looking to cool a cup of coffee, adding cold milk.
4. A bottle with a kilo of ice cream will melt slower than another with a quarter of a kilo of the same ice cream. This is produced by the equation in which the mass determines the characteristics of the thermal equilibrium.
5. When an ice cube is placed in a glass of water, a thermal equilibrium also occurs. The only difference is that equilibrium implies a change of state, because it goes through 100 ° C where water goes from solid to liquid.
6. Add cold water at a rate of hot water, where equilibrium is reached very quickly at a colder temperature than the original.

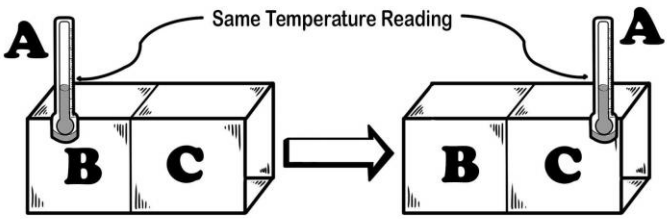
Activity 5. T.E ConAn

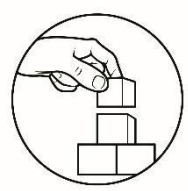
This activity is known as Thermal Equilibrium: Conceptual Analysis. Analyze the following concept on thermal equilibrium.

1. A solid X is in thermal equilibrium with a solid Y, which is at the same temperature as a third solid Z. The three bodies are of different materials and masses. Which one of the following statements is certainly correct?

   a) X and Y have the same heat capacity.
   b) X and Y have the same internal energy.
   c) It is not necessary that Y should be in thermal equilibrium with Z.
   d) There is no net transfer of energy if X is placed in thermal contact with Z.

2. Consider the case: If thermometer A is in thermal equilibrium with object B, and B is in thermal equilibrium C, then A is in thermal equilibrium with C. What will be reading on thermometer A when it is moved over to make contact with C?





What's More

Activity 6. Correct Me If I'm Wrong

Determine whether the provided statements are correct or incorrect. Write TRUE if it is correct and FALSE if it is incorrect, then change the underline words.

_____1. If two object are in thermal <u>in equilibrium</u>, they have the same temperature.

_____2. <u>First Law</u> of Thermodynamics was first formulated by Ralph H. Fowler in 1931.

_____3. In thermal equilibrium, Since $T_A = T_B$ and $T_A = T_C$, therefore $T_B = T_C$.

_____4. The thermal equilibrium is achieved by the <u>transfer of work</u> between the hotter and the colder objects.

_____5. The thermal equilibrium is a state that is achieved when the substances are in <u>contact</u> with each other.

What I Have Learned

Activity 7. Thermo-filler

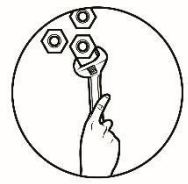
Fill in the blanks to complete the paragraph.

The (1) ___ was first formulated by Ralph H. Fowler in 1931. Its main concern is (2) __ **,** in which two bodies are said to be in thermal equilibrium if they have the same temperature. Zeroth Law of Thermodynamics states that if object A is in thermal equilibrium with object B and object A is in thermal with the third object C, then object B must be (3) __with object C.

The Thermal equilibrium is a state that is achieved when the substances are in contact with each other and they are at the same.

The thermal equilibrium is achieved by the transfer of heat between the (4) __ and the (5) ___ objects.

The Laws of thermodynamics are classified into four, the (6) _____, (7) __ , (8) __ and (9) __ , Thus, this laws are applied to air conditioners and (10) _____.



What I Can Do

Activity 8. Zeroth FBD

Direction: Illustrate the Free Body Diagram of the scenario presented below.

If object **X** is in thermal equilibrium with object **Y**, and **Y** is in thermal equilibrium **Z**, then **X** is in thermal equilibrium with **Z**. Suppose object **X** is a laboratory thermometer, what will be the reading on object **X** when it is moved over to make contact with **Z**?

Assessment

Multiple Choice. Choose the letter of the best answer. Write the chosen letter on the space provided before each number.

1. What is the first law of Thermodynamics?
   A. Conservation of energy C. Newton's laws
   B. Conservation of mass D. Principle of energy

2. Which of the following systems only allows for the exchange of energy with the surroundings?
   A. Closed C. Open
   B. Isolated D. None of the above

3. Which temperature scale does NOT have negative values?
   A. Celsius C. Kelvin
   B. Fahrenheit D. All of these

4. Why is the Zeroth law of thermodynamics important or necessary?
   A. Because you have to first define your terms, in particular: temperature.
   B. Because you have to first define your terms, in particular: volume.
   C. Because you have to first define your terms, in particular: pressure.
   D. Because you have to understand what thermal equilibrium is.

