# Module 14
# The Laws of Thermodynamics

## What this module is about

The Law of Conservation of Energy is such a powerful tool in understanding our physical world. Because of this, we are able to explain how objects behave – from the very small atomic particles to the very large planetary bodies. In this module we will study how the law of energy conservation is restated through the laws of thermodynamics. For us to do it, we will go through the following lessons:

- **Lesson 1 – Historical Background of Thermodynamics**
- **Lesson 2 – First Law of Thermodynamics**
- **Lesson 3 – Second Law of Thermodynamics**
- **Lesson 4 – Heat Engines and Refrigerators**

## What you are expected to learn

After going through this module, you are expected to:

1. trace the historical background and development of thermodynamics;
2. relate internal energy, heat and mechanical work in thermodynamic systems;
3. describe the direction of heat flow in natural processes; and
4. analyze the directions of thermodynamic processes in heat engines and refrigerators.

## How to learn from this module

Going through this module can be both a fun and a meaningful learning experience. All you need to do is make use of your time and resources efficiently. To do this, here are some tips for you:

1. Take time in reading and understanding each lesson. It is better to be slow but sure than to hurry finishing the module only to find out that you missed the concepts you are supposed to learn.

2. Do not jump from one chapter to another. Usually, the lessons are arranged such that one is built upon another, hence an understanding of the first is essential in comprehending the succeeding lessons.
3. Be honest. When answering the test items, do not turn to the key to correction page unless you are done. Likewise, when performing experiments, record only what you have really observed.
4. Safety first. Perform the experiments with extra precaution. Wear safety gears whenever necessary.
5. Don't hesitate to ask. If you need to clarify something, approach your teacher or any knowledgeable person.

## *What to do before (Pretest)*

**Multiple Choice. Select the letter of the option that correctly answers the question or completes the statement.**

1. Which of the following laws of physics becomes the foundation of thermodynamics?
    a. Newton's laws of motion
    b. Law of conservation of energy
    c. Law of universal gravitation
    d. Law of conservation of momentum

2. The word *thermodynamics* stems from two Greek words meaning
    a. conservation of heat
    b. interactions of heat
    c. study of heat
    d. movement of heat

3. When heat is added to a system, all of the following may happen EXCEPT
    a. increase in internal energy.
    b. decrease in the system's temperature.
    c. external work is done by the system.
    d. increase in the pressure in the system.

4. When you place a cube of ice in your palm, heat flows
    a. from your palm to the ice cube.
    b. from the ice cube to your palm.
    c. simultaneously to your palm and to the ice.
    d. from the ice to the environment.

5. What must be the sink temperature of a frictionless heat engine so that it can be 100% efficient?
    a. 0 $^0$C
    b. 0 K
    c. equal to its input temperature
    d. less than its input temperature

6. All real refrigerators require **work** to get heat to flow from a cold area to a warmer area. Which of the following parts of the refrigerator does **work** for this purpose?
    a. coils
    b. lamp
    c. condenser
    d. motor

7. What is the efficiency of a heat engine that operates between reservoirs of temperatures as 1400 K and 1000 K?
    a. 4%
    b. 29%
    c. 40%
    d. 100%

8. A system does no work even when heat is added to it. Which of the following may happen to the system?
    a. The system expands
    b. The internal energy of the system increases
    c. Both a and b
    d. Neither a nor b

9. The working substance used in most refrigerators is a
    a. gas that is easy to liquefy.
    b. gas that is hard to liquefy.
    c. liquid that is easy to solidify.
    d. liquid that is hard to solidify.

10. What do you call an object that does not significantly change in temperature and internal energy even when heat is removed or added to it?
    a. Heat sink
    b. Reservoir
    c. Working substance
    d. Heat engine

11. Which of the following explains why it is **NOT** possible to extract heat from a reservoir to do work and to expel the heat to a reservoir of the same temperature as the source reservoir?
    a. Heat does not travel for objects of the same temperature.
    b. Energy is not conserved for interactions of objects of the same temperature.
    c. The working substance is not present for such a system.

d. The engine would be very inefficient.

12. The natural direction of heat flow is from high-temperature reservoir to a low-temperature reservoir, regardless of their respective heat contents. This fact is incorporated in the
    a. first law of thermodynamics.
    b. second law of thermodynamics.
    c. law of conservation of energy.
    d. law of conservation of entropy.

13. In any process the maximum amount of mechanical energy that can be converted to heat
    a. depends on the intake temperature.
    b. depends on the intake and exhaust temperature.
    c. depends on whether kinetic or potential energy is involves.
    d. is 100%.

14. A heat engine takes in heat from a reservoir, does work using this energy and expels heat at another reservoir with
    a. the same temperature as the source reservoir.
    b. lower temperature than the source reservoir.
    c. higher temperature than the source reservoir.
    d. either higher or lower temperature than the source reservoir.

15. The heat intake of heat engines come from the
    a. burned fuel.
    b. interaction of the engine with its surroundings.
    c. friction between the engine's piston and cylinder.
    d. all of the above

**Key to answers on page 27**

**Can you still recall the following terms?**

Before we begin our lesson on thermodynamics, let us review some important concepts you have learned in the previous modules. To know whether you have already mastered these concepts or not, how about challenging yourself with this short test?

## *What you will do*

**Activity 1.1**

**Direction: Fill in the boxes with the correct letters to complete the statement below. Below the statement, you can find the definition of the term being referred to in the statement.**

1. A cup and a drop of boiling water have the same [boxes] of 100° Celsius.

   **(It is the measure of the hotness and coldness of a body.)**

2. The ocean and a cup of seawater may have the same temperature but different [boxes] energy.

   **(It is the energy associated to the random motion of all molecules in a substance)**

3. When two objects having different temperature are placed in contact with one another, [boxes] flows from the hot object to the cold object.

   (**It is the energy in transit from a body of higher temperature to a body of lower temperature)**

4. Matter does not contain heat; rather it contains [boxes] energy.

   **(It is the sum total of the potential and kinetic energies of the molecules of a substance)**

5. As the water boils, the lid of the pot begins to move up. We say the air inside has done [boxes] on the lid as it pushes the lid upward.

