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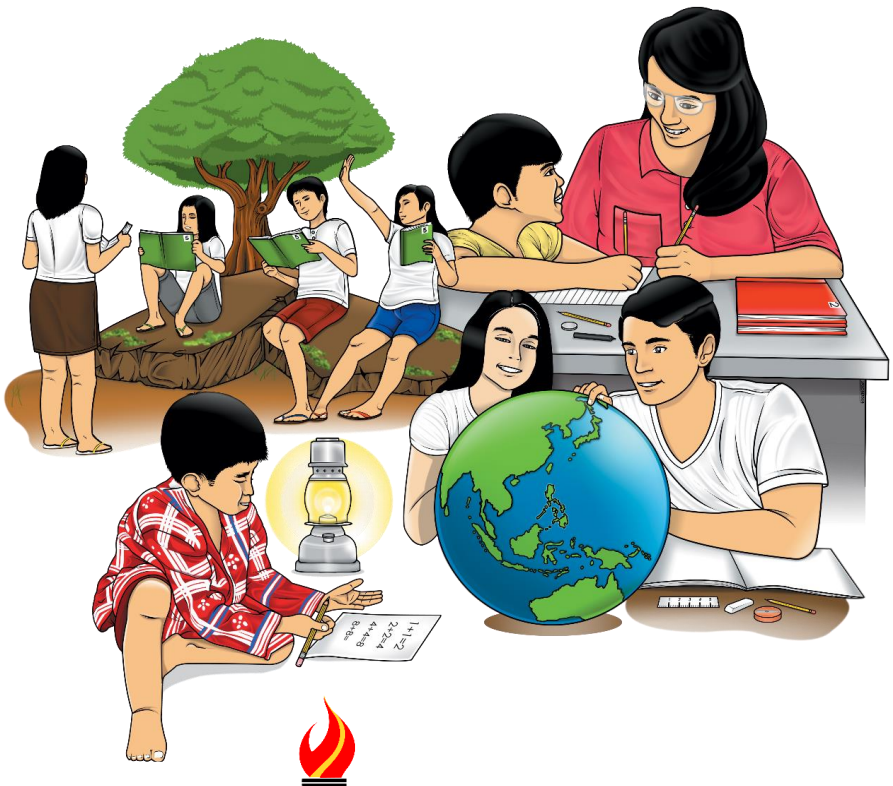
DEPARTMENT OF EDUCATION

Science

Quarter 4 – Module 7:
Heat and Work



ALTERNATIVE DELIVERY MODE
ADM

Science – Grade 9
Alternative Delivery Mode
Quarter 4 – Module 7: Heat and Work
First Edition, 2021

Published by the Department of Education
Secretary: Leonor Magtolis Briones
Undersecretary: Diosdado M. San Antonio

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Printed in the Philippines by _____

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Science

Quarter 4 – Module 7:

Heat and Work

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Introductory Message

This Self-Learning Module (SLM) is prepared so that you, our dear learners, can continue your studies and learn while at home. Activities, questions, directions, exercises, and discussions are carefully stated for you to understand each lesson.

Each SLM is composed of different parts. Each part shall guide you step-by-step as you discover and understand the lesson prepared for you.

Pre-tests are provided to measure your prior knowledge on lessons in each SLM. This will tell you if you need to proceed on completing this module or if you need to ask your facilitator or your teacher's assistance for better understanding of the lesson. At the end of each module, you need to answer the post-test to self-check your learning. Answer keys are provided for each activity and test. We trust that you will be honest in using these.

In addition to the material in the main text, Notes to the Teacher are also provided to our facilitators and parents for strategies and reminders on how they can best help you on your home-based learning.

Please use this module with care. Do not put unnecessary marks on any part of this SLM. Use a separate sheet of paper in answering the exercises and tests. And read the instructions carefully before performing each task.

If you have any questions in using this SLM or any difficulty in answering the tasks in this module, do not hesitate to consult your teacher or facilitator.

Thank you.

What I Need to Know

This module will help you learn another interesting topic which emphasizes on heat and work. It provides explanations on how heat can do work and how doing work releases heat.

