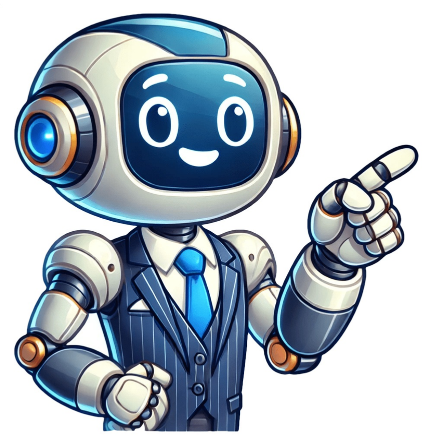
I'm not a robot



By touching a hot-water bottle, we get heat by conduction. Heat conduction (or thermal conduction) is the movement of heat from one object to another one that has different temperature when they are touching each other. For example, we can warm our hands by touching hot-water bottles. When the cold hands touch the hot-water bottle, heat flows from the hotter object (hot-water bottle) to the colder one (hand). People make things with different thermal conductivity, for example cookware to heat things or insulated containers to keep hot things hot or cold things cold. Other ways to transfer heat are by thermal radiation and/or convection. Usually more than one of these processes happen at the same time. In the atomic theory solids, liquids and gases are made of tiny particles called "atoms". The temperature of the material measures how fast the atoms are moving and the heat measures the total amount of energy due to the vibration of the atoms. Conduction can happen when one part of a material is heated. The atoms in this part vibrate faster and are more likely to hit their neighbors. The collisions cause those atoms also to move faster, passing the heat energy to them. In this way the energy travels through the solid. (Rather like the way energy passes along a set of tumbling dominos). The atomic picture also helps explain why conduction is more important in solids: in solids the atoms are close together and unable to move around. In liquids and gases the particles can move past each other, so the collisions are less common. The law of heat conduction, also known as Fourier's law, means that the rate, in time, of heat transfer through a material is proportional to the negative gradient in the temperature and to the area at right angles, to that gradient, through which the heat is flowing: ∂ Q ∂ t = − k ∮ S ∇ T · d S {\displaystyle {\frac {\partial Q}{\partial t}}=-k\oint _{S}{abla T\cdot \,dS}} Linear heat flow where: Q is the amount of heat transferred, and t is the time taken, and k is the material's thermal conductivity' and S is the area through which the heat is flowing, and T is the temperature. Thermal conductivity usually varies with temperature, but the variation can be small, over a significant range of temperatures, for some common materials. Heat transfer Convection Thermal radiation Retrieved from " We have already defined Heat Conduction while learning about heat transfer. Heat conduction is the transfer of heat from the hotter part of the material to its colder part without the actual movement of the particles. During the heat conduction process heat energy is transferred only to the successive molecules. In this process, molecules do not leave their mean position at all. So in conduction particles of the medium transfers heat without leaving the mean position. Heat conduction does not take place in liquids and solids. This happens because molecules of both gases and liquids move randomly or in a specific direction. How do conduction heat transfer works When one end of a metal bar is heated, molecules at this end begin to vibrate faster and faster. These particles at the hot end have a greater kinetic energy of vibration in compassion to the particles that are not directly under heat exposure. These faster moving particles/molecules collide with their neighboring molecules. Figure 3: Transfer of heat at molecular level. Here from the figure you can see how heat is being transferred at the molecular level through the vibrations of molecules at heated end to the colder end. During the collision, they transfer some of their energy to the neighboring molecules. This way faster moving or vibrating molecules transmit the heat energy to neighboring molecules. These, in turn, transfer some of their energy to the molecules near them. Thus the energy is transferred by molecular collision from the hot end of the object to its cold end. The transfer of heat continuous until two ends of the object are at the same temperature. This way energy of thermal motion is passed along from one molecule to the next keeping their mean position fixed. Solid substances which conduct heat easily are good conductors of heat. For example silver, copper etc. All metals are a good conductor of heat. Those substances which do not conduct heat easily are called bad conductors of heat. For examples of wood, cloth, air, paper etc. Generally, good conductors of heat are also good conductors of electricity. Everyday conduction examples In winter, metallic handle appears to be colder than the wooden door. This happens because metallic handle is the good conductor of heat and heat flows from our body to the handle. So it feels cold Cooking utensils are provided with wooden handles. This is because wooden handle do not allow conduction of heat from hot utensil to hand. A new quilt is warmer than old quilt because new quilt contains more air in its pores as compared to the old quilt. A refrigerator is provided with insulated walls to minimise the chance of heat flowing into the refrigerator from outside. Important terms related to Conduction (1) The steady state of a substance:- To understand the steady state of a substance let us consider a solid metal bar. We now heat one end of the metal bar. This way one end of the rod is at a higher temperature and another end of the rod is at a lower temperature.From the discussion about the transfer of heat by conduction, we know that heat energy is transferred only to the successive molecules. Let us divide the solid metal bar into various segments as shown below in the figure Figure 4 : Transient or non stationary state of Heat Transfer through the process of conduction in a metal bar. Here if the metal bar is not insulated heat is lost to the atmosphere by convection and radiation. This can be prevented by placing some non conducting material around the bar. If we start providing heat to the bar at end P then each section of the bar get heat from its adjacent previous section. That is section C will get heat from section B and section B will get heat from Section A. Again consider sections A, B and section C. Now section B gets heat from section A. Some part of heat received is absorbed due to which temperature of section B increases. Some part of this heat received flows to the atmosphere. Remaining part of the heat is transferred to adjacent section C. In this state temperature of every cross-section of the bar. Goes on increasing with time. This is the transient or variable state of heat conduction. Figure 5 : Transient or non stationary state of Heat Transfer through the process of conduction in a metal bar. Here if the metal bar is not insulated heat is lost to the atmosphere by convection and radiation. This can be prevented by placing some non conducting material around the bar. With the passage of time and continuous supply of heat, a state is reached when the temperature of each section becomes uniform. In this state, no heat is absorbed by any section of the bar. This state of the bar when the temperature of every cross-section of the bar becomes constant and there is no further absorption of heat in any part is called Steady-State or Stationery-State. It is important to note here that (1) The different sections of the metal bar have a different temperature, but the temperature of each section remains constant with the passage of time. (2) The temperature decreases as me more away from the hot end. Heat lost