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DEPARTMENT OF EDUCATION

General Physics 1

Quarter 2 Module 13:
Heat Engine, Entropy and Second Law of Thermodynamics

SELF-LEARNING MODULE

DEPARTMENT OF EDUCATION - SOCCSKSARGEN

General Physics 1 – Grade 12
Self-Learning Module (SLM)
Quarter 2 Module 13 : Heat Engine, Entropy and Second Law of Thermodynamics
First Edition, 2020

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Organizational · Nurturing · Engaging

Introductory Message

For the facilitator:

Welcome to the **General Physics 1 Grade 12** Self-Learning Module (SLM) on **Heat Engine, Entropy and Second Law of Thermodynamics**.

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 1 Grade 12** Self-Learning Module (SLM)
Heat Engine, Entropy and Second Law of Thermodynamics.

Every time you drive a car, turn on an air conditioner, or cook a meal, you reap the practical benefits of thermodynamics, the study of relationships involving heat, mechanical work, and other aspects of energy and energy transfer.

Two fundamental concepts govern energy as it relates to living organism: the First Law of Thermodynamics states that total energy in a closed system is neither lost nor gained – it is only transformed. The Second Law of Thermodynamics states that entropy constantly increases in a closed system.

More specifically, the First Law states that energy can neither be created nor destroyed: it can only change form. Therefore, through any and all processes, the total energy of the universe or any other closed system is constant. Also, the second law dictates that entropy always seeks to increase over time.

Entropy is a fancy word for chaos or disorder. The theoretical final or equilibrium state is one in which entropy is maximized, and there is no order to anything in the universe or closed system.

The scope of this module permits it to be used in many different learning situations. The language used recognizes the diverse vocabulary level of students. The lessons are arranged to follow the standard sequence of the course. But the order in which you read them can be changed to correspond with the textbook you are now using.

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 of the 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

Heat is the easiest and cheapest form of energy to obtain, because all we need to do to liberate is to burn a fuel such as wood, coal, or oil. The real problem is to turn heat into mechanical energy so it can power cars, ships, airplanes, electric generators, and machines of all kind.

In order to change heat into a more usable form, we must extract some of the energy of the random motion of atoms and molecules and convert it into the regular motion of a piston or a wheel. Such conversion cannot take place efficiently, for the same reason that it is easier to shatter a wine glass than to reassemble the fragments: The natural tendency of all physical systems is toward increasing disorder. This tendency, whose role in the evolution of the universe is quite as central as are those the various conservation principles, is an expression of the Second Law of Thermodynamics.

After going through this module, you are expected to:

1. calculate the efficiency of a heat engine;
2. describe reversible and irreversible processes;
3. explain how entropy is a measure of disorder;
4. state the 2nd Law of Thermodynamics; and
5. calculate entropy changes for various processes e.g., isothermal process, free expansion, constant pressure process, etc.

What I Know

Direction: Read and understand the questions. Write the letter of the correct answer on a separate sheet.

1. Which of the following processes is thermodynamically reversible?
   A. constant volume and constant pressure
   B. free expansion
   C. hyperbolic and pV =c
   D. isothermal and adiabatic

2. For a thermodynamic process to be reversible, what should be the temperature between hot body and working substance?
   A. Infinity
   B. Maximum
   C. Minimum
   D. Zero

3. A heat engine moving an efficiency of 0.20 takes in 2000 J of energy from the hot reservoir in one cycle. In the same time, how much work will it perform?
   A. 0 J
   B. 120 J
   C. 400 J
   D. 1000 J

4. Which statements is correct about the Second Law of Thermodynamics?
   A. Heat will not flow spontaneously from a cold object to hot object.
   B. No heat engine can have efficiency greater than 30%.
   C. The random motion of gas molecules will decrease if energy is added to a gas.
   D. There is no process that can make heat flow from a cold object to a hot object.

