Chapter: Thermal Energy

1

What is temperature?

- When you swim in water, touch a hot pan, or swallow a cold drink, your sense of touch tells you whether something is hot or cold.
- However, the words *cold*, *warm*, and *hot* can mean different things to different people.

1

Temperature

- To understand temperature, think of a glass of water sitting on a table.
- The water might seem perfectly still, but water is made of molecules that are in constant, random motion.
- Because these molecules are always moving, they have energy of motion, or kinetic energy.

1

Temperature

- **Temperature** is a measure of the average value of the kinetic energy of the molecules in random motion.

- The more kinetic energy the molecules have, the higher the temperature.

1

Temperature

- The higher the temperature, the faster the molecules are moving.

1

Thermal Expansion

- When the temperature of an object is increased, its molecules speed up and tend to move farther apart.
- This causes the object to expand.

1

Thermal Expansion

- When the object is cooled, its molecules slow down and move closer together.
- This causes the object to shrink, or contract.

1

Thermal Expansion

- The amount of expansion or contraction depends on the type of material and the change in temperature.
- Liquids usually expand more than solids.

1

Measuring Temperature

- The temperature of an object depends on the average kinetic energy of all the molecules in an object.

- It is impossible to measure the kinetic energy of all the individual molecules.

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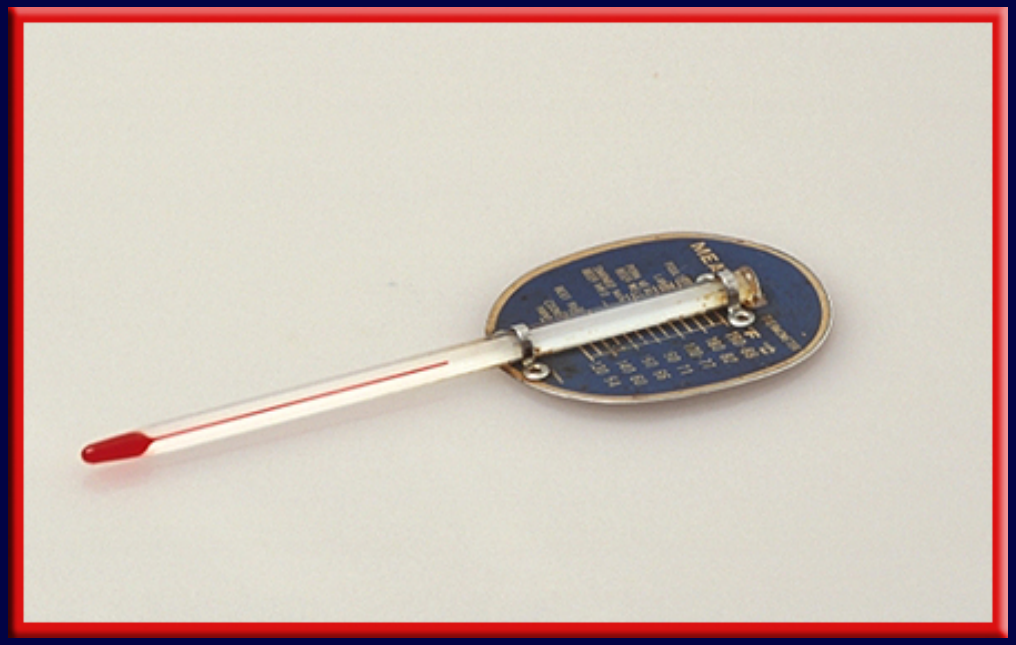
Measuring Temperature

- A more practical way to measure temperature is to use a thermometer.
- Thermometers usually use the expansion and contraction of materials to measure temperature.