to the atmosphere can be prevented by covering the metal bar with an insulating material. In this case, at a steady state total heat transfer take place by conduction. From hot and (higher temperature) of the bar to cold end (lower temperature). (2) Isothermal Surface :- The surface of a substance whose all particles or molecules are at the same temperature is called an isothermal surface. Figure 5 below shows two isothermal surface P and Q. Here temperature of all points on surface P is same. Temperature of surface P is not same as the temperature of surface Q. (3) Temperature Gradient :- The rate of change of temperature with distance in the direction of flow of heat is called temperature gradient Let us consider the figure given below Figure 6 : Locus of equal temperatures form an isothermal surface.. Above figure shows two isothermal surfaces P and Q. Surface P is at temperature $(T+\Delta T)$ and surface Q is at temperature T. Sections P and Q in the above figure are isothermal surfaces. Let Δx be the normal distance between these two surfaces. Now the temperature of section P is greater than the temperature of section Q. Let $(T+\Delta T)$ be the temperature of section P and T be the temperature of section Q; then the temperature gradient is written as \begin{align} \text{grad.} T & = \frac{\text{change in Temp}}{\text{Normal distance}} \\ & =\frac{T-(T+\Delta T)}{\Delta x} \\ & =-\frac{\Delta T}{\Delta x} \\ \end{align} The temperature gradient is the positive quantity in direction of increasing temperature. Since heat always flows from higher temperature to lower temperature. The temperature gradient along the direction of heat flow has a negative value. (4) The rate of heat flow :- The quantity of heat transferred from an isothermal region per unit time in the direction of heat propagation is called the rate of heat flow. It is denoted by H. It is also known as heat current. If Q is the amount of heat transferred in time t; then $$H=\frac{Q}{T}$$ Units are $Kcal{s ^{ - 1}} $, $J{s ^{ - 1}}$ and $cal{s ^{ - 1}}$ (5) The specific rate of heat flow:- The rate of heat flow per unit area is called the specific rate of heat flow. It is denoted by q. $q=\frac{H}{A}$ Units are $Kcal.{m^{ - 2}}{s^{ - 1}}$, $K{m^{ - 2}}{s^{ - 1}}$ and $Cal.cm^{ - 2}{s^{ - 1}}$ Also Read Share — copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt — remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution — You must give appropriate credit , provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation . No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. Diagram showing the transfer of thermal energy via conduction. Credit: Boundless Heat is an interesting form of energy. Not only does it sustain life, make us comfortable and help us prepare our food, but understanding its properties is key to many fields of scientific research. For example, knowing how heat is transferred and the degree to which different materials can exchange thermal energy governs everything from building heaters and understanding seasonal change to sending ships into space. Heat can only be transferred through three means: conduction, convection and radiation. Of these, conduction is perhaps the most common, and occurs regularly in nature. In short, it is the transfer of heat through physical contact. It occurs when you press your hand onto a window pane, when you place a pot of water on an active element, and when you place an iron in the fire. This transfer occurs at the molecular level—from one body to another—when heat energy is absorbed by a surface and causes the molecules of that surface to move more quickly. In the process, they bump into their neighbors and transfer the energy to them, a process which continues as long as heat is still being added. The process of heat conduction depends on four basic factors: the temperature gradient, the cross section of the materials involved, their path length, and the properties of those materials. A temperature gradient is a physical quantity that describes in which direction and at what rate the temperature changes in a specific location. Temperature always flows from the hottest to coldest source, due to the fact that cold is nothing but the absence of heat energy. This transfer between bodies continues until the temperature difference decays, and a state known as thermal equilibrium occurs. Cross-section and path length are also important factors. The greater the size of the material involved in the transfer, the more heat is needed to warm it. Also, the more surface area that is exposed to open air, the greater likelihood for heat loss. So shorter objects with a smaller cross-section are the best means of minimizing the loss of heat energy. Heat conduction occurs through any material, represented here by a rectangular bar. The rate at which it is transfers depends in part on the thickness of the material (rep. by A). Credit: Boundless Last, but certainly not least, is the physical properties of the materials involved. Basically, when it comes to conducting heat, not all substances are created equal. Metals and stone are considered good conductors since they can speedily transfer heat, whereas materials like wood, paper, air, and cloth are poor conductors of heat. These conductive properties are rated based on a "coefficient" which is measured relative to silver. In this respect, silver has a coefficient of heat conduction of 100, whereas other materials are ranked lower. These include copper (92), iron (11), water (0.12), and wood (0.03). At the opposite end of the spectrum is a perfect vacuum, which is incapable of conducting heat, and is therefore ranked at zero. Materials that are poor conductors of heat are called insulators. Air, which has a conduction coefficient of .006, is an exceptional insulator because it is capable of being contained within an enclosed space. This is why artificial insulators make use of air compartments, such as double-pane glass windows which are used for cutting heating bills. Basically, they act as buffers against heat loss. Discover the latest in science, tech, and space with over 100,000 subscribers who rely on Phys.org for daily insights. Sign up for our free newsletter and get updates on breakthroughs, innovations, and research that matter—daily or weekly. Feather, fur, and natural fibers are all examples of natural insulators. These are materials that allows birds, mammals and human beings to stay warm. Sea otters, for example, live in ocean waters that are often very cold and their luxuriously thick fur keeps them warm. Other sea mammals like sea lions, whales and penguins rely on thick layers of fat (aka. blubber) – a very poor conductor – to prevent heat loss through their skin. This same logic is applied to insulating homes, buildings, and even spacecraft. In these cases, methods involve either trapped air pockets between walls, fiber-glass (which traps air within it) or high-density foam. Spacecraft are a special case, and use insulation in the form of foam, reinforced carbon composite material, and silica fiber tiles. All of these are poor conductors of heat, and therefore prevent heat from being lost in space and also prevent the extreme temperatures caused by atmospheric reentry from entering the crew cabin. Conduction, as demonstrated by heating a metal rod with a flame. Credit: Thomson Higher Education The laws governing conduction of heat are very similar to Ohm's Law, which governs electrical conduction. In this case, a good