



Introduction to Meteorology

03 Energy and temperature

Introduction



We cannot see it directly, but energy is used in our everyday life. Solar energy is a good example of which we can see and feel the warmth. The Earth's temperature, which is changed by this solar energy, is one of the main factors that control the Earth's climate. When someone asks about the weather, the first thing to mention is a temperature which varies within various timescales – seasons, days, and hours – and changes spatially

Contents



1. Types of energy
2. Temperature
3. Temperature data

Learning objectives



1. Explain the definition of energy and types of energy.
2. Understand the difference between temperature and heat, and various temperature scales.
3. Explain how to use temperature data.

Learning Activities

1. Types of energy

In general, energy is the "ability to do work". Energy can move an object and boil water in a kettle. The international System of Units (SI Unit) of energy is Joule (J). One calorie of thermal energy is equivalent to 4.2 J of energy.

$$1\text{cal} = 4.2\text{J}$$

Power is the rate at which work is done, or the rate at which energy is consumed. Watt is the unit of power. One watt is defined as the work or energy consumption rate of one joule per second.

Energy can be divided into primary energy and secondary energy. The primary energy refers to the energy that can be obtained from nature, such as solar energy, which is the source of energy, hydroenergy, wind energy, wave energy, fossil fuels (coal, oil and gas). The secondary energy is one that transforms or uses primary energy, such as electricity and city gas. These energies are mainly consist of kinetic, potential, and thermal energy.

Learning Activities

1. Types of energy

1) Kinetic energy

The energy associated with the motion of an object is called kinetic energy. Consider, for example, a hammer hitting a nail. Upon the movement of the hammer, the nail can be driven into a board. The faster the hammering, the greater the kinetic energy. Likewise, when hammering at the same speed, a heavier hammer generates more kinetic energy than a lighter one does. Typhoon wind has much more energy than local wind does, because it is more intense and faster. Kinetic energy is the energy associated with the motion of an object and is defined as:

$$E_k = \frac{1}{2}mv^2$$

here m is the mass of the object, and v is the speed of the object. Examples of the kinetic energy in nature are raindrops, water running along the river, tidal and wind power. The kinetic energy of an object increases as the object accelerates, and decreases as the speed decelerates by friction.

Learning Activities

1. Types of energy

2) Potential energy

Potential energy is a type of energy an object has as a result of its position. The stored energy of position is referred to as potential energy. For example, when a spring is compressed or stretched within its elastic limit, the spring stores potential energy from its equilibrium position. Everything on Earth has gravitational potential. So if you lift an object at a certain height in the opposite direction of gravity, then that object also has potential energy. The potential energy due to gravity is expressed as

$$E_p = mgh$$

where m is mass, g is gravitational acceleration, h represents the height from the reference point. For example, cloud particles at any elevation have potential energy to fall due to gravitational attraction of the Earth. When raindrops fall, the potential energy is converted to kinetic energy. The higher the raindrop, the larger the potential energy. The same principle applies to hydroelectric power generation

Learning Activities

1. Types of energy

3) Thermal energy

Thermal energy is the energy in the form of heat due to temperature gradient and moves from an object at a higher temperature to an object at a lower temperature. Temperature is a measure of average kinetic energy of atoms and molecules, where higher temperature corresponds to higher energy. Thus, when an object is in the form of a solid, liquid, or gas, the kinetic energy of the molecule is the greatest in gas which has an irregular motion. The relationship between kinetic energy of a molecule and temperature can be explained by the following equation.

$$\frac{1}{2} m_0 \overline{v^2} = \frac{3}{2} k T$$

here m_0 is the molecular mass, v is the molecular velocity, and K is the Boltzmann constant, T represents the temperature. For example, heating a large volume of air will speed up the movement of air molecules. However, the distance between the molecules becomes farther away, and the air density becomes smaller. Conversely, if the air is cooled, the density of the molecules will increase rather than slow down. Based on these kinetic characteristics, we use the expression "warm and light air" or "cold and dense air".