   **(It is the product of the force on an object and the distance through which the object is moved)**

How did you find the test? Are you ready to proceed to our next lesson now? Make sure that before you go on any further, you already have mastered these concepts because you will be using them all throughout this module. If you are not so sure of your answers, you may turn to the key to answers.

**Key to answers on page 27**

## Lesson 1 Introduction and Historical Background of Thermodynamics

What happens whenever we use energy to do work? If you try to rub your hands briskly, what is produced? Heat, right? Do you observe that heat is also produced every time you use your appliances at home? How about when you drive a car? In the above observations, do you think there is a relationship between energy, mechanical work and heat?

**Thermodynamics** is the study of heat and its transformation to mechanical energy. It is coined from the Greek words meaning "movement of heat". Because it was developed in the 1800's when the atomic and molecular nature of matter was yet to be understood, thermodynamics bypasses the microscopic and molecular details of systems. Rather, it focuses on the macroscopic (macro, meaning large scale) level – mechanical work, pressure, temperature and their roles in energy transformation.

Like the other branches of physics, thermodynamics is also governed by laws which are restatements of the law of conservation of energy. Do you still remember this law? This module will discuss the two important laws of thermodynamics. But before that, let us travel back and take a look at how this field is developed.

Historically, the term **energy**, which may be defined as the capacity to produce an effect, was used as early as the 17th century in the study of mechanics. The transfer of energy in the form of heat was not correctly associated with mechanical work, however, until the middle of the $19^{th}$ century when the first law of thermodynamics or the principle of the conservation of energy was properly formulated.

In 1824 the French military engineer Sadi Carnot introduced the concept of the heat-engine cycle and the principle of reversibility, both of which greatly influenced the development of the science of thermodynamics. Carnot's work concerned the limitations on the maximum amount of work that can be obtained from a steam engine operating with a high-temperature heat transfer as its driving force. Later that century, his ideas were developed by Rudolf Clausius, a German mathematician and physicist into the second law of thermodynamics, which introduced the concept of entropy. Ultimately, the second law states that every process that occurs in nature is irreversible and unidirectional, with that direction being dictated by an overall increase in entropy. It, together with the first law, forms the basis of the science of classical thermodynamics.

Classical thermodynamics does not involve the consideration of individual atoms or molecules. Such concerns are the focus of the branch of thermodynamics known as statistical thermodynamics. This field attempts to express macroscopic thermodynamic properties in terms of the behavior of individual particles and their interactions. It has its roots in the latter part of the 19th century, when atomic and molecular theories of matter began to be generally accepted.

The 20th century has seen the emergence of the field of non-equilibrium or irreversible thermodynamics. Unlike classical thermodynamics, which assumes that the initial and final states of the substance being studied are states of equilibrium (i.e., there is no tendency for a spontaneous change to occur), non-equilibrium thermodynamics investigates systems that are not at equilibrium. Early developments in non-equilibrium thermodynamics by the Norwegian-American chemist Lars Onsager concerned systems near, but not at, equilibrium. The subject has since been expanded to include systems far away from equilibrium.

## *What you will do*

**Self-Test1.1**

1. Thermodynamics focuses on the macroscopic details of systems. Which of the following is NOTused to describe a system macroscopically?
    a. Temperature
    b. Pressure
    c. Work
    d. Mass

2. Which of the following types of engines was first used and studied?
    a. Steam engines
    b. Gasoline engines
    c. Diesel engines
    d. Internal combustion engines

3. Who introduced the concept of heat engine and reversibility on thermodynamics?
    a. Rudolf Clausius
    b. Sadi Carnot
    c. Blaise Pascal
    d. Robert Boyle

4. Which of the following is TRUE about thermodynamics?
    a. It is based on conservation principle.
    b. It deals with energy.
    c. It discusses direction of heat movements.
    d. All of the above

5. According to the laws of thermodynamics, all processes occurring in nature are
    a. reversible and unidirectional
    b. irreversible and unidirectional
    c. reversible and bidirectional
    d. irreversible and bidirectional

**Key to answers on page 27**

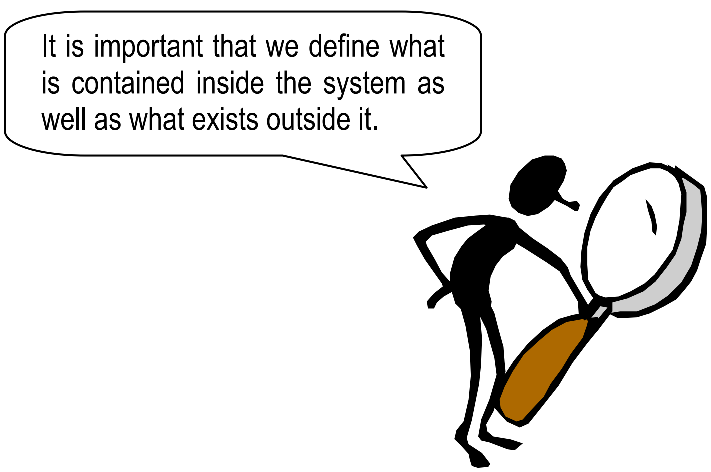
## Lesson 2 First Law of Thermodynamics

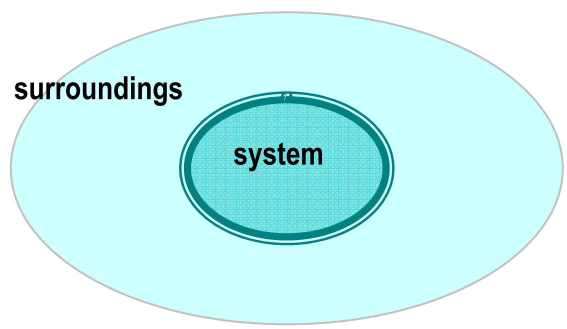
The first law of thermodynamics is an extension of the law of energy conservation when applied to thermodynamic systems. Can you still recall what this law is about? The **Law of Conservation of Energy** states that:

> **"Energy cannot be created nor destroyed. It can only be transformed into another form but the total amount of energy remains the same."**

How energy is conserved is shown when you eat breakfast in the morning. The chemical energy in food will be converted into mechanical energy that enables you to do work like walking, running, and climbing stairs. But not all the chemical energy in the food you take will be transformed into mechanical energy. Some of it will be released from your body as heat, that is, when you sweat and feel warm. So you see, in the law of conservation of energy, we talk here of energy, work and heat. How are these three quantities related when we speak of thermodynamic systems?