conductor is a material that allows electrical current (i.e. electrons) to pass through it without much trouble. An electric insulator, by contrast, is any material whose internal electric charges do not flow freely, and therefore make it very hard to conduct an electric current under the influence of an electric field. In most cases, materials that are poor conductors of heat are also poor conductors of electricity. For instance, copper is good at conducting both heat and electricity, hence why copper wires are used so widely in the manufacture of electronics. Gold and silver are even better, and where price is not an issue, these materials are used in the construction of electrical circuits as well. And when one is looking to "ground" a charge (i.e. neutralize it), they send it through a physical connection to the Earth, where the charge is lost. This is common with electrical circuits where exposed metal is a factor, ensuring that people who accidentally come into contact are not electrocuted. This view of the nose section of space shuttle Discovery, build of heat-resistance carbon-composites. Credit: NASA Insulating materials, such as rubber on the soles of shoes, is worn to ensure that people working with sensitive materials or around electrical sources are protected from electrical charges. Other insulating materials like glass, polymers, or porcelain are commonly used on power lines and high-voltage power transmitters to keep power flowing to the circuits (and nothing else!) In short, conduction comes down to the transfer of heat or the transfer of an electrical charge. Both happen as a result of a substance's ability to allow molecules to transfer energy across them. Citation: What is heat conduction? (2014, December 9) retrieved 1 June 2025 from This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only. Thermal conduction is the flow of thermal energy (heat) from higher to lower temperatures through molecular vibrations and collisions. Conduction occurs within an object or from a hot object to a cold object in contact with the former. It can occur in solids, liquids, and gases but is primarily observed in solids where molecules are closely packed. Heat will continue to flow until thermal equilibrium is reached. Conduction Warming hands by touching a hot bodyHeating one end of a metal rodHeating a frying pan on top of a stoveHot air immediately above the Earth's surface How is Heat Transferred Through Thermal Conduction According to kinetic theory, matter is made of particles that are in constant random motion. This motion manifests as thermal energy, which depends on the temperature. The higher the temperature, the higher the thermal energy. The motion of particles, whether translatory or vibrational, leads to collisions. The particles transfer energy among themselves. Consequently, heat travels from a high-temperature region to a low-temperature region. For thermal conduction to occur, there has to be a temperature gradient. Fourier's law of thermal conduction states that the time rate of heat transfer through a material is proportional to the negative temperature gradient and the area through which the heat flows at right angles to that gradient. Mathematically, Fourier's law can be written as \[Q = – K A \frac{\Delta T}{\Delta x} \] Where Q: Heat transfer rate (Js-1 or W) K: Thermal conductivity (Wm-1K-1) A: Cross-sectional area (m2) \(\frac{\Delta T}{\Delta x} \): Temperature gradient (Km-1) Suppose heat flows through a conductor of thickness d whose ends are at temperatures TA (hot) and TB (cold). The heat flowing per second through the conductor is \[Q = KA\frac{T_B – T_A}{d} \] Heat Conduction Equation Thermal conductivity is a physical property of substances. In the above equation, suppose A = 1, d = 1, and (TA – TB) = 1. Then K = Q Thus, thermal conductivity is defined as the amount of heat flowing through a conductor of unit length, whose cross-section has a unit area and whose ends are at a unit temperature difference. Metals have high thermal conductivity because their valence electrons are delocalized and can efficiently conduct heat. For example, the thermal conductivities of silver and copper are 406 Wm-1K-1 and 385 Wm-1K-1, respectively. Insulators are poor conductors of heat. They have voids in between the atoms, which interfere with heat transfer. For example, the thermal conductivity of wood ranges from 0.04 to 0.12 Wm-1K-1. Air is a poor conductor of heat. Its thermal conductivity at 0 ˚C is 0.024 Wm-1K-1. Article was last reviewed on Monday, January 2, 2023 Share — copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt — remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution — You must give appropriate credit , provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation . No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. How can financial brands set themselves apart through visual storytelling? Our experts explain how.Learn MoreThe Motorsport Images Collections captures events from 1895 to today's most recent coverage.Discover The CollectionCurated, compelling, and worth your time. Explore our latest gallery of Editors' Picks.Browse Editors' FavoritesHow can financial brands set themselves apart through visual storytelling? Our experts explain how.Learn MoreThe Motorsport Images Collections captures events from 1895 to today's most recent coverage.Discover The CollectionCurated, compelling, and worth your time. Explore our latest gallery of Editors' Picks.Browse Editors' FavoritesHow can financial brands set themselves apart through visual storytelling? Our experts explain how.Learn MoreThe Motorsport Images Collections captures events from 1895 to today's most recent coverage.Discover The CollectionCurated, compelling, and worth your time. Explore our latest gallery of Editors' Picks.Browse Editors' Favorites Heat transfer is a fundamental process that occurs whenever there is a temperature difference between objects or within a system. It happens through three distinct mechanisms: conduction, convection, and radiation. Each of these processes follows specific physical principles and plays crucial roles in our daily lives, from cooking food to keeping buildings comfortable. Understanding how heat moves from one place to another helps us design more efficient systems, improve energy conservation, and solve practical problems in engineering and healthcare. Table of Contents Heat transfer is the movement of thermal energy from a hotter object or region to a cooler one. This movement always occurs in the direction of decreasing temperature, following the second law of thermodynamics. The rate at which heat transfers depends on the temperature difference, the properties of the materials involved, and the specific mechanism of transfer. Before diving into the mechanisms, it's important to understand that heat is a form of energy associated with the random motion of atoms and molecules. The faster these particles move, the higher the temperature of the substance. Conduction is the transfer of heat through direct contact between substances, without any motion of the substances themselves. It occurs primarily in solids but can also happen in liquids and gases. How conduction works At the molecular level, conduction occurs when energetic (hot) particles collide with less energetic (cooler) particles. During these collisions, energy transfers from the higher-energy particles to the lower-energy ones. This process continues until thermal equilibrium