

# HEAT AND TEMPERATURE

## Temperature and Heat

Physics is concerned with the study of **Energy**.

There are many different forms of energy – heat, light, sound, electrical, kinetic, potential. All of these forms of energy have the **ability to do work**.

One form of energy may be transformed into another. For example; potential (stored chemical) energy is converted to heat energy during combustion. Kinetic energy (as a result of friction) and electrical energy may also be converted to heat.

It is not possible to measure heat directly, Heat is a measure of **the total kinetic energy of the atoms or molecules in a body**.

Because heat is a form of energy the units it is measured in are Joules (J) or kilo Joules (kJ). The **heat content** of a body will depend on its **temperature**, its **mass**, and the **material** it is made of. Heat energy is always transferred from an object at high temperature to one at lower temperature.

Temperature is **not** the same as heat, Temperature measures **the degree of hotness** of a body (“how hot”). It doesn’t depend on the mass or the material of an object. It can be thought of as a measure of **the average kinetic energy of the atoms or molecules in a body**.

As the temperature decreases, the kinetic energy of the particles will decrease. At some point the kinetic energy of the particles will reach zero. The temperature at which this would occur is known as “absolute zero”.

Temperature is measured using a variety of temperature scales. The most commonly used are described in the next two sections.

## The Celsius Scale (°C)

This scale puts the freezing point of water at 0°C and the boiling point of water at 100°C. The temperatures in between are divided up into 100 units (degrees).

- The disadvantages of this scale are:

- There may be temperatures below 0°C.

The pressures and volumes of gases do not change in proportion to Celsius temperature.

## The Kelvin Scale (K)

This scale has absolute zero as the zero point on it’s scale. The size of the degree is the same as a Celsius degree.

Advantages:

- There are no negative temperatures
- Pressures and volumes of gases will change in proportion to Kelvin temperature.

Absolute zero is 273 degrees below 0°C.

To convert from Celsius degrees to Kelvin degrees: add 273.

To convert from Kelvin degrees to Celsius degrees: subtract 273.

For example:

K	0	273	373
°C	-273	0	100

There are many different types of thermometer used for measuring temperature e.g. mercury, alcohol, bi-metallic strip, thermocouple, electrical resistance, brightness thermometer etc.,

## Water as an Extinguishing Agent

Water is very effective as an extinguishing agent because of its cooling effect. Why is this so? Would other liquids have the same cooling effect?

When sand and water are exposed to the same amount of heat energy from the sun, you will have observed that sand gets much “hotter” (attains a higher temperature) than water. This is because water has a much higher specific heat than sand. This means that for each degree temperature rise it will

absorb a greater amount of heat than sand. The “specific heat” of a substance measures the amount of heat absorbed by 1 kilogram of the substance when it’s temperature is raised by 1°C.

## Examples

Substance	Specific heat (kJ/kg/°C)
water	4.20
carbon tetrachloride	0.85
alcohol	2.56
iron	0.46
aluminium	0.90
copper	0.40
ice	2.10
earth, sand etc	0.84 (approx)

This tells you that it will take 4.20 kilo Joules of heat energy to raise the temperature of 1 kilogram of water by 1°C.

Carbon tetrachloride has been used in the past as an extinguishing agent, yet it only takes 0.85 kilo Joules of heat energy to raise the temperature of 1 kilogram of carbon tetrachloride by 1°C. Carbon tetrachloride was obviously not used for its cooling effect!

Water is effective as a cooling agent because of its **very high specific heat**.

The second cooling effect of water is due to the amount of heat that is absorbed as the liquid water turns to steam. This quantity is known as the latent heat of vaporisation. This measures the amount of heat absorbed as 1 kilogram of a liquid is changed to gas (vapour).

## Examples

Substance	Latent heat (of vaporisation)
Water	2260 kJ/kg
alcohol	860 kJ/kg

Again, water is effective as a cooling agent because of its **very high latent heat of vaporisation**.

### For example:

When 1kg water at 0°C heats to 100°C  
the heat absorbed = 420 k Joules,

When 1kg water at 100°C changes to steam at 100°C  
the heat absorbed = 2260 k Joules.

These figures show that most of the cooling effect of water occurs when water is turned to steam.

## Transmission of Heat

Heat may be transferred from one place to another in three ways:

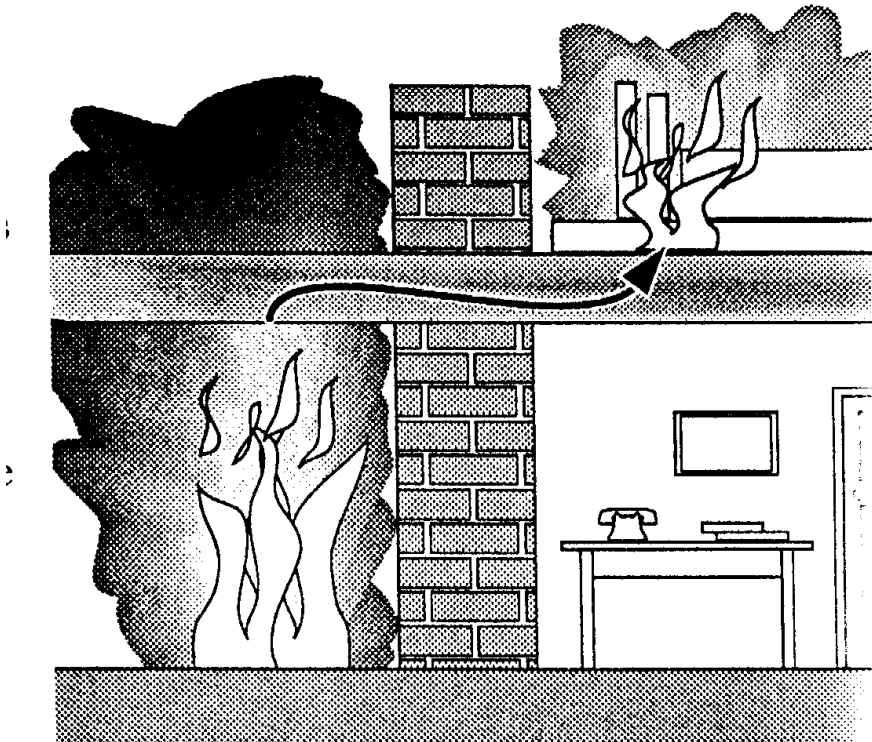
- conduction
- convection
- radiation
- direct burning

Often a combination of all four processes takes place at the same time, especially in a fire situation. If we wish to contain heat, then these processes must be prevented.

## Conduction

Conduction is most obvious in solids. All liquids (except mercury) and gases are very poor conductors of heat. When a solid heats up, its particles gain kinetic energy and increase the energy with which they vibrate. Conduction occurs when heat energy travels through a body, passing from particle to particle as they vibrate against each other. A good conductor must have particles which are close enough together to collide with sufficient force for energy to be transferred. Metals are all good conductors of heat especially copper, aluminium and silver, because they have “free” electrons which are easily able to transfer heat energy.

### Fire spread by conduction of heat along a steel girder.



This illustration shows how fire spread may occur in a building where a steel girder passes through an otherwise fireproof wall. This is because of the heat conducted along the beam. Metal doors or door handles subject to heat on one side rapidly conduct heat to the other side.

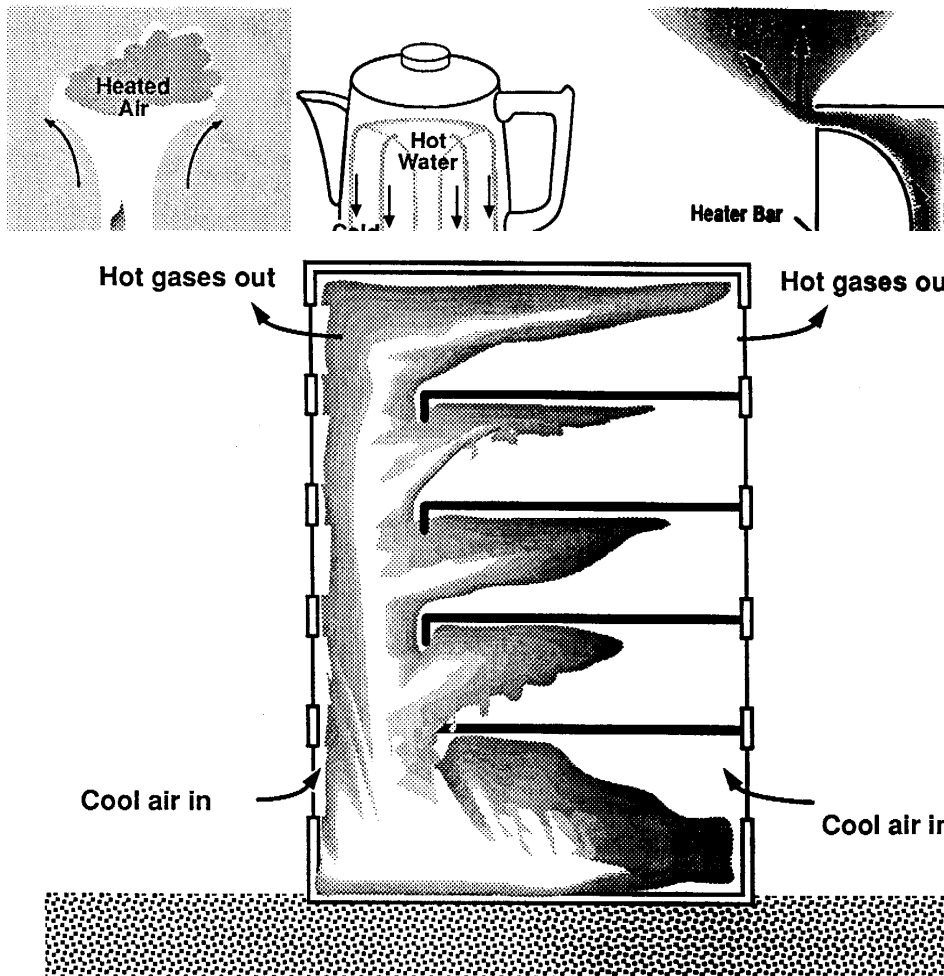
The presence of an insulator (poor conductor) may trap heat and cause heat build-up until ignition temperature is reached, e.g. faulty electric blankets under eiderdowns or pillows.