But let us first define what a thermodynamic system is. In thermodynamics, a **system** is any region completely enclosed within a well-defined boundary and everything outside this system is considered its **surroundings**. The system might be a biological organism, a mechanical device or the whole of the earth's atmosphere.




The first law is all about the relationship between internal energy, heat, and work. To find out how these three quantities are related, perform this simple activity:

## *What you will do*

**Activity 2.1 Popping popcorns**

**What you will need**

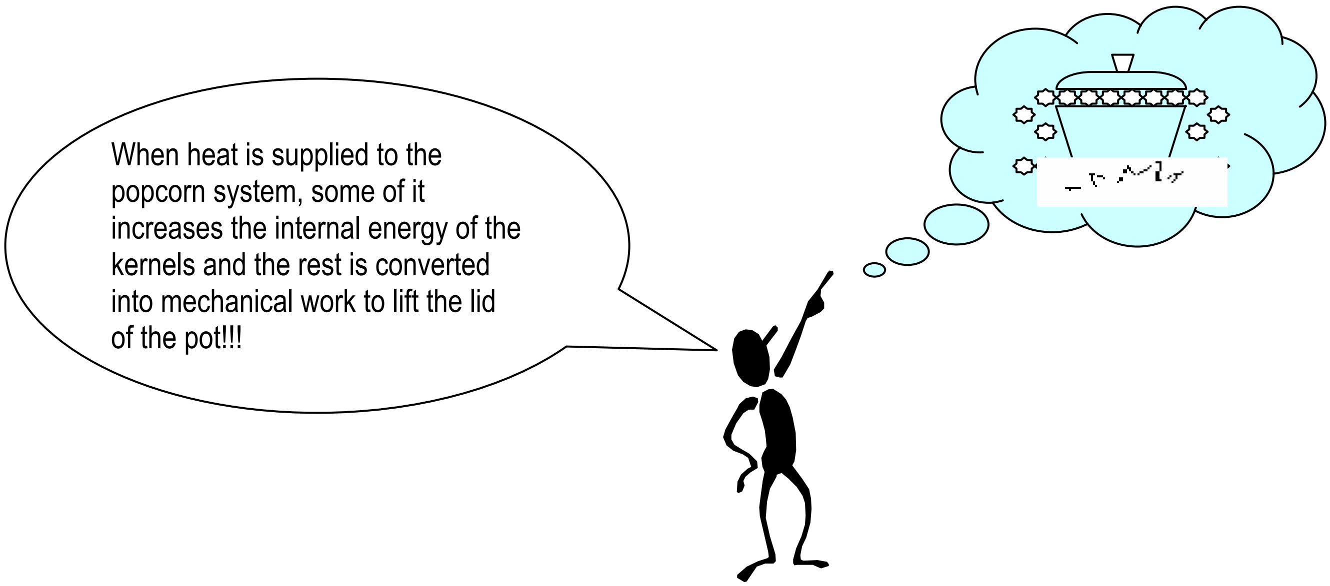
- A pack of popcorn kernels
- a small pot with lid
- stove

**What to do**

1. Place the pot over low fire and wait for a few seconds to make the pot hot.
2. Put the popcorn kernels in the pot and cover it with the lid.
3. After a few minutes, what happens to the kernels?
4. Wait for another few minutes for all the kernels to pop. What do you observe on the lid of the pot?

To analyze the experiment above, it is important for you to define clearly what exactly is and is not included in the system. What do you think is the thermodynamic system that we should consider here? Is it the popcorn, the pot, the lid, or the stove? In order for us to describe clearly the energy transfer in and out of the system, we only have to consider the popcorn to be the thermodynamic system in this experiment and the pot and its lid to be the surroundings.

When the popcorn inside the pot was placed over fire, what quantity is being added into the system? It is **heat**, right? Energy is added to the popcorn by conduction of heat. Now, what happened to the kernels after heat is supplied to them? Of course, each kernel began to pop and expand. In this process, what changes took place in the popcorn? First, the temperature of the popcorn increased; second, as the popcorn expands its volume also increased and consequently, pressure is also raised. Because of these changes in the state of the popcorn, what happened to its **internal energy**? Definitely, it also increased. Now, when almost all the popcorn kernels have popped, what do you observe with the lid of the pot? The lid began moving up as the popcorn pushed their way out of the pot to give space for other popcorns inside to expand. Can you guess what the popcorn has done to the lid of the pot? Of course, **work**! The popcorn has done work by pushing the lid up to a certain distance. Can you see the relationship now?




This is the First Law of Thermodynamics: The heat added to a system is equal to the sum of the increase in internal energy plus the external work done by the system.

In simple terms,

**Heat input = increase in internal energy + work output**

The first law of thermodynamics is not just about popping popcorns. It provides the basic principle used in heat engines, from steam turbines to nuclear reactors. It has its obvious application in transportation.

A train that runs in a steam engine operates by burning wood or coal in the engine. Heat is generated, thus increasing the temperature of the engine's water. As the water boils, it produces steam. The expansion of this steam does work and propels the train forward.

Even the jet engines of airplanes or the common automobile engines use the heat of combustion of their fuel to do work in making these vehicles move.

## *What you will do*

**Self-Test 2.1**

**Select the letter of the choice that correctly answers the questions or completes the statements.**

1. The heat added to a system is used to increase the system's
    a. internal energy.
    b. work input.
    c. pressure.
    d. all of the above

2. The first law of thermodynamics is a restatement of what conservation principle?
    a. Law of conservation of mass
    b. Law of conservation of momentum
    c. Law of conservation of energy
    d. Law of conservation of charges

3. Which of the following illustrates the work done by steam emerging from boiling water in a kettle?
    a. The steam pushes the cover of the kettle.
    b. The steam blows objects placed near it.
    c. The steam emerging from the kettle's mouth produces sound.
    d. All of the above

4. If 5 J of energy is added to a system that does no external work, by how much will the internal energy of that system be raised?
    a. 0 J
    b. 5 J
    c. 10 J
    d. Cannot be determined

5. Steam engines operate by boiling water to produce steam. The work done by steam is due to

    **I. the expansion of water as it turns into steam**

    **II. the thermal energy supplied by the burning wood or coal in the engine**

a. I only
b. II only
c. Both I and II
d. Neither I nor II

**Key to answers on page 27**

## Lesson 3 Second Law of Thermodynamics

Let us begin studying the second law by performing a simple experiment.