is reached, meaning both objects have the same temperature. The rate of conductive heat transfer depends on several factors: Temperature difference: The greater the temperature difference between two objects, the faster heat will transfer between them. Cross-sectional area: Heat transfers more quickly through larger contact areas. Distance: Heat transfers more slowly over longer distances. Material properties: Different materials conduct heat at different rates, a property known as thermal conductivity. Thermal conductivity Thermal conductivity is a measure of a material's ability to conduct heat. Materials with high thermal conductivity, such as metals (copper, aluminum, silver), conduct heat efficiently. Materials with low thermal conductivity, like wood, plastic, and air, are poor conductors and are often used as insulators. The formula for conductive heat transfer is: $Q = kA(T_2 - T_1)/d$ Where: Q = heat transfer rate (in watts) k = thermal conductivity of the material A = cross-sectional area $T_2 - T_1$ = temperature difference d = distance or thickness Everyday examples of conduction Conduction manifests in numerous ways in our daily lives: Cooking: Heat transfers from a hot pan to food through conduction. Touching hot objects: When you touch something hot, heat conducts to your hand. Ice melting: When ice is placed on a warm surface, heat conducts from the surface to the ice, causing it to melt. Medical applications: Hot water bottles or ice packs applied to the body use conduction to transfer heat. Convection: Transfer Through Fluid Movement Convection is the transfer of heat through the movement of fluids (liquids and gases). Unlike conduction, convection involves the actual movement of the heat-carrying medium. Natural vs. forced convection Convection comes in two forms: Natural convection: Occurs when fluid motion is caused by density differences due to temperature variations. Hot fluids rise because they are less dense, while cooler fluids sink. This creates a natural circulation known as a convection current. Forced convection: Happens when an external force, like a fan or pump, moves the fluid. This typically results in faster heat transfer than natural convection. How convection works The process of convective heat transfer involves several steps: Heat transfers to a fluid by conduction from a surface. The fluid near the surface becomes less dense as it warms up. The warmer fluid rises (in natural convection) or is moved (in forced convection). Cooler fluid replaces the warmer fluid near the heat source. This cycle continues, creating a continuous flow of heat away from the source. Everyday examples of convection Convection is ubiquitous in our environment: Home heating systems: Radiators heat air, which rises and circulates throughout the room. Ocean and atmospheric currents: These global systems distribute heat across the planet. Boiling water: As water heats, convection currents form before boiling begins. Cooling systems: Computer fans, air conditioners, and car radiators all use forced convection to remove heat. Cooking: Boiling, using a convection oven, or even stirring soup all involve convective heat transfer. Radiation: Transfer Through Electromagnetic Waves Radiation is unique among heat transfer mechanisms because it doesn't require a medium—it can occur in a vacuum. This process involves the emission of electromagnetic waves from all matter that has a temperature above absolute zero. How radiation works Thermal radiation is a form of electromagnetic radiation emitted by objects due to their temperature. The key characteristics of radiative heat transfer include: No medium required: Unlike conduction and convection, radiation can travel through empty space. Proportional to temperature: The amount of radiation emitted increases dramatically with temperature (proportional to T^4, where T is absolute temperature). Surface properties matter: Dark, rough surfaces generally absorb and emit radiation better than light, smooth, reflective surfaces. Line of sight: Radiation travels in straight lines until it's absorbed, reflected, or transmitted by another object. The Stefan-Boltzmann law describes the power radiated from a black body (perfect emitter): $P = \sigma A T^4$ Where: P = power radiated (watts) σ = Stefan-Boltzmann constant A = surface area T = absolute temperature (Kelvin) For real objects, we include emissivity (ε), a measure of how efficiently a surface emits energy compared to a black body: $P = \varepsilon \sigma A T^4$ Everyday examples of radiation Radiation affects us constantly: Sunlight: The primary way Earth receives heat from the Sun. Feeling warmth from a fire: You can feel the heat even without touching the flames or having the air between you and the fire become hot. Infrared heaters: These directly warm people and objects rather than heating the air. Microwave ovens: Use electromagnetic waves to heat food directly. Thermal imaging cameras: Detect infrared radiation emitted by objects to create heat-map images. Comparing the Three Heat Transfer Mechanisms Understanding the differences and relationships between these mechanisms helps in applying them effectively: Speed comparison Radiation: Fastest (travels at the speed of light) Conduction: Speed depends on material properties but is generally faster in solids than convection in fluids Convection: Typically slowest due to the physical movement of fluids Medium requirements Conduction: Requires direct contact between materials Convection: Requires a fluid (liquid or gas) Radiation: No medium required; works in a vacuum Combined effects In real-world situations, heat transfer rarely occurs through just one mechanism. For example: A cup of hot tea loses heat through conduction (to the cup), convection (air currents above the surface), and radiation (infrared emissions). Home insulation works by minimizing conductive heat transfer through walls while also reducing convective air movement and sometimes reflecting radiant heat. The human body regulates temperature using all three mechanisms—conduction (touching cold/hot surfaces), convection (blood circulation and air movement around the body), and radiation (emitting infrared energy). Applications in Nursing and Healthcare Heat transfer principles are particularly relevant in nursing and healthcare settings: Temperature regulation and monitoring Body temperature regulation: Understanding how the body loses heat helps in treating conditions like hyperthermia or hypothermia. Fever management: Cooling techniques like cold compresses (conduction), fans (forced convection), or cooling blankets use heat transfer principles. Infant care: Newborns, especially premature infants, have difficulty regulating body temperature and require careful thermal management. Therapeutic applications Hot and cold therapy: Used for pain relief, inflammation reduction, and muscle relaxation. Radiant warmers: Used in neonatal care to maintain infant body temperature through radiation rather than heating the surrounding air. Hyperthermia treatment: Some cancer treatments use localized heating to target tumor cells. Cryotherapy: Uses extreme cold to destroy abnormal tissue. Infection control Sterilization: Heat sterilization methods rely on conduction and convection to destroy microorganisms. UV sterilization: Uses radiative energy to kill pathogens on surfaces and in air. Practical Implications and Innovations The principles of heat transfer drive numerous innovations and practical