TRAINENERGY

Module 2.2

Heat transfer mechanisms

Learning Outcomes

- On successful completion of this module learners will be able to
- Describe the 1st and 2nd laws of thermodynamics.
- Describe heat transfer mechanisms.

First law of thermodynamics

- The first law of thermodynamics,

  "an expression of the principle of conservation of energy, states that energy can be changed from one form to another, but cannot be created or destroyed".
- Example –

  Electrical energy input to an incandescent light bulb. Approximately 10% of the electrical energy is changed to generate light.

  The remaining 90% changes to generate heat.

Second law of thermodynamics

- "Heat can spontaneously flow from a higher-temperature region to a lower-temperature region, but not the other way around".
- Example –

  Switch off the electricity supply to an incandescent bulb, then over a few minutes, the heat energy dissipates from the hot bulb to the cooler air around it.

Heat transfer

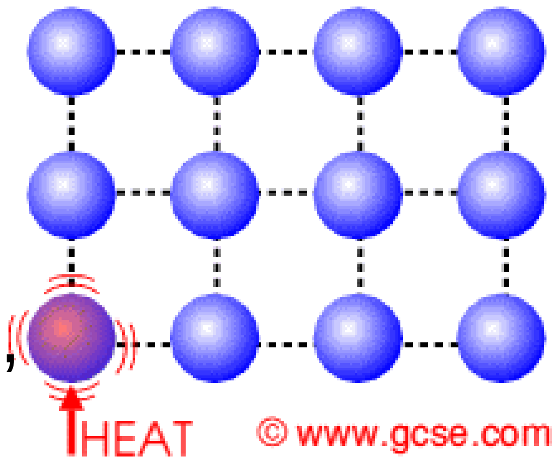
- Heat Transfer is the transfer of energy from one body to another due to a temperature difference between the bodies.

  (2nd law – heat flows from hot to cold)
- The bodies may be solids or flowing fluids as in a heat exchanger.
- There are three fundamental methods of heat transfer:
- Conduction, Convection and Radiation.

Heat transfer by conduction.

- Heat is transferred by conduction within a body or substance by direct molecular communication.

Every atom is physically bonded to its neighbours in some way. If heat energy is supplied to one part of a solid, the atoms vibrate faster.

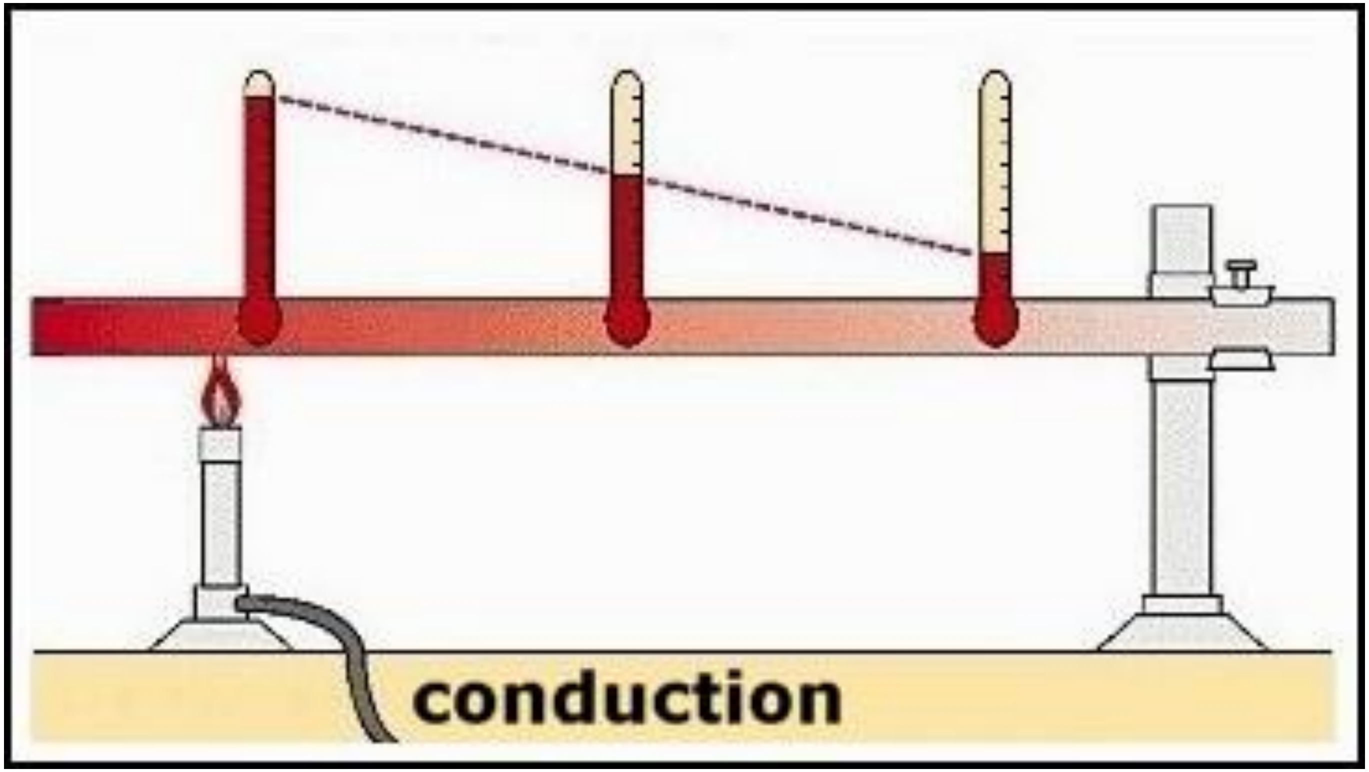


As they vibrate more, the bonds between atoms are shaken more. This passes vibrations on to the next atom, and so on:

Heat transfer by conduction - continued.