5. Which of the following is the primary function of heat engine?
   A. Convert heat into work
   B. Create a large amount of energy from heat
   C. Create heat
   D. Destroy energy and replace it with work

6. Which is best to describe entropy?
   A. Another term for heat
   B. A quantity that increases as the disorder of a system increases
   C. A quantity that is conserved in any thermal process
   D. Something that never locally decreases in any process

7. What happens to the amount of usable energy in a system over time?
   A. Decreases
   B. Increases
   C. Increases sometimes decrease
   D. Remains constant

8. Which of the following statements best describes the 2nd Law of thermodynamics?
   A. The internal energy of the universe is constant
   B. Energy can neither be created nor destroyed
   C. When an isolated system undergoes a spontaneous change, the entropy of the system will increase
   D. At absolute zero, the entropy of the perfect crystal is considered to be zero.

9. Which of the following statements will always apply when a reversible chemical reaction has attained equilibrium?
   A. All reactants will convert to products
   B. The reactions proceeds alternately in the forward and reverse direction
   C. The Gibbs free energy of the system reaches a minimum
   D. The forward reaction will dominate over the reverse reaction.

10. The ideal heat engine operates between two temperatures of 600K and 900K. What is the efficiency of the engine?
   A. 50%
   B. 33%
   C. 80%
   D. 100%

11. The irreversibility of a process occurs due to what reason?
   A. Equilibrium during the process
   B. Involvement of dissipative effects
   C. Lack of equilibrium during the process
   D. Either A or B or Both

12. Which of the following is true about entropy?
   A. Entropy always increases in a spontaneous process
   B. It is a measure of how spread out thermal energy is within a system
   C. The entropy of the universe is a maximum 0 K
   D. The total entropy of the universe always decreases

13. Which of the following is an example of reversible process?
   A. Firing a bullet from a gun
   B. Quickly pouring a hot water into cold water
   C. Slowly pouring hot water into cold while allowing the container to achieve ambient temperature
   D. Striking a match

14. Which is true about reversible engine?
   A. Acts as a refrigerator
   B. Cause no increase in net entropy
   C. Does no net work
   D. Generates no net heat

15. If heat be exchanged in a reversible manner, which of the following properties of the working substance will change accordingly?
   A. Enthalpy
   B. Entropy
   C. Internal Energy
   D. Temperature

Lesson 1	Second Law of Thermodynamics; Heat Engine; and Entropy

Learning Objectives:

1. Calculate the efficiency of a heat engine;
2. Describe reversible and irreversible processes;
3. Explain how entropy is a measure of disorder;
4. State the 2nd Law of Thermodynamics; and
5. Calculate entropy changes for various processes e.g., isothermal process, free expansion, constant pressure process, etc.

What's In

Activity 1: Fix me!

Direction: Arrange the scrambled letters to form a correct word. Write your answer on the separate sheet

1. **ADCITIABA**
   -It is defined as one with no heat transfer into or out of the system.

2. **ERMOTHALIS**
   - It is a constant-temperature process, any heat flow into or out of the system must occur slowly enough that thermal equilibrium is maintained.

3. **OROCHICIS**
   - It is constant-volume process. When the volume of a thermodynamic system is constant, it does no work on its surroundings.

4. **IROBAICS**
   - It is a constant-pressure process, generally none of the three quantities ΔU, Q, and W is zero.

5. **LICCCY**
   - It is a process where the system starts and returns to the same thermodynamic state.

What's New

This time, we will perform activity related to heat, work and internal energy!

Activity 2: Looks Can Be Deceiving!

Materials:

activity sheets	hot and cold water
writing materials	used folder/ index card
2 pcs transparent bottle (glass)	2 pcs plate

dye or dyubos (red and blue) or any color of food coloring

CAUTION!!!

Be careful in handling hot objects.