5. Which of two temperature change are equivalent?
   A. 1K = 1°F C. 1 Re = 1 K
   B. 1°F =1°C D. 1°F = 1°F

6. Suppose you mix two identical blocks of metal, one having a temperature of 10°C and the other 20°C. Is it possible for the colder block to cool to 5°C and the warmer block to warm to 25°C?
   A. No, because it will violate the first law of thermodynamics.
   B. Yes, because it adheres to the Zeroth law of thermodynamics.
   C. No, because it will violate the Zeroth law of thermodynamics.
   D. No, because, it will violate the second law of thermodynamics.

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   B. Irritates the skin
   C. Evaporates very quickly
   D. Stimulates the nerve endings

9. Which law of thermodynamics dictates that for objects to be in thermal equilibrium, they must have a common temperature?
   A. Zeroth law
   B. First law
   C. Second law
   D. Third law

10. To which mathematical property is zeroth law of thermodynamics similar?
   A. Associative property
   B. Commutative property
   C. Distributive property
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   A. 426°C
   B. 117°C
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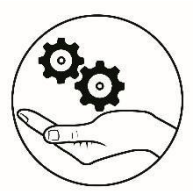
   D. -117°C

12. Why is the sun and the Earth not in thermal equilibrium?
   A. The mass of the sun is much greater than the mass of the Earth.
   B. There is vast amount of empty space between the sun and Earth.
   C. The diameter of the sun is much greater than the diameter of the Earth.
   D. The sun is in thermal contact with Earth.

13. Steam point is equal to 100°C, which is equal to
   A. -373 K
   B. -173 K
   C. 373 K
   D. 173 K

14. When thermodynamic equilibrium exists for a system, what will happen to its entropy?
   A. Maximum B. minimum C. zero D. undefined

15. If we feel no cold or hot, we call it?
   A. Temperature constancy
   B. Thermal constancy
   C. Thermal equilibrium
   D. Temperature equilibrium



Additional Activities

INFOGRAPHICS

Direction: Based on the lesson, you will make an infographics regarding the relationship of Zeroth law of thermodynamics, thermal equilibrium and temperature.

COMPONENTS	EXCEEDS EXPECTATIONS	MEETS EXPECTATIONS	NEEDS MORE WORK
COLORS	The color choices enhance the visibility of the infographic. Different saturations of the same color are used wisely.	The color choices are fine, but too many colors may have been used.	The color choices for the infographic are not visually pleasing and detract from the infographic.
LAYOUT	The layout of the infographic adheres to the inverted pyramid style - main point on top, secondary point next, and supporting details at the bottom.	The layout of the infographic includes all three components - main point, secondary point, and supporting details - but is not organized in the inverted pyramid style.	The infographic is lacking one or two of the components of good infographic design - main point, secondary point, or supporting details.
INFORMATION ORGANIZATION	The infographic utilizes one of the LATCH (location, alphabetical, timeline, category, or hierarchy) information organization formats to allow the viewer to understand the information in the infographic.	The infographic utilizes some components of the LATCH (location, alphabetical, timeline, category, or hierarchy) information organization formats, but the cohesiveness of the information presentation is lacking.	No information organization choice (location, alphabetical, timeline, category, or hierarchy) is present in the infographic.
CITATIONS	Full bibliographic citations for all sources used are included.	The URL of sources used are included.	No citations to sources used are included.

