Science Focus 7 - Unit 3

Teaching Notes

Topic 1 – Using Energy from Heat (p. 188-191)

Examples of using Thermal energy for heating and cooking:

Open fires

Wood-burning fireplaces

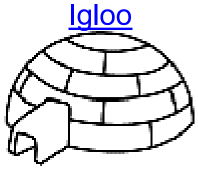
Modern Buildings

Pioneer stoves

Modern stoves

Solar Heating

Igloo



Sod House ….. Soddies

Technologies, like micro-sensors, have advanced the use of thermal energy in heating and cooking.

Topic 1 Review p. 191

Topic 2 - Measuring Temperature (p. 192-201)

A relative idea about temperature is that it tells you how hot or cold something is.

This can be accomplished by using our senses:

- Touch (sensitive nerve endings on your skin can detect changes in temperature)
- Sight (the color of the material giving off heat)

Relative ways to determine the temperature are not always reliable or safe.

Thermometers

Thermometers are more reliable devices that measure temperature
The Italian scientist Galileo invented the first air thermometer around 1600 and it has, and will continue to be, improved upon.

Temperature Scales

Early thermometers
(like the one Galileo invented)
did not have any scale
(markings with numbers)
to determine precise temperature

The 1st precise scale was developed by Anders Celsius in 1742. He used 'degree' as the unit of temperature. All of his standards for comparison to make his markings (on his scale) were based on the properties of water.

- 0^o was assigned the temperature at which ice melts at sea level
- 100^o was assigned the temperature at which liquid water boils at sea level
- The region between (above and below, as well) these two extremes was separated into 100 equal units (degrees)

The two fixed temperatures that Celsius chose can be used to **calibrate** a thermometer (p. 195)

Pressure also affects the freezing and boiling points of water. Extremely high pressure can cause ice to melt at a temperature below 0^o (Ice skaters actually glide on a thin layer of water). Low pressure enables water to boil at a temperature below 100^o. (On top of Mt. Everest, water boils at 69^o)

Absolute zero is the coldest possible temperature -273^o and is used by scientists. The Kelvin scale was developed by William Thomson – a.k.a. Lord Kelvin – and the markings on the scale are not called degrees, but are simply called **Kelvins**.

0^o Celsius is equal to -273.15^o Kelvin

The Right Device for the Job

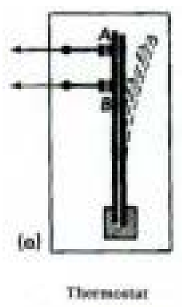
Measuring different extremes of temperatures means using different types of devices to measure these extremes. The thermometers used for this purpose have:

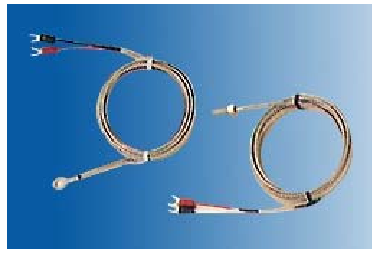
- A **sensor** – a material which is affected by changes in some feature of the environment, such as temperature
- A **signal** – provides information about the temperature, such as an electric current
- A **responder** – which indicates the data with a pointer, light or other mechanism using the signal

Thermocouple

Two wires of different metals are twisted together.

When heat is applied to one end an electric current is produced. (the amount of current depends on the temperature and the type of wires) This current can turn on and off a switch or valve.

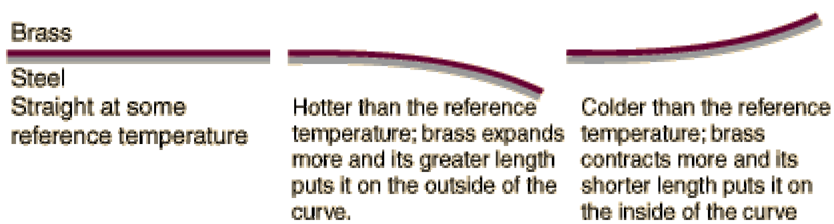




The Bimetallic Strip

A bimetallic strip is made of two different metals joined (fused) together, often formed into a coil.