**What you will need**

- 2 blocks of metals of the same size and dimensions
- thermometer

**What to do**

1. Place one block of metal in the freezer for about 10 minutes. Before taking it out from the freezer, measure its temperature using a thermometer.
2. At the same time, put the other block over fire or immerse it in boiling water. Measure its temperature also.
3. Get the two blocks and place them in contact for 3 – 5 minutes. Get the temperature of each block.
4. Record your data in the table below.

| Blocks | Temperature (°C) | |
|---|---|---|
| | Before contact | After contact |
| Block A (hot) | | |
| Block B (cold) | | |

What did you observe in the experiment? After the blocks are placed in contact, what happened to their temperatures? The hot block became cooler and the cold block became warmer, right? If so, what does this tell you? Because of the reduced temperature of the hot block, we can say that heat is removed from the hot block and transported to the cooler block and to the surroundings. If we neglect the block’s interaction with the surroundings, we can also say that the cooling of the hot block is proportional to the warming of the cold block. This is true because energy is conserved.

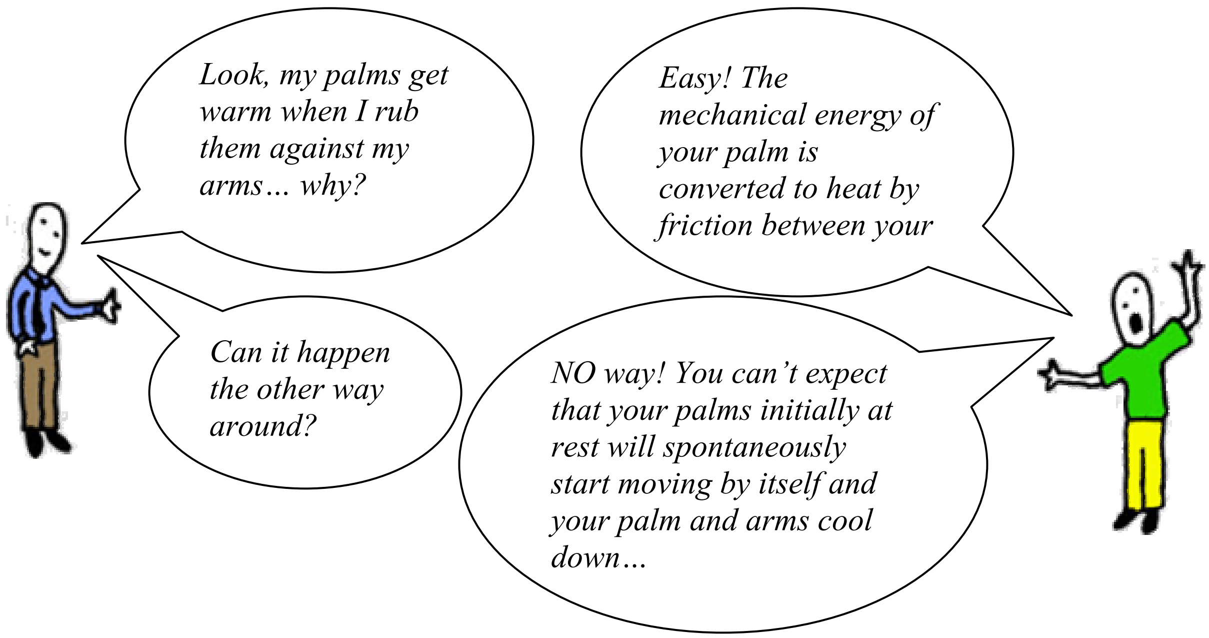
This observation on the direction of heat does not just hold true for the blocks we have experimented. In fact, it governs all natural phenomena. The way ice melts, the changes in weather and operation of engines are all governed by the second law of thermodynamics.

**Remember this**

**Heat always naturally travels from object of internal energy at higher temperature to object of internal energy of lower temperature.**

Is it also possible that heat travels from a cold object to a hot object? Hmm, well you might be thinking it maybe possible. After all, it will not violate the law of conservation of energy. But it seems to violate the second law! This will now remind us that thermodynamic processes occurring in nature are irreversible. Irreversible processes are those that proceed spontaneously in one direction but not conversely.

Before we wrap up our discussion of the second law, let us consider another scenario illustrated in the comic strip on the next page.




Indeed, it is very easy to convert all mechanical energy into heat. But heat can only be partially converted to mechanical energy. We have never succeed in building a machine that converts heat completely into mechanical energy so it can power up cars, ships, and other machines of all kinds. Again, why not?

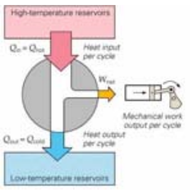
The answer to this has something to do with the second law of thermodynamics stated as:

**Remember these:**

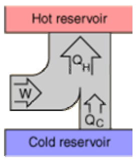
- **The natural direction of heat flow is from object of higher temperature to object of lower temperature.**
- **It is impossible to construct an engine operating in cycle that converts heat totally into mechanical energy to do an equivalent amount of work.**

But can we really not reverse the process? Of course we can but we have to do something to alter the natural process such that it would not violate both the first and the second laws of thermodynamics. We will know how to reverse the process as we study heat engines and refrigerators:

**Let us take a quick look!**



- **Heat engines take heat from a hot reservoir, use some of it to do work and exhaust the rest to a cooler reservoir as waste.**




- **Refrigerators take heat from a cold reservoir and partially transport it to a hotter reservoir by doing some amount of work.**

## *What you will do*

**Self-Test 3.1**

**Select the letter of the option that answers each question or completes the statements.**

1. When an ice cube is placed in a glass of hot water, heat moves
   a. from the ice cube to the water.
   b. from the water to the ice cube.
   c. from the ice cube to the glass.
   d. from the ice cube to the surrounding air.

2. All processes occurring in nature are
   a. reversible.
   b. irreversible.
   c. ideal.
   d. spontaneous.

3. When a book slides over a table
   a. mechanical energy is converted to heat.
   b. heat is converted to mechanical energy.
   c. heat is converted to work.
   d. mechanical energy is converted to friction.

