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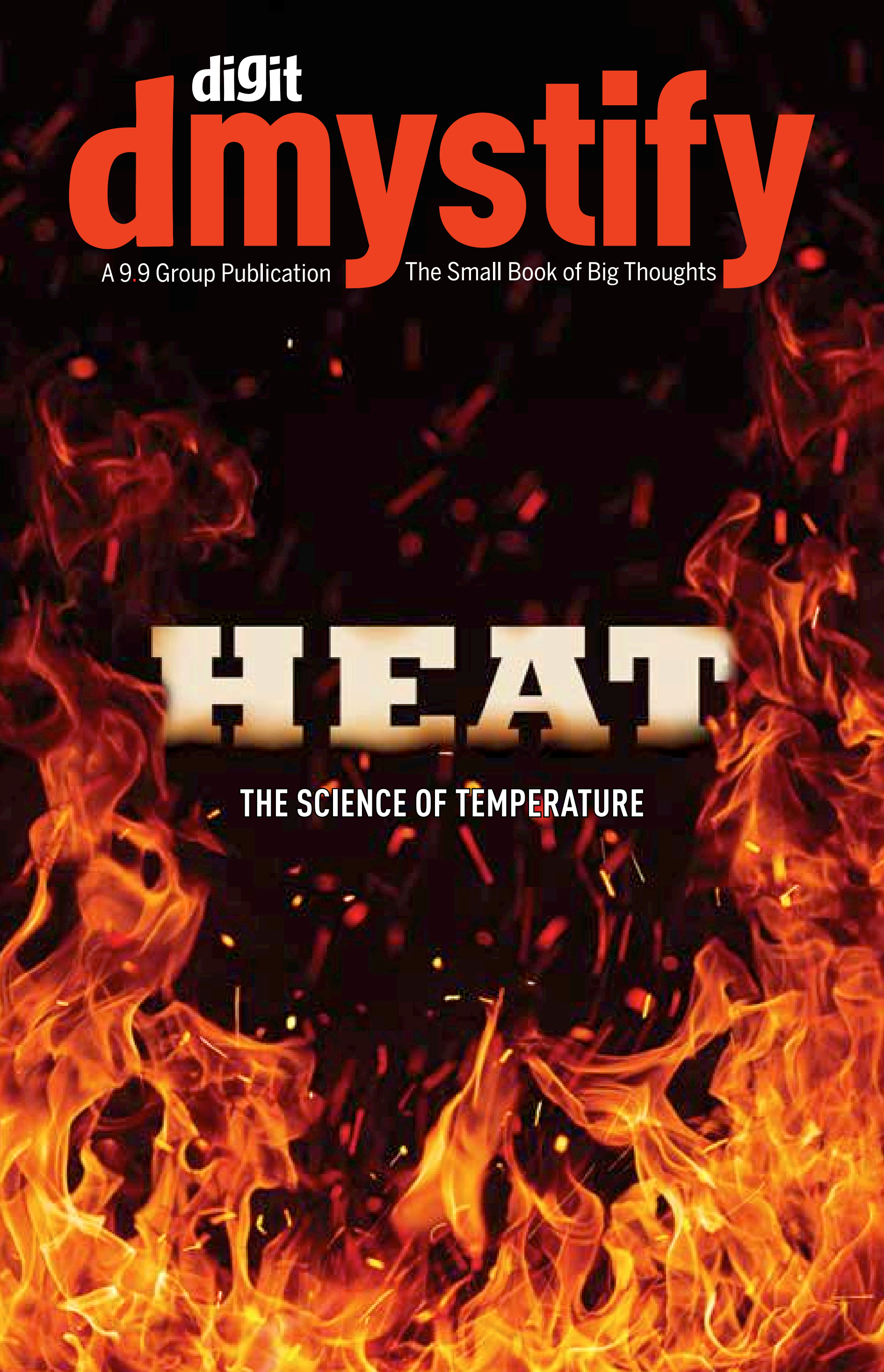

HEAT

THE SCIENCE OF TEMPERATURE

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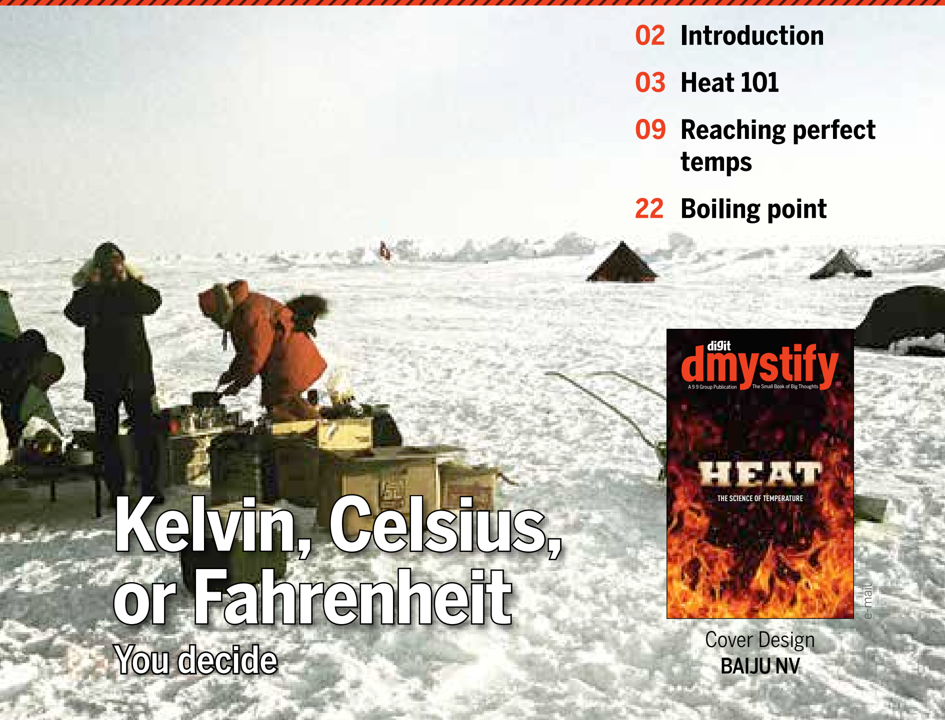
September 2022

INSIDE



Kelvin, Celsius, or Fahrenheit

You decide

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Sizzling hot science

Heat. We know of heat as something that, on the one hand, helps us cook food and ensure that we have sustainable living conditions on the planet, and on the other hand, has the potential to burn everything that we see around us to a crisp. We see heat being present around us in different processes and phenomena. From everything to digestion to the time you flick a match stick, there is heat being produced. However, given all that is going on around us, we tend to give very little thought to the different aspects of heat, the science behind the different processes it involves, and how it impacts our daily lives.

In this book, we aim to bring to you the basic science of heat, the laws and the principles associated with it, and a few different ways in which heat plays a role in our daily lives. So hold on tight – things are about to get hot! ■

Heat 101

Understand the basics that build the foundation for all things hot and cold

Whenever we talk about heat, we often tend to just stick to the concept of temperature. However, there's much more to what meets the eye and, more importantly, what makes it into our textbooks. As we build up our understanding of heat through this book, you'd get to know concepts which might have been unknown to you, or you might have skimmed past. But before all of that, we'll introduce you to the concept of heat and help you understand the differences between heat and temperature. This would set a foundation for you to build on as you read through this book.