- Heat transfer by conduction is characterised by a continuously decreasing temperature in the direction of heat flow and by the absence of motion within the substance.
- It is the only mechanism of heat transfer within solids.
- When a steel bar is heated on one end, the other end becomes warm by conduction.

Heat transfer by conduction along a metal bar. Source: www.vtaide.com



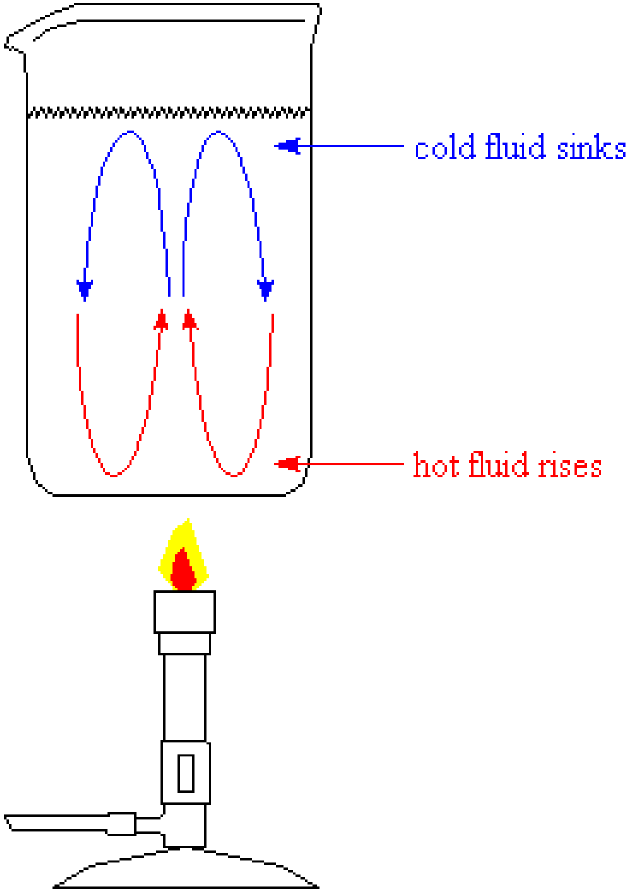
Heat transfer by convection.

- Moving fluids can transfer heat from one body or region to another by convection.
- When the fluid motion is due to a density difference arising from a temperature difference, the heat transfer is termed natural convection.
- Example –

  When a container of water is heated on a stove, the hot low-density water near the bottom rises and transfers heat to the upper regions of the container by natural convection.

Heat transfer by natural convection in a container of water.

Source: www.bluffton.edu



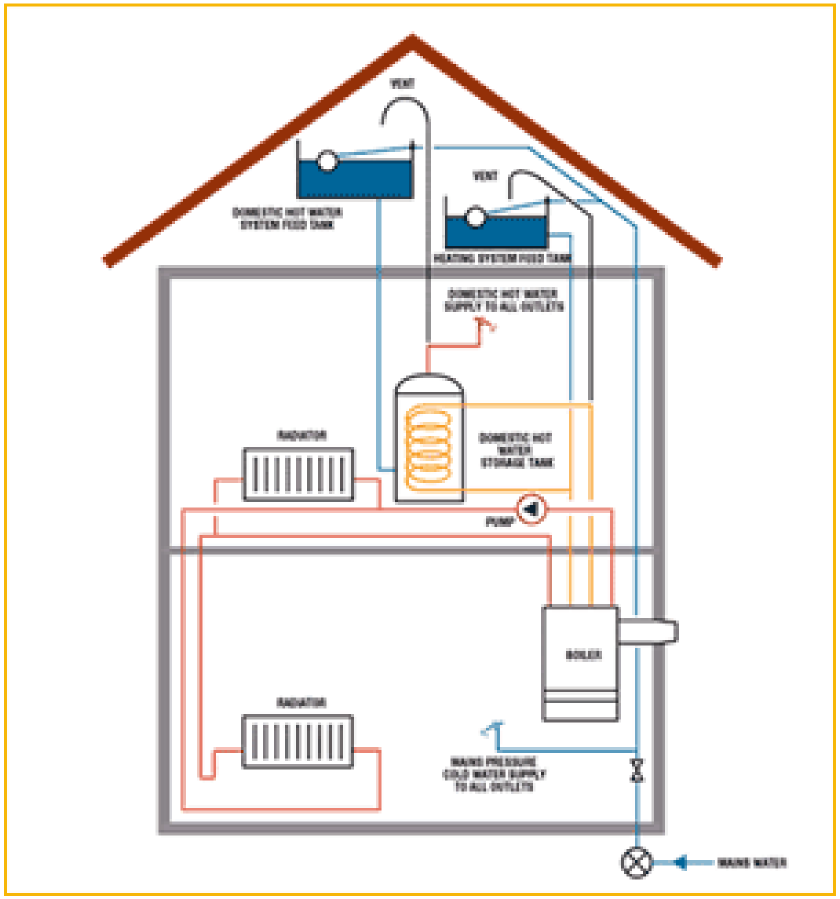
Heat transfer by convection - continued

- Where the fluid flow is produced by a fan, pump, or any mechanism other than temperature differences within the heat transfer device, the process is termed forced convection.
- Example –

  In a hot water central heating system, water heated by the boiler is generally pumped around the circuit (forced convection) to transfer heat to the radiators.