4. Two objects of different temperatures are insulated from their surroundings. If the hotter object cools by 4 K, the other object
    a. also cools by 4 K.
    b. warms by 4 K.
    c. warms by less than 4 K.
    d. may become warmer or cooler depending on the type of materials the object is made of.

5. Heat naturally travels
    a. from cold to hot objects.
    b. from hot to cold objects.
    c. from/to objects of the same temperature.
    d. cannot be predicted.

**Key to answers on page 27**

## Lesson 4 Heat Engines and Refrigerators

### Heat Engines

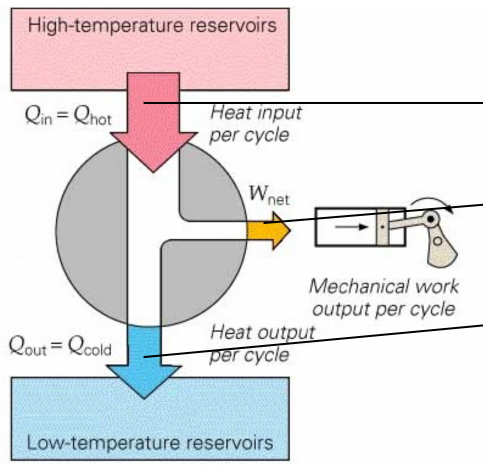
What is your concept of an engine? Maybe you're thinking of the engines that run cars and trucks, or the engines farmers use to pump water to their crops. These are the most modern kinds of engines that we have now that make use of commercial fuels like gasoline. What was life like before gasoline was discovered? Do you know that the people used water to run the first kind of engines, the steam engines? How did they do that? They boiled water to produce steam. The steam formed then spun the turbines connected to the wheels of their vehicles.

Although steam engines are primitive compared to the engines we have now, their process of operation remained generally the same. A **heat engine** is any device that changes internal energy into work.

Heat engines operate between reservoirs of different temperatures. A **reservoir** is any body that can give off or accept heat without a significant change in its internal energy or temperature. Every heat engine has working substances in them. The **working**

**substance** is a quantity of matter that undergoes inflow and outflow of heat, compression, expansion and sometimes change in phase.

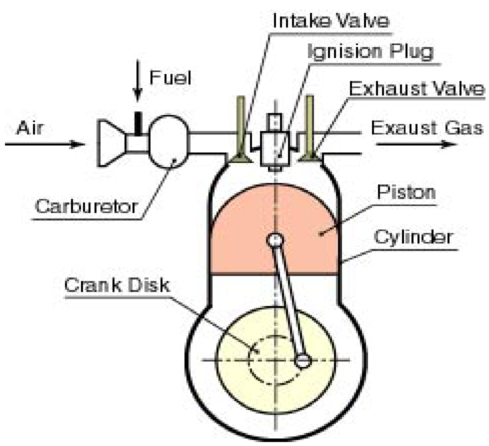
Let's take a look at the schematic diagram of a heat engine.




**The heat engine**

- absorbs heat from a reservoir of higher temperature thus increasing its internal energy
- converts some of this energy to work
- expels the remaining energy as heat to a reservoir of lower temperature. This low-temperature reservoir is called **sink.**

One of the examples of heat engine is a gasoline engine. This is like the one that runs motorcycles and other machines at home.




The burning fuel in the combustion chamber is the high temperature reservoir

The energy from the burned fuel does work on the pistons of the engine. How? It makes the piston move up and down, and this eventually makes the gears of the motorcycle move.

The energy that is not used to do work is expelled as exhaust to the low-temperature reservoir, which is its surroundings.

We can see from our example that not all the energy is used to do work. The remainder is expelled in the heat sink. This is another statement of the second law of thermodynamics.

An engine that converts energy into more work and less waste is said to be more efficient. However, Sadi Carnot have found out that while it is true that we can express efficiency in terms of work, the efficiency of ideal heat engines depends only on the temperatures of the hot and cold reservoir. According to him, an engine operating between two reservoirs of higher temperature difference is more efficient than an engine operating between reservoirs of nearly the same temperatures.

To compute the ideal efficiency of heat engines, we use the formula shown in the box.

$$\textbf{Ideal Efficiency} = \frac{T_{hot} - T_{cold}}{T_{hot}} \times 100$$

If an engine extracts heat from a 2730 Kelvin reservoir and expels heat at 1730 Kelvin reservoir, it has an efficiency of

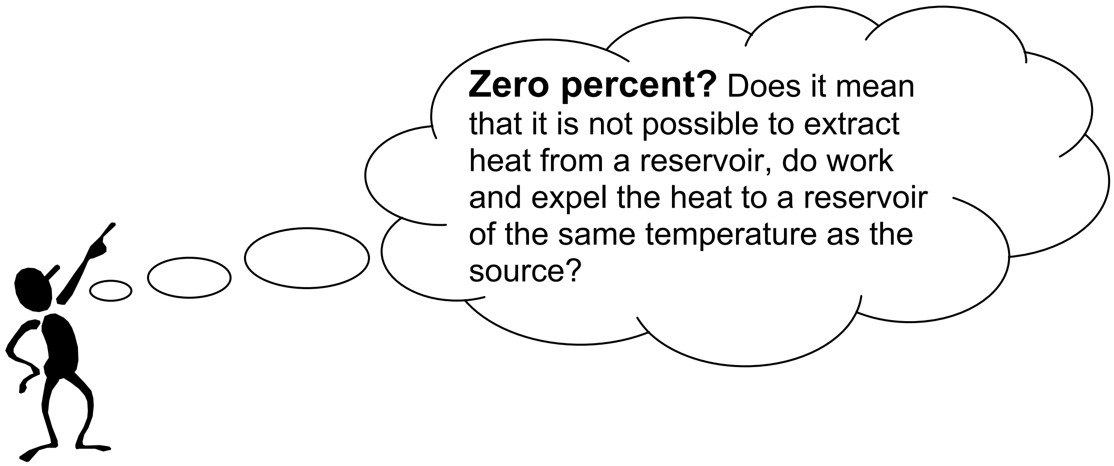
$$\textbf{Ideal Efficiency} = \frac{2730\text{ K} - 1730\text{ K}}{2730\text{ K}} \times 100 = 36.63\%$$

Let us see what happens when the engine extracts heat from a 10, 730 K reservoir instead.

$$\textbf{Ideal Efficiency} = \frac{10730\text{ K} - 1730\text{ K}}{10730\text{ K}} \times 100 = 83.87\%$$

What if the engine operates between two reservoirs of the same temperature? Let's say, 1730 K. Let's compute again.

$$\textbf{Ideal Efficiency} = \frac{1730\text{ K} - 1730\text{ K}}{1730\text{ K}} \times 100 = 0\%$$




That's correct! The last situation explains why airplanes cannot make use of the heat from the atmosphere to do work because the source and the sink (the atmosphere) are practically the same!