When heat is applied to the end, one of the metals will expand faster than the other and the coil can operate a switch or valve just as the thermocouple does.



The Recording Thermometer

When a bimetallic coil strip is attached to a long arm lever, with a marker at the end and a drum that has graph paper, a recording thermometer can be made. This instrument works much the same as a seismograph.

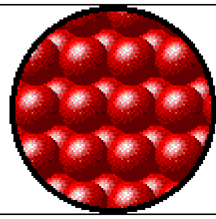
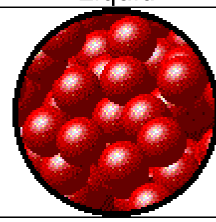
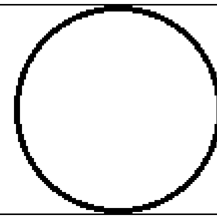
The Infrared Thermogram

If an object is warmer than absolute zero it gives off infrared radiation (IR). The infrared radiation can be photographed with special films or detected by special sensors that display colored images. The brightness or color of the image indicates the temperature of the object.

Topic Review p. 201

Topic 3 - The Particle Model, Temperature and Thermal Energy

Particle Model:

Solid	Liquid	Gas
		
Particles are closely packed together	Particles can slip past each other	Particles have lots of space between them

The Particle Model of Matter is a scientific description of the tiny particles that make up all things. The key elements in this model are:

All substances are made of tiny particles too small to be seen
The particles are always in motion
The particles have spaces between them

Temperature and the Particle Model

When heat is added to a substance, the particles move faster. When heat is lost from a substance the particles move slower.

The motion of the particles increases when the temperature increases.
The motion of the particles decrease when the temperature decreases

Temperature indicates the **average energy** (speed) of the particles in motion in a substance.

What is Energy?

Energy is the measure of a substance's ability to do work - or cause changes.
There are two important elements that occur:
Changes happen when there is a difference of energy (every useful energy system has a high-energy source that powers the changes)

Energy is always transferred in the same direction:
from a high-energy source (hot) to something of lower energy (cold).

Thermal Energy and Temperature Changes

When heat is transferred in a space the average energy of the particles - the temperature of the substance - is affected, by increasing or decreasing. The change in temperature depends on the number of particles affected.

What Energy is … and is NOT

Energy is not a substance. It cannot be seen, weighed or take up space. Energy is a condition or quality that a substance has. Energy is a property or quality of an object or substance that gives it the ability to move, do work or cause change.

The Law of Conservation of Energy states that:

Energy cannot be created or destroyed.
It can only be transformed from one type to another,
or passed from one object, or substance to another.

Topic Review p. 208
Wrap-Up (Topics 1-3) p. 209

Topic 4 - Expansion and Contraction

As the **average energy** *of particles* **increases**, *the spaces between the particles increases.*
They **expand** *(increase their volume) as the temperature increases.*

As the ***average energy*** *of particles* **decreases**, *the spaces between the particles decreases.*
They **contract** *(decrease their volume) as the temperature decreases.*

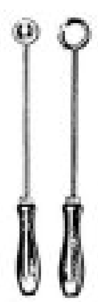
Pure substances are matter made up of only one kind of particle, which can be a solid liquid or a gas.

These phases, or states have very specific properties in relation to the particle model.

	Solids	**Liquids**	**Gases**
Shape and Size	Keep their shape and size	Take the shape of the container	No definite shape or size
Compressibility (volume)	Cannot be compressed (fixed volume)	Almost incompressible (fixed volume)	Can be compressed (volume changes)

Expansion and Contraction in Solids

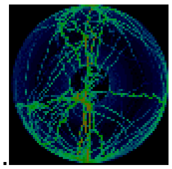
Solids can become longer or shorter depending on the average energy of the particles. **Table 1 (p. 211)** gives measurements of different solid materials at different temperatures.