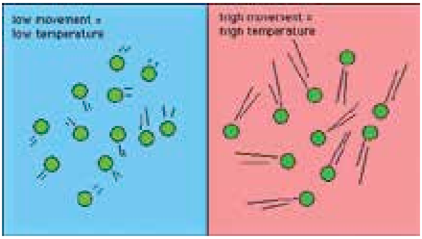
The basics

We experience heat in several forms. As gamers, our PC components generate heat, and on the rare occasions when we decide to step out, it is the Sun giving us heat. Those are the only two sources that we mentioned, but right from the palms of your hand, if rubbed together, to the engine of a car, most things are capable of generating heat.

In all the ways that heat is being generated, there is energy conversion happening. For example, if you are rubbing your palm to generate heat, then mechanical energy is getting converted into heat energy. Likewise, in every process, there is one form of energy that is being converted into heat energy. But where does this energy come from? Let's turn to science and find our answers.

In the very first definition that you'd find when you search about heat energy, you'll have your answer. The definition goes – "Heat is the internal energy of molecules constituting the body. It flows from a hot body to a colder one, when they are kept in contact with each other." Still confused? Let's elaborate.

As you would know that each body is made up of molecules which have their own energy stored in them. This stored energy is the sum of their kinetic and potential energy. So, the sum of the energy stored in each of these individual molecules is called its total internal energy, which is also often dubbed as its heat energy.



Straight and easy

When the kinetic energy of these molecules, due to an external influence increase, the body becomes hotter, and when it falls, then it becomes colder. And the opposite is for potential energy of molecules. For example, in a cube of ice, the kinetic energy of molecules of water is low, but their potential energy is high, and in a bowl of boiling hot water, the kinetic energy is high while their potential energy is low. Here too, during the process of heating and cooling, there is change in the form of energy, which gets translated into heat energy being expelled or stored in.

To make sure that you properly understand the concept of heat as energy, we'd like to clarify that any object does not possess heat. It is the measure of its internal energy, which when increases or decreases, causes a change in the level of hotness or coldness of the body. And, this change in internal energy happens because of the transfer of energy from an external source to the receiving body that is undergoing a change in its heat.

What's the quantity?

When measuring energy, it is important to define its unit. Units are governed by the nature of the form of energy. We covered this in our dmystify about units, you can refer to that book if needed. So, in the case of heat, since it's a form of energy, we take the same unit for heat, as we'd take for energy. The unit is – joule (J). That's the S.I. unit. The C.G.S. unit of heat is erg. The relationship between these two units is as follows:

$$1\ \text{J} = 10^7\ \text{erg}$$

While these two are the most well-known units of heat, there are other units in which heat is measured too. They are – calorie (cal) and kilocalorie (kcal). The relationship between these two units of heat, as you may have guessed it, is as follows:

1 kilocalorie = 1000 calories

There's a definition of the unit calorie too, that we need to understand before we move ahead. It is that – One calorie is the quantity of heat energy that is needed to raise the temperature of 1g of water by 1 degree Celsius. However, this definition only stands true when we are talking about uniform heating of water. The assumption here is that the amount of heat that is required to raise the temperature of 1 g of water through 1 degree Celsius at each initial temperature is the same. This is not true in most cases, as there is non-uniform thermal expansion of water taking place when it is being heated.

This gives us a newer and more accurate definition of one calorie which is – One calorie of heat energy is the amount of energy that is required to raise the temperature of 1 g of water from 14.5 degree Celsius to 15.5 degree Celsius. This definition is more precise, as it does not take into account any assumptions, thereby eliminating any variables that might cause anomalies during scientific measurements.

James Joule – The man after whom the unit is named

From the definition above, we are also able to define one kilo calorie as – The amount of heat energy that is required to raise the temperature of 1 kilogram of water from 14.5 to 15.5 degree Celsius.

These two units, since they relate to the same thing, which is heat energy, are also interrelated. Their connection is like:

$$1 \text{ cal} = 4.186 \text{ J}$$

When performing everyday calculations, generally the approximation used is:

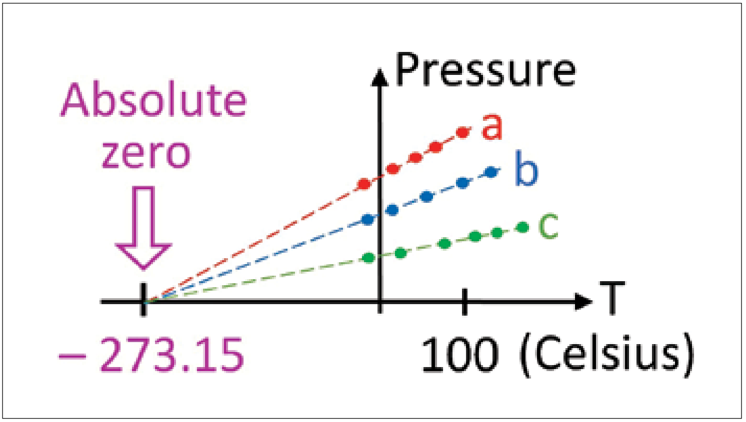
$$1 \text{ cal} = 4.2 \text{ J}$$

How hot?

You may have noticed that during this entire introduction to the concept of heat and its units, we mentioned yet did not touch upon the concept of temperature. Well, it's because it has its own story and needs an entire sub-section dedicated to it. And that's what it is. Let's talk about temperature!

First, the definition. It goes as follows – Temperature is defined as a parameter that helps us define the level of hotness or coldness of its body. It is also responsible for helping us determine the direction of flow of heat energy from one body to the other when they are kept in contact with each other.

After reading the above definition, you might think that if two bodies are kept in contact, their temperature is the same and their heat must be the same too. Well, you'd be wrong. In this case, despite no heat exchange taking place between the two



Makes sense?

bodies, the amount of heat contained within the two bodies could potentially be vastly different. It depends on factors like the mass, temperature, and the material that the body(ies) are made up of.

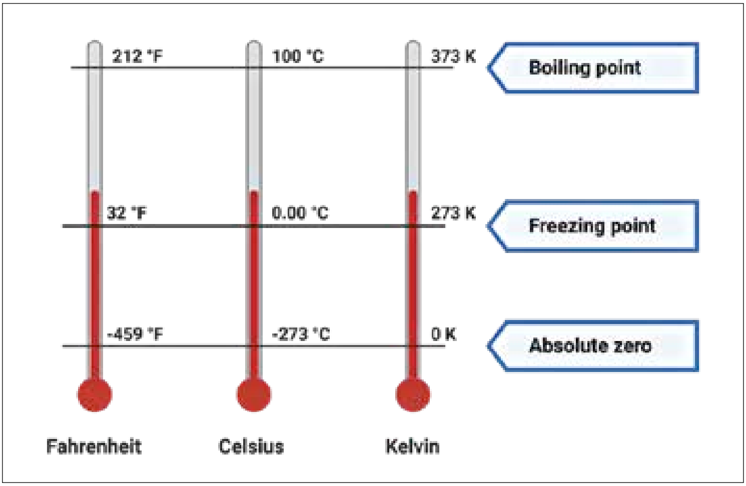
How much is too much?

As we did while explaining heat, let's have a look at the units of temperature. The process of measuring the temperature of the body is called thermometry.

The SI unit of temperature, in which is measured during scientific experiments mostly, is kelvin (K). But for daily use, depending upon the country that you live in, there are two other units of temperature used, which are Celsius and Fahrenheit. They are interrelated, and we'll establish a relationship between them, later. However, now that we have the units that we need, let's move on to defining what's the scale on which they are placed and how they are used.

On a temperature scale, there are two points. The lower one, when dealing with both Celsius and Fahrenheit, is the ice point. And the one on the higher extreme is the steam point. Ice point on the Celsius scale is zero degree Celsius, which translates to 32 degrees on the Fahrenheit scale. The steam point on the Celsius scale is, 100 degrees Celsius and on the Fahrenheit scale is, 212 degrees.