**Refrigerators**

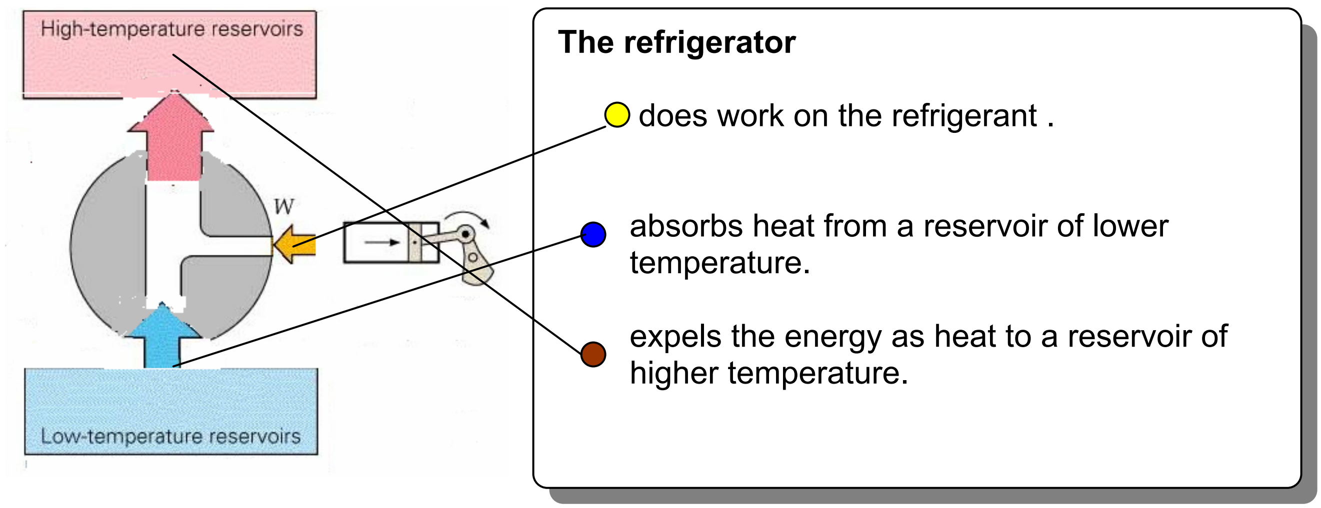
Although internal energy will not spontaneously flow from a cold region to a hot region, it can be forced to do so by doing work on the system. Refrigerators and heat pumps are examples of heat engines which cause energy to be transferred from a cold area to a hot area. Usually this is done with the aid of a phase change, i.e., a refrigerant liquid is forced to evaporate and extract energy from the cold area. Then it is compressed and forced to condense in the hot area, dumping its heat of vaporization into the hot area.

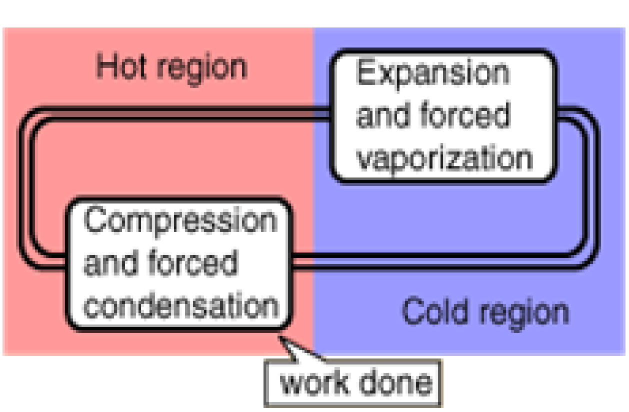
Let us now see how a refrigerator works by relating it to the processes of a heat engine. If you open the refrigerator, you will feel that the temperature inside is lower than the temperature outside. We can also call the inside and outside portions of the refrigerator as cold and hot reservoirs, respectively.

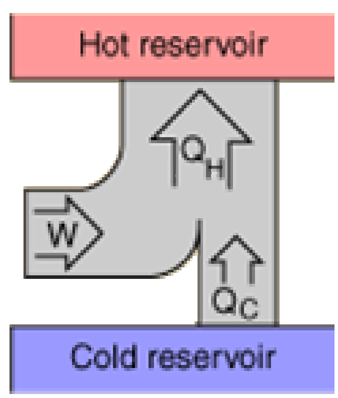
When we place food inside the refrigerator, what happens to the food temperature? It becomes cooler, right? Does this mean that for the food's temperature to drop, heat must have been removed from it? But is it not true that the inside part of the refrigerator is the cold reservoir and the outside part is the hot reservoir? In short, heat must have moved from cold to hot reservoir!

A refrigerator is a heat engine in which work is done on a refrigerant substance in order to collect energy from a cold region and exhaust it in a higher temperature region, thereby cooling the cold region further. A refrigerator, working in a process of transporting heat from cold to hot reservoir is indeed a reversed heat engine! How is this done? Is there also work involved?

Let us see the engine diagram to understand this better.




It is clear from the diagram that the flow of heat can only be reversed by a refrigerator if the energy is supplied to the engine. All real refrigerators require work to get heat to flow from a cold area to a warmer area. Where does this energy come from?