The following are the lessons contained in this module:

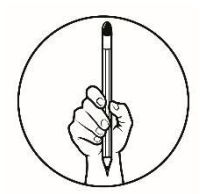
1. How heat is converted to work?
2. How is work related into heat?

The module focuses on achieving this learning competency:

Construct a model to demonstrate that heat can do work. S9FE-IVe-42

After going through this module, you are expected to:

1. Define heat and work
2. Describe how doing work releases heat
3. Cite examples where doing work is converted into heat



What I Know

Directions: Read each question carefully then choose the letter of the best answer. Write your answer on a separate sheet of paper.

1. What is energy in transit called?
   a. Thermodynamics
   b. Temperature
   c. Heat
   d. Work

2. Which refers to the study of conversions between thermal energy and other forms of energy?
   a. thermal energy
   b. thermal expansion
   c. thermodynamics
   d. thermometer

3. What is a measure of how hot or cold an object is compared to a reference point?
   a. Temperature
   b. Conductor
   c. Thermometer
   d. Thermodynamics

4. What refers to the sum of all kinetic and potential energies in the system?
   a. Gravitational energy
   b. Mechanical energy
   c. Nuclear energy
   d. Electrical energy

5. Which represents the SI unit for work?
   a. Newton
   b. Watts
   c. Calorie
   d. Joule

6. What is the happens to internal energy when both heat transfer (Q) and work done (W) are equal?
   a. The internal energy is equal to the difference of heat and work. increases
   b. The internal energy is equal to the sum of heat and work. decreases
   c. The internal energy remains the same.
   d. The internal energy has no net charge. is not affected

7. Heat is added in our body by metabolizing food, and our body does work in breathing, walking, and other activities. If we return in the same state at the end of the day, how will you describe the work and heat of our body?
   a. The amount of heat is equal to the work done
   b. Internal energy is zero.
   c. Both a and b
   d. Work done is greater than the heat added.

8. When the work is done upon the object, that object gains energy. What type of energy is acquired by the objects upon which work is done?
   a. Electrical energy
   b. Heat energy
   c. Mechanical energy
   d. Work energy

9. Which refers to the sum of kinetic and potential energies of its particles and their interactions?
   a. Mechanical energy
   b. Internal energy
   c. External energy
   d. Heat energy

10. A system's internal energy can be changed by transferring energy by either work, heat, or a combination of the two. What Law explains the system?
   a. Law of heat
   b. First law of thermodynamics
   c. Second law of thermodynamics
   d. Internal energy law

11. How does heat and work affect a system?
   a. heat and work both contribute to the total internal energy of a system
   b. heat and work do not affect to the total internal energy of a system
   c. without heat and work, there will be no internal energy of the system
   d. heat and work affects the system in a negligible impact

12. Which of the following is NOT correct?
   a. Heat and work are related.
   b. Work is measured in joules.
   c. Heat cannot be completely converted into work.
   d. Heat is a form of energy.

13. Which of the following is an example of work converted into heat?
   a. Heat engine
   b. Hand rubbing
   c. Gas stove
   d. Hot air balloon

14. What happens to the molecules in the balloons when heated?
   a. molecules collide into the balloon with more energy
   b. molecules freeze into the balloon with less energy
   c. molecules collide into the balloon with less energy
   d. molecules freeze into the balloon with no energy

15. What is the net change in internal energy (ΔU) if the amount of work done (W) is the same as the amount of energy transferred in by heat (Q)?
   a. The net internal energy is zero.
   b. The net internal energy is 1.
   c. The net internal energy is 100.
   d. The net internal energy cannot be determined.

Lesson 1 Heat and Work

You have learned in your previous years the concepts of heat and temperature. You have also learned the difference between the two. This module will help you learn another interesting topic which emphasizes on heat and work. It provides explanations on how heat can do work and how doing work releases heat.