## Convection

Convection is the transfer of heat by the movement of the heated particles themselves. This can only take place in liquids and gases because in solids the particles are not able to move from their fixed positions.

When a liquid or gas is heated, it expands and becomes less dense. The lighter liquid or gas rises allowing a flow of cooler material to take its place. This in turn becomes heated and so a current is set up. Heat will continue to be transferred through the available space in this way until it is evenly distributed.

This transfer of heat is used in domestic hot water systems.



In a fire situation, convection currents can carry hot gases and burning fragments up through stairwells and open lift shafts, spreading fire to the upper parts of a building. A current of cool air replaces the hot gases, providing a continuous supply of oxygen for the fire.

## Radiation

Radiation is the way we receive heat energy from the sun. It does not require a medium for its transmission (i.e. it can travel through empty space) and is in the form of electromagnetic energy waves which travel in the same way as light or radio waves.

When these energy waves fall on a body, the energy may be:

- absorbed
- transmitted
- reflected

When radiant energy is **absorbed** the body will rise in temperature. A rack of clothes left in front of a radiant heater will continue to absorb heat until it reaches ignition temperature. Black and dull surfaces absorb (and radiate) heat much more efficiently than white shiny surface

The amount of heat energy received decreases with the square of the distance from a radiant source, for example, if an object is moved to twice the distance from a source, it will only receive a quarter of the heat energy it would have received at the original distance.

Radiant energy is **transmitted** through clear materials such as glass. The glass does not heat up.

Radiant heat from the sun may be concentrated by means of a magnifying glass, sufficient to ignite flammable material.

Shiny, silver surfaces will **reflect** radiant energy and not heat up. This is the reason for the silver coating on a fire-fighter's jacket.

Usually heat is transferred by each of these processes at the same time. It is the fire-fighter's task to prevent this transfer taking place, if possible.

## Direct Burning

Some agencies use the term 'direct burning' to describe how physical contact of the flame with other available fuel spreads a fire. By this form of direct fire spread, the heat of a fire will transfer across any area where there is a line of fuel for the fire to follow.

Some examples of direct burning are:

- Fire spreading along a piece of wood and setting fire to other pieces of wood that are in contact with it.
- A candle placed close enough to an object that the flame touches it.

## Summary

### Heat and Temperature

- Heat is a form of energy.
- Heat is a measure of the total kinetic energy of the particles in a body
- Heat is measured in Joules (J) or kilojoules (kJ).
- Heat energy flows from bodies of high temperature to bodies of lower temperature.
- The heat content of a body depends on its mass, temperature and the material it is made of.
- Temperature is the degree of hotness.
- Temperature is a measure of the average kinetic energy of the particles in a body.
- At absolute zero, the particles have zero kinetic energy.
- If heat is put into a body, the temperature rises (unless a change of state is taking place).
- Temperature scales used are Celsius ( $^{\circ}\text{C}$ ) and Kelvin (K):

$$\text{K} = ^{\circ}\text{C} + 273 \quad ^{\circ}\text{C} = \text{K} - 273$$

### Water as an Extinguishing Agent

- Specific heat is the amount of heat required to raise the temperature of 1 kg of substance by  $1^{\circ}\text{C}$ .
- The latent heat of vaporisation is the amount of heat required to change 1 kg of a substance from a liquid to a gas or vapour.
- Water is a very effective cooling agent because of its high specific heat and high latent heat of vaporisation.
- More heat is required to change water to steam than to raise its temperature to boiling point.

### Transmission of Heat

- Heat is transferred by conduction, convection and radiation and direct burning.
- Conduction takes place in solids when the heat energy is transferred from particle to particle, by collision.
- Metals are good conductors of heat
- Fire spread by conduction may take place along steel beams.
- Convection takes place in liquids and gases, when the substance itself moves, carrying the energy with it.
- Fire spread may take place by convection when hot gases rise to the top of a building
- Replacement of hot gases by cooler ones when convection takes place means a fire may have a continuous supply of oxygen.
- Radiation is the transfer of heat by energy waves.
- Radiant energy may be absorbed, transmitted, reflected
- Black, dull surfaces are good absorbers (and radiators).
- White, shiny or silver surfaces are good reflectors.
- Transparent materials transmit radiant energy.

- Radiant energy decreases with the square of the distance from the source.
- Fire spread by radiation may take place when materials continue to absorb radiant energy until ignition temperature is reached.