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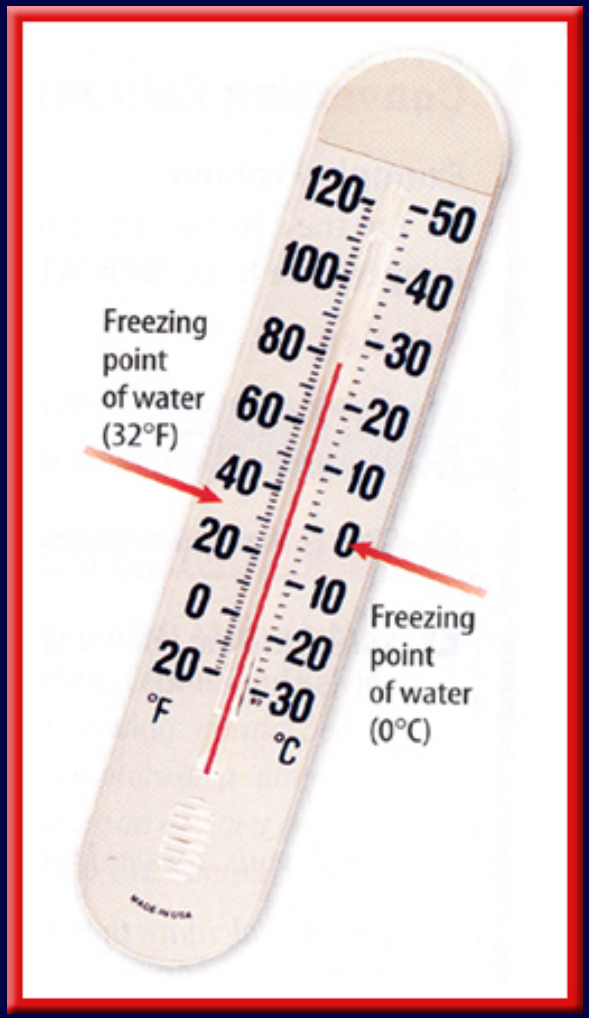
Temperature Scales

- To be able to give a number for the temperature, a thermometer has to have a temperature scale.
- Two common temperature scales are the Fahrenheit and Celsius scales.



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Temperature Scales

- On the Fahrenheit scale, the freezing point of water is given the temperature 32°F and the boiling point 212°F.
- The Fahrenheit scale is used mainly in the United States.
- On the Celsius temperature scale, the freezing point of water is given the temperature 0°C and the boiling point is given the temperature 100°C.

1

Converting Fahrenheit and Celsius

- You can convert temperatures back and forth between the two temperature scales by using the following equations.

Temperature Conversion Equations

To convert temperature in °F to °C: $°C = (\frac{5}{9})(°F - 32)$

To convert temperature in °C to °F: $°F = (\frac{5}{9})(°C) + 32$

1

The Kelvin Scale

- On this scale, 0 K is the lowest temperature an object can have.
- This temperature is known as absolute zero.
- You can change from Celsius degrees to Kelvin degrees by adding 273 to the Celsius temperature.

1

Thermal Energy

- Molecules also have potential energy.
- Potential energy is energy that the molecules have that can be converted into kinetic energy.
- The sum of the kinetic and potential energy of all the molecules in an object is the **thermal energy** of the object.

1

The Potential Energy of Molecules

- The molecules in a material exert attractive forces on each other.
- As a result, the molecules in a material have potential energy.
- As the molecules get closer together or farther apart, their potential energy changes.

1

Increasing Thermal Energy

- Temperature and thermal energy are different.
- Suppose you have two glasses filled with the same amount of milk, and at the same temperature.
- If you pour both glasses of milk into a pitcher, the temperature of the milk won't change.

1

Increasing Thermal Energy

- However, because there are more molecules of milk in the pitcher than in either glass, the thermal energy of the milk in the pitcher is greater than the thermal energy of the milk in either glass.

1

Question 1

Which of the following does NOT depend on how fast the molecules in a substance are moving?

A. kinetic energy
B. thermal energy
C. potential energy
D. temperature

1

Answer

The answer is C. Kinetic energy depends on the speed of the molecules; temperature depends on the average kinetic energy of the molecules, and thermal energy is the sum of the kinetic and potential energy of the molecules.

1

Question 2

When the temperature of an object is increased, molecules in the substance speed up and move _____.

A. toward the surface
B. away from the surface
C. closer together
D. farther apart

1

Answer

The answer is D. The molecules tend to move farther apart, causing the material to expand.

1

Question 3

The two most common temperature scales are the _____ and the _____ scale.

Answer

The answer is Fahrenheit and Celsius. In science you will also encounter the Kelvin scale.

2

Heat and Thermal Energy

- **Heat** is thermal energy that is transferred from one object to another when the objects are at different temperatures. 

- The amount of heat that is transferred when two objects are brought into contact depends on the difference in temperature between the objects.