Direction:

1. Completely fill one bottle with hot water. Keep filling until the water reaches the neck of the bottle.

2. Completely fill one bottle with cold water. Keep filling until the water reaches the neck of the bottle.

3. Add dye or any food color to the bottle with hot water. Watch how the drops of dye or food color mix in the water.

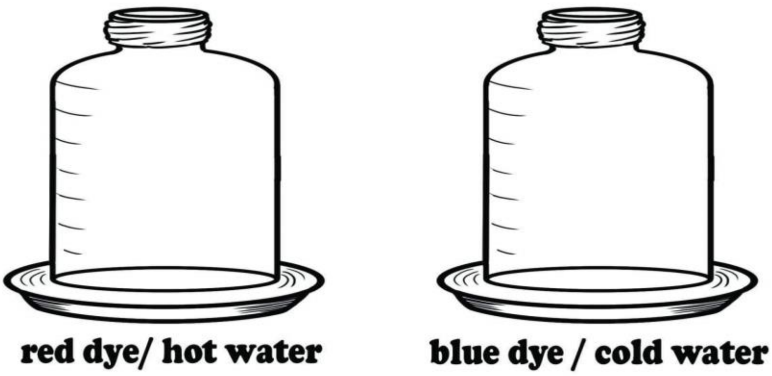


Figure 1: Bottles with hot and cold water

4. Place the two plastic plates on a table. Put one cold-water bottle on one plate, and one hot-water bottle on the other plate.

5. Cut a piece of used folder/index card slightly bigger than the opening of a bottle, and then place the card on the mouth of the hot-water bottle. Gently tap the index card. This will help to make sure that the card is in contact with the entire rim of the bottle.

6. Carefully and slowly invert the hot bottle without touching the paper, and place it directly on top of the cold-water bottle on the plate. Line up the mouths of the bottles, but leave the used folder/index card in place. This will be the set-up.

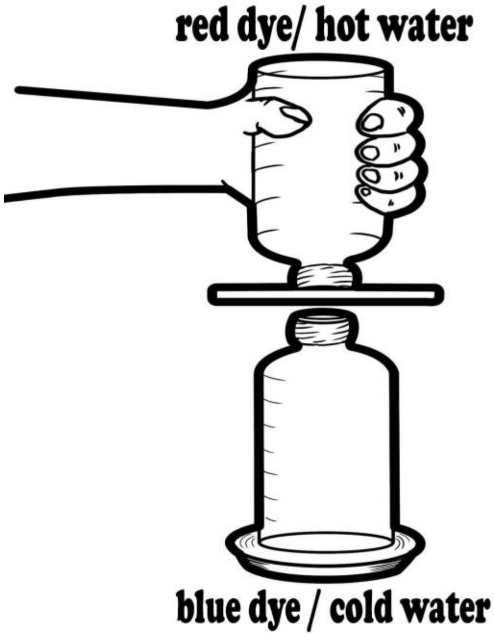
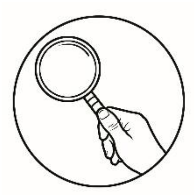


Figure 2. The Inversion of the bottles

Guide Question

1. What happens to the water in the bottle?
2. What causes the behavior of the water in the bottles?



What is It

In the first activity, there is flow of energy from the substance with higher temperature (water) to the substance with lower temperature (ice). In the second case, the flow of energy will be from the ice to the water that is why the ice became more frozen and the water's temperature increased. Both scenarios do not violate the first law of thermodynamics. Energy can be conserved in each case. However, the first law of thermodynamics does not tell the whole story. Many thermodynamic processes proceed naturally in one direction but not the opposite. For example, heat by itself always flows from a hot body to a cooler body, never the reverse. Why not? It has something to do with the directions of thermodynamic processes and is called the second law of thermodynamics.

Heat engine is any device that converts heat into mechanical work. For a heat engine to perform, the following requirements must be present: heat source (High Temperature Reservoir), heat sink (Low Temperature Reservoir), and the engine must perform work (Useful work).