This is the **Ball and Ring Apparatus** that demonstrates expansion of a solid

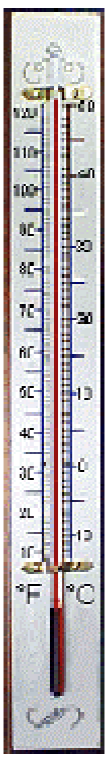
Expansion and Contraction in Gases

When the particles in a gas are **heated**, their average energy increases and they need more room, so they **expand**. When the particles in a gas are **cooled**, the volume decreases, or **contracts**, because the particles need less room.

Under extremely high temperature conditions (like the temperatures inside the Sun, particles can be split into what makes them up (electrons and ions).

This creates **a fourth state of matter called plasma**.

Expansion and Contraction in Liquids



When the particles in a liquid are heated,
their average energy increases
and they need more room, so they **expand**.

When the particles in a liquid are cooled,
the volume decreases, or **contracts**,
because the particles need less room.

This is demonstrated by the liquid used in a thermometer. As the liquid expands and contracts, it moves up and down the inside tubing (**the bore**) of the thermometer.

Topic 4 Review p. 217

Topic 5 - The Particle Model and Changes of State

Heat Capacity and Specific Heat Capacity

The amount of of temperature change, when thermal energy is added to the particles is another property that particles in different materials have. Different materials will increase or decrease their average energy depending on how much thermal energy is provided.

Heat Capacity is the amount of thermal energy that warms or cools an object by 1° C (it depends on the mass and the type of particle the object is made of).

Specific Heat Capacity is the amount of thermal energy that warms or cools 1 gram, of a specific type of particle, by 1° C.

Changes of State

Some substances like water (or wax) can undergo observable changes through all three states of matter - solid liquid and gas.

Some substances, like hydrogen, require high pressures and low temperatures (-253° C) to make the particles slow down enough for them to change their state from a gas to a liquid.

Any pure substance can exist in all three states of matter.

Melting and Boiling Points

When heat is transferred in a space the average energy of the particles - the temperature of the substance - is affected, by increasing or decreasing. A substance will change it's state when it reaches certain temperatures - called **boiling and melting points**.

Table 3 (p. 221) At everyday temperatures on Earth, most substances are either gases or solids.

What Happens When A Liquid Evaporates?

In a liquid, the particles are moving very quickly.

At the surface, some of the particles are able to escape into the air, while others do not have enough energy to escape and remain in the liquid.

As high energy particles escape, the average energy of the remaining particles is less and so the liquid cools.

The cool liquid then cools the surface on which it is resting.

This is called **evaporative cooling**. It is common and useful in many situations:

- Joggers cooling down as their sweaty clothes dry out
- Water cools down a roof on hot summer day
- A wet cloth is placed on your forehead when you have a fever

Why The Temperature Stays The Same

During a phase change, the average energy of the particles (**temperature**) remains the same, but the particles are rearranging themselves.

Particles become less organized as their energy increases, so the substance changes from a solid to a liquid to a gas.

As the energy of the particles becomes less, the particles rearrange themselves more orderly, so a gas changes to a liquid and then to a solid.

The total energy of the particles changes - by increasing or decreasing, because the particles are not increasing or decreasing their speed, just their arrangement.

The average energy (**temperature**) doesn't change.

The energy change is hidden from a thermometer and
is called **'hidden heat'** or **'latent heat'**.

Topic Review p. 225

Topic 6 - Transferring Energy

Energy can be transferred in three ways

Radiation Transfers Energy

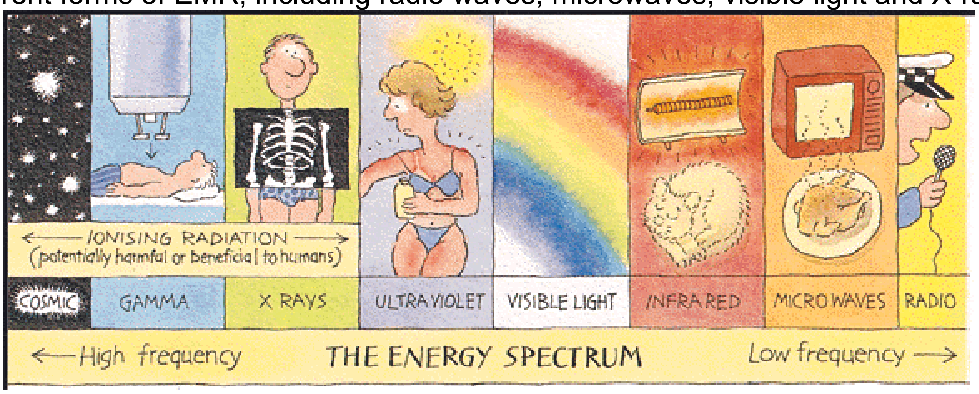
Energy can be transferred even though there are no particles to transfer the energy. This type of energy transfer is called radiation.