applications: Energy efficiency Building insulation: Designed to minimize conductive heat loss. Double-glazed windows: Reduce heat transfer by trapping air (a poor conductor) between glass panes. Reflective roofing: Reduces radiative heat gain from the sun. Heat exchangers: Recover waste heat through controlled conduction and convection. Future developments Emerging technologies continue to leverage heat transfer principles in innovative ways: Smart fabrics: Clothing that adapts its insulating properties based on environmental conditions. Phase-change materials: Store and release heat at specific temperatures. Improved medical devices: More precise thermal treatments for various conditions. Nanoscale heat transfer: Opening new possibilities for extremely localized thermal management. Conclusion Heat transfer through conduction, convection, and radiation is a fundamental process that impacts virtually every aspect of our lives. From maintaining our body temperature to cooking food, heating buildings, and enabling countless industrial processes, these mechanisms work constantly—often in combination—to move thermal energy from one place to another. For nursing students, understanding these principles provides valuable insight into therapeutic applications, temperature regulation, and many medical technologies. The ability to apply heat transfer concepts can improve patient comfort, treatment efficacy, and overall care quality. What do you think? How might you apply your understanding of heat transfer mechanisms to improve patient care in clinical settings? Can you identify situations in healthcare where controlling one mechanism of heat transfer might be more important than others? Thermal energy can be transferred from one energy store to another. There are three main methods of heat transfer and they are conduction, convection and radiation. And we already know what you are thinking ...."Who cares?" we hear you cry. Well you should. No really, this will affect every single on of you and could save you a fortune in energy bills in the future. Understanding how heat moves will save you money. Think you are already an expert on heat transfer? Then why not have try at our quiz straight away or watch a couple of our videos as a quick reminder. Heat Conduction:Heat conduction is how heat moves from one object to another when they are in direct contact.It happens mainly in solids, where particles (atoms or molecules) pass energy to neighbouring particles.Examples: Touching a hot pan, warming your hands by a fire, or heating a metal rod.How Heat Travels:Imagine a line of people passing a ball from one end to the other. The ball represents heat energy.In solids, particles vibrate and bump into each other, transferring heat.The faster the particles move, the hotter the material becomes.Thermal Conductivity:Some materials conduct heat better than others.Metals (like copper and silver) are excellent conductors because their particles can easily pass energy.Insulators (like wood or air) don't conduct heat well because their particles are less mobile.Applications:Cooking: Heat conduction in pots and pans.Keeping Warm: Insulating materials (like clothing) help retain body heat.Home Comfort: Insulation in walls and windows keeps homes warm.Heat conducts through solids. Some time that is useful.... lots of times it isn't and we need to prevent it. Watch our video to learn all about conductors and insulators and the meaning of thermal conductivity! More importantly, understand why controlling the rate of conduction is so important for you!What is Convection?Convection is the movement of heat caused by the motion of warm matter (usually liquids or gases).When part of a fluid (like air or water) is heated, it expands, becomes less dense, and rises.Cooler fluid then moves in to take its place, creating a continuous cycle called a convection current.Examples of Convection:Atmospheric Circulation: Warm air rises near the equator, creating wind patterns that move heat around the Earth.Ocean Currents: Warm ocean water near the equator flows toward the poles, affecting climate and marine life.Seismic activity: Convection currents in the earth Mantle cause the tectonic plates to move leading to earthquakes!Heaters and Radiators: Wall heaters (like radiators) warm rooms through convection.How It Works:Imagine a pot of soup on the stove. As the soup heats up, the hot liquid rises, and cooler soup moves in to replace it.This process transfers heat throughout the soup, making it warm all over.Natural Convection:Happens when fluids (liquids or gases) are heated.Hotter molecules rise, while cooler ones sink, creating a circular flow.Think of a lava lamp—the rising blobs represent convection currents!Practical Applications:Wind: Convection in the atmosphere causes wind.Room Ventilation: Open windows allow fresh air to enter and cool the room.Cloud Formation: Convection helps form clouds in the sky. And don't forget lava lamps!Convection currents drive some of the most powerful process on our planet from seismic activity to the weather itself. At the same time, it is the way that our houses are heated and our kettles boil. Convection is everywhere and you definitely should care about it. Watch our most popular video ever as the science geeks explain....Infrared Radiation: Infrared radiation is an electromagnetic wave that can travel through a vacuum. Heat from the Sun reaches us through space by traveling as infrared radiationEmission and Absorption: Objects can absorb (take in), emit (give out), and reflect infrared radiation. The hotter an object, the faster it will emit infrared radiation. Black, dull surfaces are good absorbers and emitters. White, shiny surfaces are bad absorbers and emitters!No Particles Involved: Unlike conduction and convection, infrared radiation doesn't require particles. It can transfer energy even in a vacuum, such as outer space.Feeling the Sun's Warmth: We feel the warmth of the Sun because of the infrared radiation it emits.Transfer Mechanism: Radiation transfers heat energy from a region of high temperature to a region of low temperature without the need for any particles. It works through the vacuum of spaceInfrared radiation is detected by thermal imaging cameras and night vision goggles. We need to think about the colours of materials when designing buildings. Understanding how different materials absorb and emit infrared radiation helps engineers design better insulation materials. For instance, reflective surfaces can minimize heat loss through radiation. The Earth's atmosphere absorbs and re-emits infrared radiation. This natural process helps keep our planet warm. However, human activities (such as burning fossil fuels) can enhance this effect, leading to global warming.Everything you need to know about heat radiation in one place. Join the science geeks as they discover the wonders of this important part of the electromagnetic spectrum. How is it different to conduction and convection? And what vital role does colour play with this method of heat transfer.This quiz isn't easy and will test your comprehension of the difference between conduction, convection and radiation. Do you know the details? Will you triumph, can you, literally, take the heat? There's only one way to find out! Conduction is one of the three modes of heat transfer while the other two are convection and radiation. There are several practical instances of conduction heat transfer in everyday life, in which heat is