Heat Transfer Overview and Dynamic Equation in Terms of the Process and the Movement of Energy Based on the Temperature Difference

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Abstract
Heat transfer is the process of the movement of energy due to a temperature difference. The calculations are interested in include determining the final temperatures of materials and how long it takes for these materials to reach these temperatures. This can help inform the level of insulation required to ensure heat is not lost from a system. Typically, heat loss is proportional to a temperature gradient. Heat transfer is the process of the movement of energy due to a temperature difference. This paper is devoted to give a systematic introduction to a new passive cooling techy for solar cells, aiming to open a new opportunity for solar cells' cooling. The calculations are interested in include determining the final temperatures of materials and how long it takes for these materials to reach these temperatures. This can help inform the level of insulation required to ensure heat is not lost from a system. Characteristically, heat loss is proportional to a temperature gradient. Heat transfer can be achieved by conduction, convection or radiation. Thermodynamics, along with thermal hydraulic analysis, deals with the transfer of heat to and from a working fluid and the performance of work by that fluid. Subsequently, the transfer of heat to a working fluid is central to thermodynamics, a short excursion into the techy of heat transfer is useful to tie thermodynamics to real-world devices. Heat transfer processes are never ideal, and a study of the techy of heat transfer will develop an understanding of the tradeoffs in the design of the devices that actually accomplish heat transfer. Heat transfer techy provides the basis on which heat exchangers are designed to accomplish the actual transfer of thermal energy. Additionally, the results of this beneficial study are important for several domains such as the industrial world, the educational world, as well as the scientific world in addition to researchers who aimed for some investigations outcome based on Heat transfer processes.

Keywords: *Heat transfer, thermal energy, thermal conduction, thermal convection, thermal radiation, transfer of energy.*

1.1. Introduction

Heat transfer is a discipline of thermal engineering that concerns the generation, use, conversion, and exchange of thermal energy between physical systems (Mansuripur and Jakobsen, 2020); (Bejan, 2020). Heat transfer is classified into various mechanisms, such as thermal conduction, thermal convection, thermal radiation, and transfer of energy by phase changes (Bejan, 2020). Engineers also consider the transfer of mass of differing chemical species, either cold or hot, to achieve heat transfer (Fedosov and Bakanov, 2020); (Mahardika and Haryani, 2020); (Chen and Akbarzadeh, 2020); (Ahmed et al., 2020); (Li and

Cao, 2020);(Yan et al., 2020). While these mechanisms have distinct characteristics, they often occur simultaneously in the same system (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020). Thermodynamics, along with thermal hydraulic analysis, deals with the transfer of heat to and from a working fluid and the performance of work by that fluid. Since the transfer of heat to a working fluid is central to thermodynamics, a short excursion into the techy of heat transfer is useful to tie thermodynamics to real world devices. Heat transfer processes are never ideal and a study of the techy of heat transfer will develop an understanding of the trade-offs in the design of the devices that actually accomplish the heat transfer (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020). Heat transfer techy provides the basis on which heat exchangers are designed to accomplish the actual transfer of thermal energy (Fedosov and Bakanov, 2020); (Mahardika and Haryani, 2020); (Chen and Akbarzadeh, 2020); (Ahmed et al., 2020); (Li and Cao, 2020);(Yan et al., 2020).

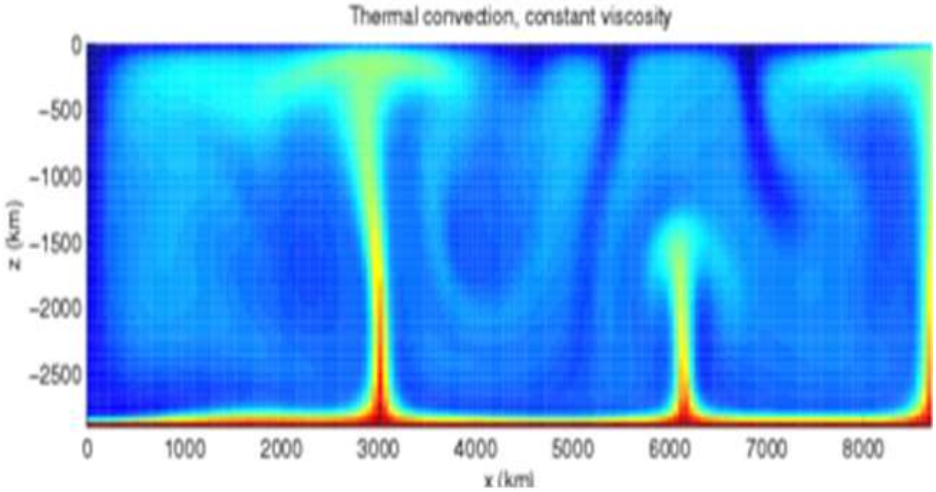

Figure.1.1. Simulation of thermal convection in the Earth's mantle. Colors span from red and green to blue with decreasing temperatures.

Heat conduction, also called diffusion, is the direct microscopic exchange of kinetic energy of particles through the boundary between two systems (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020). When an object is at a different temperature from another body or its surroundings, heat flows so that the body and the surroundings reach the same temperature, at which point they are in thermal equilibrium. Such spontaneous heat transfer always occurs from a region of high temperature to another region of lower temperature (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020), as described in the second law of thermodynamics. Heat convection occurs when bulk flow of a fluid (gas or liquid) carries heat along with the flow of matter in the fluid (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020). The flow of fluid may be forced by external processes, or sometimes (in gravitational fields) by buoyancy forces caused when thermal energy expands the fluid (for example in a fire plume), thus influencing its own transfer. The latter process is often called "natural convection" (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020). All convective processes also move heat partly by diffusion, as well. Another form of convection is forced convection.