When talking about the Kelvin scale, one of the most important things that one needs to keep in mind, when taking about it, is that there's no degrees added to the expression of temperature in kelvin. You just say that the body is at x kelvin, and not x degrees kelvin. Talking about the ice and boiling points, the ice point on the Kelvin scale is at 273 K, and the steam point is at 373 K.



Changing scales

Now, that you know about the three different scales and units of measurement, let's explore how you'd convert them from one to other. Here's how it goes –

We know that there are 100 intervals between the ice and steam point on the Celsius scale, and the Fahrenheit scale on the other hand, has – 212-32 = 180 divisions between the steam and the ice points.

This means that – 100 units on Celsius scale = 180 units on Fahrenheit scale

Therefore,

1 unit on the Celsius scale = 180/100 = 9/5

However, we know that 0 degrees Celsius is the same as 32 degrees Fahrenheit. Therefore, 32 must be added to yield the correct value of temperature.

This means,

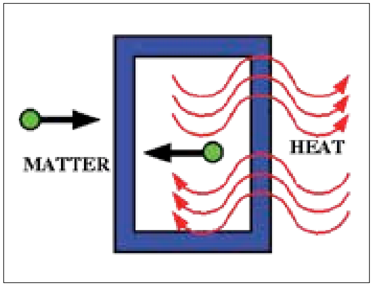
$$F = (9/5 \times C) + 32$$

Similarly, when we flip the equation to solve for C, we get:

$$C = 5/9\,(F-32)$$

Now, when it comes to Kelvin, we know what's the ice point and the steam point on that scale. You have seen us convert the Fahrenheit scale to Celsius, and vice versa. We challenge you to convert the equation to yield you the temperature in Kelvin, when you are given the temperatures in either Celsius or Fahrenheit.

Just to wrap the chapter up, let's look at an interesting relationship that temperature and heat share with each other. We will be finding out about the factors that affect the quantity of heat that is absorbed by a body to increase its temperature.



More mass results in longer heat transfer

Interconnected

Well, as you may have seen it coming, the quantity of heat that is absorbed by a body is generally dependent on three factors, which are as follows –

- Mass
- Increase in temperature
- Material

After years of trials, testing, and experimentation, the following observations were made with regards to the effect of these three aspects affecting the temperature of a body:

- The objects of different mass, despite being made of the same substance and material absorb different amount of heat energy to undergo the same change of temperature. So, if we represent the amount of heat energy absorbed using Q and the mass of the body with the letter m, we get the following mathematical relation –
  $Q \propto m$
- If there are two objects of the same weight, made of same materials/substances, to change their temperature by varying amounts, they'd absorb different amounts of heat. Here, if we use the same notations as above, we get the following mathematical relation -
  $Q \propto \Delta m$
- If two objects have the same mass, but are made from different substances/materials, they'd absorb different amounts of heat energy to change their temperature by the same amount. To understand the heat absorption capacities of different materials, to ensure consistent mathematical calculations, we define the specific heat capacity of each material. It is represented using c. The specific heat capacity of a material is specific to it and varies depending upon the material.

Now, that we know of the effect of all the three factors, let's form a single consolidated equation that would help us relate each of these three quantities with one another.

$$Q = c\, m\Delta t$$

These were the basic concepts related to heat that would help you understand the rest of the explanations better. In the next chapter, we'd look more into the concept of specific heat capacity, latent heat, and better understand the concept of change of state of substances. ■

Reaching perfect temps

"It's a cold world. You gotta bring your own heat."
– *Ariel Nyalila*

Well now you have the basics prepared. So now it's time to move on and take a plunge into the world of some more interesting concepts about heat. The ones that govern the way we perceive and see heat in our daily lives. We'll cover concepts like latent heat, specific heat, and laws of thermodynamics. The ride is interesting so hold on!

How much is this one's capacity?

Before talking in detail about the concept of specific heat capacity, let's have a look at the concept of heat capacity and understand what it means.

Heat capacity of the body basically is the amount of heat energy that is required to increase the temperature of the body by 1 degree Celsius or 1 kelvin. And, having read a bit about specific heat capacity in the last chapter, you'd be aware that the heat capacity of a body is dependent on various factors, which are later accommodated by the concept of specific heat capacity.

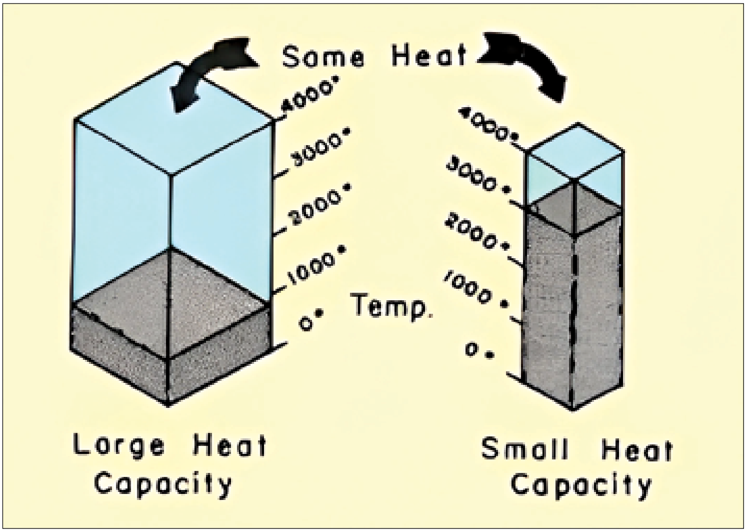
The symbol that is used to mathematically denote heat/thermal capacity is C' and the formula to calculate is as follows –

C' = amount of heat energy supplied/rise in temperature

OR

$$C' = Q/\Delta t$$

(Q is the amount of heat energy supplied, Δt is the change in temperature in degree Celsius or Kelvin)



Plain and simple

Having read the last chapter, you'd have figured out that, when talking numbers, it is important to also understand the units that are associated with various quantities and measurements of heat. So, let's take a look at the unit of heat capacity.

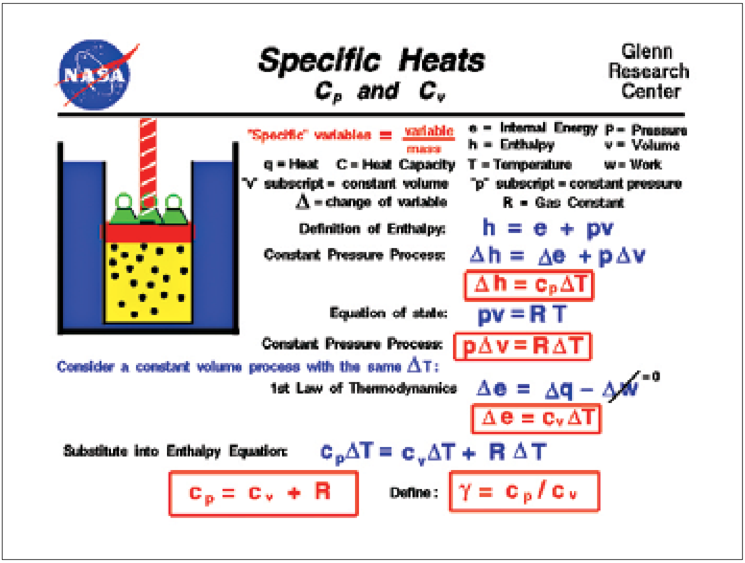
From the definition, we know that heat capacity is the measure of the amount of heat energy that needs to be supplied to a body to raise its temperature by one degree Celsius or one kelvin. Thus, the unit of heat capacity would be – joule per kelvin (J/K). Likewise, when representing temperature using degree Celsius, we have the unit to be – joule per degree C (J/°C).