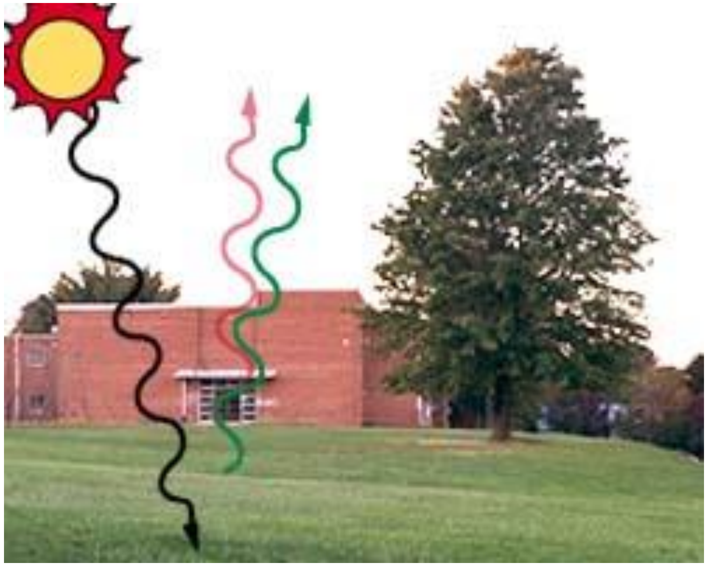
Heat transfer by forced convection

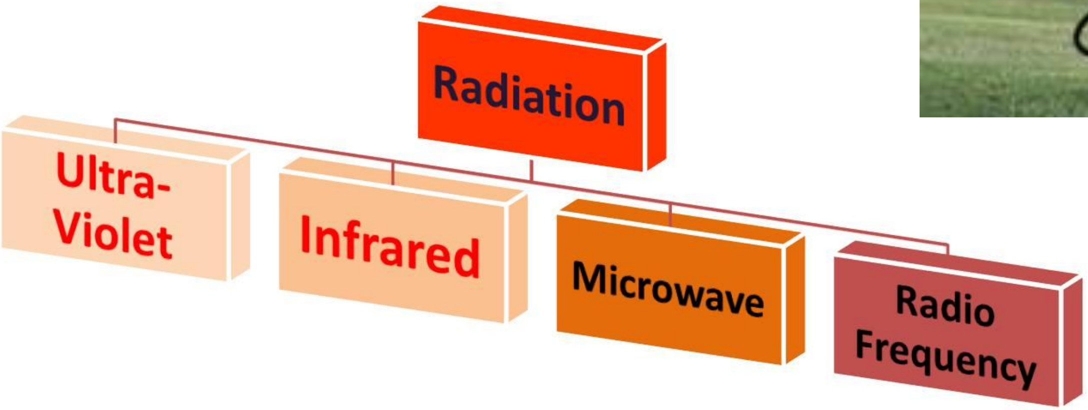
a) Water pump forces heat transfer from boiler to radiator.



Heat transfer by radiation.

- Heat transfer by radiation involves a wave action similar to light transmission.

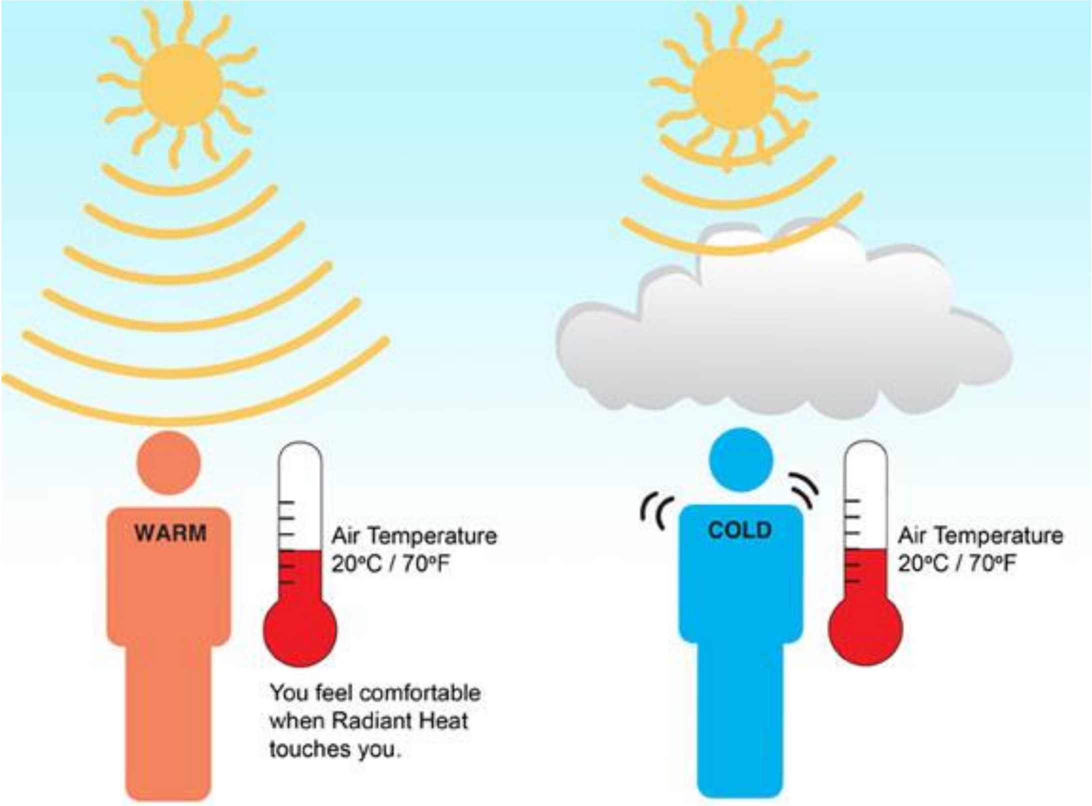




Heat transfer by radiation.