Radiation is the transfer of energy without any movement of matter.

Energy that is transferred in this way is called **radiant energy** or **electromagnetic radiation** (**EMR** for short).

Radiant energy travels in ***waves*** (much like a **tsunami**). 

These waves can travel through space, air, glass and many other materials. There are different forms of EMR, including radio waves, microwaves, visible light and X-rays.



If the energy source is a warm object, like the sun, some of the thermal energy is transferred as a type of **EMR** called **infrared radiation** (**IR**) or **'heat radiation'**.

Properties (characteristics) of Radiant Energy are:

- Waves of radiant energy can travel in a vacuum.
- All waves travel, across empty space, at an extremely high speed (300 Million m/s).
- Radiant energy travels in a straight line.
- they behave like waves
- they can be absorbed and reflected by objects

All kinds of radiant energy interact with matter:

- **Reflection** occurs if the energy cannot penetrate the surface of the material it comes into contact with.
- **Absorption** occurs if the energy penetrates part way into the object.
- **Transmission** occurs if the energy penetrates completely, passing through the object with no absorption of energy.

Absorbing / Emitting Energy

Dull dark objects **absorb** radiant energy when they are cool,
and emit radiant energy when they are hot. (eg. asphalt sidewalk)

Light, shiny objects or surfaces do not absorb radiant energy readily
and do not emit radiant energy readily. (eq. ice surface)

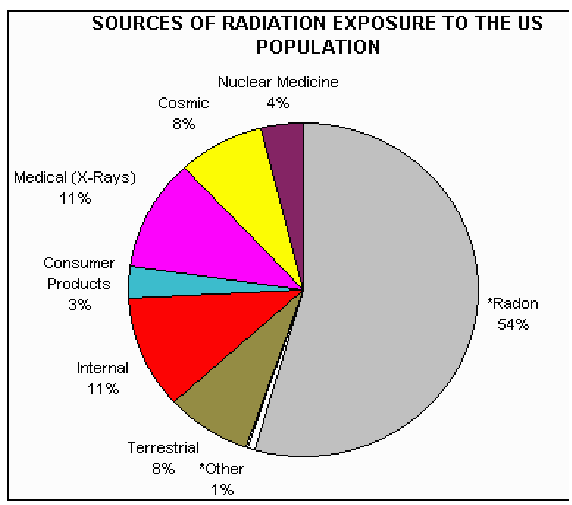
Radiant emission of energy from the body depends on surface area (smaller areas help to retain heat, whereas, larger areas radiate heat).
This is evident in the adaptations of many species of animals who have successfully adapted to their environments:

- desert animals - eg. Fox p. 140
- killer whales - the killer whale's fusiform body shape and reduced limb size decreases the amount of surface area exposed to the external environment. This helps killer whales conserve body heat.
- the polar bear has black skin to absorb radiant energy with transparent hair that transmits ultraviolet radiation to the skin.

Most radiation (82%) people are exposed to, comes from natural sources. By far the largest source is radon, an odorless, colorless gas given off by natural radium in the Earth's crust. Artificial radiation, mostly from medical uses and consumer products, accounts for about eighteen percent of our total exposure. The nuclear industry is responsible for less than one percent.
Radiation can be detected, measured and controlled.
The measurement of radiation is by the amount of radioactivity present
or the amount of radiant energy given off.