Here are some of the key questions for you to think about after finishing this module:

1. How is heat converted to work?
2. How is work related into heat?

What's In

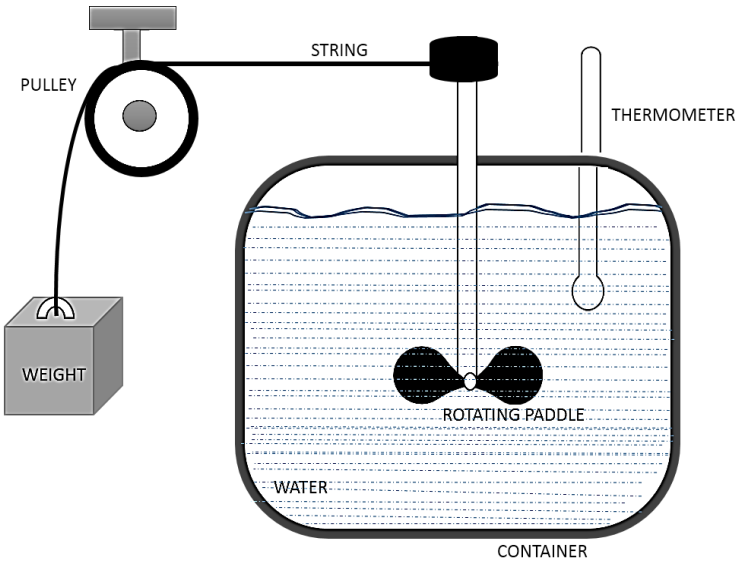


Figure 1. Joule's Experimental Setup
Illustrator: Mitchel A. Aranco

James Prescott Joule experimentally proved the mechanical equivalence of heat and work. In his experiment, Joule used a container filled with water, a paddle wheel, a certain weight, and a thermometer. He put the paddle inside a container which he connected to a hanging object. As the object fell, the paddle wheel rotated doing work on the water. The potential energy of the object decreases as it fell. Joule observed that the water's temperature rose as the wheel rotated.

Joule's experiment showed that the work done on the system can be measured by the fall of the weight. When work is done, the temperature of the system increases. A temperature change indicates that there is a transfer of heat. Therefore, the work done is equivalent to the heat transfer within the system. Heat, like work, is a method of transferring energy. Heat is the transfer of thermal energy while work is the transfer of mechanical energy.

The work done by rubbing hands vigorously for few seconds makes your hand feel warmer. When you hammer a nail, both tools become warmer. Similarly, when heat is added in our body by metabolizing food, our body does work in breathing, walking, running, playing, exercising and other activities.

What's New

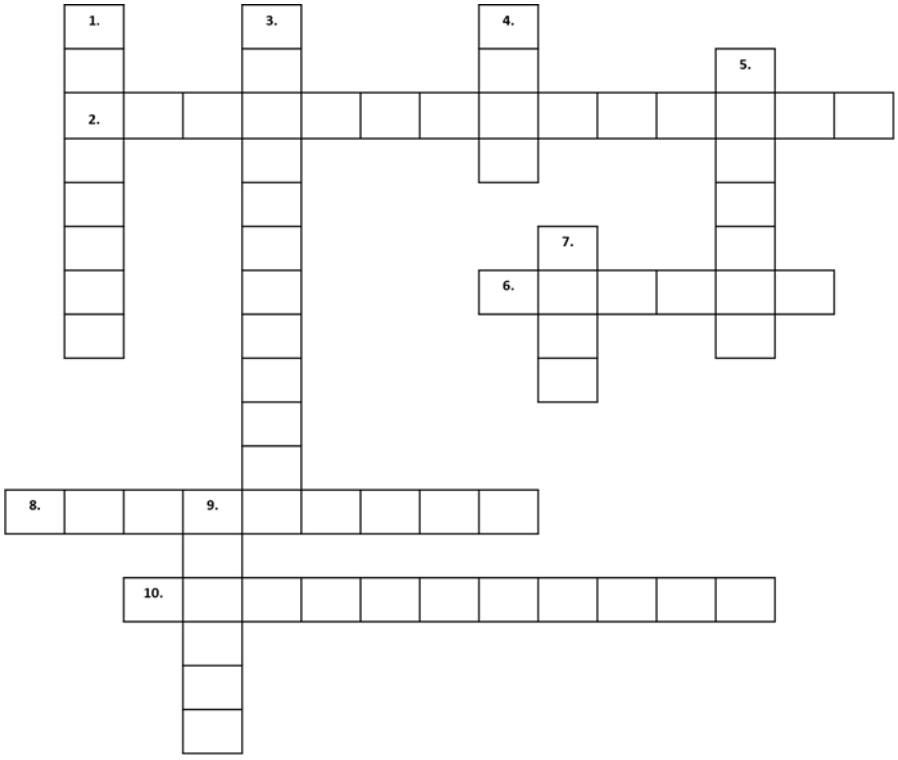
Heat and work are related. The utilization of heat to do work is often referred to as heat engines. It is a device that does work by using heat transfer or the changing thermal energy as the energy source.