2

Transfer of Heat

- When heat is transferred, thermal energy always moves from warmer to cooler objects.
- Heat never flows from a cooler object to a warmer object.
- This process of heat transfer can occur in three ways—by conduction, radiation, or convection.

2

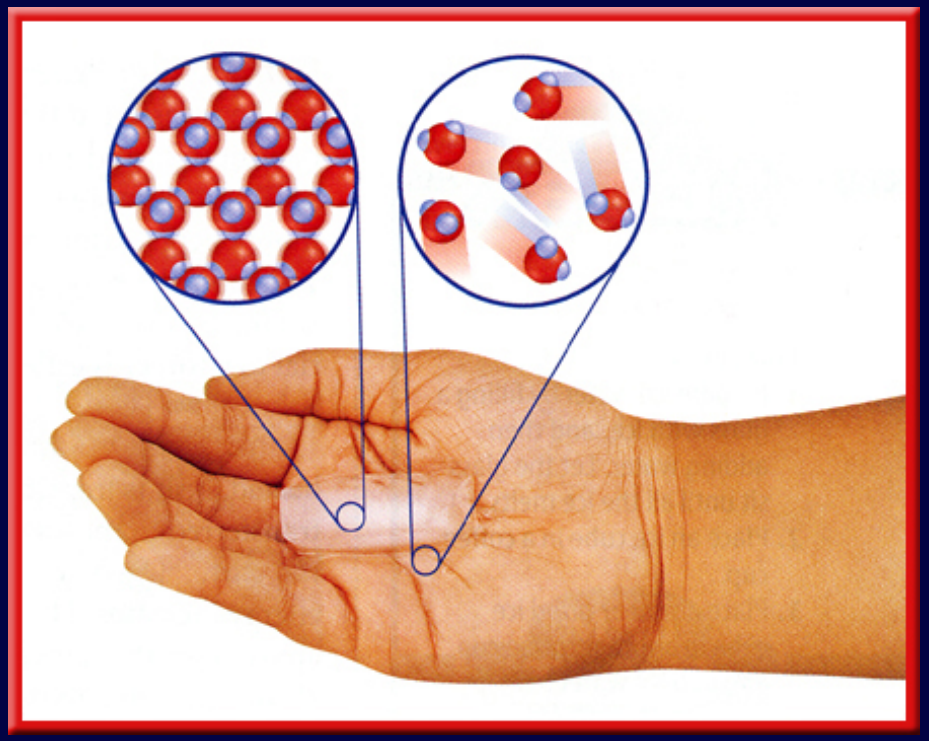
Conduction

- Transfer of heat by direct contact is called conduction.
- **Conduction** occurs when the particles in a material collide with neighboring particles.

2

Conduction

- Imagine holding an ice cube in your hand.
- The faster-moving molecules in your warm hand bump against the slower-moving molecules in the cold ice.



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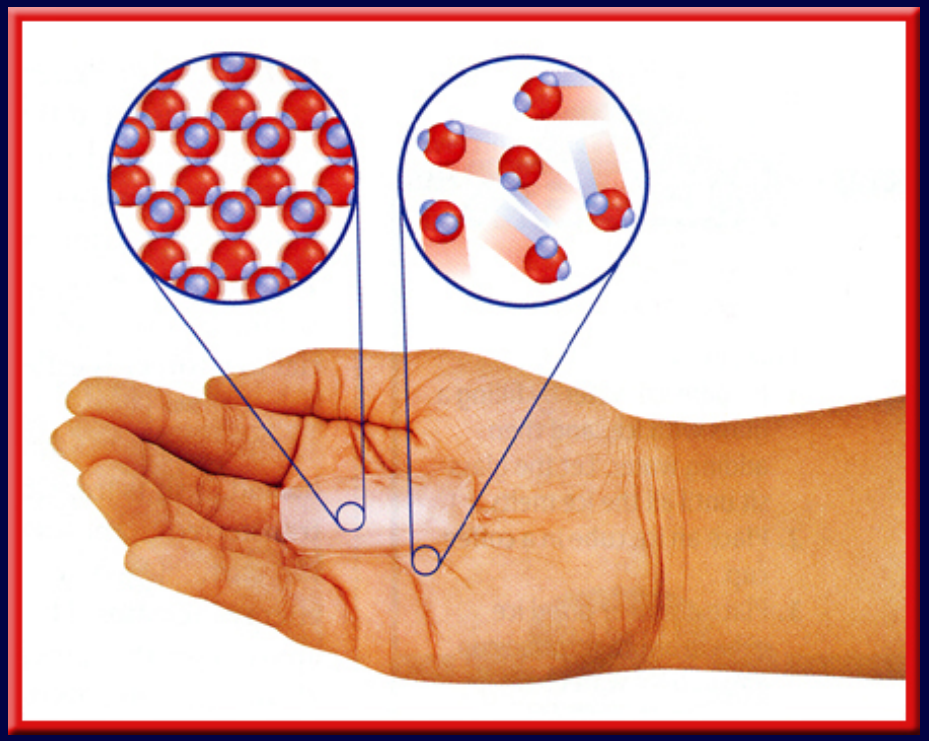
Conduction