- Heat can be transferred by radiation through a vacuum, most gases and some liquids.
- Radiant energy can be transported by
  a) Ultra-violet radiation.
  b) Infrared
  c) Microwave
  d) Radio frequency

The sun transmits solar energy to the earth by radiation



Source: www.valorfireplaces.com

Radiant heat energy can be blocked by shading.

Infrared radiation is useful in providing heat energy

Approximately one-half of the energy reaching the earth from the sun is light;

that is, it is within the visible portion of the spectrum.

The remainder arrives as Infrared heat and a small amount of ultraviolet light

(Source: http://users.rcn.com).

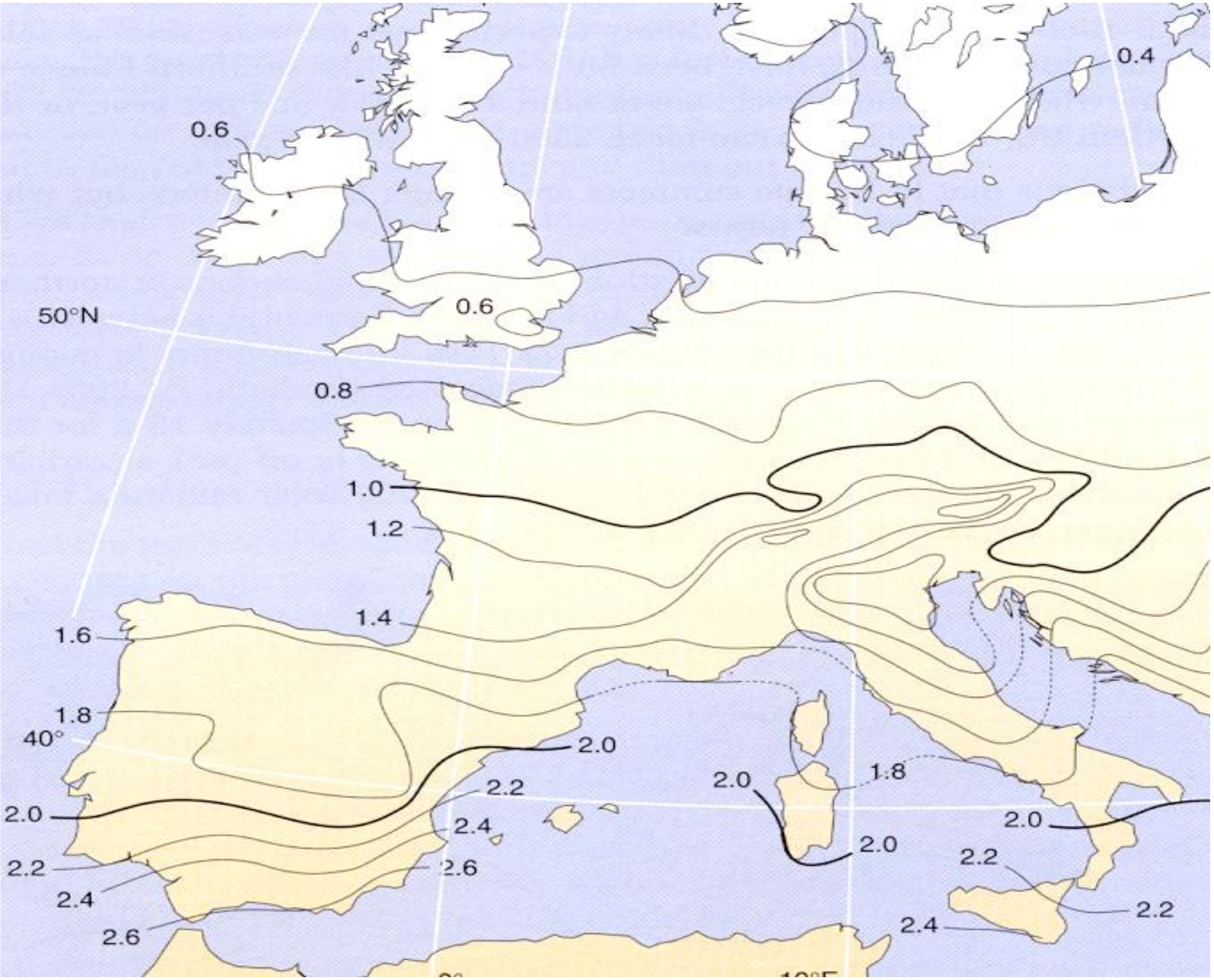
All warm bodies emit infrared radiation

- The higher the temperature of a body, the greater the amount of radiant energy emitted.
- Infrared radiation from a house.
- Red shows where most heat is lost - through the windows and roof
- Source : www.bbc.co.uk

Average Energy available from the suns radiant energy.(on a horizontal surface)

- Northern Europe
  (Ireland, UK, Denmark, northern Germany)
  January 0.5 kWh/m^2 per day.
  July 5.0 kWh/m^2 per day.
- Southern Europe
  (Spain, Italy and Greece)
  January 1.5 – 2.0 kWh/m^2 per day.
  July 6.0 – 7.5 kWh/m^2 per day.
- Source: Renewable Energy -Power for a Sustainable Future, 2nd Edition, Edited by Godfrey Boyle , Oxford University Press, ISBN 0-19-926178-4, Chapter 2.3, Page 23.