In general, heat cannot be wholly transformed into work because thermal energy when converted is mostly dissipated into the system as wasted. Example is the car's thermal energy or heat which comes out of the exhaust or from the radiator. It is wasted energy.

Adding heat to a system is possible so that the system can do mechanical work. Doing mechanical work on the system will increase its internal energy. Rubbing two dry sticks together and they'll become hot. If the process happens quickly, little amount of heat is conducted out of the system, then most of the work increases the internal energy, thus, making the temperature rise.

Activity 1. Word puzzle associated to heat and work.

Direction. Fill in the crossword puzzle with words described from the sentences below. Match the number of the sentence to the boxes placed down or across the grid.

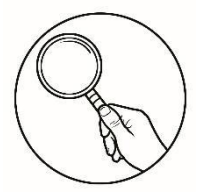


Across

2. a change from one form of energy to another
6. absolute or an ideal scale temperature scale used by most scientists
8. the energy that results from the position or shape of an object
10. the measure of how hot or cold an object is

Down

1. the sum of kinetic and potential energies of all particles in the system
3. the scientific principle that states "energy is neither lost nor created"
4. the transfer of mechanical energy
7. the transfer of thermal energy between molecules within a system
5. energy that results from the motion of an object
9. the ability to do work



What is It

Internal energy is the total energy contained in an object, including kinetic and potential energy. Internal energy is a microscopic mechanical energy, the sum of kinetic energies of all its particles and potential energies of interaction among these particles. It depends on its thermodynamic state such as heat transfer and work done. There are many ways to increase the internal energy of a thermodynamic system. If we add heat to the system and the system does no work, we increase its internal energy increases. If no heat is added during the expansion or work done by the system against its surroundings, internal energy decreases. And if we remove heat, we reduce the internal energy of the object. Internal energy is also proportional to the change in temperature since heat is also related to it. Thermal energy is related to the kinetic energy or the random motion of molecules and atoms. When an object is heated, the average kinetic energy of the molecules increases and decreases as it is cooled. You may heat the cocoa to increase the temperature or set aside to decrease the temperature due to energy gained or lost respectively.

When both work done and heat transfer occurs, the first law of thermodynamics states that the change in internal energy of a system equals the net heat transfer into the system minus the net work done by the system. This law is based on the principle of conservation of energy that it can neither be created nor destroyed. However, it can be transferred from one place to another and converted to and from other forms of energy. Heat and work both contribute to the total internal energy of a system. The law is expressed as

$$\Delta U = Q - W,$$

where

ΔU is the change in internal energy,

Q is heat added

W is work

Here's the sign convention used for the first law of thermodynamics.