## *What you will do*

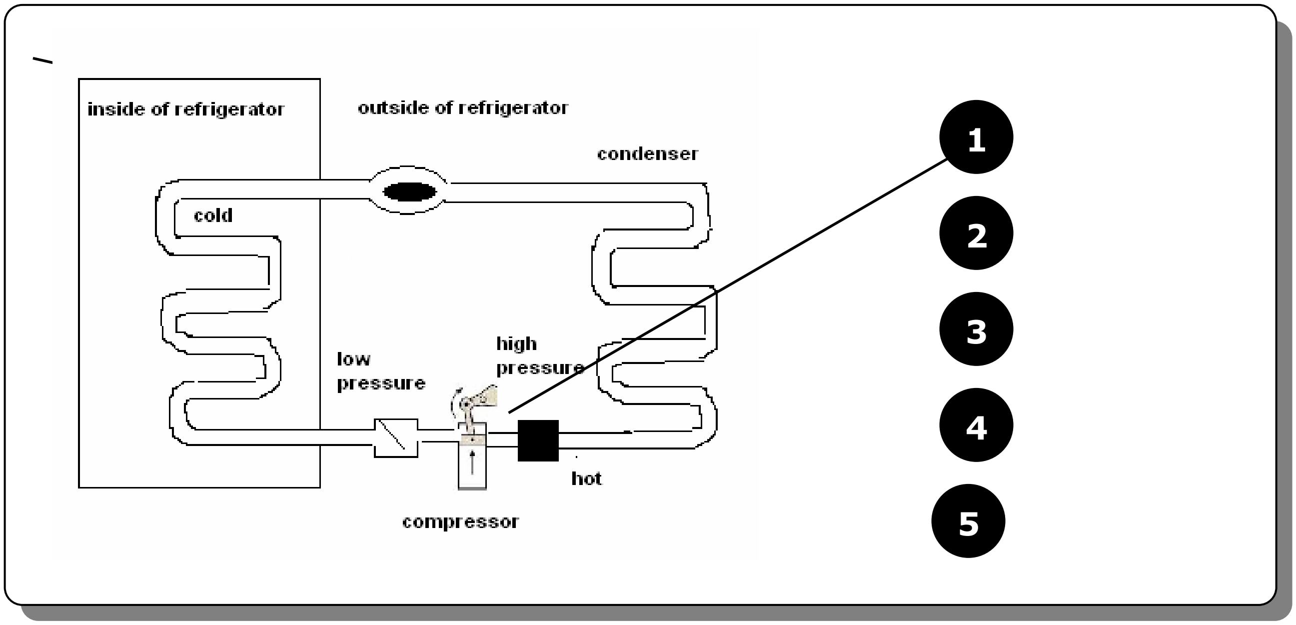
**Activity 4.1 A close look at a refrigerator**

The working substance in a refrigerator is usually freon, a gas that easily liquefies. How does the system work? It is based on the principle that an expanding gas tends to cool.

Here's something you will do to understand this better. Read the following steps on how a refrigerator works. After that, look for a real refrigerator and try to locate the motor and the condenser and evaporator coils. Finally, in the given illustration, label the locations where the different processes in a refrigerator take place. Good luck!

1. The compressor takes in freon and compresses then delivers it to the condenser coil at high temperature and pressure. The compressor is driven by a motor that does work on the working substance in the next cycles.
2. The surrounding air in the condenser coils is cooler than the refrigerant so the refrigerant gives off heat and partially condenses to liquid.
3. The refrigerant expands in the expansion valve. As it expands, it cools considerably so that the refrigerant is cooler than the surrounding of the evaporator coil which is the inside of the refrigerator
4. The condensed refrigerant then absorbs heat from its surroundings. As a result, the contents of the refrigerator become colder and the refrigerant becomes warmer that it eventually vaporizes to gas.
5. The fluid enters the compressor again to repeat the cycle.

Now it's your turn! Can you locate the five processes in a refrigerator in the following diagram? The first step is done for you!




Key to answers on page 27

## *What you will do*

**Self-Test 4.1**

**Write T if the statement is true and F if the statement is false.**

_____ 1. A refrigerator needs external energy to transport heat from the cold reservoir to the hot reservoir.

_____ 2. A heat engine is an object that can give off or accept heat without a significant change in its temperature or internal energy.

_____ 3. A heat engine becomes more efficient as the temperature difference between the hot and cold reservoir increases.

_____4. Iron maybe used as substitute of freon in refrigerators.

_____ 5. A heat engine takes in heat from the low temperature reservoir, does work using this energy, and expels the rest in the heat sink at the high-temperature reservoir.

**Key to answers on page 27**

## *Let's summarize*

In this module, we have learned that:

1. Thermodynamics is the study of heat and its transformation to mechanical energy
2. Thermodynamics is one of the branches of physics that discusses the Law of conservation of energy.
3. The **first law of thermodynamics** relates heat, internal energy and work output of thermodynamic systems. According to this law, the heat added to a system is used to increase the internal energy of the system and to do work.
4. In thermodynamics, a **system** is any region completely enclosed within a well-defined boundary and everything outside this system is considered its **surroundings**. The system might be a biological organism, a mechanical device or the whole of the earth's atmosphere.

5. Heat always naturally travels from object of internal energy at higher temperature to object of internal energy of lower temperature.

6. **The second law of thermodynamics** tells us that it is impossible to construct an engine operating in cycle that converts heat totally into mechanical energy to do an equivalent amount of work. This law governs the operations of heat engines and refrigerators.

7. **Heat engines** take heat from a hot reservoir, use some of it to do work and exhaust the rest to a cooler reservoir as waste

8. **Refrigerators** take heat from a cold reservoir and partially transport it to a hotter reservoir by doing some amount of work.

## *Posttest*

**Directions: Select the letter of the option that correctly answers the given questions. Write your answer on a separate sheet of paper.**

1. The laws of thermodynamics are basically re-statements of conservation of
   a. mass.
   b. charge.
   c. energy.
   d. momentum.

2. Which of the following best describes thermodynamics?
   a. It is the study of the hotness and coldness of a body.
   b. It is the study of the atomic and molecular nature of matter.
   c. It is the study of energy and its transformations.
   d. It is the study of the interaction between heat and temperature.

3. What happens when heat is added to a system?
   a. The internal energy increases and work is done on the system.
   b. Internal energy increases and external work is done by the system.
   c. The internal energy decreases and no external work is done.
   d. The internal energy decreases and external work is done.