Solar radiation on horizontal surface (kWh per square metre per day), Europe, January



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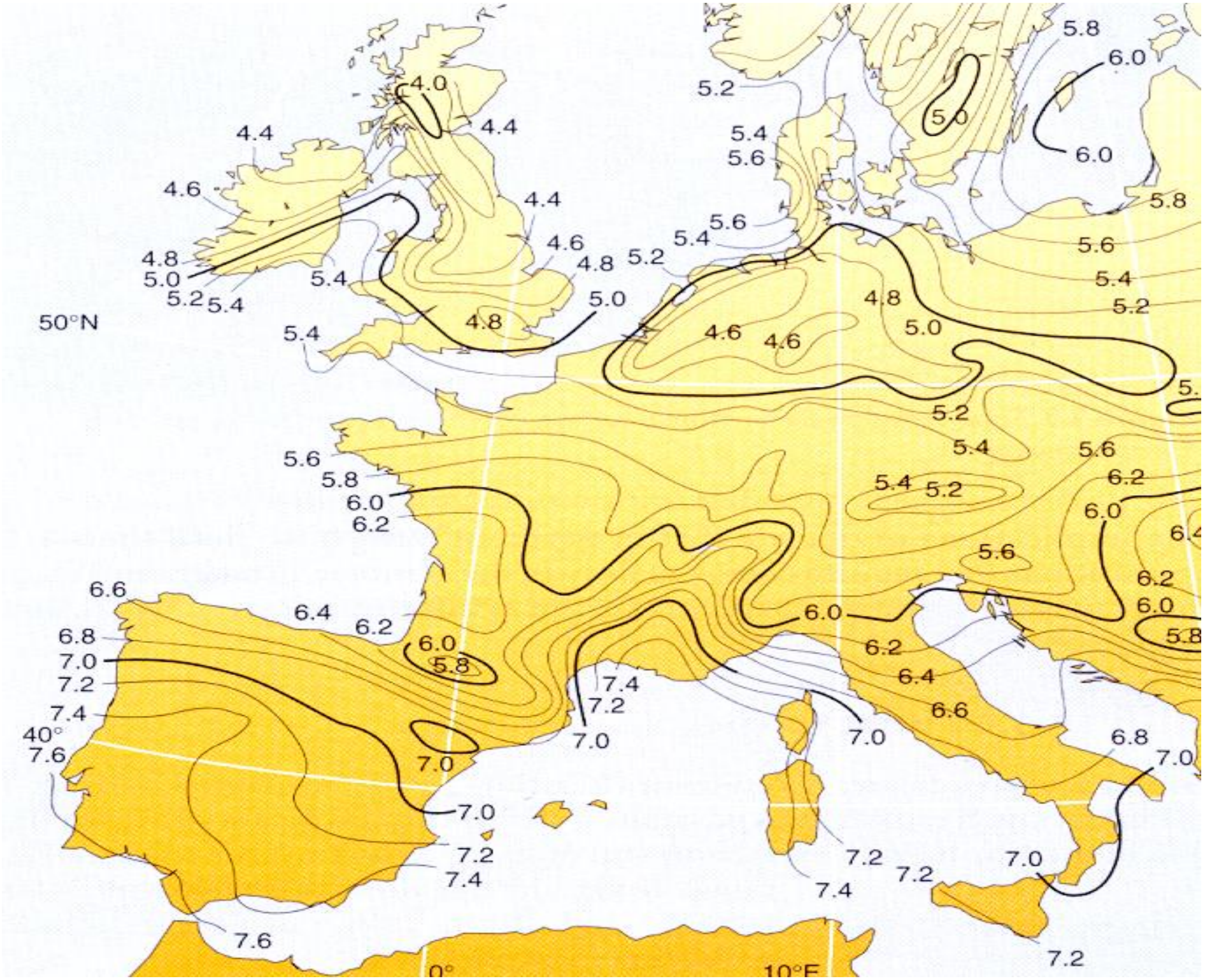
Solar radiation on horizontal surface (kWh per square metre per day), Europe, July