Heat (Q)	+	If added to the system
	-	If removed from the system
Work (W)	+	If work is done by the system
	-	If work is done on the system
Internal Energy	$\Delta U>0$	Internal energy increases
	$\Delta U<0$	Internal energy decreases
	$\Delta U=0$	Internal energy remains the same (cyclical process)

One good example of a thermodynamic system is our body. Any collection of objects that may have the potential to exchange with its surrounding is called a thermodynamics system. Your body does work when sleeping, working, exercising, studying, watching tv and doing other related activities. Even when you're eating, work is done, but not as much as the added heat to your body by metabolizing the food. Our body undergoes a cyclical thermodynamic process if we assume that all added heat (Q) will be used to do or perform work (W). Thus, internal energy remains the same ($\Delta U=0$).

$$\Delta U = Q - W$$

Since, net Q = net W

$$\Delta U=0 \quad \text{(cyclical process)}$$

Eating food can increase the internal energy (ΔU) of your body since the work done (W) is less than the heat (Q) added. Since, Q and W are both positive and W < Q, the internal energy increases ($\Delta U>0$) since a positive value can be obtained from the given situation following the first law of thermodynamics.

$$\Delta U = Q - W$$

$$\Delta U = (+Q) - (+W)$$

$$\Delta U = \text{positive value}$$

$\Delta U>0$

Several forms of exercise can help you lose weight by using the internal energy (ΔU) stored in your body in the form of fat. You do a lot of work (W) when you exercise, and your body warms up through perspiration (-Q). Internal energy decreases ($\Delta U<0$) since a negative value can be obtained from the given situation following the first law of thermodynamics.

$$\Delta U = Q - W$$

$$\Delta U = (-Q) - (+W)$$

$$\Delta U = \text{negative value}$$

$\Delta U<0$

What's More

Activity 2. Heat and Internal Energy

Objective

The learners will demonstrate how heat causes the internal energy of the water increase.

Precautionary Measures

Read carefully the assigned home activity. When performing the activity, look for a safe and well-ventilated place protected from spills, children and pets. The activity should be done with adult supervision.

Materials:

cooking pot
thermometer
700ml or 3 cups of water
gas or electric stove

In case that no thermometer available at home, make a homemade thermometer by following the procedure below.

Figure 2. Dropping of dye or food color on the bottle. Photo Credit: Mitchel Aranco

1. Add a few drops of dye or food coloring of any color on the bottle.

Figure 3. Filling the bottle with cold water. Photo Credit: Mitchel Aranco

2. Fill the bottle with cold water.

Figure 4. Placing the straw in the bottle. Photo credit: Mitchel A. Aranco

3. Place a long straw into the bottle. Pack a clay or a dough tightly around the mouth of the bottle and straw. Keep the straw at the center of the bottle.

Figure 5. Setting the bottle into the hot container. Photo Credit: Mitchel A. Aranco

4. Put the bottle into the container of hot water. Be careful when using hot water

Procedure:

Step 1. Put 700 ml or 3 cups of water into a pot.

Step 2. Place a pot of water into a gas or electric stove. Measure the initial temperature of the water.

Step 3. Let the water boil and measure its temperature.

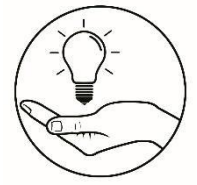
Step 4. Remove the pot from the stove and measure the temperature of the water.

Guide Questions:

Q1. Compare the temperature of water before it is boiled, while it is boiling, and after it has boiled.
Q2. What does the increase in temperature indicate?

Now you have seen that heat can increase the temperature of the water. cause the internal energy of the water to increase. Internal energy also increases since it is proportional to the change in temperature.

Temperature before boiling (°C)	Temperature while boiling (°C)	Temperature after boiling (°C)



What I Have Learned

Activity 3. Modified True or False.

Write **True** if the statement is correct, but if it's False, **change the underlined word or group of words** to make the whole statement true. Write your answer on the space provided before the number.

_____1. Heat engine is a device that converts thermal energy into <u>mechanical work.</u>

_____2. Doing mechanical work on the system will <u>decrease</u> its internal energy.

_____3. Internal energy is <u>proportional</u> to the change in temperature.

_____4. <u>Only heat</u> contributes to the total internal energy of the system.

_____5. Internal energy stored in the body is in the form of <u>fats.</u>

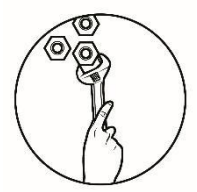
_____6. Heat <u>can be</u> completely transformed into work.