- Heat flows from your warmer hand to the colder ice, and the slow-moving molecules in the ice move faster.



- As a result, the ice becomes warmer and its temperature increases.

2

Conduction

- Conduction usually occurs most easily in solids and liquids, where atoms and molecules are close together.

- Then atoms and molecules need to move only a short distance before they bump into one another and transfer energy.

2

Radiation

- Heat is transferred from the Sun to Earth by radiation.
- Heat transfer by **radiation** occurs when energy is transferred by electromagnetic waves.

2

Radiation

- The transfer of thermal energy by radiation can occur in empty space, as well as in solids, liquids, and gases.

2

Radiation

- The Sun is not the only source of radiation.
- All objects emit electromagnetic radiation, although warm objects emit more radiation than cool objects.
- The warmth you feel when you sit next to a fireplace is due to heat transferred by radiation from the fire to your skin.

2

Convection

- In a gas or liquid, molecules can move much more easily than they can in a solid.
- As a result, the more energetic molecules can travel from one place to another, and carry their energy along with them.
- This transfer of thermal energy by the movement of molecules from one part of a material to another is called **convection**.

2

Transferring Heat by Convection

- As a pot of water is heated, heat is transferred by convection.
- First, thermal energy is transferred to the water molecules at the bottom of the pot from the stove.
- These water molecules move faster as their thermal energy increases.

2

Transferring Heat by Convection

- Because the molecules are farther apart in the warm water, this water is less dense than the cooler water.
- As a result, the warm water rises and is replaced at the bottom of the pot by cooler water.
- The cooler water is heated, rises, and the cycle is repeated until all the water in the pot is at the same temperature.

2

Natural Convection

- Natural convection occurs when a warmer, less dense fluid is pushed away by a cooler, denser fluid.
- Wind movement near a lake or ocean can result from natural convection.
- Air is heated by the land and becomes less dense.

2

Natural Convection

- Denser cool air rushes in, pushing the warm water up.
- The cooler air then is heated by the land and the cycle is repeated.

2

Forced Convection

- Forced convection occurs when an outside force pushes a fluid, such as air or water, to make it move and transfer heat.
- A fan is one type of device that is used to move air.

2

Thermal Conductors

- A **conductor** is any material that easily transfers heat.
- Some materials are good conductors because of the types of atoms or chemical compounds they are made up of.

2

Thermal Conductors

- Certain materials, such as metals, have some electrons that are not held tightly by the nucleus and are freer to move around.
- These loosely held electrons can bump into other atoms and help transfer thermal energy.
- The best conductors of heat are metals such as gold and copper.

2

Thermal Insulators

- An insulator is a material in which heat doesn't flow easily.
- Liquids and gases are usually better insulators than solids are.
- Air is a good insulator, and many insulating materials contain air spaces that reduce the transfer of heat by conduction within the material.

2

Thermal Insulators

- Materials that are good conductors, such as metals, are poor insulators, and poor conductors are good insulators.

- Houses and buildings are made with insulating materials to reduce heat conduction between the inside and outside.

2

Thermal Insulators

- Fluffy insulation is put in the walls.
- Some windows have double layers of glass that sandwich a layer of air or other insulating gas.

2

Heat Absorption

- Why is pavement hotter than grass?
- The change in temperature of an object as it absorbs heat depends on the material it is made of.

2

Specific Heat

- The amount of heat needed to change the temperature of a substance is related to its specific heat.
- The **specific heat** of a substance is the amount of heat needed to raise the temperature of 1 kg of that substance by 1°C. 