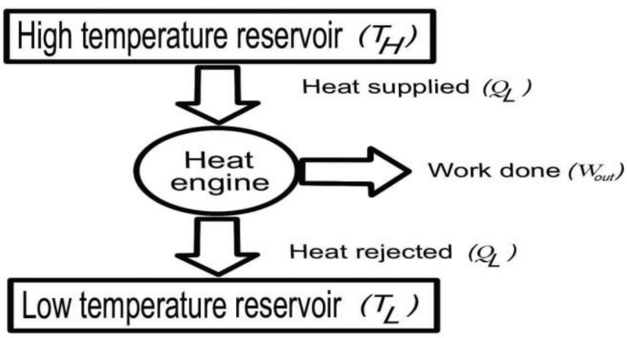


Figure 4. Heat Engine Diagram

From the diagram, heat is taken in by the engine from the high-temperature reservoir. The energy absorbed by the heat engine is used to perform useful work. However, not all heat absorbed by the engine can be converted into useful work.

There will always be a portion that will be expelled as waste. The waste heat goes to the low-temperature reservoir or the heat sink.

A heat engine does work by transferring heat from high-temperature reservoir to the low-temperature reservoir. The energy converted as useful mechanical work is equal to the difference in the heat input and the heat output.

$$\mathbf{W = Q_H - Q_C}$$

The greater the difference between the heat input and the heat output, the more work can be produced. All heat engines operate in a cycle of repeated sequences of heating (or compressing) and pressurizing the working fluid, the performance of mechanical work, and rejecting unused or waste heat to a heat sink.

Ideally, we would like to convert all the heat QH into work; in that case we would have QH = W and QC = 0. Experience shows that this is impossible; there is always some heat wasted, and QC is never zero. We define the thermal efficiency of an engine, denoted by e, as the quotient

$$e = \frac{W}{Q_H}$$

The thermal efficiency e represents the fraction of QH that is converted to work. To put it in another way, e is what you get divided by what you pay for.

Sample Problem 1

A certain engine turns 800 J of input energy into 560 J of useful work and the rest of the energy is released to the surroundings.
A) How much energy is released to the given environment?
B) What is the efficiency of an engine?

A) Given: Q_H = 800 J
W = 560 J
Find: Q_C
Solution: $Q_C = Q_H - W$
$= 800\ J - 560\ J$
$= 240\ J$
B) Find: e
Solution:

$$e = \frac{W}{Q_H}$$

$$e = \frac{560J}{800J}$$

$$e = 0.7$$

Reversible Process

A thermodynamic process is reversible if the process can return back in such that both the system and the surroundings return to their original states, with no other change anywhere else in the universe. It means both system and surroundings are returned to their initial states at the end of the reverse process.

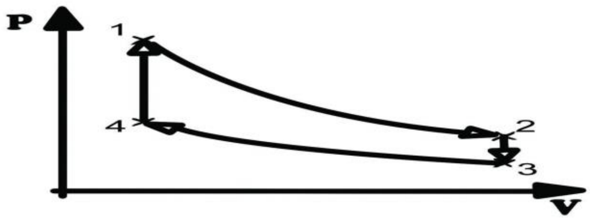


Figure 5. Reversible Process Diagram

In the figure above, the system has undergone a change from state 1 to state 2. The reversible process can reverse completely and there is no trace left to show that the system had undergone thermodynamic change. During the reversible process, all the changes in state that occur in the system are in thermodynamic equilibrium with each other.

Irreversible Process

Irreversible processes are a result of straying away from the curve, therefore decreasing the amount of overall work done. An irreversible process is a thermodynamic process that departs from equilibrium. In terms of pressure and volume, it occurs when the pressure (or the volume) of a system changes dramatically and instantaneously that the volume (or the pressure) do not have the time to reach equilibrium.