_____7. If the amount of work done (W) is the same as the amount of energy transferred in by heat (Q), the net change in internal energy is <u>1.</u>

_____8. The temperature of the system <u>increases</u> when work is done on the system.

_____9. James Prescott Joule proved that the work done is equivalent to the heat transfer within the system.

_____10. Heat is a form of energy.



What I Can Do

Although we cannot see it, thermal energy can work for us. To demonstrate this, a simple project that you can make at home with a hot air balloon will help you discover how heat works. Follow the procedure below.

Precautionary Measures

Read carefully the assigned home activity. When performing the activity, look for a safe and well-ventilated place protected from spills, children and pets. Conduct the experiment with adult supervision.

Materials

8-inch Balloon

Empty 1 liter glass bottle

2 pans

Enough Ice & Cold Water to fill one Pan

Enough Hot Boiling Water to fill another Pan

Procedures

Step 1- Place 8-inch balloon around the mouth of the empty 1 liter bottle.

Step 2 -Fill one pan with ice and cold water and fill the other pan with hot boiling water.

Step 3 - Place 1-liter bottle in the pan containing hot water and observe the balloon for 30-40 seconds.

Step 4 - Remove 1-liter bottle from a pan containing hot water and observe the balloon.

Step 5 – Place 1-liter bottle in the pan with ~~the~~ cold water and observe the balloon for 30-40 seconds.

Step 6 - Remove the bottle from the cold water and place on the table.

Guide Questions:

1. What happened to the balloon when placed in a pan with hot water?
2. What happened to the balloon when placed in a pan with cold water? Based on the activity, what causes the balloon to inflate and deflate?

Summary

- Work is the transfer of energy by any process other than heat. Like heat, the unit measurement for work is joule (J).
- The first law of thermodynamics states that the change in internal energy of a system equals the net heat transfer into the system minus the net work done by the system. Heat and work both contribute to the total internal energy of a system.
- From the equation $\Delta U = Q - W$, if the amount of work done (W) is the same as the amount of energy transferred in by heat (Q), there will be no net change in internal energy.
- If heat is added, internal energy is increased. And if we remove heat, we reduce the internal energy of the object.
- Thermal energy is related to the kinetic energy or the random motion of molecules and atoms.
- When an object is heated, the average kinetic energy of the molecules called temperature increases and decreases as an object is cooled.
- Energy cannot be created or destroyed. However, it can be transferred from one place to another and converted to and from other forms of energy.
- The sign convention used for the first law of thermodynamics.
    - Heat (Q) is + if it is added to the system
    - Heat (Q) is - If removed from the system
    - Work (W) is + If it is done by the system
    - Work (W) is - if it is done on the system
    - $\Delta U>0$ Internal energy increases
    - $\Delta U<0$ Internal energy decreases
    - $\Delta U=0$ Internal energy remains the same (cyclical process)

Assessment

Multiple Choice. Select the letter of the best answer from among the given choices.

1. What is energy in transit called?
   a. Thermodynamics b. Temperature c. Heat d. Work
2. Which represents the SI unit for work?
   a. Newton b. Watts c. Calorie d. Joule
3. What refers to the sum of all kinetic and potential energies in the system?
   a. Gravitational energy c. Nuclear energy
   b. Mechanical energy d. Electrical energy
4. Which refers to the study of conversions between thermal energy and other forms of energy?
   a. Thermal energy c. Thermodynamics
   b. Thermal expansion d. Thermometer
5. What is a measure of how hot or cold an object is compared to a reference point?
   a. Temperature b. Conductor c. Thermometer d. Thermodynamics
6. A system's internal energy can be changed by transferring energy by either work, heat, or a combination of the two. What Law explains the system?
   a. Law of heat
   b. First law of thermodynamics
   c. Second law of thermodynamics
   d. Internal energy law
7. Which refers to the sum of kinetic and potential energies of its particles and their interactions?
   a. Mechanical energy c. External energy
   b. Internal energy d. Heat energy
8. When the work is done upon the object, that object gains energy. What type of energy is acquired by the objects upon which work is done?
   a. Electrical energy
   b. Heat energy
   c. Mechanical energy
   d. Work energy