transferred without producing motion in the molecules of a substance.In this article, we're going to discuss:What is Conduction heat transfer?Fourier's law used for conduction heat transfer:2.1. Assumptions in Fourier law of heat conduction:Thermal conductivity and Thermal resistance:Conduction heat transfer equation:Types of conduction heat transfer:One dimensional steady state heat conduction:Conduction heat transfer examples:Conduction is the mode of heat transfer in which the transfer of heat from one position to another position is done by means of molecular vibration without changing its lattice position. The heat transfer by conduction is mostly considered in the case of solid materials in which the molecules has the same lattice position throughout the heat transfer process.It also occurs in liquid or gas molecules, When the motion of the molecules is not considered.The heat transfer by the conduction takes place by the molecular vibration and by the movement of electrons.Some of the real world examples of conduction are as follows:During the ironing of clothes, the heat is transferred from iron to cloth by conductionThe handle of the pan kept on the gas stove becomes hot even if it is not directly subjected to the heat. This occurs because the heat is transferred from the pan to the handle by conduction.The components attached to the vehicle engines become hot as it gains heat by conduction from the engine.The Fourier law of heat conduction states that the rate of heat transfer (Q) in a homogeneous solid material is directly proportional to the temperature gradient in the direction of heat flow (`\frac{dT}{dx}`) and area of a cross-section perpendicular to the direction of flow (A).Mathematically, the Fourier law can be expressed as,Q ∝ A `\frac{dt}{dx}`Q = – KA .`\frac{dt}{dx}`Where,`\frac{dt}{dx}` = Temperature gradient in the direction of heat flowA = Cross-sectional areaK = Thermal conductivityThe negative sign in equation of heat conduction indicates that the heat flows in direction of high temperature to low temperature. Thus, the negative sign compensates for the negative nature of the temperature gradient.The Fourier law of heat conduction has following assumptions:Thermal conductivity is constant throughout the material.No internal heat generation occurs in the body.There is a constant temperature gradient.The flow of heat is unidirectional and occurs in steady-state conditions.The surfaces are isothermal.Thermal conductivity is the ability of a material to transfer heat through it. Hence the material with higher thermal conductivity has a higher rate of heat transfer and the material with less thermal conductivity shows a lower rate of heat transfer. Thermal conductivity is denoted by the symbol 'K'.From the Fourier law of conduction, the magnitude of thermal conductivity can be given by,`K=\frac{Q}{A.\frac{dt}{dx}}`Therefore, the thermal conductivity can be defined as the rate of heat transfer per unit cross-sectional area and per unit temperature gradient in the direction of heat flow.The unit of thermal conductivity in the SI system is given by,`K=\frac{Q}{A.\frac{dt}{dx}}` = `\frac{W}{m^{2}.\frac{K}{m}}` =W/mKTherefore, the SI unit of thermal conductivity is W/m.KSimilarly the unit of thermal conductivity in FPS system is given by,`K=\frac{Q}{A.\frac{dt}{dx}}` = `\frac{\text{Btu/hr}}{ft^{2}.\frac{ ° F}{ft}}`K = Btu/hr.ft.°FTherefore, the FPS unit of thermal conductivity is Btu/hr.Ft.°F.Factors affecting thermal conductivity of materials:The thermal conductivity of a material is influenced by the following factors:1) Presence of free electrons:The free electrons easily travel into the material hence it can transfer the heat at a faster rate.Hence as the number of free electrons present in the material increases, the thermal conductivity of the material also increases.The number of free electrons present in metals is higher therefore metals have higher thermal conductivity.2) Presence of impurity:The thermal conductivity of the material is higher in its pure form. The thermal conductivity of material decreases with an increase in impurities or alloying elements.Example: The thermal conductivity of pure copper is higher than brass.3) Density:The thermal conductivity of material increases with an increase in its density because of the increase in the rate of molecular collision.4) Temperature:In the case of solid materials as the temperature increases, the vibration of molecules also increases, and therefore the movement of free electrons decreases, and hence the thermal conductivity decreases.In the case of liquids, as the temperature increases the density of liquid decreases. Therefore, the thermal conductivity of liquid decreases.5) Material structure:The crystalline structure has a higher rate of thermal conductivity while the amorphous material has a lesser value of thermal conductivity.6) Presence of moisture:The thermal conductivity of material increases with an increase in moisture content in the material.Thermal resistance is the resistance to the conduction heat transfer that is given by the ratio of the thickness of the object to the product of thermal conductivity and area of cross-section.Thermal resistance is also known as the reciprocal of thermal conductance.Mathematically it is expressed as,`R_{th}=\frac{x}{KA}`Therefore, the Fourier equation for heat conduction can be written as,`Q=-\frac{\Deltat}{R_{th}}`The SI unit of thermal resistance is given by,`R_{th}=\frac{x}{KA}` = `\frac{m}{[\frac{W}{m.K}][m^{2}]}``R_{th}=\frac{K}{W}`Therefore, SI unit of thermal resistance is K/WThe FPS unit of thermal resistance is given by,`R_{th}=\frac{x}{KA}` = `\frac{ft}{[\text{Btu/hr}.ft. °F][ft^{2}]}``R_{th}` = °F.hr/BtuTherefore, the FPS unit of thermal resistance is °F.hr/Btu.Thermal resistance for the composite section:The composite section consists of a number of layers of different materials. These layers are arranged in series in the direction of heat flow or in parallel to the direction of heat flow.Here are the methods to find the equivalent resistance for both types of arrangements.1) Layers in series:For n number of layers of heat transfering bodies arranged in series, the equivalent thermal resistance is given by,`R_{th(eq)}=R_{th(1)}+R_{th(2)}`+`R_{th(3)}+\cdots R_{th(n)}`2) Layers in parallel:For n number of heat transferring bodies arranged parallelly to the direction of heat flow, the equivalent thermal resistance is given by,`\frac{1}{R_{th(eq)}}=\frac{1}{R_{th(1)}}`+`\frac{1}{R_{th(2)}}+\cdots \frac{1}{R_{th(n)}}`The heat conduction equation shows the heat distribution in the object over time. The equations for heat conduction for the different coordinate systems are given below:-The general heat conduction equation in cartesian coordinates is given below:`\frac{\partial }{\partial x}(K_{x}\frac{\partial t}{\partial x})+\frac{\partial }{\partial y}(K_{y}\frac{\partial t}{\partial y})`+`\frac{\partial }{\partial z}(K_{z}\frac{\partial t}{\partial z})+q_{g}=\rho C\frac{\partial t}{\partial \tau }`Where,∂t/∂x = Temperature gradient along x-direction∂t/∂y = Temperature gradient along y direction∂t/∂z = Temperature gradient along z directionKx, Ky, Kz = Thermal conductivity in X, Y, and Z direction`q_{g}` = Rate of heat generation per unit volume∂t/∂τ = Rate of temperature change with respect to timeρ = Density of the materialC = Specific heatFor constant thermal conductivity:-For constant thermal conductivity in X, Y, and Z-direction, the equation is reduced