2

Specific Heat

- More heat is needed to change the temperature of a material with a high specific heat than one with a low specific heat.

2

Thermal Pollution

- Some electric power plants and factories that use water for cooling produce hot water as a by-product.
- If this hot water is released into an ocean, lake, or river, it will raise the temperature of the water nearby.

2

Thermal Pollution

- This increase in the temperature of a body of water caused by adding warmer water is called **thermal pollution**.

2

Effects of Thermal Pollution

- Increasing the water temperature causes fish and other aquatic organisms to use more oxygen.

- Because warmer water contains less dissolved oxygen than cooler water, some organisms can die due to lack of oxygen.

2

Reducing Thermal Pollution

- Thermal pollution can be reduced by cooling the warm water produced by factories, power plants, and runoff before it is released into a body of water.
- Cooling towers are used to cool the water from some power plants and factories.

2

Question 1

When heat moves from one object to another as a result of direct contact, the process is known as _____.

A. conduction
B. convection
C. radiation
D. expansion

2

Answer

The answer is A. Conduction is occurring when you hold a cup of hot chocolate and feel the warmth in your hand.

2

Question 2

Heat can be transferred through empty space only by _____.

A. convection
B. forced convection
C. radiation
D. conduction

2

Answer

The answer is C. Heat is transferred from the Sun to Earth by radiation.

2

Question 3

When water in a cooking pot on a stove is heated, the water at the bottom becomes warmer than the water above. The warm water is less dense and rises, cooling as it transfers thermal energy to the cooler water above. As this water cools, it becomes more dense and sinks to the bottom of the pot. This process is an example of the transfer of thermal energy by _____.

2

A. radiation
B. convection
C. insulation
D. thermal pollution

2

Answer

The answer is B. Convection occurs when thermal energy is transferred by the movement of molecules from one place to another in a material.

3

Heat Engines

- The engines used in cars, motorcycles, trucks, and other vehicles are heat engines.

- A **heat engine** is a device that converts thermal energy into mechanical energy.

3

Heat Engines

- Mechanical energy is the sum of the kinetic and potential energy of an object.

3

Forms of Energy

- Chemical energy is energy stored in the chemical bonds between atoms.

- Radiant energy is the energy carried by electromagnetic waves.

3

Forms of Energy

- Nuclear energy is energy stored in the nuclei of atoms.

- Electrical energy is the energy carried by electric charges as they move in a circuit.

3

The Law of Conservation of Energy

- When energy is transformed from one form to another, the total amount of energy doesn't change.
- According to the law of conservation of energy, energy cannot be created or destroyed.
- Energy only can be transformed from one form to another.

3

Internal Combustion Engines

- In **internal combustion** engines, the fuel burns in a combustion chamber inside the engine.
- Many machines, including cars, airplanes, buses, boats, trucks, and lawn mowers, use internal combustion engines.

3

Internal Combustion Engines

- Most cars have an engine with four or more combustion chambers, or cylinders.
- Usually the more cylinders an engine has, the more power it can produce.
- Each cylinder contains a piston that can move up and down.

3

Internal Combustion Engines

- A mixture of fuel and air is injected into a combustion chamber and ignited by a spark.
- When the fuel mixture is ignited, it burns explosively and pushes the piston down.
- The up-and-down motion of the pistons turns a rod called a crankshaft, which turns the wheels of the car.

3

Refrigerators

- A refrigerator is a heat mover.
- It absorbs heat from the food and other materials inside the refrigerator.
- Then it carries the heat to outside the refrigerator, where it is transferred to the surrounding air.

3

Refrigerators

- A refrigerator contains a material called a coolant that is pumped through pipes inside and outside the refrigerator.
- The coolant is the substance that carries heat from the inside to the outside of the refrigerator.