If we were to use calorie as the unit of heat, the unit of heat capacity would be – cal per degree C (cal/°C) and kcal per degree Celsius (Jkcal/°C), if the heat was represented using kilocalories.

That's pretty specific

We know that heat capacity of a body is the measure of heat required to raise its temperature by one degree Celsius or one Kelvin, as a whole. However, when talking about specific heat capacity of a body, we talk about the amount of heat required for per unit mass of that substance.

Thus, specific heat capacity of a body is defined as – The heat capacity per unit mass of the body made of that specific material/substance. In other words, specific heat capacity of a body has much more to do with the substance/material that it's



made of, rather than its mass. To calculate the specific heat capacity of a substance/material, we use the following formula –

$$c = C'/m$$

(***c*** is the specific heat capacity, ***C'*** is the heat capacity of the body, ***m*** is the mass of the body)

We also know that $C' = Q/\Delta t$

Thus,

$$c = Q / m\Delta t$$

From the above equation, we can derive another equation for specific heat capacity, which will be – Specific heat capacity of a substance is the amount of heat energy that is required to raise the temperature of a unit mass of a given substance by one degree Celsius or one Kelvin.

The equation when written in terms of ***Q*** is represented as –

$$Q = m \times c \times \Delta t$$

Now that we have an understanding of the concept of heat capacity and specific heat capacity, we can establish a relationship between the two. It goes as follows –

$$C' = m \times c$$

(***c*** is the specific heat capacity, ***C'*** is the heat capacity of the body, ***m*** is the mass of the body)

We can conclude from the explanations that, higher the specific heat capacity of a material, the more heat energy is required to increase its temperature.

Now that we know what effect mass and material have on the heat absorption and repulsion of a body, let's now have a look at the modes and ways of heat transfer between bodies. There are three basic ways in which heat transfer takes place between bodies, and we will have a look at each of those three methods of heat transfer now.

SPECIFIC HEAT CAPACITIES OF SOME COMMON MATERIALS/SUBSTANCES:

Substance/Material	Specific heat capacity c (J/g °C)
Air	1.012
Aluminum	0.89
Argon	0.5203
Copper	0.385
Granite	0.79
Graphite	0.71
Helium	5.1932
Iron	0.45
Lead	0.129
Lithium	3.58
Mercury	0.14
Methanol	2.14
Sodium	1.228
Steel	0.466
Titanium	0.523
Water (ice, 0°C)	2.09
Water	4.184
Water (steam, 100°C)	2.03

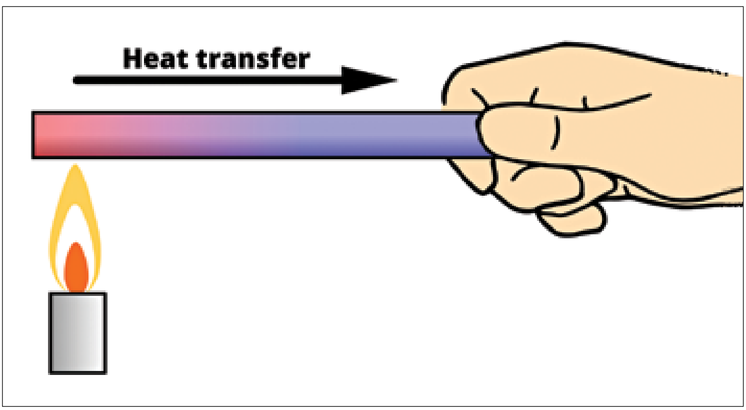
(Source: The University of Texas at Austin)

Staying in place

The first of the three methods of conduction of heat are called as conduction. For heat to be transferred from one body to the other, there needs to be contact between its surfaces. The two parts between which heat transfer is taking place are stationary, however, their molecules vibrate at a very small scale, enabling the transfer of heat. This leads us to the definition of this form of heat transfer – Conduction is referred to as the process of heat transfer where heat is transferred from one part of a body to the other, or between two bodies, which themselves are stationary, and most importantly, in contact with each other.

To better understand conduction, let's take the example of a row of erect dominoes and how it would topple when one end is provided with kinetic energy. So, in this case, imagine that you have a closely placed stack of dominoes. When you flick the first domino, you are providing kinetic energy to the domino, which is translated to the next domino that is in contact with it, and this chain reaction continues, until the very last domino has acquired kinetic energy and toppled.

Now, imagine a block of iron being heated from one end. Each molecule as it gains heat, as explained in the first chapter, sees a rise in its kinetic energy. It starts vibrating. As its vibrations increase, it starts transferring those to the other stationary molecules. This cascading effect continues until the very last molecule has reached a certain level of vibrations. This means that the entire body has heated up. If there was another piece of a conducting material attached to the any surface of that heated iron piece, the heat would transfer from that to the other, by the virtue of the vibrations that would be transferred between the molecules that are in contact.



Moving ahead

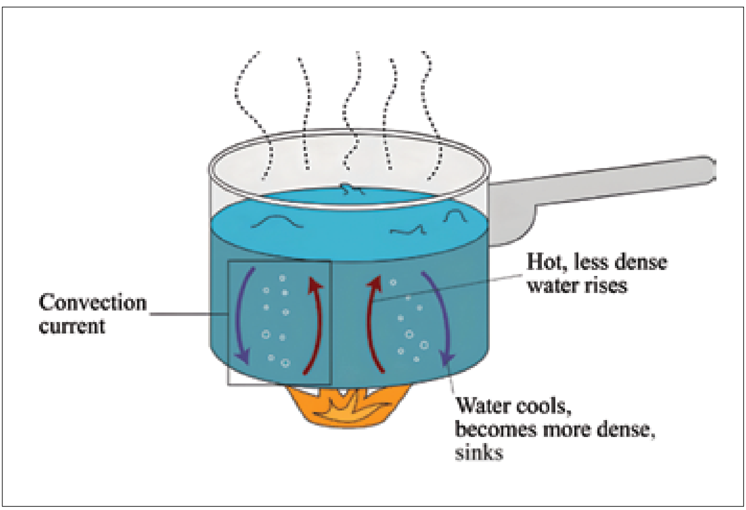
However, we know that not all the materials can have transfer of heat through this process, for example, plastic. Such materials are called insulators. These are defined as the materials that do not conduct heat easily. This implies that they have high specific heat capacities, compared to conductors, which are known to carry heat easily because of their low specific heat capacities. Don't believe us? Well look at the table we just presented in the last section.

Moving around

After reading the last subhead and the process of heat transfer described beneath it, you must have guessed what this one is going to be. At least you would have guessed what happens to the molecules when heat is transferred. If you answer was through the actual movement of molecules, then yay! You're correct!

During the process of heat transfer through convection, we see that the molecules of the substance that is being heated show physical movement, going from one part of the substance to the other, causing a change in temperature. This form of heat transfer is mostly seen in liquids. The molecules of the liquid that are exposed to the flame, tend to heat up, and move upwards, pushing the colder molecules down. This cycle goes on until the entire body of the liquid has been heated uniformly.