as,`\frac{\partial ^{2}t}{\partial x^{2}}+\frac{\partial ^{2}t}{\partial y^{2}}`+`\frac{\partial ^{2}t}{\partial z^{2}}+\frac{q_{g}}{K}=\frac{1}{\alpha }\frac{\partial t}{\partial \tau }`Where, α = `\frac{K}{\rho\times C}` = Thermal diffusivityFor steady-state heat conduction with constant thermal conductivity:-For steady-state heat conduction (`\frac{\partial t}{\partial \tau }` = 0) with constant thermal conductivity, the equation can be reduced as,`\frac{\partial ^{2}t}{\partial x^{2}}+\frac{\partial ^{2}t}{\partial y^{2}}`+`\frac{\partial ^{2}t}{\partial z^{2}}+\frac{q_{g}}{K}=0`For no heat generation, steady-state conduction and for constant thermal conductivity:For no heat generation (`q_{g}=0`), steady-state conduction and for constant thermal conductivity, the equation can be reduced as,`\frac{\partial ^{2}t}{\partial x^{2}}+\frac{\partial ^{2}t}{\partial y^{2}}`+`\frac{\partial ^{2}t}{\partial z^{2}}=0`The equation is applicable for the objects having cylindrical shape.The general heat conduction equation in cylindrical coordinates is given by,`{[\frac{\partial ^{2}t}{\partial r^{2}}+\frac{1}{r}\frac{\partial t}{\partial r}+\frac{1}{r^{2}}\frac{\partial ^{2}t}{\partial \phi ^{2}}`+`\frac{\partial ^{2}t}{\partial z^{2}}]+q_{g}=\frac{1}{\alpha }\frac{\partial t}{\partial \tau `The equation is applicable for the object having spherical shape.General heat conduction equation in spherical coordinates is given by,`[\frac{1}{r^{2}sin^{2}\theta }.\frac{\partial ^{2}t}{\partial \phi ^{2}}`+`\frac{1}{r^{2}sin\theta }.\frac{\partial }{\partial \theta }(sin\theta \frac{\partial t}{\partial \theta })`+`\frac{1}{r^{2}}\frac{\partial }{\partial r }(r^{2} \frac{\partial t}{\partial r })]`+ ` \frac{q_{g}}{K}=\frac{1}{\alpha }\frac{\partial t}{\partial \tau }`The conduction heat transfer is classified on the basis of temperature variation with respect to time and temperature variation with respect to distance.Based on temperature variation with respect to time, the conduction heat transfer is classified as,In steady state heat conduction, the temperature of an object doesn't change with respect to time or we can say that in steady-state conduction the change in temperature with respect to time is negligible.Mathematically it is stated as,`\frac{\partial t}{\partial \tau }=0`Where,∂t = Change in temperature∂`\tau ` = Time intervalExample: Heat generated due to the electric current.In unsteady state heat conduction, the temperature of an object changes with respect to time.Hence in this case, the temperature change with respect to time is considerable.Mathematically it is expressed as,`\frac{\partial t}{\partial \tau }e 0`Example: Heating or Cooling of waterBased on temperature variation with respect to space, the conduction heat transfer is classified as,In one-dimensional heat conduction, the temperature gradient in the two dimensions is negligible in comparison with the third dimension.Mathematically, it is expressed as,`\frac{\partial ^{2}t}{\partial x^{2}}`>>`\frac{\partial ^{2}t}{\partial y^{2}}` and `\frac{\partial ^{2}t}{\partial z^{2}}``\therefore \frac{\partial ^{2}t}{\partial y^{2}}` and `\frac{\partial ^{2}t}{\partial z^{2}}\approx 0`In two-dimensional heat conduction, the temperature gradient in one dimension is negligible in comparison with the other two dimensions.Mathematically, it is expressed as,`\frac{\partial ^{2}t}{\partial x^{2}} and \frac{\partial ^{2}t}{\partial y^{2}}`>>`\frac{\partial ^{2}t}{\partial z^{2}}``\therefore \frac{\partial ^{2}t}{\partial z^{2}}\approx 0`In three-dimensional heat conduction, the temperature gradient is present in all three dimensions.`\frac{\partial ^{2}t}{\partial x^{2}} and \frac{\partial ^{2}t}{\partial y^{2}}` and `\frac{\partial ^{2}t}{\partial z^{2}}` `eq` 0Following are the different cases of one-dimensional steady-state heat transfer:-A) Heat conduction through a plane wall:-The one-dimensional steady-state heat conduction through the plane wall is given by,`Q=\frac{(t_{1}-t_{2})}{\frac{L}{KA}}`It is also written as,`Q=\frac{(t_{1}-t_{2})}{R_{th}}` —[as `R_{th}=\frac{L}{KA}`]Where`t_{1}-t_{2}` = Temperature difference between two surfacesL = Thickness of the wallK = Thermal conductivity of the plane wallA = Area of a cross-section of plane wallB) Heat conduction through composite wall:The composite plane walls are made by arranging layers of the different materials in series or in parallel.1) Walls in series:For plane was arranged in series, the rate of heat transfer is given by,Q = `Q_{1-3} = Q_{1-2} = Q_{2-3}`Q=`\frac{t_{1}-t_{3}}{R_{th(A)}+R_{th(B)}}` = `\frac{t_{1}-t_{2}}{R_{th(A)}}` = `\frac{t_{2}-t_{3}}{R_{th(B)}}`Q=`\frac{t_{1}-t_{3}}{\frac{L_{A}}{K_{A}A_{A}}+\frac{L_{B}}{K_{B}A_{B}}}` = `\frac{t_{1}-t_{2}}{\frac{L_{A}}{K_{A}A_{A}}}` = `\frac{t_{2}-t_{3}}{\frac{L_{B}}{K_{B}A_{B}}}`2) Walls in parallel:For plain wall arranged parallel, the rate of heat transfer is given by,Q = `Q_{1} + Q_{2}`Q =`\frac{t_{1}-t_{2}}{\frac{L_{1}}{K_{1}A_{1}}}` + `\frac{t_{1}-t_{2}}{\frac{L_{2}}{K_{2}A_{2}}}`C) Heat conduction through hollow cylinder:The heat transfer by conduction through hollow cylindrical shape is given by,Q = `\frac{t_{1}-t_{2}}{\frac{ln(\frac{r_{2}}{r_{1}})}{2\pi KL}}`Where,`t_{1}` = Inner surface temperature`t_{2}` = Outer surface temperature`r_{1}` = Inner radius of cylinder`r_{2}` = Outer radius of cylinderK = Thermal conductivity of cylinderL = Length of cylinderFor cyclinder `R_{th}` =`\frac{ln(\frac{r_{2}}{r_{1}})}{2\pi KL}` , therefore the equation can also written as,Q = `\frac{t_{1}-t_{2}}{R_{th}}`D) Heat conduction through hollow sphere:The heat transfer by conduction through hollow sphere is given by,Q = `\frac{t_{1}-t_{2}}{\frac{(r_{2}-r_{1})}{4\pi K r_{1}r_{2}}}`Where,`r_{1}` = Inner radius of sphere`r_{2}` = Outer radius of sphereK = Thermal conductivity`t_{1}` = Inner surface temperature`t_{2}` = Outer surface temperatureFor sphere, the thermal resistance is given by`R_{th}` =`\frac{(r_{2}-r_{1})}{4\pi K r_{1}r_{2}}`Therefore the equation can also written as,Q = `\frac{t_{1}-t_{2}}{R_{th}}`1] For the wall shown below, the area perpendicular to the direction of flow is 1.5 m². The temperature at the left side of the wall is 1500°C and at the right side is 40°C. Thus find the rate of heat transfer through the wall. (`K_{A}` = 0.65 W/mK,`K_{B}` = 0.3 W/mK)Given:`K_{A}` = 0.65 W/mK`K_{B}` = 0.3 W/mKA = 1.5 m²`t_{1}` = 1500 °C = 1773 K`t_{2}` = 40 °C = 313 K`L_{A}` = 0.1 m`L_{B}` = 0.15 mSolution:Total thermal resistance for the wall is given as follows,`R_{th}` = `R_{th(1)}+R_{th(2)}``R_{th}` = `\frac{L_{A}}{K_{A}.A}` + `\frac{L_{B}}{K_{B}.A}``R_{th}` = `\frac{0.1}{0.65 \times 1.5}` + `\frac{0.15}{0.3 \times 1.5}``\mathbf{R_{th}}` = 0.435 K/WThe rate of heat transfer through the wall is given by,`Q=\frac{(t_{1}-t_{2})}{R_{th}}``Q=\frac{1773 – 313}{0.435}`This is the rate of heat transfer through the wall.2] The hollow cylinder has an inside radius of 0.5 m, an outside radius of 1 m, and a length of 1.5 m. The temperature on the inside surface of the cylindrical wall is 1650°C and on the outside surface is 25°C. Thus find the rate of heat transfer through the cylinder. (`K_{\text{cylinder}}` = 0.55 W/mK)Given:`K_{\text{cylinder}}` = 0.55 W/mK`r_{1}` = 0.5 m`r_{2}` = 1 m`t_{1}` = 1650°C = 1923 K`t_{2}` = 25 °C = 298 KL = 1.5 mSolution:The thermal resistance for the cylindrical surface is given by,`R_{th}` =`\frac{ln(\frac{r_{2}}{r_{1}})}{2\pi KL}``R_{th}` =`\frac{ln(\frac{1}{0.5})}{2\pi \times 0.55 \times 1.5}``R_{th}` = 0.1337 