Radiation in the Environment

Radiation is a natural part of our environment. Humans have always lived on earth in the presence of radiation. Natural radiation reaches earth from outer space and continuously radiates from the rocks, soil, and water on the earth. Background radiation is that which is naturally and inevitably present in our environment. Levels of this can vary greatly. People living in granite areas or on mineralized sands receive more terrestrial radiation than others, while people living or working at high altitudes receive more cosmic radiation. A lot of our natural exposure is due to radon. a gas which seeps from the earth's crust and is present in the air we breathe.



Conduction, Energy Through Solids

In solids, where the particles are closely packed together, thermal energy can be transferred from one particle to another very easily. Thermal conduction is the process of transferring thermal energy by the direct collisions of the particles. The spaces between the particles, in different solids, determines how quickly these collisions can take place. Good conducting materials are those materials where there is little space between the particles - like most metals. Poor conductors, like glass and wood are called heat insulators. These insulators when wrapped around an object slow down the rate of thermal conduction.

Applications

Metals are good conductors of heat, so they are used extensively in cooking, because they transfer heat efficiently from the stove top or oven to the food.

Hot and cold packs are used to treat muscle injuries.

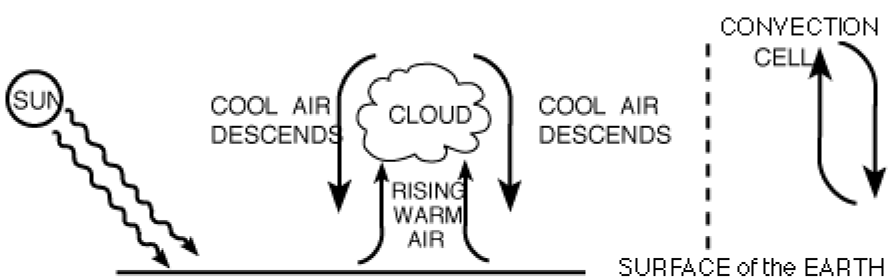
The Safety Lamp (The Davy Lamp) Davy invented his miner's safety helmet in 1815. The lamp of this safety helmet would burn safely and emit light even when there was an explosive mixture of methane and air present. Davy did not patent the lamp. (see explanation - Did You Know - p. 127)

The Radiator of a car transfers heat away from the engine, so that the gasoline being used will not ignite. (Antifreeze is used to achieve this)

The use of diamonds to transfer the heat generated by small electronic devices. Diamonds are called "ice" with good reason. Objects feel cold not only because they are at a lower temperature than our bodies, but also because they can transfer or conduct the heat away from us. When you touch a diamond to your lips, it feels ice-cold because it robs your lips of their heat. The capacity of a diamond to conduct heat distinguishes it readily from other gems and exceeds that of copper, an excellent thermal conductor, by about 4 times at room temperature. This exceptional property of diamond is increasingly being used for extracting heat from electronic devices to make them smaller and more powerful.
A Great Science Resource can be found at Science Net.

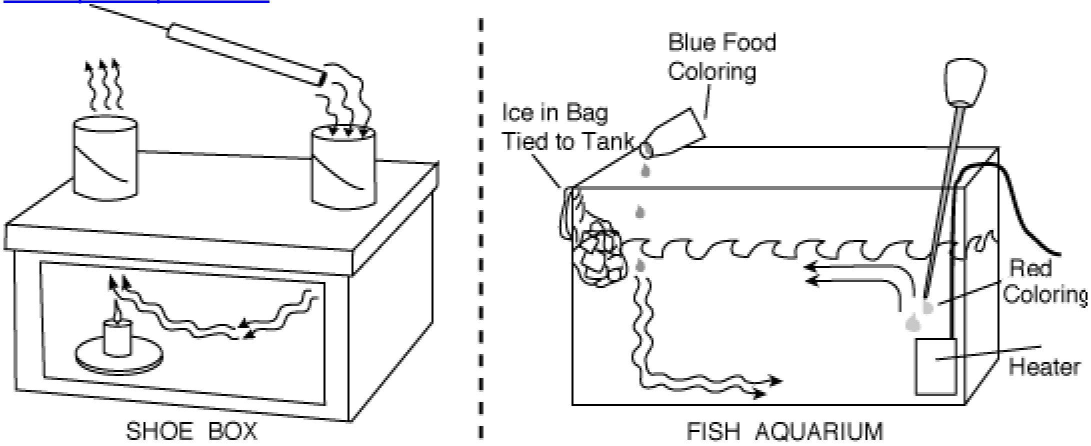
Convection, Energy on the Move

Thermal energy can be transferred by fluids in a third way, by the circular motion of the particles, called convection.