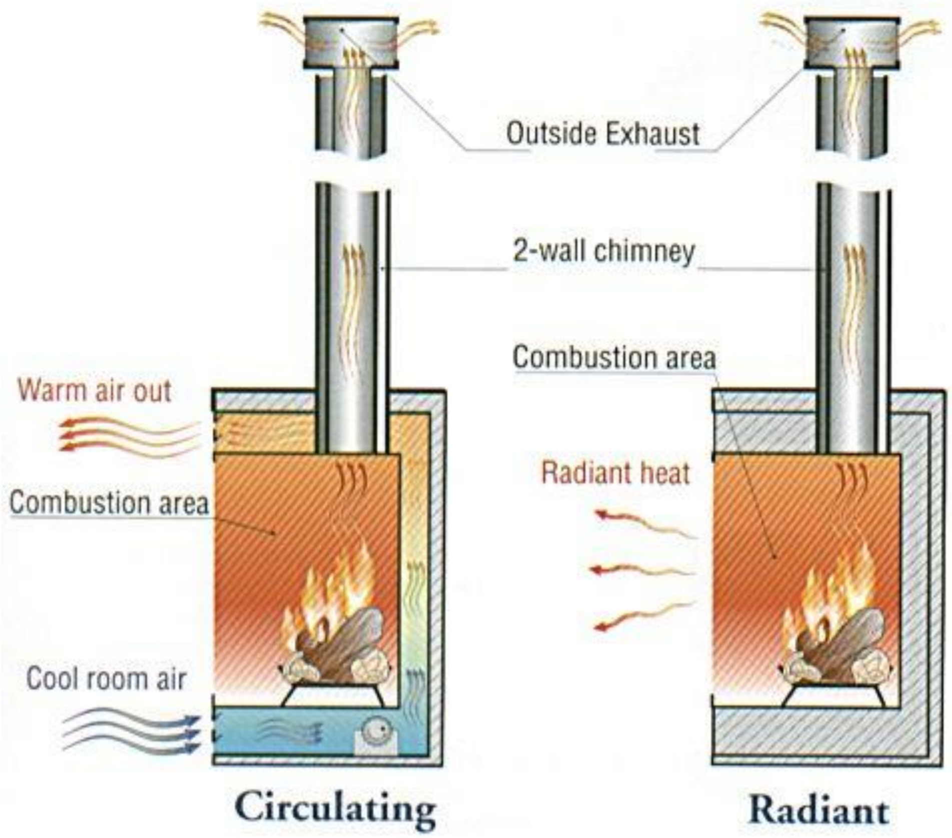
Heat transfer by radiation – continued.

- Underfloor heating is a form of space heating which achieves indoor climate control primarily through thermal conduction and thermal radiation rather than convection (forced or natural air movement). Underfloor heating can be supplied by circulating heated water or by electric cable, mesh, or film heaters.

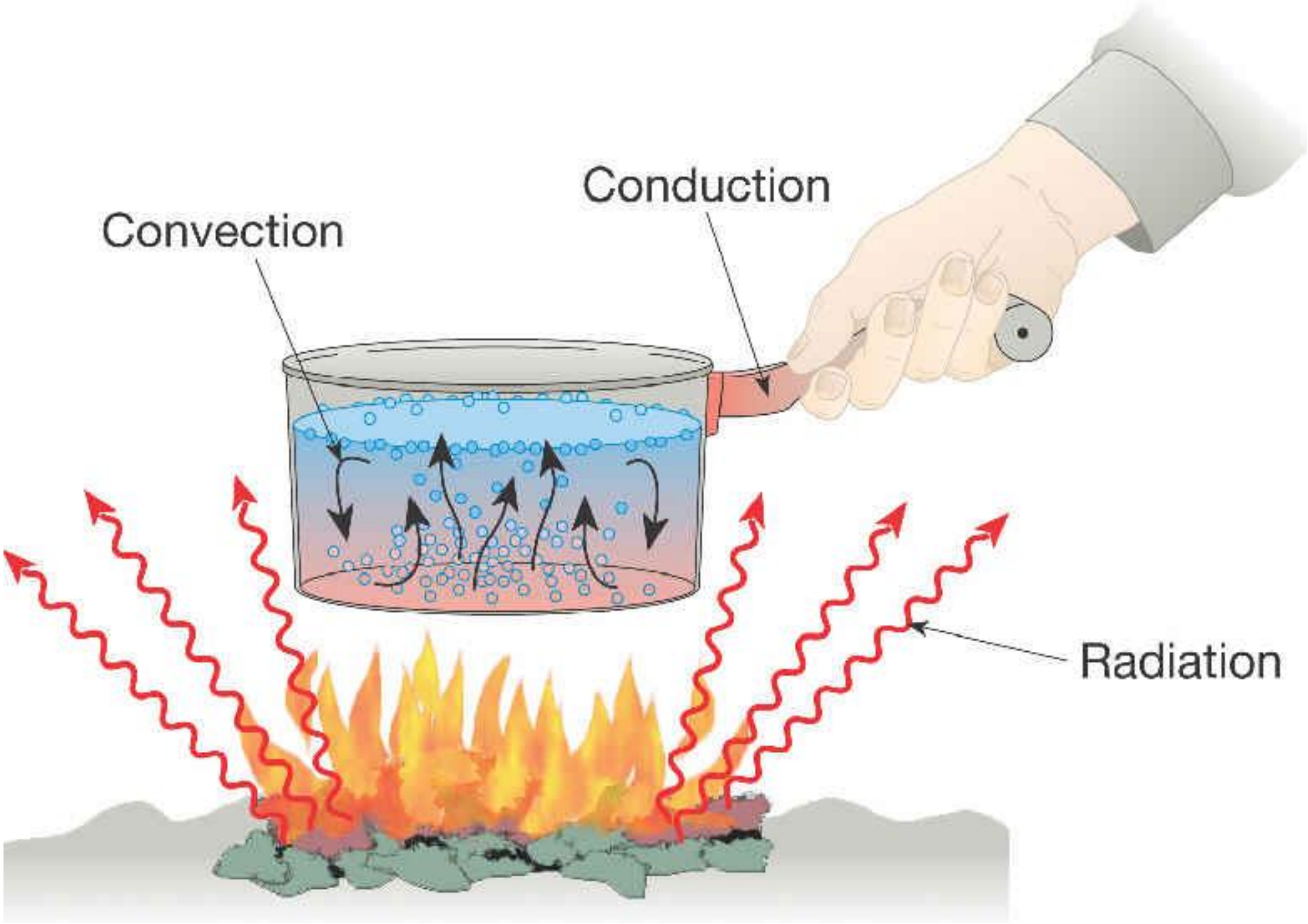
Heat transfer by radiation – continued.