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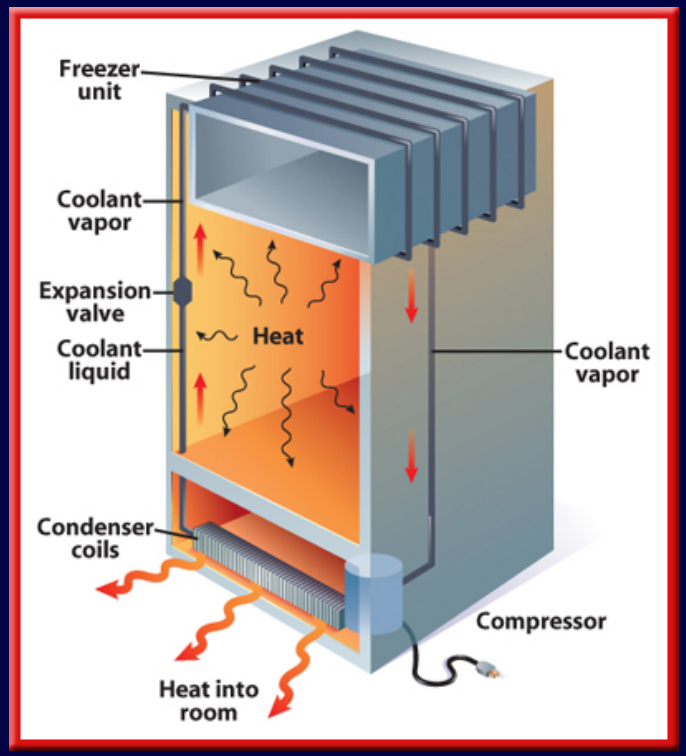
Absorbing Heat

- Liquid coolant is forced up a pipe toward the freezer unit.



- The liquid passes through an expansion valve where it changes into a gas.

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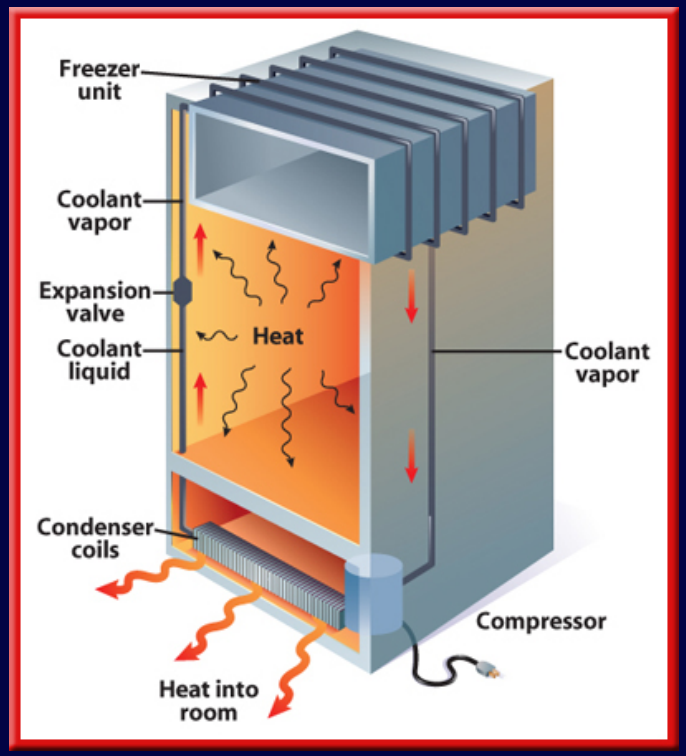
Absorbing Heat

- When it changes into a gas, it becomes cold.
- The cold gas passes through pipes around the inside of the refrigerator.

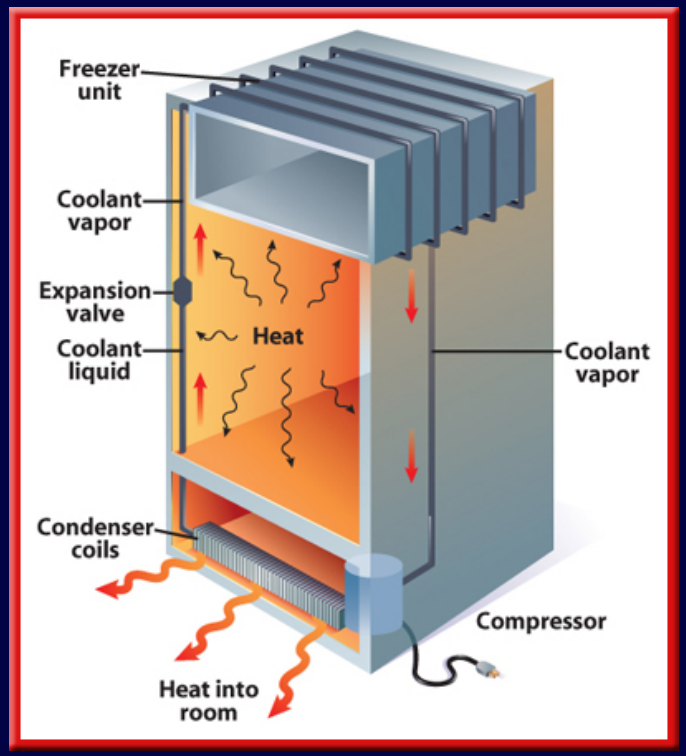


- Because the coolant gas is so cold, it absorbs heat from inside the refrigerator, and becomes warmer.