In convection, the warmer particles transfer their energy to the cooler particles as they move in a circular pattern, called **a convection current**.

A simple experiment



-  **Lava lamps** are good examples to see **CONVECTION CURRENTS** in action.

- Birds and para-gliders make use of **'thermals'** to help them soar and glide - helping them to conserve energy when they migrate.

- Convection currents are also involved in creating the force of magnetism that surrounds the earth.

- The convection oven is another of the many practical applications of convection. The heat inside the oven, helps to provide uniform beating as the convection current transfers the heat evenly inside the oven.

- Heating occurs through currents in a fluid, such as radiator water heating and flowing from the basement to heat a radiator on a floor above.

Analyzing Energy Transfer Systems

What happens when energy is transferred? The energy is not lost, it is only changed. Particles allow this transfer of energy to take place. The example of a Volleyball is given in the textbook on page 232.
Carrie's energy in her fist transferred to the ball, which transferred it to the floor. Conduction occurred, when the energy in her fist was conducted by the particles in her fist to the particles in the ball. The particles in the ball conducted the energy to the particles in the floor. The particles in the air were also warmed by the flight of the ball and the particles transferred this energy by convection currents which were created in the air.

Features of Energy Transfer Systems

All energy systems have five common features:

Energy Source - this is where the energy comes from that can be transferred throughout the energy system. The energy source can be mechanical, chemical, radiant, nuclear or electrical.

Direction of Energy Transfer - energy is always transferred away from the concentrated sources. Changes in non-living systems spread out the energy evenly.

Transformations - energy can change its form when it is transferred

Waste Heat - almost all of the energy is transferred directly from particle to particle, but some of the energy can be lost to the surroundings.

Control Systems - a control device can start and stop the transfer of energy (a thermostat in a home heating system)

Topic Review p. 236
Wrap-Up (Topics 4-6) p. 237

Topic 7 - Sources of Thermal Energy

This Topic expands on what you thought about and learned in Topic 1 about USING Energy. Much of the energy use for cooking and heating was found to be natural gas and electricity. These sources of Energy can undergo transformations before they are used for cooking and heating. There may also be environmental concerns in using each source of energy.

Chemical Energy

Chemical Energy can be transformed into Thermal Energy when wood, or coal is burned.
(**Environmental Impacts:** pollution caused by the burning of these fossil fuels)

Electrical Energy

Electricity is produced in many ways. Hydro-electric dams use the force of gravity which pulls the water over the dam to turn turbines, which are attached to generators, which produce the electrical energy from the mechanical energy of the generators.
Electricity can also be produced at thermo-electric (fuel-burning) generating stations that burn fossil fuels.
(**Environmental Impacts:** **wildlife in the area of the dam lose valuable habitat, plants may perish when the river which was blocked overflows its banks to create the reservoir for the dam, commercial enterprises may be adversely affected, pollution by the burning of fossil fuels, heated waste water can affect organisms in lakes where this waste water is dumped.**)

Mechanical Forces

Mechanical forces that push or pull objects often release thermal energy, as do Frictional forces.
(**Environmental Impacts**:

Geothermal Energy

Volcanoes, hot springs and geysers are sources of geothermal energy - energy from the interior of the earth. The thermal energy from these events can produce hot water or steam, which can be then piped to a power plant at the surface. This can be used to run turbines which produce electrical energy. HRD (hot, dry rock) can be used as another technique to generate thermal energy. (Water is pumped into cracks in the earth's crust. It returns to the surface as steam, which can be used to generate electricity.
(**Environmental Impacts**: **more extensive use of this clean and environmentally friendly technique, could reduce the threat of oil spills, the pollution caused by burning fossil fuels and the wastes from mining fossil fuels.)**