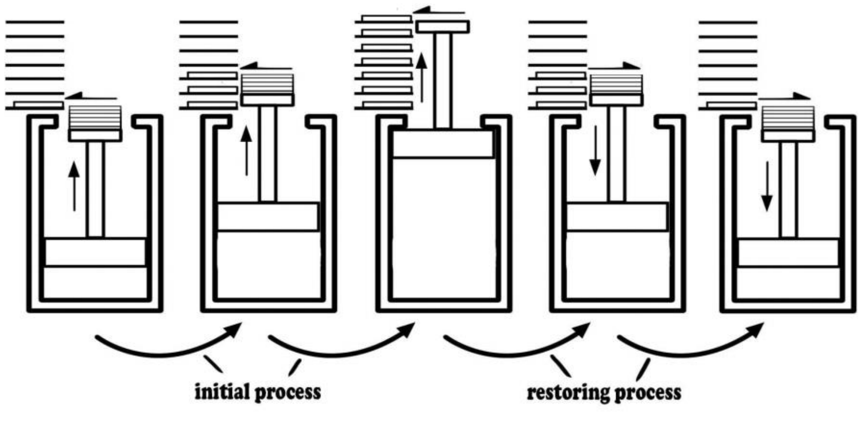


Figure 6. The Irreversible process diagram

A classic example of an irreversible process is allowing a certain volume of gas to release into a vacuum. By releasing pressure on a sample and allowing it to occupy a large space, the system and surroundings are not in equilibrium during the expansion process.

Here little work occurs. However, there is a requirement of significant work, with a corresponding amount of energy dissipation as heat flows to the environment. This is in order to reverse the process.

The first statement of the 2nd law says that heat flows in one direction in a natural process. The second statement tells us that a heat engine will always produce wasted heat: therefore, no heat engine can convert all the absorb heat into mechanical energy.

The third statement is about the quality of energy as it is transformed from one form to another. As energy is converted, some will always go to waste and only a portion will be beneficial. As it continues, the energy tends to be less and less useful; thus, becoming disorganize. The third statement for 2nd law provides that: *Natural systems tend to proceed toward a state of greater disorder.*
The measure of this degree of disorder is known as **entropy**. The statement above is also known as the **law of entropy**. According to the second law, entropy always increases. The amount of disorder depends on the amount of heat absorb by a system and its absolute temperature.

So that $$\Delta S = \frac{\Delta Q}{T}$$

Where: ΔS = change in entropy of a system (cal/K)(J/K)
ΔQ = amount of heat absorbed (cal or J)
T = the absolute temperature of a system (K)

Entropy is positive if heat is absorbed and negative if heat is released. The entropy of a system can increase or decrease, but the entropy of the universe is always increasing.

Sample problem 1

Find the change in the entropy of ice that absorbed 334 000 J of heat energy at 0°C.

Given: ΔQ = 334 000 J
T = 0°C or 273 K

Find: ΔS

Solution: $\Delta S = \frac{\Delta Q}{T}$

$= \frac{334\ 000\ J}{273\ K}$

= 1223.44 J/K

Sample Problem 2

A 0.010 kg cube of ice at 0^0C lies on ground whose temperature is 20^0C. Calculate the change in entropy that results from heat transfer from the ground to the ice, causing the ice to melt and become 0.010 kg of water at 0^0C. The ground is considered a very large reservoir whose temperature remains constant at 20^0C.

Solution:

We will calculate the entropy changes of the ice and ground separately, and then add them to find the net entropy change.