3

Releasing Heat

- The heat absorbed by the coolant cannot be transferred to the air.
- The warm coolant gas then passes through a compressor that compresses the gas.
- When the gas is compressed, it becomes warmer than room temperature.



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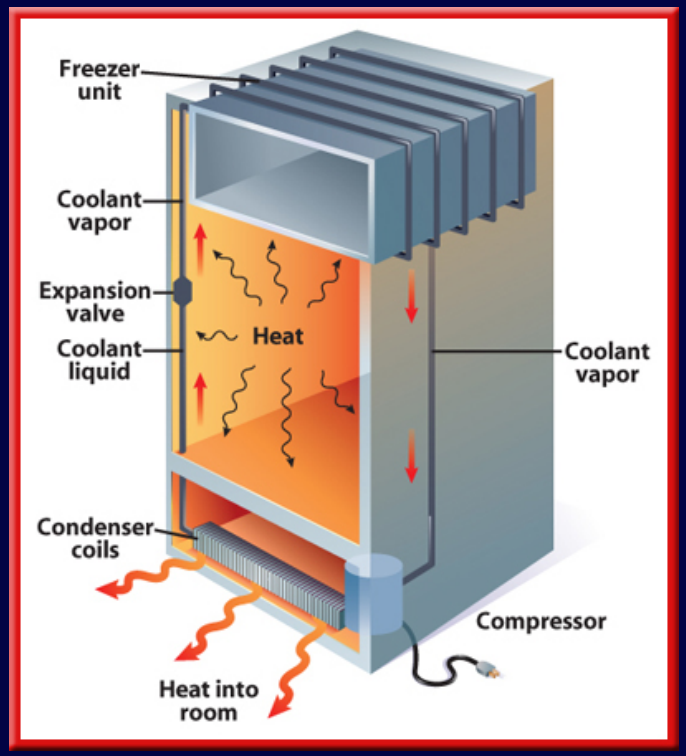
Releasing Heat

- The gas then flows through the condenser coils, where it transfers heat to the cooler air in the room.
- As the coolant gas cools, it changes into a liquid.



- The liquid is pumped through the expansion valve, changes into a gas, and the cycle is repeated.

3

Air Conditioners

- Most air conditioners cool in the same way that a refrigerator does.
- Heat from inside the house is absorbed by the coolant within pipes inside the air conditioner.