Solar Energy (A Solar Energy Information Resource)

Solar energy is clean and is guaranteed not to run out. It is not available all the time (nighttime, less in winter/ than in summer).
There are two techniques that can help to overcome these issues. (See Figure 3.32, page 243)
Passive solar heating - uses the materials in the structure to absorb, store and release the solar energy.
Active solar heating - uses mechanical devices to collect and distribute the thermal energy.
(**Environmental Impacts**: **some devices may have an impact on the aesthetics where they are located**)

Wind Energy

Wind energy is the energy of moving air, and is a result of solar energy and convection. As the sun heats up the air, the warm air rises and cools off. The cooler air falls, creating the convection currents called thermals. These convection currents on a global basis, form the Earth's wind systems. The windmill is a turbine (a wheel with fan blades), which is connected to a generator. When the windmill spins the generator produces electricity. (**Environmental Impacts**: **aesthetics**)

More Sources of Thermal Energy

The living organisms burn food (chemical energy) in their bodies to generate body heat (thermal energy).
A composter is another source of thermal energy. Decomposers break down food and as these chemical changes occur, thermal energy is produced, which in turn helps speed up the process of decomposition.
(**Environmental Impacts: waste management**)

Fossil Fuels

An energy resource is anything that can provide energy in a useful form. Most energy supplies come from fossil fuels (in Alberta and throughout the world). Fossil Fuels are chemicals from plants and other organisms that died and decomposed millions of years ago and have been preserved underground.
(**Environmental Impacts: global warming, changing climate zones around the world, plant growth, depleted water resources and thermal pollution**)

Fossil Fuels: Two Problems

The widespread use of fossil fuels has created 2 primary problems.

1- these energy sources are non-renewable and their supplies are running out
2- they produce toxic chemicals which can harm the environment by producing a greenhouse effect resulting in global warming

Co-generation uses some of the two-thirds of the energy release by the burning of fossil fuels as thermal energy, to heat a building, or a fuel, to generate electrical energy.

Topic Review p. 247

Topic 8 - Conserving Our Fossil Fuels

Despite the many disadvantages of using fossil fuels, we continue to use them. Coal is burned to generate electricity. Oil and natural gas are abundant in Alberta and we use it, maybe more than we should. Alternatives to using these non-renewable resources need to be utilized, so that future generations of Albertans can continue to thrive in our beautiful province.

It's Hot In Here

Programmable thermostats and other technologies have provided many ways to conserve energy and save money. A recirculating hot water system (Figure 3.41, p. 252) saves energy and produces instant hot water at all times.

It's Cold In Here

Refrigerators and air conditioners are thermal energy movers. A thermal energy mover is a device that transfers thermal energy from one location to another at a different temperature. The operation of these devices require **refrigerants** (liquids that evaporate easily at low temperatures) to remove thermal energy from food. As the refrigerant evaporates, it absorbs the thermal energy from the food so it cools down. This warmed gas is then compressed and releases the thermal energy into the room.

Danger: Thermal Energy

Some harmful effects of thermal energy are:

- burning ourselves on a hot utensil (us)
- forest fires (our environment)
- burning houses (our belongings)
- Storage and use of fossil fuels can pose a forest fire risk, but also can pollute the environment, by leaking into the groundwater and soil.

By-Products of Thermal Energy Use

Not all the dangers of using thermal energy are as obvious as the ones already discussed.

- One of the products (**carbon dioxide**) that is released from the burning of fossil fuels is a greenhouse gas, which traps heat energy in our atmosphere and leads to global warming.
- **Sulfur-dioxide** is released when coal and natural gas are burned. This gas is an irritant to the eyes, nose and throat.
- **Carbon monoxide** is produced when a fire burns without enough oxygen. It is clearless, odorless and very lethal. It hinders the brain's reasoning ability and can kill you.
- Smoke detectors and carbon monoxide detectors should be installed in every building to protect the people from being overcome by these lethal gases.

Topic Review p. 256

Wrap-Up (Topics 7 - 8) p. 257 **UNIT REVIEW pgs. 262 - 265**