The heat needed to melt 0.010 kg of ice is given by

$$\mathbf{\Delta Q = mL_f}$$
$$= (0.010kg)(335\ 000J/kg)$$
$$= +3350J$$

The change in entropy of the ice when it melts is

$$\mathbf{\Delta S_{ice}} = \frac{\Delta Q}{Tice}$$

$$= \frac{+3350\ J}{273K}$$
$$= +12.3\ J/K$$

The ground loses just as much heat as the ice gained. Thus, the entropy change of the ground is

$$\mathbf{\Delta S_{ground}} = \frac{\Delta Q}{Tground}$$

$$= \frac{-\ 3350J}{(273+20)K}$$

$$= -11.4\ J/K$$

The net change in entropy is

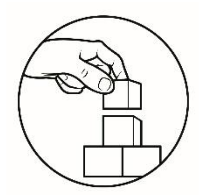
$$\mathbf{\Delta S = \Delta S_{ice} + \Delta S_{ground}}$$

$$= +12.3\ J/K + (-11.4J/K) = +0.9\ J/K$$

Since the entropy change is positive, the process is allowed by the second law of thermodynamics.

The Second Law of Thermodynamics

It states that heat generally cannot flow spontaneously from a material at lower temperature to material at higher temperature; it is impossible to convert heat completely into work in a cyclic process and natural systems tend to proceed toward a greater disorder.