mThe heat transferred outside of the cylinder is given by,Q =`\frac{t_{1}-t_{2}}{R_{th}}``Q = \frac{1923 – 298}{0.1337}`FAQs:What is an example of heat transfer by conduction?Examples of the heat transfer by conduction are as follows,1] Heat conducted during ironing of clothes2] Transfer of heat from the engine to fins.What are the types of conduction of heat?The conduction heat transfer can be classified as follows:Based on temperature variation with respect to time:1) Steady-state heat conduction2) Un-steady state heat conductionBased on temperature variation with respect to space:1) One-dimensional heat conduction2) Two-dimensional heat conduction3) Three-dimensional heat conductionHow does conduction work in ironing clothes?During ironing, the heat from the surface of the iron is conducted to the clothes without causing bulk motion of the molecules of iron or cloth. The three types of heat transfer are conduction, convection, and radiation.Heat transfer occurs when thermal energy moves from one place to another. Atoms and molecules inherently have kinetic and thermal energy, so all matter participates in heat transfer. There are three main types of heat transfer, plus other processes that move energy from high temperature to low temperature.Heat transfer is the movement of heat due to a temperature difference between a system and its surroundings. The energy transfer is always from higher temperature to lower temperature, due to the second law of thermodynamics. The units of heat transfer are the joule (J), calorie (cal), and kilocalorie (kcal). The unit for the rate of heat transfer is the kilowatt (KW).The three types of heat transfer differ according to the nature of the medium that transmits heat:Conduction requires contact.Convection requires fluid flow.Radiation does not require any medium.Conduction is heat transfer directly between neighboring atoms or molecules. Usually, it is heat transfer through a solid. For example, the metal handle of a pan on a stove becomes hot due to convection. Touching the hot pan conducts heat to your hand.Convection is heat transfer via the movement of a fluid, such as air or water. Heating water on a stove is a good example. The water at the top of the pot becomes hot because water near the heat source rises. Another example is the movement of air around a campfire. Hot air rises, transferring heat upward. Meanwhile, the partial vacuum left by this movement draws in cool outside air that feeds the fire with fresh oxygen.Radiation is the emission of electromagnetic radiation. While it occurs through a medium, it does not require one. For example, it's warm outside on a sunny day because solar radiation crosses space and heats the atmosphere. The burner element of a stove also emits radiation. However, some heat from a burner comes from conduction between the hot element and a metal pan. Most real-life processes involve multiple forms of heat transfer.Conduction requires that molecules touch each other, making it a slower process than convection or radiation. Atoms and molecules with a lot of energy have more kinetic energy and engage in more collisions with other matter. They are "hot." When hot matter interacts with cold matter, some energy gets transferred during the collision. This drives conduction. Forms of matter that readily conduct heat are called thermal conductors.Conduction is a common process in everyday life. For example:Holding an ice cube immediately makes your hands feel cold. Meanwhile, the heat transferred from your skin to the ice melts it into liquid water.Walking barefoot on a hot road or sunny beach burns your feet because the solid material transmits heat into your foot.Iron clothes transfers heat from the iron to the fabric.The handle of a coffee cup filled with hot coffee becomes warm or even hot via conduction through the mug material.One equation for conduction calculates heat transfer per unit of time from thermal conductivity, area, thickness of the material, and the temperature difference between two regions:$Q = [K \cdot A \cdot (T_{hot} - T_{cold})] / d$Q is heat transfer per unit timeK is the coefficient of thermal conductivity of the substanceA is the area of heat transferThot is the temperature of the hot regionTcold is the temperature of the cold regiond is the thickness of the bodyConvection is the movement of fluid molecules from higher temperature to lower temperature regions. Changing the temperature of a fluid affects its density, producing convection currents. If the volume of a fluid increases, than its density decreases and it becomes buoyant.Convection is a familiar process on Earth, primarily involving air or water. However, it applies to other fluids, such as refrigeration gases and magma. Examples of convection include:Boiling water undergoes convection as less dense hot molecules rise through higher density cooler molecules.Hot air rises and cooler air sinks and replaces it.Convection drives global circulation in the oceans between the equators and poles.A convection oven circulates hot air and cooks more evenly than one that only uses heating elements or a gas flame.The equation for the rate of convection relates area and the difference between the fluid temperature and surface temperature:$Q = h_c \cdot A \cdot (T_s - T_f)$Q is the heat transfer per unit timehc is the coefficient of convective heat transferA is the area of heat transferTs is the surface temperatureTf is the fluid temperatureRadiation is the release of electromagnetic energy. Another name for thermal radiation is radiant heat. Unlike conduction or convection, radiation requires no medium for heat transfer. So, radiation occurs both within a medium (solid, liquid, gas) or through a vacuum.There are many examples of radiation:A microwave oven emits microwave radiation, which increases the thermal energy in foodThe Sun emits light (including ultraviolet radiation) and heatUranium-238 emits alpha radiation as it decays into thorium-234The Stephan-Boltzmann law describes relationship between the power and temperature of thermal radiation:$P = e \cdot \sigma \cdot A \cdot (T_r - T_c)^4$P is the net power of radiationA is the area of radiationTr is the radiator temperatureTc is the surrounding temperaturee is emissivityσ is Stefan's constant ($\sigma = 5.67 \times 10^{-8} W m^{-2} K^{-4}$)While conduction, convection, and radiation are the three modes of heat transfer, other processes absorb and release heat. For example, atoms release energy when chemical bonds break and absorb energy in order to form bonds. Releasing energy is an exergonic process, while absorbing energy is an endergonic process. Sometimes the energy is light or sound, but most of the time it's heat, making these processes exothermic and endothermic.Phase transitions between the states of matter also involve the absorption or release of energy. A great example of this is evaporative cooling, where the phase transition from a liquid into a vapor absorbs thermal energy from the environment.Faghri, Amir; Zhang, Yuwen; Howell, John (2010). Advanced Heat and Mass Transfer. Columbia, MO: Global Digital Press. ISBN 978-0-9842760-0-4.Geankoplis, Christie John (2003). Transport Processes and Separation Principles (4th ed.). Prentice Hall. ISBN 0-13-101367-X.Peng, Z.; Doroodchi, E.; Moghtaderi, B. (2020). "Heat transfer modelling in Discrete Element Method (DEM)-based simulations of thermal processes: Theory and model development". 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