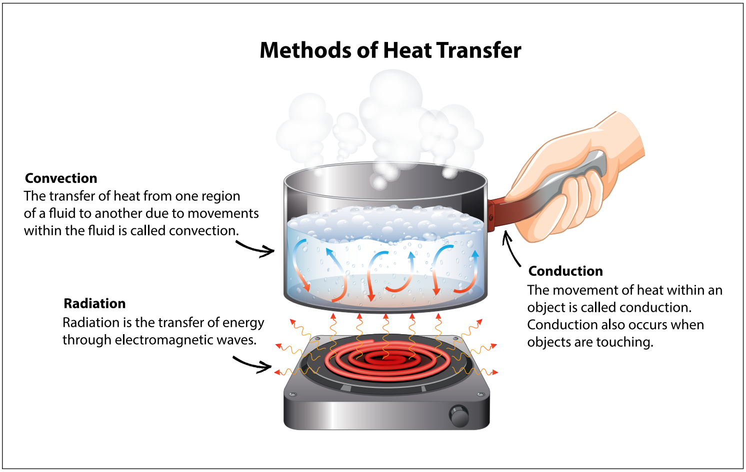
There is a very interesting natural phenomenon, land and sea breeze that can easily be explained using this form of heat transfer. But we'll reserve them for the last chapter. Let's move on to exploring the next process of heat transfer for now.



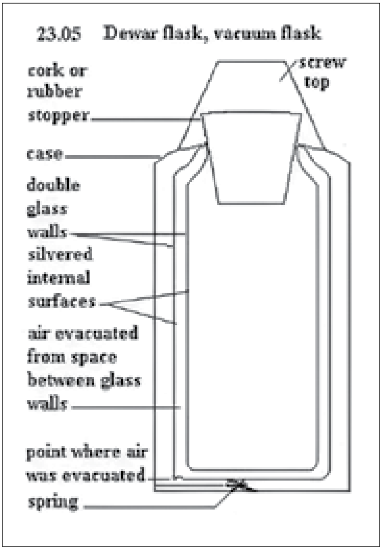
Convection current in water

Through vaccum

The process of heat transfer through a vacuum is called radiation. We saw that the last two processes of heat transfer required a medium to take place, radiation does not need a medium at all to take place. The best example of heat transfer through radiation is the transmission of heat from the Sun to the Earth.



To explain in the crudest way possible, in radiation, the source releases a beam of small energy packets that travel in a straight line, and transfer heat energy when they hit a surface. The ability of a surface to absorb radiation completely depends on its colour. From experimentation over the years, we know that black colour is the best absorber of radiation, while the colour white is the worst when it comes to absorbing heat. Reflective surfaces too are known to stop the transfer of heat through radiation.



Flasky business

Now that we know the basics of all three processes of heat transfer, let's look at the best place where we see our understanding of these processes come in effect. It is the thermos flask. In a thermos flask, we see transfer of heat through all the three processes being stopped.

Look at the figure, and follow:

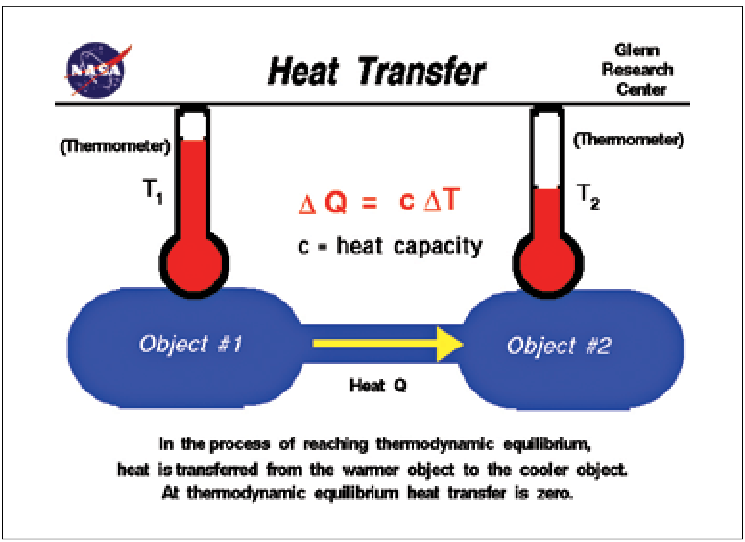
- The silvered insides of the wall inhibit heat transfer through radiation,
- The vacuum between the walls of the flasks stops convection, and
- Finally, the glass or plastic inner lining of the flask stops heat transfer through conduction, since both these are bad conductors of heat.

Relations with work

Before moving any further, it is important to establish the relationship that exists between heat and thermodynamics. What this basically says, is that both work and heat act as a medium of adding energy to a system.

Let's take the example of a small iron block in a piston. We know that when an external force will be applied the molecules of the iron block will come closer, and its density would increase. The same would happen when there is heat introduced into the system. Now, if someone's presented with the iron block in its condensed final state, they won't be able to tell if the block became denser after heat was applied on it, or if it was the result of force being applied.

This means that the internal energy of a high temperature object resides in the random motion of its molecules. And, when they are moving randomly, increasing



the temperature of the object, you cannot tell whether this increase in temperature a result of external heat that was being given to the object or work being done on it.

The laws

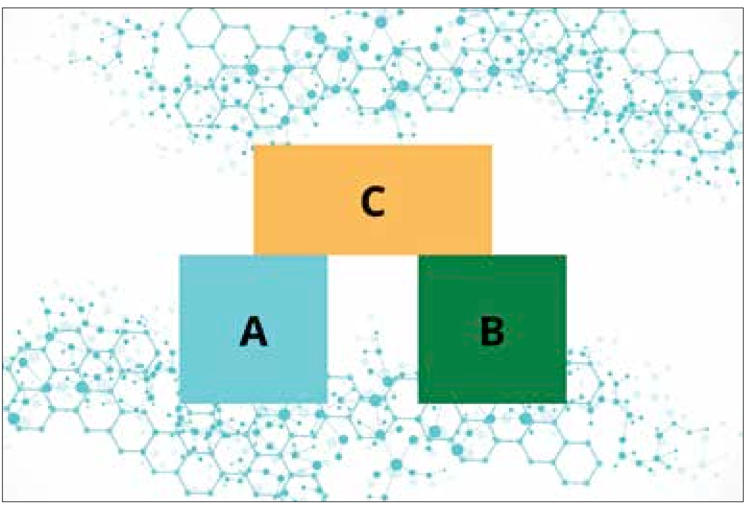
There is no concept in the world of science that can be explained without a set of laws. The ones governing heat, are called the Laws of Thermodynamics. So, in this section we will be covering the three laws of thermodynamics and understand the implications of all the three laws.

The zeroth law of thermodynamics goes as follows – If two bodies A and B are in thermal equilibrium with the third body C, then body A and B are also in thermal equilibrium with each other.

This law is quite straight forward. We know that when two bodies of varying temperatures will be in contact with each other, there will be exchange of heat between the bodies, until they are at the same temperature. Well, now if we take three bodies and place them in contact with one another, the same would happen. And this my friends, what the zeroth law of thermodynamics says.

Coming to the first law of thermodynamics, it says that – The net change in the total energy of a system is equal to the heat added to the system, minus the work done by the system. We have already explained the relationship between work and heat to you, so you would have made the connections.

The second law of thermodynamics says that – In all the spontaneous processes,



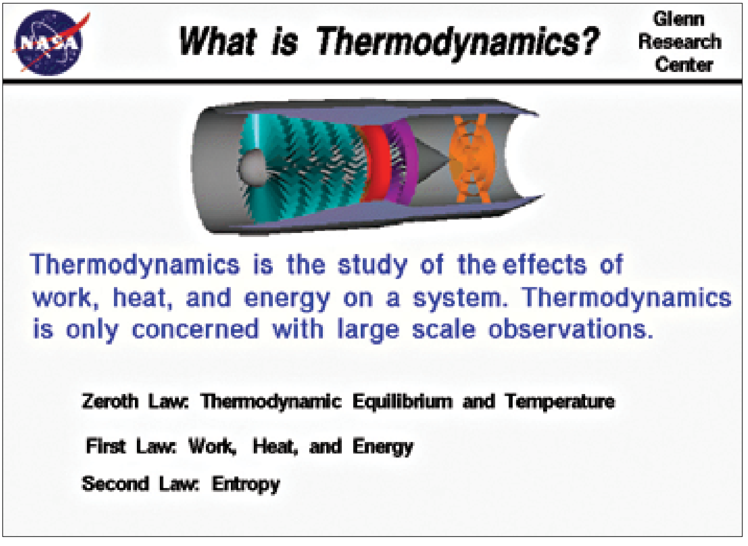
Three blocks in thermal equilibrium

the entropy of the universe increases. It means that when there is an increase in the activity of the molecules of any substances, the disorder in the universe, or energy that is unavailable to do work also increases. Moving on to the third law.