- Underfloor heating is a form of space heating which achieves indoor climate control primarily through thermal conduction and thermal radiation.
- Radiator based central heating systems achieve indoor climate control through convection (forced or natural air movement).
- Underfloor heating can be supplied by circulating heated water or by electric cable, mesh, or film heaters.

A hot stove heats surrounding objects by convection and radiation.



Conduction, convection and radiation



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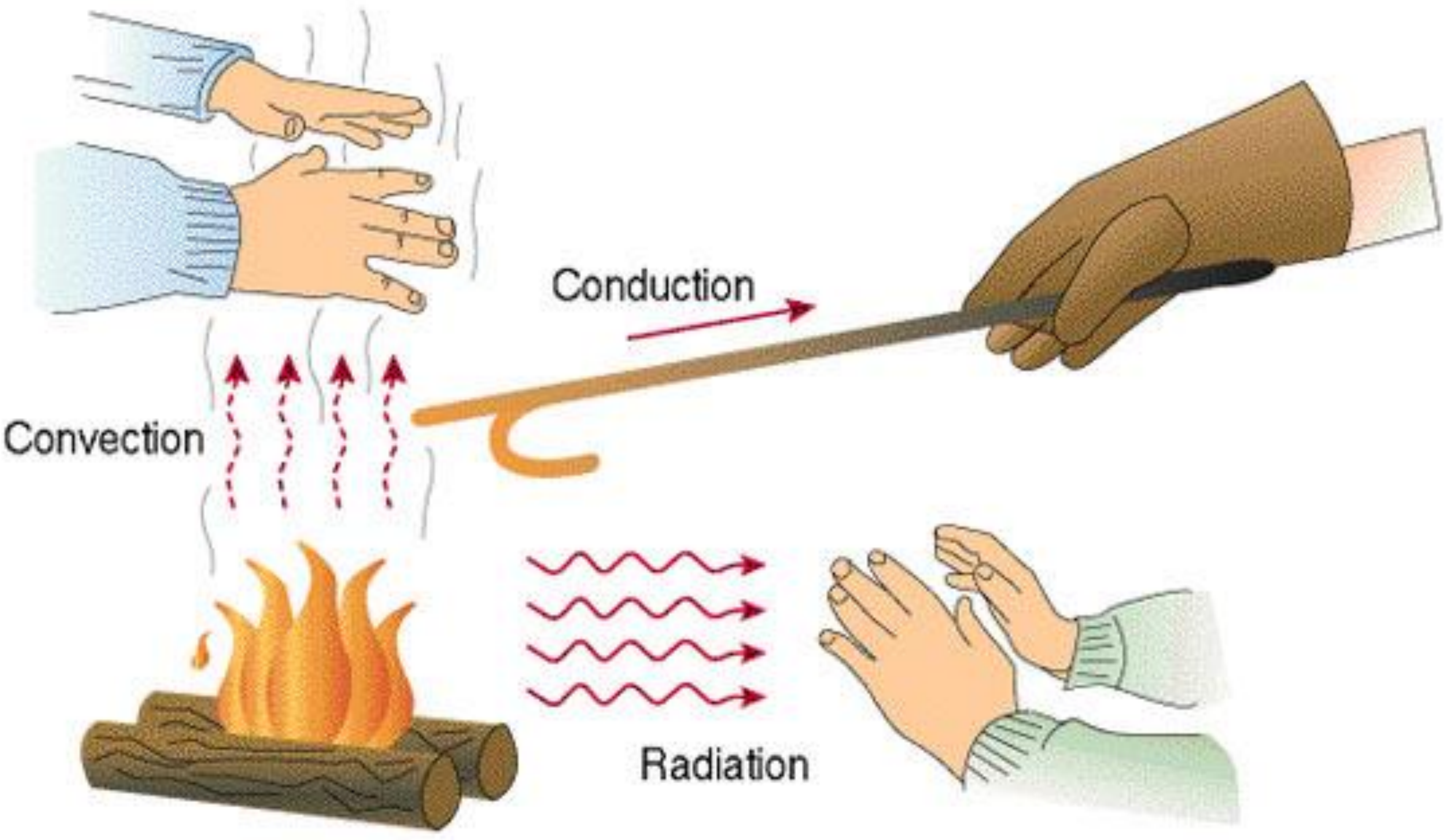
Conduction, convection and radiation



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- Heat energy is transferred from homes by conduction through the walls, floor, roof and windows.
- It is also transferred from homes by convection. for example, cold air can enter the house through gaps in doors and windows, and convection currents can transfer heat energy in the loft to the roof tiles.
- Heat energy also leaves the house by radiation through the walls, roof and windows.

How are these laws of thermodynamics relevant to energy usage in buildings?

- Buildings consume energy for space heating, water heating and lighting.
- This energy cannot be created, but instead must be converted from some other source to provide heat and light energy. (1st law)
- During the 1900's the energy source has mainly been fossil fuels.
- Fossil fuels heat our buildings to 20 ^{O}C and our hot water to 60 ^{O}C.

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- continued.