3

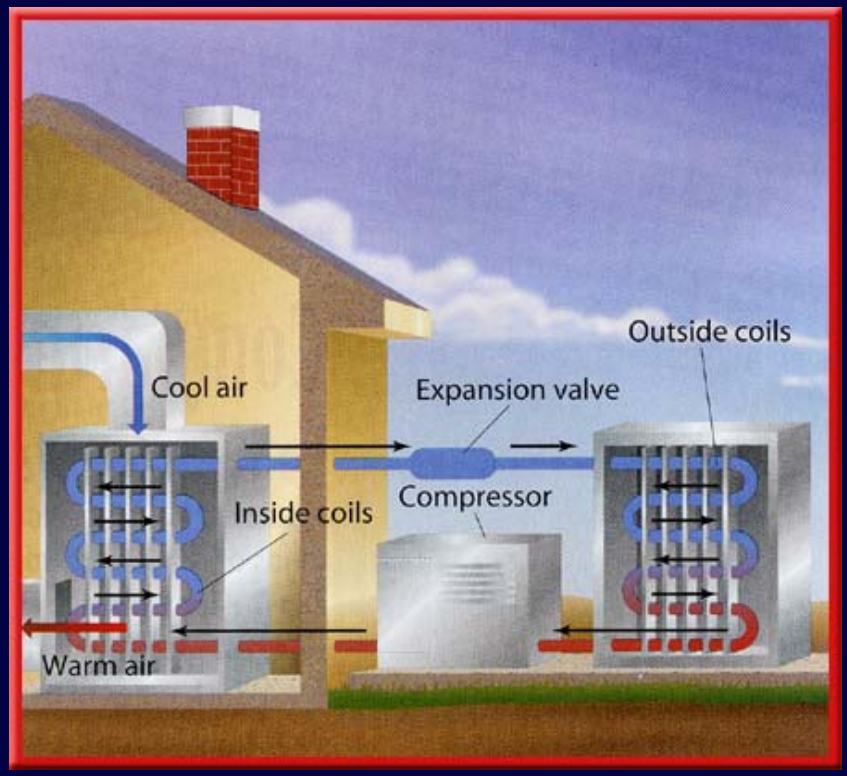
Air Conditioners

- The coolant then is compressed by a compressor, and becomes warmer.
- The warmed coolant travels through pipes that are exposed to the outside air. Here the heat is transferred to the outside air.

3

Heat Pumps

- A heat pump moves heat from one place to another.
- In heating mode, the coolant absorbs heat through the outside coils.



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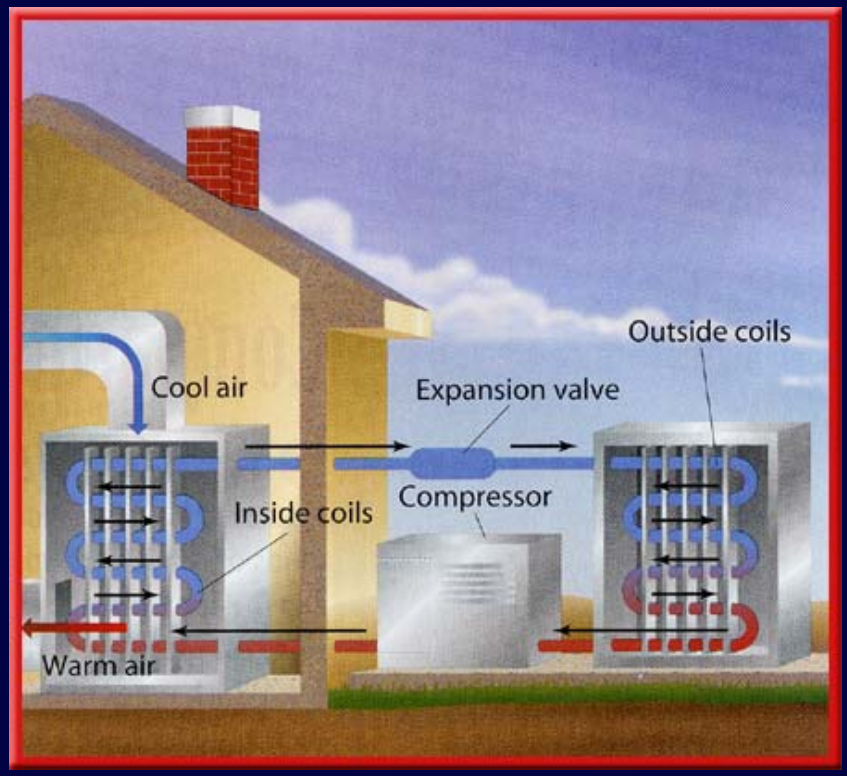
Heat Pumps

- The coolant is warmed when it is compressed and transfers heat to the house through the inside coils.
- When a heat pump is used for cooling, it removes thermal energy from the indoor air and transfers it outdoors.



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Question 1

What is the law of conservation of energy?

Answer

According to the law of conservation of energy, energy can never be created or destroyed. Energy only can be changed from one form into other forms.

3

Question 2

A _____ engine ignites the fuel in the combustion chamber without using a spark plug.

A. gasoline
B. diesel
C. two-stroke
D. four-stroke

3

Answer

The answer is B. In a diesel engine, the fuel mixture is compressed so much that it becomes hot enough to ignite.

3

Question 3

How does a refrigerator work?

3

Answer

Liquid coolant passes through an expansion valve where it changes to a gas. When this happens, it grows cold. The cold gas passes through pipes around the inside of the refrigerator, absorbing heat from inside. Then it passes through a compressor, becoming warmer than the outside air. Heat is then transferred from the coolant to the outside air.

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