The third and the final law of thermodynamic states – The value of entropy of a completely pure crystalline substance is zero at absolute zero temperature. This means as the temperature of a substance decreases, the random movement of its molecules, known as entropy also drops.

A section of a NASA article on the topic of thermodynamics, establishes the relationship between the four laws in the best way possible. Here's what it says:

"The zeroth law of thermodynamics involves some simple definitions of thermodynamic equilibrium. Thermodynamic equilibrium leads to the large scale definition of temperature, as opposed to the small scale definition related to the kinetic energy of the molecules. The first law of thermodynamics relates the various forms of kinetic and potential energy in a system to the work which a system can perform and to the transfer of heat. This law is sometimes taken as the definition of internal energy, and introduces an additional state variable, enthalpy. The first law of thermodynamics allows for many possible states of a system to exist. But experience indicates that only certain states occur. This leads to the second law of thermodynamics and the definition of another state variable called entropy. The second law stipulates that the total entropy of a system plus its environment can not decrease; it can remain constant for a reversible process but must always increase for an irreversible process."



It's latent

Having read about the laws of thermodynamics, we come to the last part of this chapter, which is latent heat. This will be forming the basis of the processes of change of states of water which we will be exploring in the next chapter.

To start with the definition, latent heat is defined as – The amount of heat absorbed or released by a body during change of phase, without showing any change in temperature.

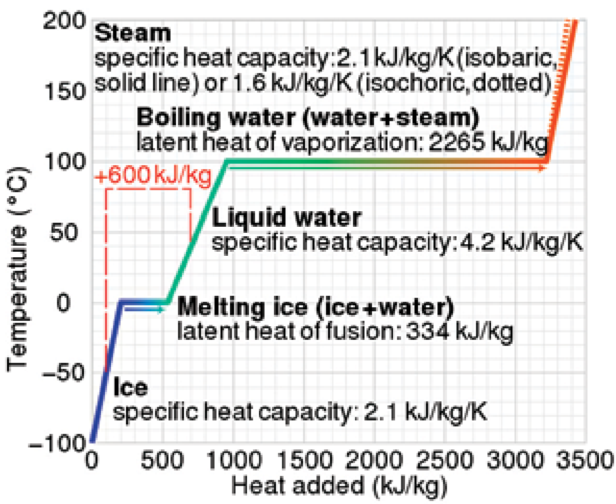
In simpler words, this is the amount of extra energy that is required by the molecules of a substance to transit from being in one state to the other. When this heat is expressed in terms of the mass of the substance, it is called, specific latent heat.

The mathematical formula to calculate specific latent heat is follows:

$$L = Q/m$$

(L is the specific latent heat, Q is the heat energy supplied during phase change, m is the mass of the substance that is undergoing phase change)

In real life, one of the places where we see latent heat being mentioned a lot is when we talk about the process of fusion of ice. The specific latent heat of melting of ice is the amount of heat energy required to melt a unit mass of ice at zero degree Celsius to water at the same temperature. And, when it is freezing of water, the amount of heat required to change liquid water to ice at the constant rate of zero degree Celsius, it's called the specific latent heat of fusion of ice. There are several explanations of the concept of latent heat, but we'll reserve those for later.



Changing states

We talked about latent heat and mentioned the ways in which it affects the change of state of matter. But we did not take a deep dive into what change of state actually is. So, let's get started!

The basic principle behind change of state of matter due to heat is the change in the energy of the atoms making up a substance. See, every material is made up of molecules, and depending upon the state that it is in, solid, liquid or gas, there are varying levels of intermolecular forces holding the atoms together. And heat energy when supplied to that substance, or taken away from it, causes its constituent atoms to undergo a change in their levels of intermolecular force of attraction. Now have a look at what happens during each conversion:

From solid to liquid to gas:

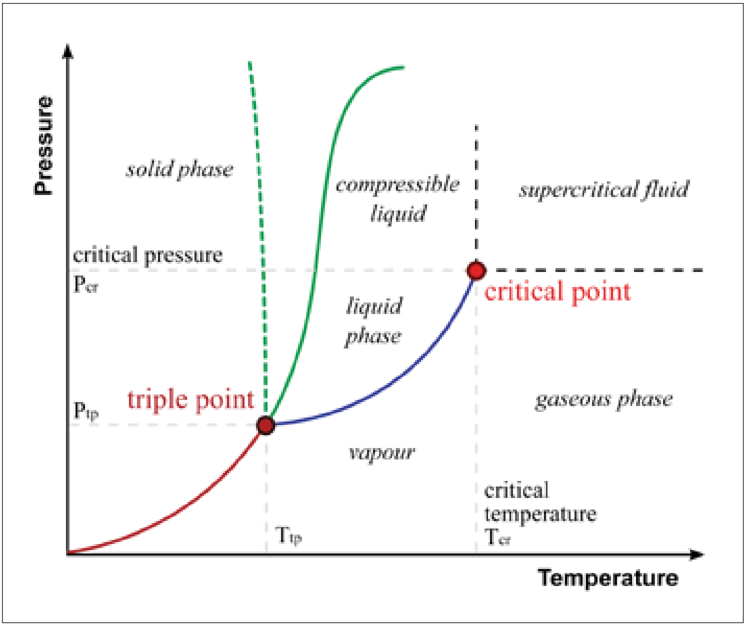
- The intermolecular force of attraction between molecules of solids and liquids is relatively high.
- Heat energy supplies the extra energy needed for them to surpass the force holding them together with surrounding atoms.
- Once enough energy has been supplied, the energy possessed by each molecule surpasses the intermolecular force of attraction.
- The heat energy is converted into kinetic energy and they start moving around.
- This causes an increase in the distance between the molecules, and we see solids transform into liquids, and liquids to gas.

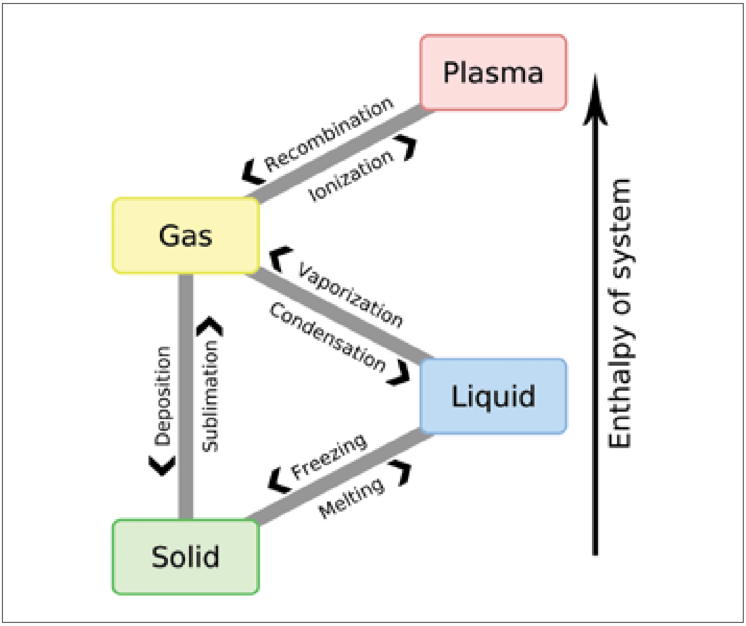
From gas to liquid to solid:

- The intermolecular force of attraction is low in gases and liquids when compared to solids.
- When heat energy is withdrawn from their system, the kinetic energy in the molecules gets converted into potential energy.
- There is also an increase in the intermolecular force of attraction.
- This causes the molecules to come closer together, and this is when gases turn to liquids, and liquids turn into solids.