- The concentrated energy in the fossil fuel has been used to do useful work in heating buildings, heating water and generating electricity.
- Over time the heat energy in our heated buildings and heated water dissipates to cooler areas, mainly into the atmosphere. (2^{nd} law).
- More energy must be used to re-heat our buildings and hot water.

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- continued.

- The fossil fuels on this planet were formed over millions of years.
- Fossil fuels are not renewable resources since they being used up much faster than they are being generated.
- Oil may run out approx year 2050
- Natural gas may run out year 2060
- Coal may run out year 2140

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- continued.

- Burning of fossil fuels releases Carbon Dioxide (CO_2) into the atmosphere.
- CO_2 is considered to be a greenhouse gas which contributes to global warming.

Action required.

- People who can influence the energy usage in buildings must
  a) Try to minimise the demand for fossil fuels in buildings in order to conserve the reducing supply of fossil fuels.
  b) Try to minimise the usage of fossil fuels in buildings to help reduce global warming.
  b) Try to maximise renewable and sustainable energy sources to replace fossil fuels.

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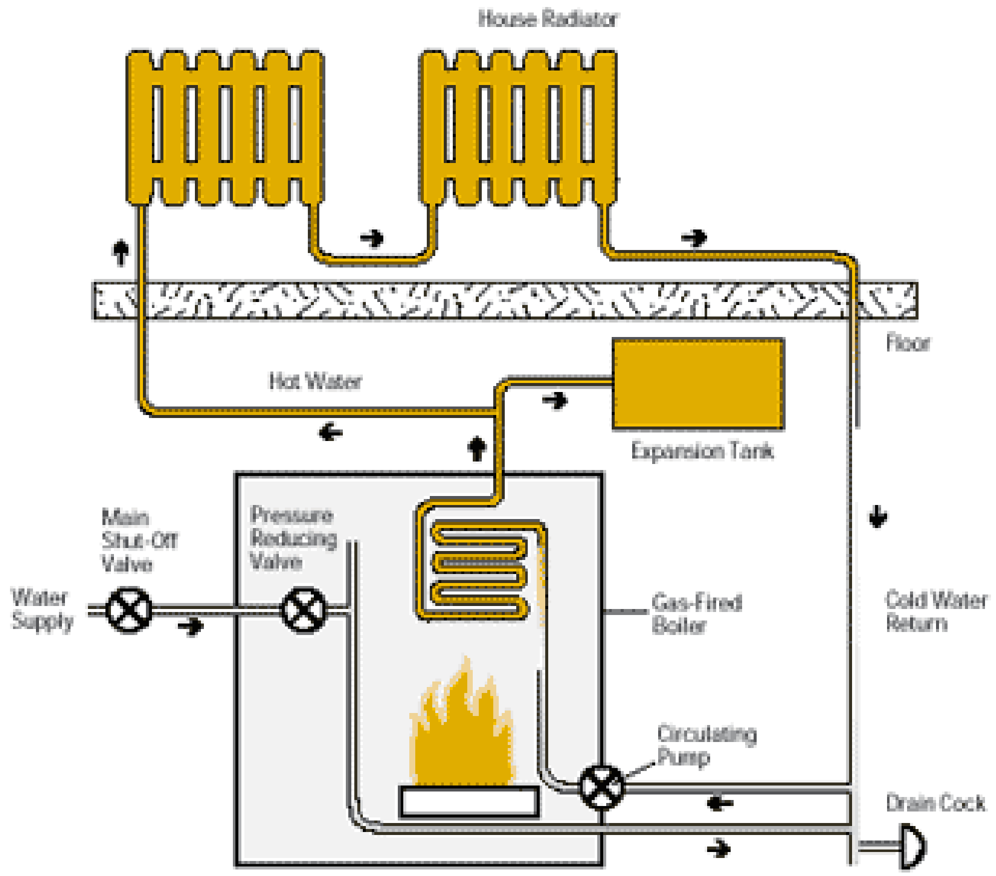
Typical water heating systems.

- Typical hot water room heating systems use a combination of conduction heat transfer and convection heat transfer.
- Conduction occurs when fuel is burned to generate a flame. The heat from that flame is transferred by conduction, through a metal sheet to the water.
- Convection, either natural or forced, then carry the heat, through the water to the space to be heated.

Space heating systems uses conduction and convection heat transfer.



Source: http://oee.nrcan.gc.ca

Module summary.

- The first law of thermodynamics states that energy can be changed from one form to another, but cannot be created or destroyed.
- Task:

  Give a number of examples of this in relation to energy use in buildings.

Module summary continued.

- The second law of thermodynamics states that heat can spontaneously flow from a higher-temperature region to a lower-temperature region, but not the other way around.
- Task:

  Give a number of examples of this in relation to energy use in buildings.

Module summary continued.

- People who can influence the energy usage in buildings now have a given responsibility.
- Task:

  List those responsibilities.

  Explain how these responsibilities could be achieved.

Module summary continued.

- Heat can be transferred by conduction.
- Task:

  Describe how conduction works.

  Give a number of examples of this in relation to energy use in buildings.

Module summary continued.

- Heat can be transferred by convection.
- Task:

  Describe how convection works.

  Give a number of examples of this in relation to energy use in buildings.

Module summary continued.

- Heat can be transferred by radiation.
- Task:

  Describe how radiation works.

  Give a number of examples of this in relation to energy use in buildings.

References:

- Renewable Energy –
  Power for a Sustainable Future, 2nd Edition,
  Edited by Godfrey Boyle ,
  Oxford University Press, ISBN 0-19-926178-4.