According to Charles's law, when the gas pressure is constant, the volume increases as the temperature increases. If the air is cooled down, its atoms and molecules will move more and more slowly until the air reaches the lowest temperature possible. At this temperature, called absolute zero, the atoms and molecules will possess a minimum amount of energy and theoretically no thermal motion. The absolute zero (0K) corresponds to -273°C .

Learning Activities

2. Temperature

The temperature is a measure of how cool or hot it is relative to a certain threshold. Air is a mixture of atoms and molecules. They are not visible, but they move in all directions, like a bee, spiraling, twisting, spinning and colliding with other atoms or molecules. Near the Earth's surface, air molecules must travel about 1,000 times their own diameter to collide with other molecules. But not all atoms and molecules move at the same speed at the same time, but some move fast, some move slowly. The energy of such movement is called kinetic energy. A measure of the average kinetic energy of an atom or molecule is a temperature. Therefore, temperature is a measure of the average kinetic energy of the atoms or molecules that make up the air.

The molecular speed changes as the material gains or loses its energy. Once energy is obtained, the molecular motion accelerates, and the temperature rises. If it loses energy, the atom or molecule motion slows down and the temperature drops. However, it should be noted that the temperature is not a measure of the total kinetic energy of the molecules.

For example, let 's say you want to melt ice with warm water filling a bathtub and a cup of boiling water, respectively. The temperature of a cup of boiling water is higher than that of the water in the bath. However, the amount of a cup of water is very small, so it has less kinetic energy than the water in the bathtub. So, more ice can melt in water in the bath than in a cup of boiling water. This is because that a cup of water contains a relatively small amount of molecules resulting in smaller total amount of kinetic energy despite the fast movement of atoms and molecules in a cup of boiling water.

Learning Activities

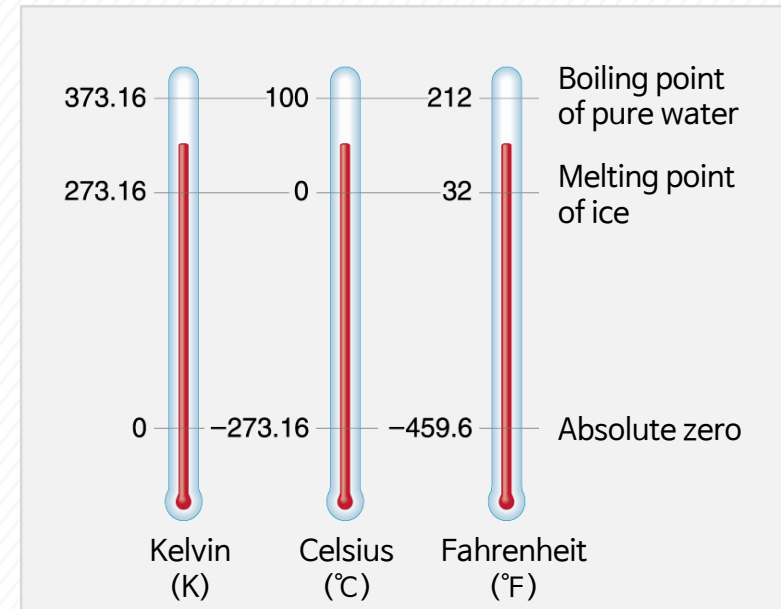
2. Temperature

1) Temperature scales

Temperature scales include Kelvin Fahrenheit and Celsius scale. The Celsius scale is commonly used in most of countries for measuring temperature, whereas the Fahrenheit scale is used in the United States.

Kelvin temperature scale is named after the British scientist Lord Kelvin who first introduced the scale. Absolute zero is the starting point for this scale. Since the Kelvin scale contains no negative values, it can be easily adopted for scientific calculations. It has clear reference point. On the Celsius scale, ice melts at 0° and pure water boils at 100° . Kelvin scale has a melting point at 273.15 and a boiling point at 373.15.