This is how heat energy plays a role in the change of state of matter.

So far, in this chapter, we read about the difference between heat capacity and specific heat capacity, established a relation between the two, and then explored the different processes of heat transfer, finally landing up at the laws of thermodynamics. So, as long as the basic science of heat goes, this is pretty much all that we needed to cover here in this book, to ensure that you have a smooth sailing ahead! ■


Pressure
solid phase
compressible liquid
supercritical fluid
critical pressure
P_{cr}
critical point
liquid phase
triple point
P_{tp}
gaseous phase
vapour
critical temperature
T_{cr}
T_{tp}
Temperature


Plasma
Recombination
Ionization
Gas
Vaporization
Condensation
Deposition
Sublimation
Liquid
Freezing
Melting
Solid
Enthalpy of system

Boiling point

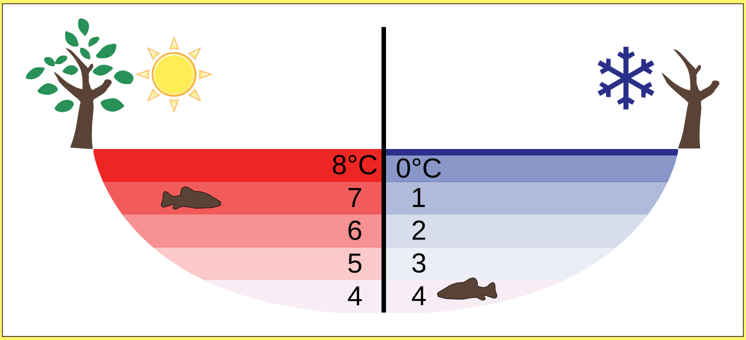
Heat waves... Where do they come from where do they go?

Now that you have read and understood the basics of heat, in this chapter we bring to you different phenomena that are based on the principles of heat, the weird ways in which water behaves at certain temperatures, and the reason why Earth is heating up!

Expanding anomalously

Probably one of the most interesting behaviours of water as a substance is its anomalous expansion. Before we go into a long storytelling about the history and mystery of this behaviour exhibited by water, let us take you through the concept of thermal expansion.

Thermal expansion is defined as – The expansion of a substance when it's heated. The concept is pretty straight forward and there is nothing to explain here. When an



Science saves fish!

object is heated, it expands. If there is an increase in its length, the expansion is called cubical. If there is an increase in the volume of the object upon heating, it is called cubical expansion.

Now, depending upon the state and nature of the substance that makes up that matter, we see different behaviours being exhibited. For example, when they are heated, gases are the ones that expand the most, followed by liquids, and lastly solids. At certain temperatures, some substances, contract on heating. This is called their anomalous expansion.

Water also exhibits similar behaviour when its transitioning from four to zero degree Celsius. You might think that due to the decrease in temperature, water would contract as usual. But, in this temperature range, instead of contracting, it expands! A similar anomalous behaviour is exhibited by water when it is being heated from zero to ten degree Celsius. In this temperature range, when change of temperature is taking place, the density of water, instead of decreasing, increases until the four degrees Celsius mark.

As a consequence of this anomalous behaviour exhibited by water, we see water pipelines in the open during cold nights, bursting open, and only the top layer of lakes freezing, trapping the heat inside, and saving the ecosystem in lakes from the freezing cold weather outside.

Measuring body temps

Well, if there was one device that works with the concept of heat and almost every one of us has had an experience with, it would be a thermometer. Thermometers are used in all sorts of temperature measurements around us. But one thing that remains a mystery for many is their working principle. So, let's have a look at how thermometers work.

The basic working principle is simple, that is mercury expands in size when heated. So, as you may have seen in most mercury thermometers, there is a reservoir of mercury at the base, containing a small amount of mercury. When it is exposed to heat/rise in temperature, it expands. Since it has nowhere else to go, but up the tiny slit that is created in the glass tube, it rises up, indicating the temperature of the body that it is in contact with.

Now, the reason mercury forms the best fluid to be put into a thermometer is because as determined through experimentation, it is the one of the only fluids whose expansion, has been found to be in direct proportion to the amount of heat it is exposed to. Another fluid that is known to perform similar to mercury and have a similar behaviour and is used in thermometers is alcohol. Since alcohol is a clear fluid, generally a colouring reagent is added to it, making it visible as it moves up and down the tube of the thermometer.

Sensing the rising mercury

It wasn't until very recently that we had the reasoning or evidence to understand how humans perceived change in temperature and pressure. We knew that there was a biological mechanism in place, but no one knew how it functions.

It was in September 2021, that David Julius and his team of researchers and another researcher, Ardem Patapoutian, both of whom were working independently,

Getting hotter by the day

capitalised on their years of research and discovered TRPM8. This receptor worked in a way completely opposite to that of the previously discovered, TRPV1. It was activated when the temperature came within a particular range of coldness, and here, in place of capsaicin, menthol was used to activate the receptor. This discovery got the researchers, the Nobel Prize that year!

We haven't delved into much detail about these receptors, but if you want to learn more about this, you can go to the following link: *https://dgit.in/HeatPerception*

The pleasant breezes

All of you may have read or heard about the phenomenon of land and seas breeze. As

Source: **bgrfx via FreePik**

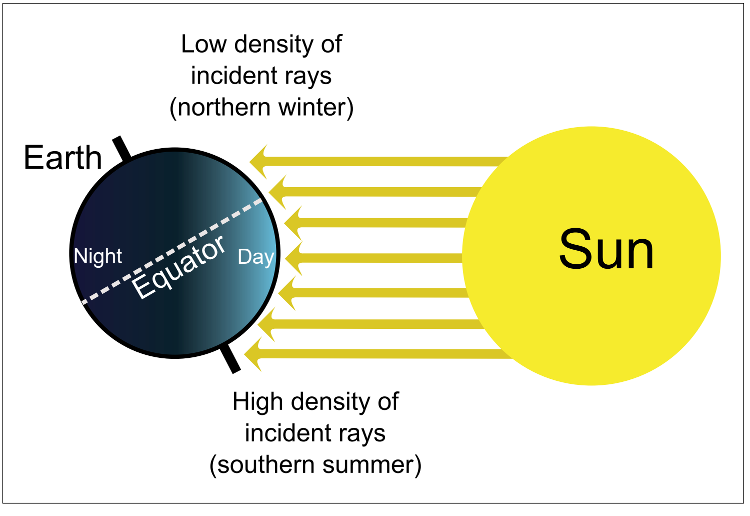
it turns out, they are closely connected with the processes of heat transfer via convection. So much so, that they are called convection currents.

The science behind the phenomenon of land and seas breeze originates from the difference in the temperature of air above the land and the sea. What happens is, during the day, land gets heated much faster than sea, thus the air above the land, rises up, making way for the colder air from above the surface of the sea to move in and replace it. During night-time, the land cools faster, making the air above it colder than what we have above sea, which takes time to cool down. Thus, the colder air from the land tends to move to replace the hotter air from above the sea, which has risen up. This forms a continuous cycle throughout the day and night, giving rise to the phenomenon which we have come to know as the land and sea breeze.