Answer Key

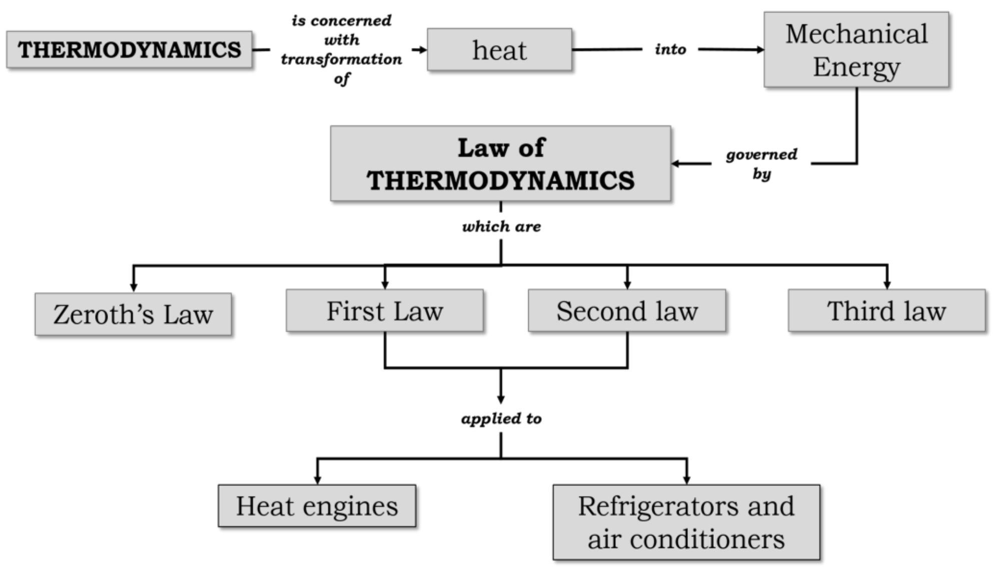
Pre-Assessment

1	. B	6	. A	11	. D
2	. C	7	. A	12	. A
3	. C	8	. D	13	. D
4	. B	9	. D	14	. C
5	. C	10	. C	15	. C

ACTIVITY 1: Thermo-Jumble

1. Zeroth Law
2. Pressure
3. Temperature
4. Energy
5. Expansion

ACTIVITY 2: Concept Box



ACTIVITY 4: Table Completion

DEGREE CELSIUS (^0C)	KELVIN (K)	DEGREE FARENHEIT (^0F)
37 ^0C	**1. 310.15 ^0K** 37 ^0C + 273.15	**2. 98.6 ^0F** (37^0C x 9/5 + 32)
3. -273.15 ^0C 0K – 273.15	**0 K**	**4. -459.67 ^0F**
5. 37.78 ^0C (100^0F - 32) x 5/9	**6. 310.93 K**	**100 ^0F**
20 ^0C	**7. 293.15 K** 20 ^0C + 273.15	**8. 68 ^0F** (37^0C x 9/5 + 32)
9. -273.15 ^0C 546.30K – 273.15	**546.30 K**	**10. 523.67 ^0F**

ACTIVITY 3: Mixt and Match

1. D-Boiling Point
2. A-Normal body temperature
3. E-Normal room temperature
4. B-Freezing Point

5 . C-Absolute Zero

ACTIVITY 7: Thermo-filler

1. Zeroth Law of Thermodynamics
2. Thermal Equilibrium
3. Equilibrium
4. Hotter
5. Colder
6. Zeroth Law
7. First Law
8. Second Law
9. Third Law
10. Refrigerators

ACTIVITY 6: Correct Me If I'm wrong

1. True
2. Zeroth Law of Thermodynamics
3. True
4. Transfer of Heat
5. True

Activity 5: T.E ConAn

1. **Option D is the correct answer. There is no net transfer of energy if X is placed in thermal contact with Z.**

   Since the solid X and Z have the same temperature so there is thermal equilibrium between them. If Y is in thermal equilibrium with X then the Y and Z will also be in the thermal equilibrium. By the zeroth law of thermodynamics, no heat will be transferred between the X and Z.

2. **The reading on thermometer A stays the same when it is moved over to make contact with object C.**

   A thermometer measures its own temperature. *If two object are in thermal equilibrium, they have the same temperature.*

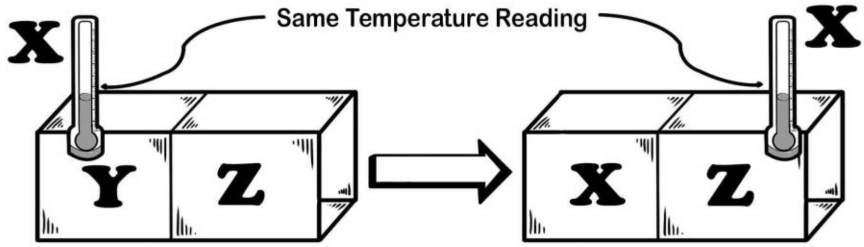
   It is through the concepts of thermal equilibrium and the Zeroth Law of Thermodynamics that we can say that thermometer measures the temperature of something else, and to make sense of the statement that two objects are at the same temperature.

Post-Assessment

1. A	6 . C	11 . D
2. C	7 . D	12 . B
3. C	8 . C	13 . C
4. D	9 . A	14 . A
5. D	10 . D	15 . C

Activity 8: Zeroth FBD

1. The reading on laboratory thermometer X stays the same when it is moved over to make contact with object Z since they in thermal equilibrium state.



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EDITOR'S NOTE

This Self-learning Module (SLM) was developed by DepEd SOCCSKSARGEN with the primary objective of preparing for and addressing the new normal. Contents of this module were based on DepEd's Most Essential Learning Competencies (MELC). This is a supplementary material to be used by all learners of SOCCSKSARGEN Region in all public schools beginning SY 2020-2021. The process of LR development was observed in the production of this module. This is version 1.0. We highly encourage feedback, comments, and recommendations

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