The Kelvin scale starts at an absolute zero, the temperature at which all molecular motions are ceased. Therefore, unlike Celsius and Fahrenheit, it is not possible to have negative values when using Kelvin scale.



<Comparison of Kelvin, Celsius, and Fahrenheit scales>

Learning Activities

2. Temperature

The relationship between Kelvin and Celsius scale can be expressed as:

$$^{\circ}\text{C} = \text{K} - 273.15 \text{ or } \text{K} = \text{C} + 273.15$$

The Fahrenheit scale was introduced by the German physicist Daniel Fahrenheit in the early 1700s. The Fahrenheit scale indicates the freezing point of water as 32° , the boiling point as 212° , and the lowest temperature obtained by mixing ice, water and salt as zero. A thermometer calibrated with 180 equal divisions between the freezing and boiling points is referred to as a Fahrenheit thermometer, and the temperature unit is $^{\circ}\text{F}$.

The Celsius scale was introduced in the late 18th century, with 0° on the scale indicating the freezing point of pure water and 100° indicating the boiling point of pure water at sea level. The freezing point and the boiling point are divided into 100 equal degrees. Therefore Celsius 1° is $180/100$, or 1.8 times greater than Fahrenheit. Put another way, an increase of temperature of 1°C equals an increase of 1.8°F . A formula for converting $^{\circ}\text{F}$ to $^{\circ}\text{C}$ is:

$$^{\circ}\text{C} = \frac{5}{9} (^{\circ}\text{F} - 32)$$

Learning Activities

2. Temperature

2) Measurement of temperature

The thermometer, which is commonly used to measure temperature, is based on the principle of liquid expansion. The most accurate and widely used thermometer is a mercury thermometer. Sometimes alcohol thermometers are used as well.

In addition, bimetallic thermometers, resistance thermometers, magnetic thermometers, maximum and minimum temperature thermometers have been developed and used depending on the purpose of use.

To measure air temperature accurately, you should always place the thermometer in the shade. If the thermometer is exposed to direct sunlight, it absorbs solar radiation and can display temperature higher than the ambient temperature. Because the temperature is not the temperature of the thermometer but the temperature of the air, the thermometer should always be placed inside the Stevenson screen which is designed to minimize the effects of radiation.

Learning Activities

2. Temperature

The Stevenson screen is always painted white to better reflect the sun's rays. The louvered sides (made of wood) allow outside air to flow around the thermometers. The door of the screen should always face away from the sun. This means that in the northern hemisphere it should face north. It is kept 1.5m above the ground to avoid strong temperature gradients at ground level. The Korea Meteorological Administration (KMA) measures the temperature every hour through the automatic weather system (AWS) installed nationwide.



〈Korea Meteorological Administration Automatic Weather System (AWS)〉

Learning Activities

3. Temperature data

1) Daily/monthly/annual temperature

The largest change in daily temperature is near the surface. Daily temperature range, defined by the difference between the daily maximum and the minimum temperature, is the largest just above the ground and decreases with height. The daily range of temperature is much larger in sunny day than in overcast day.

The greatest diurnal range of temperature occurs on high deserts where the air is fairly dry and often cloud-free. The surface warms quickly by solar energy during the day, and cools rapidly at night by radiating infrared energy to space.

On the other hand, the daily range of temperature in humid regions is generally small. Fog and clouds block part of the solar energy, lowering the maximum temperature. At night, the atmospheric moisture absorbs the earth's energy and reflects it back to the ground to keep the minimum temperature high. Cities near large bodies of water typically have smaller daily temperature range than inland cities owing to higher moisture amount in the air, and relatively slower heating and cooling in water than land.

The average of the maximum and minimum temperatures in a given 24-hour period is referred to daily mean temperature. KMA currently uses daily mean temperature by averaging temperature measured eight times a day. Most media report the minimum, maximum and daily mean temperatures for the preceding day. The average of daily mean temperature for a particular date across a 30-year period gives the average or normal temperatures for that date. The average of the daily mean temperatures for that month is the monthly temperature.