9. Heat is added in our body by metabolizing food, and our body does work in breathing, walking, and other activities. If we return in the same state at the end of the day, how will you describe the work and heat of our body?
   a. The amount of heat is equal to the work done
   b. Internal energy is zero.
   c. Both a and b
   d. Work done is greater than the heat added.
10. What is the happens to internal energy when both heat transfer (Q) and work done (W) are equal?
   a. The internal energy is equal to the difference of heat and work. increases
   b. The internal energy is equal to the sum of heat and work. decreases
   c. The internal energy remains the same.
   d. The internal energy has no net charge. is not affected
11. Which of the following is an example of work converted into heat?
   a. Heat engine
   b. Hand rubbing
   c. Gas stove
   d. Hot air balloon
12. What happens to the molecules in the balloons when heated?
   a. molecules collide into the balloon with more energy
   b. molecules freeze into the balloon with less energy
   c. molecules collide into the balloon with less energy
   d. molecules freeze into the balloon with no energy
13. What is the net change in internal energy (ΔU) if the amount of work done (W) is the same as the amount of energy transferred in by heat (Q)?
   a. The net internal energy is zero.
   b. The net internal energy is 1.
   c. The net internal energy is 100.
   d. The net internal energy cannot be determined.
14. How does heat and work affect a system?
   a. heat and work both contribute to the total internal energy of a system
   b. heat and work do not affect to the total internal energy of a system
   c. without heat and work, there will be no internal energy of the system
   d. heat and work affect the system in a negligible impact

15. Which of the following is NOT correct?

a. Heat and work are related.

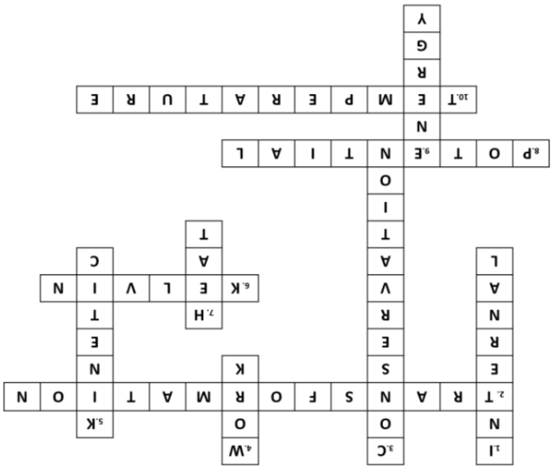
b. Work is measured in joules.

c. Heat cannot be completely converted into work.

d. Heat is a form of energy.

Answer Key

What's New



Pre-test	
1.	C
2.	C
3.	A
4.	B
5.	D
6.	C
7.	A
8.	C
9.	B
10.	B
11.	A
12.	D
13.	B

Post-test
1. C
2. D
3. B
4. C
5. A
6. B
7. B
8. C

Guide Questions

Compare the temperature of water before it is boiled, while it is boiling, and after it has boiled.

The temperature of the water after boiling is higher that than the temperature when it wasn't boiled.

Q2. What does the increase in temperature indicate?

The increase in temperature means that the substance is getting hotter. It's internal energy is rising.

What I Have Learned

1. true
2. increase
3. true
4. heat and work
5. true
6. cannot be
7. 0
8. true
9. true
10. transfer of energy

What I Can Do

Guide Questions

What happened to the balloon when placed in a pan with hot water? The balloon inflates.
What happened to the balloon when placed in a pan with cold water? The balloon deflates.
Based on the activity, what causes the balloon to inflate and deflate?
When heated, the air molecules inside start to move faster. These molecules now collide into the balloon with more energy resulting in increased pressure. The increased pressure causes the balloon to expand. When the bottle is placed into the pan of ice-cold water, the cold water causes the air inside the bottle to cool down. The air then moves out of the balloon and back into the bottle, causing the balloon to deflate.

References

Books:

DepEd Science 9 Learner's Module. (2014). P306.

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