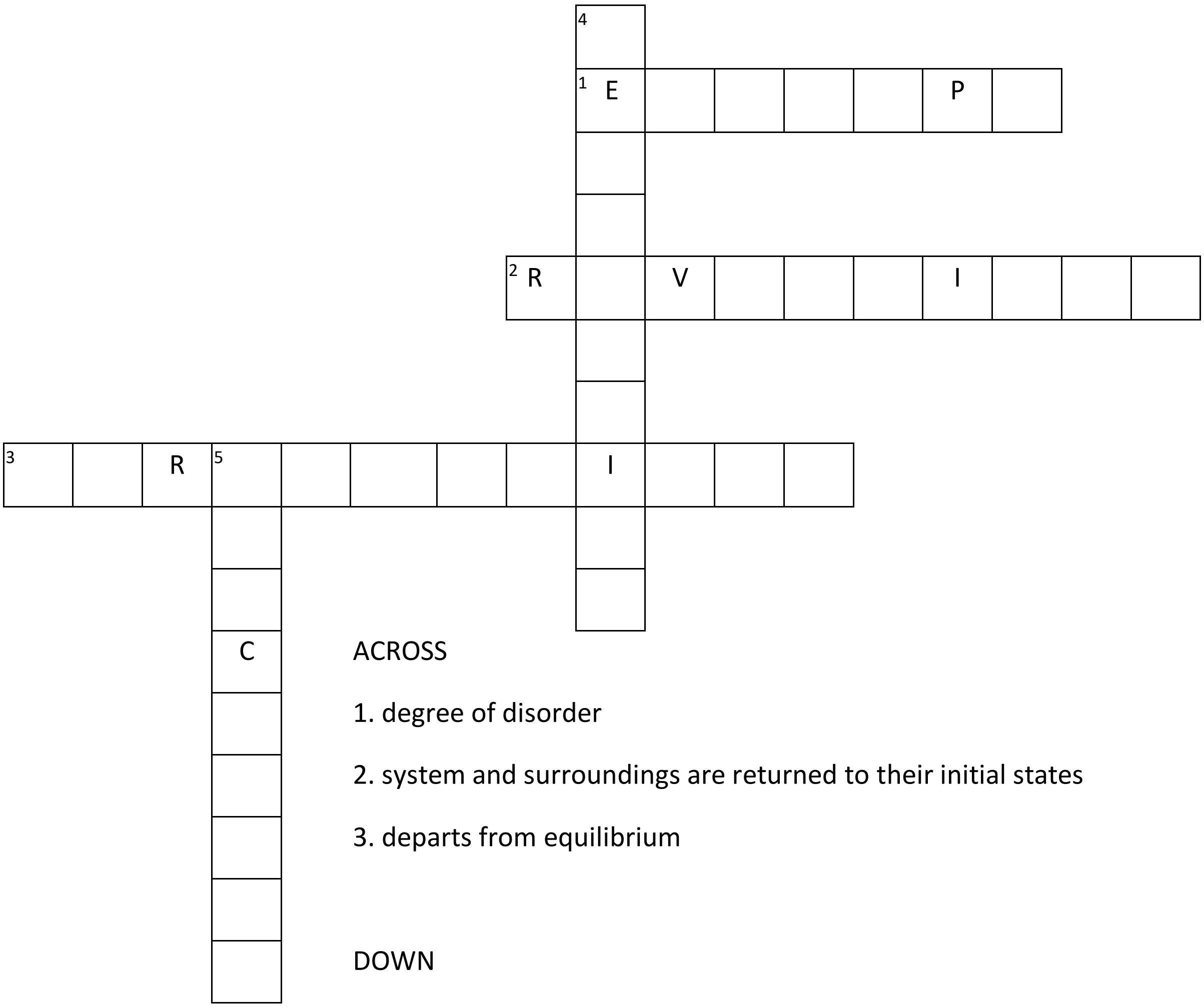


What's More

Activity 3: Work On Me!

Materials: activity sheets writing materials (pencil, pens, marker)

Direction: Fill in the missing letters in the puzzle below using the hint provided.



ACROSS

1. degree of disorder

2. system and surroundings are returned to their initial states

3. departs from equilibrium

DOWN

4.device that converts heat into mechanical work

5. represents the fraction of QH that is converted to work

Activity 4: Cool Me Down!

Materials:

activity sheet writing materials ice cubes
hot water

Procedure:

Set-up a simple experiment to understand how energy is transferred and how entropy results in a given situation.

A. Take cubes of ice. This is water in solid form, so it has a high structural order. This means that the molecules cannot move very much because it is in fixed position. The temperature of the ice is 0^0C. As a result, the entropy of the system is low.

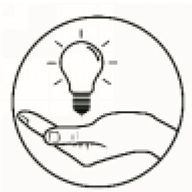
B. Allow the ice to melt at room temperature.

Guide Question:

1. What is the state of molecules in a liquid form?
2. How did the energy take place? Is the entropy of the system higher or lower? Why?

C. Heat the water to its boiling point.

3. What happens to the entropy of the system when the water is heated?



What I Have Learned

Activity 5: Test your Understanding

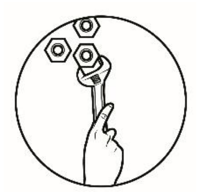
Materials:

activity sheets writing materials

Direction:

Fill in the blanks with the correct term. Write your answer on a separate piece of paper.

The (1) ____________________________ states that heat generally cannot flow spontaneously from a material at (2) ___________________________ to material at (3)__________________________; it is impossible to convert (4) ____________ completely into (5) _____________ in a cyclic process and natural systems tend to proceed toward a greater disorder.



What I Can Do

Good work! You have made it! However, you still have one more activity in which you are going to apply what you have learned in this module. It's your turn now!

Activity 6: The Submersible Ice!

Materials:

activity sheets	writing materials	Ice cubes
water	glass	timer

CAUTION!!!

Be careful in breakable objects.

Direction:

1. Prepare all the materials needed for the activity.
2. Half-filled the glass with water.
3. Place ice cubes in a glass of water.
4. Let it stay for 5 minutes and observe.

Guide Questions

1. What will happen to the ice and water?
2. Which of these two scenarios are more probable to happen? Why?
   A. The ice will melt and the water will be colder.
   B. The ice will be larger and the water will be hotter.

Assessment

Direction: Read and understand the questions. Write the letter of the correct answer on a separate sheet.