Sun's heat

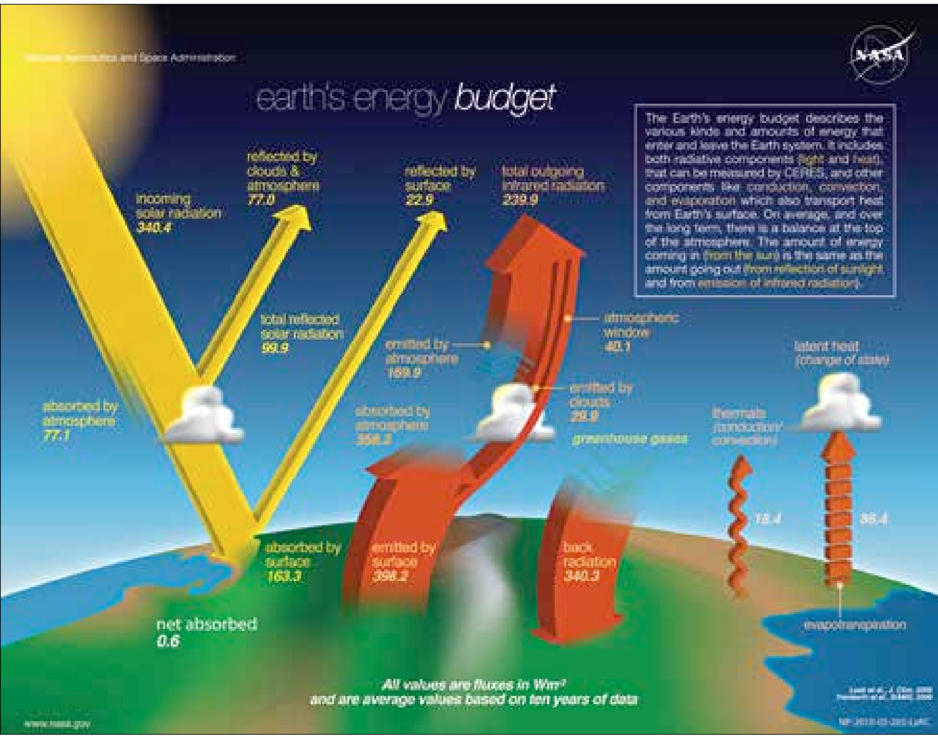
We all know different regions of the Earth have different climates. The regions close to the equator are the hottest, and as you move towards the poles, the climate tends to get colder, with the poles being some of the coldest regions of the planet. Did you know that principles of radiation have a role to play in it? If yes, then hurray! Skip the next paragraph and go on to the next section. If not, then read on and find out why it is so.

So, you must be aware that the Earth's axis is slightly tilted, by 23 degrees to be precise. You also would remember from the last chapter that radiation travels in a straight line. Right? Now as shown in the figure, as the rays from the Sun carrying the heat energy hit the planet in different regions, their intensity varies. And, since in heat



transfer via radiation, the intensity of radiation is paramount to determine the heat that is being transferred, some regions on the surface of the Earth, that tend to get lesser concentration of radiation from the Sun, tend to remain colder than the ones that get the bigger share. Interesting, isn't it!

Since we are already on the topic of radiation, this section would not be complete without us talking about global warming. So, what happens? You must know about the greenhouse effect. Right? Now what happens is, the rays of the Sun have different forms of radiation, infrared, visible light radiation, UV, and radio waves.



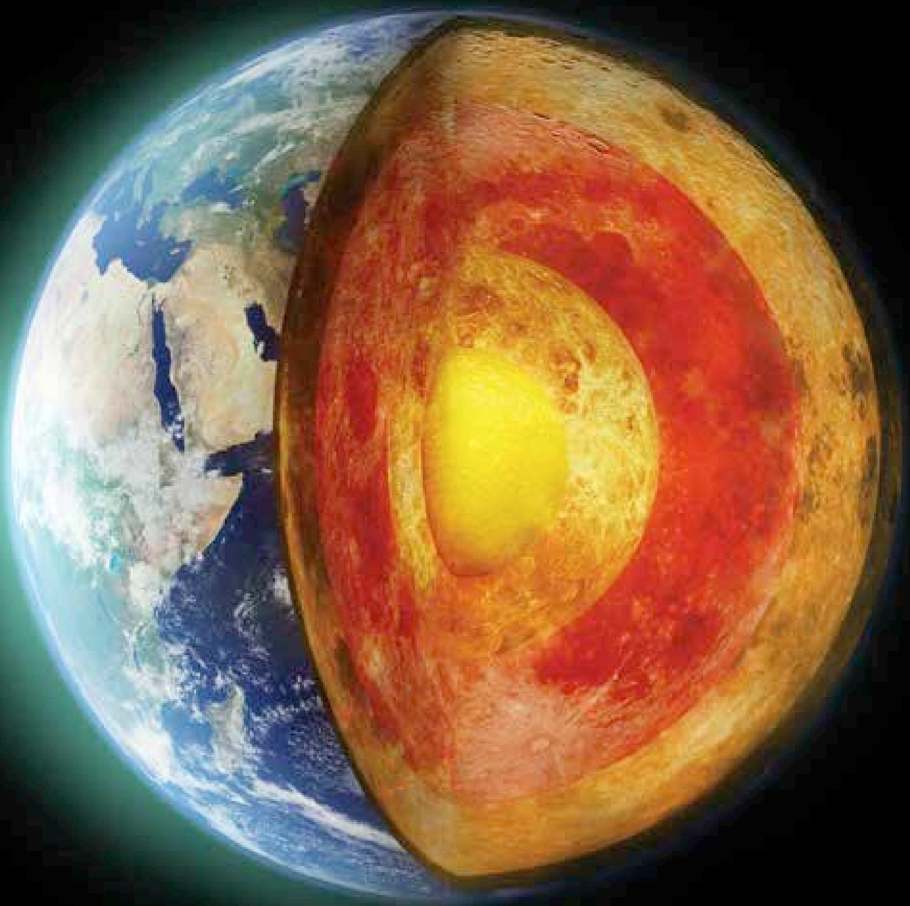
Out of these, the long wavelength infrared radiations are responsible for carrying heat energy from the Sun to Earth. Ideally what should happen is, that after reaching the surface of the planet, they should be reflected back, away from the surface, past the atmosphere, imparting only the required amount of heat.

However, the increased concentration of pollutants in the atmosphere, which we know as greenhouse gases, these waves are reflected back from the atmosphere onto the surface of the Earth, giving more heat than needed to the surface, and the surroundings that needed. And this causes an increase in Earth's temperature, giving rise to the phenomenon of global warming.

What more?

Well, if we were to sit and write about all the phenomena and places where heat is present around us, explaining the science behind everything, then an encyclopaedia wouldn't be enough. There is a lot to be read and learnt about heat that we were not able to cover in this book. However, we are confident that with the concepts that we have introduced here, you'd be able to understand most of what comes your way when you take a deeper dive into the subject of heat. Here are a few things that we found interesting, and are sure you'd like to read about heat, to expand your understanding of the subject and geek out whenever this topic comes up:

- *https://dgit.in/HeatVideo*
- *https://dgit.in/HeatVideo2*
- *https://dgit.in/HeatBook1*
- *https://dgit.in/HeatBook2*
- *https://dgit.in/HeatBook3*
- *https://dgit.in/HeatPaper1*
- *https://dgit.in/HeatPaper2* ■



Understand Earth’s Heat

https://dgit.in/IntoTheCore