The difference between the average temperature of the warmest month and the average temperature of the coldest month is called the annual temperature range. The annual temperature ranges are greatest over interior continental landmasses and smaller over larger bodies of water. The average of temperature for the entire year is the mean annual temperature.

Learning Activities

3. Temperature data

2) Applications of air temperature data

The heating degree day is developed by heating engineers for application purpose in estimating energy demand to heat buildings. It is based on the assumption that people will begin to use their stove when the mean daily temperature drops below 18°C . Therefore, the heating degree day is 18°C minus the daily average temperature. If the daily average temperature is 17°C , the heating degree day is 1. In contrast, people start to cool down indoor environment when the average daily temperature rises above 22°C . An index called the cooling degree day is used during warm weather to quantify the energy consumption to cool indoor air. The average daily temperature is converted to cooling degree days by subtracting 22°C from the mean. Information of cooling degree days allows a builder to plan the size and type of equipment that should be installed to provide adequate air conditioning. Also, using forecasts of cooling and heating degree days, energy demand for a peak period as well as annual energy demand can be estimated.

An index called growing degree days can be used as guidance for farmers on planting and for determining best time for sowing, growing and harvesting. One growing degree day is defined as a day in which the daily mean temperature exceeds the base temperature by 1 degree. The base temperature of corn is 50°F and, for peas, it is 40°F .

Summary

1. Types of energy

- Energy refers to the ability to do work, and the international unit of energy is Joule.
 - One calorie of thermal energy is equivalent to 4.2 J of energy.
 - Power is the rate at which work is done, or the rate at which energy is consumed. Watt is the unit of power defined as the work or energy consumption rate of one joule per second.
- Energy can be divided into primary energy and secondary energy.
 - Primary energy: solar energy, hydroenergy, wind energy, wave energy, and fossil fuel (coal, oil) etc.
→ energy that can be obtained from nature
 - Secondary energy: transforms and uses primary energy → electricity, city gas, etc.
- Kinetic, potential, thermal energy
 - Kinetic energy: The energy associated with the motion of an object is called kinetic energy. The kinetic energy of an object increases as the mass and speed of the object increase. Examples of the kinetic energy in nature are raindrops, water running along the river, tidal and wind power. The kinetic energy of an object increases as the object accelerates, and decreases as its speed decelerates by friction.
 - Potential energy: Potential energy is a type of energy an object has because of its position. Stored energy of position is referred to as potential energy. For example, cloud particles at any elevation have potential energy to fall due to gravity.
 - Thermal energy: Thermal energy is energy in the form of heat due to temperature gradient and transfers from higher to lower temperature. When an object is in the form of a solid, liquid, or gas, the kinetic energy of the molecule is the greatest in gas which has an irregular motion.

Summary

2. Temperature

- The temperature is a measure of how cool or hot it is relative to a certain threshold.
- Temperature scales
 - Kelvin scale: scale with absolute temperature reference. Water has a melting point of 273.15 and a boiling point of 373.15. The temperature unit starts at an absolute zero degree, assuming that all molecular motion is stopped at the temperature.
 - Fahrenheit scale: In the Fahrenheit scale, the freezing point of the water is 32° and the water boiling point is 212°. The freezing point and the boiling point are equally divided into 180 degrees.
 - Celsius scale: 0 on the scale indicating the freezing point of pure water and 100 indicating the boiling point of pure water at sea level. The freezing point and the boiling point are divided into 100 equal degrees.

Summary

3. Temperature data

- Daily range of temperature: difference between the maximum and minimum daily temperatures. It is the largest just above the ground and decreases with height.
- Daily mean temperature: average of the maximum and minimum temperatures in a given 24-hour period.
- Normal daily temperature: average of daily mean temperature for a particular date across a 30-year period. The average of the daily mean temperatures for that month is the monthly temperature.
- Annual temperature range: difference between the average temperature of the warmest month and the average temperature of the coldest month.
- Annual mean temperature: average of temperature for the entire year.