1. For a thermodynamic process to be reversible, what should be the temperature between hot body and working substance?
   A. Infinity
   B. Maximum
   C. Minimum
   D. Zero

2. A heat engine moving an efficiency of 0.20 takes in 2000 J of energy from the hot reservoir in one cycle. In the same time, how much work will it perform?
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5. Which of the following is the primary function of heat engine?
   A. Convert heat into work
   B. Create a large amount of energy from heat
   C. Create heat
   D. Destroy energy and replace it with work

6. Which is true about reversible engine?
   A. Acts as a refrigerator
   B. Cause no increase in net entropy
   C. Does not net work
   D. Generates no net heat

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   A. constant volume and constant pressure
   B. free expansion
   C. hyperbolic and pV =c
   D. isothermal and adiabatic

9. What happened to the amount of usable energy in a system over time?
   A. Decreases
   B. Increases
   C. Increases until the heat of friction equal the original potential energy in the system.
   D. Remains constant

10. Which statement best describes the Second Law of Thermodynamics?
   A. The internal energy of the universe is constant
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   B. Involvement of dissipative effects
   C. Lack of equilibrium during the process
   D. Either A or B or Both

13. Which of the following is an example of reversible process?
   A. Firing a bullet from a gun
   B. Quickly pouring a hot water into cold water
   C. Slowly pouring hot water into cold while allowing the container to achieve ambient temperature
   D. Striking a match

14. If heat be exchange in a reversible manner, which of the following property of the working substance will change accordingly?
   A. Enthalpy
   B. Entropy
   C. Internal Energy
   D. Temperature

15. Which of the following is true about entropy?
   A. Entropy always increases in a spontaneous process
   B. It is a measure of how spread out thermal energy is within a system
   C. The entropy of the universe is a maximum 0 K
   D. The total entropy of the universe always decreases

Additional Activities

Activity 7: Make a creative collage regarding the Second Law of Thermodynamics based on the statement below. The focus of the collage will be environmental preservation/protection, recycling, or waste management. Your output will be assessed based on the rubric given.

"Order is lost. The culprit is chance, and the consequence is increasing entropy. Time has a direction because the universe has a natural tendency toward disorder."

Rubric for Collage Making

CATEGORY	4	3	2	1
Creativity	All of the graphics or objects used in the collage reflect a degree of student creativity in their display.	Most of the graphics or objects used in the collage reflect student creativity in their display.	Only a few graphics or objects reflect student creativity, but the ideas were typical rather than creative.	None of the graphics or objects reflects student creativity.
Design	Graphics are cut to an appropriate size, shape and are arranged neatly. Care has been taken to balance the pictures across the area. Items are glued neatly and securely.	1-2 graphics are lacking in design or placement. There may be a few smudges or glue marks.	3-4 graphics are lacking in design or placement. Too much background is showing. There are noticeable smudges or glue marks.	Graphics are not an appropriate size shape. Glue marks evident. Most of the background is showing. It appears little attention was given to designing the collage.
Number of Items	The collage includes 15 or more items, each different.	The collage includes 10-14 different items.	The collage includes 9 different items.	The collage contains fewer than 9 different items.

Answer Key

Activity 1
Fix Me

1. Adiabatic
2. Isothermal
3. Isochoric
4. Isobaric
5. Cyclic

Activity 2

Looks Can Be Deceiving!

1. **Set-up 1 – There is no movement of the water in the bottles.**
2. **The hot water remains on top because the density of hot water is less dense than the cold one**

Pre test

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

Post test

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

Activity 5
Test your Understanding

1. **Second Law of Thermodynamics**
2. **lower temperature**
3. **higher temperature**
4. **heat**
5. **work**

Activity 6.

The Submersible Ice!

1. **The ice will float and it will dissolve in the water causing the temperature of the water to become cold.**
2. **The ice will melt and the water will be colder because the temperature of the water is higher than the ice, so heat energy from the water to the ice.**

Activity 4: Cool Me Down!

1. The state of molecule in the liquid water is in liquid form.
2. Thermal energy will be transferred from the solid form to liquid form. The entropy of the system is higher since the molecules of the liquid can easily translate or have more micro-state.
3. The entropy of the system (water) will increase when heated because its temperature also increases into a its boiling point.

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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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