4. What happens when you get inside an air-conditioned room after staying under the sun for sometime?
    a. You feel warm because heat flows from your body to the room.
    b. You feel warm because heat flows from the room to your body.
    c. You feel cold because heat flows from your body to the room.
    d. You feel cold because heat flows from the room to your body.

5. What causes the lid of a pot to move up when the water in it starts boiling?
    a. The heated air inside the pot compresses.
    b. The heated air inside the pot expands.
    c. The boiling water compresses.

6. A can fitted with a movable piston is paced over a fire. What happens when the air inside the can expands due to heating?
    a. The piston moves up.
    b. The piston moves down.
    c. The piston does not move.
    d. The piston will crush the can.

7. The internal energy of a system increases when
    a. the system expands.
    b. the pressure become low.
    c. the system gets heavier.
    d. the temperature drops.

8. The low-temperature reservoir where a heat engine operates is called
    a. surroundings.
    b. sink.
    c. working substance
    d. refrigerant.

9. In which of the following sets of temperature of two reservoirs will a heat engine be most efficient?
    a. 1140 K and 1140 K
    b. 1140 K and 0 K
    c. 1140 K and 700 K
    d. 700 K and 300 K

10. Which of the following will not likely be used as working substance in refrigerators?
    a. Freon
    b. Carbon
    c. Methane
    d. Chlorofluorocarbons (CFCs)

11. Heat is absorbed by a refrigerant in a refrigerator when it
    a. melts.
    b. vaporizes.
    c. condenses.
    d. compresses.

12. Which of the following describes all processes occurring in nature
    a. irreversible
    b. unidirectional
    c. both a and b
    d. neither a nor b

13. What is the use of the motor in the refrigerators?
    a. It regulates the power to the appliance.
    b. It does work on the refrigerant.
    c. It supplies power to the refrigerator in cases of power interruption.
    d. It liquefies the refrigerant.

14. Which of the following explains why airliners cannot make use of the heat from the atmosphere to run their engines?
    a. The atmosphere is a very large reservoir.
    b. The heat in the atmosphere may destroy their engines.
    c. It is not possible to have an engine operating at the same reservoir temperatures.
    d. All of the above

15. How do you compare refrigerators and heat engines?
    a. A refrigerator is a heat engine operating in the reverse cycle.
    b. A refrigerator needs a working substance while a heat engine doesn't.
    c. A refrigerator does not obey the laws of thermodynamics because it is the reverse of a heat engine.
    d. Both a and c

**Key to answers on page 27**

# Key to Answers

**Pre-Test**
1. b
2. d
3. b
4. a
5. b
6. d
7. b
8. b
9. a
10. b
11. a
12. b
13. d
14. b
15. a

**Lesson 1**

**Activity 1.1**
1. Temperature
2. Thermal
3. Heat
4. Internal
5. work

**Self-Test 1.1**
1. d
2. a
3. b
4. d
5. b

**Lesson 2**

**Self-Test 2.1**
1. a
2. c
3. d
4. b
5. c

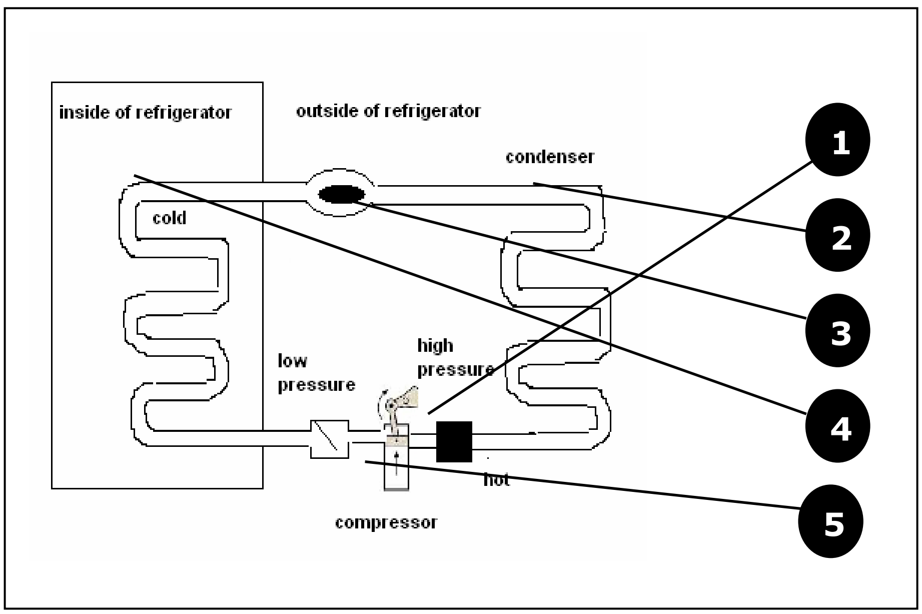
**Lesson 3**
**Self-Test 3.1**
1. b
2. b
3. a
4. b
5. b

**Lesson 4**

**Activity 4.1**
- see diagram on the box at the bottom of this page

**Self-Test 4.1**
1. T
2. F
3. T
4. F
5. F

**Posttest**
1. c
2. c
3. b
4. c
5. a
6. a
7. a
8. b
9. b
10. b
11. b
12. c
13. b
14. c
15. a




**-End of Module-**

## References

Hewitt, P.G. (1997). *Conceptual physics.* USA: Addison-Wesley Publishing Co., Inc.

Navasa, D. & Valdez, B.J. (2001). *Physics.* Quezon City: Sibs Publishing House, Inc.

Tan, M. (2001). *TIMSS-LIKE test items in science and mathematics.* DOST-SEI, UPNISMED, Pundasyon Para sa mga Guro ng Agham at Matematika, Ink.

Tillery, B.W. (1999). *Physical science.* Singapore: WCB McGraw-Hill.

Urone, P. (2004). *Physics with health science applications.* Manila.

Yong Loo Wan, Wai Kwok & Fong See Tho Weng. (2004). *Physics insights.* Phil. Edition. Pearson Educ. South Asia PTE LTD.

Tillery, B. W. (1999). *Physical Science*. Singapore: WCB McGraw Hill

Young, H. D., et. al. (2004). *University Physics*. USA: Pearson Education Inc.

Van Heuvelen, A. (1986). *Physics: A General Introduction Second Edition.* Canada: Little Brown and Company (Canada) Limited