1.2. Heat transfer physics

Heat is defined in physics as the transfer of thermal energy across a well-defined boundary around a thermodynamic system. The thermodynamic free energy is the amount of work that a thermodynamic system can perform. Enthalpy is a thermodynamic potential, designated by the letter "H", that is the sum of the internal energy of the system (U) plus the product of pressure (P) and volume (V) (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020). Joule is a unit to quantify energy, work, or the amount of heat. Heat transfer is a process function (or path function), as opposed to functions of state; therefore, the amount of heat transferred in a thermodynamic process that changes the state of a system depends on how that process occurs, not only the net difference between the initial and final states of the process (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020).

Thermodynamic and mechanical heat transfer is calculated with the heat transfer coefficient, the proportionality between the heat flux and the thermodynamic driving force for the flow of heat. Heat flux is a quantitative (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020), vectorial representation of heat-flow through a surface (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020).

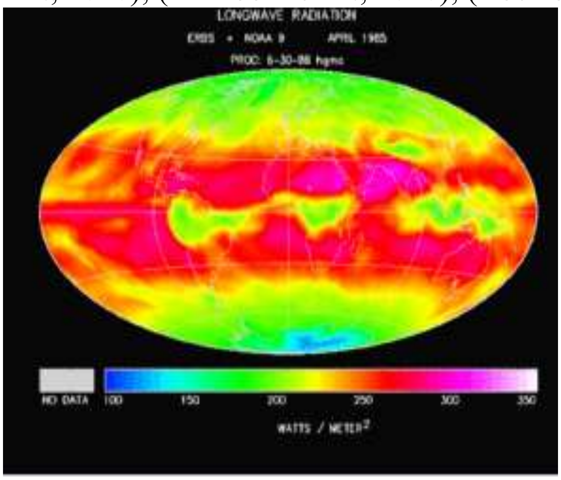

Figure.1.2. Earth's long wave thermal radiation intensity, from clouds, atmosphere and surface.

The transport equations for thermal energy as a Fourier's law, mechanical momentum as announced by Newton's law for fluids, which is associated with mass transfer as a Fick's laws of diffusion which are similar, (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020) and analogies among these three transport processes have been developed to facilitate prediction of conversion from any one to the others (Mahardika and Haryani, 2020); (Chen and Akbarzadeh, 2020); (Ahmed et al., 2020); (Li and Cao, 2020);(Yan et al., 2020). Thermal engineering concerns the generation, use, conversion, and exchange of heat transfer. As such, heat transfer is involved in almost every sector of the economy. In addition, (Fedosov and Bakanov, 2020); (Mahardika and Haryani, 2020); (Chen and Akbarzadeh, 2020); (Ahmed et al., 2020); (Li and Cao, 2020);(Yan et al., 2020) Heat transfer is classified into various mechanisms, for instance, thermal conduction, thermal convection, thermal radiation, and transfer of energy by phase changes (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020).

1.3. Aim and objective

- To determinate the final temperatures of materials and how long it takes for these materials to reach these temperatures.
- To understand the process of the movement of energy due to a temperature difference.
- The calculations are interested in include determining the final temperatures of materials and how long it takes for these materials to reach these temperatures.

- To ensure heat is not lost from a system.
- Heat transfer can be achieved by conduction, convection or radiation.
- Thermodynamics, along with thermal hydraulic analysis, deals with the transfer of heat to and from a working fluid and the performance of work by that fluid.
- A working fluid is central to thermodynamics, a short excursion into the techy of heat transfer is useful to tie thermodynamics to real-world devices.
- Heat transfer processes are never ideal, and a study of the techy of heat transfer will develop an understanding of the tradeoffs in the design of the devices that actually accomplish heat transfer.
- Heat transfer technology provides the basis on which heat exchangers are designed to accomplish the actual transfer of thermal energy.

1.4. Research questions

- **RQ1:** What's the processing stages of Al-Mn based aluminum alloys production of automotive heat transfer?

Rational1: the microstructure, phase composition, physical properties which is associated with processing of Al-Mn based aluminum alloys utilized for the production of automotive heat transfer.

- **RQ2:**What are applications of heat transfer advantages and disadvantages?

Rational2: based on some authors that presented in the literature review section (Saleh et al., 2020); (Chumpia and Hooman, 2019); (ATAER et al., 2020) etc. hey has announced that several the traditional and conventional heat transfer market remains limited as presented in Table.1.2. some aluminum applications of heat transfer advantages and disadvantages (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020).

Literature review

Jin et al., (2015) has announced that a new aluminum alloys, based on a commercial Al-Mn-Cu brazing sheet core alloy, with increasing alloying element Mg up to 2 wt.%, have been developed for automotive heat exchanger units in service at above 200°C. The new Al-Mn-Cu-Mg alloys are to be used as the core material in brazing sheets for vacuum and nickel brazing technologies (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020). They were DC cast to 3.75″ lab sized ingots, scalped, re-heated to 520°C, hot rolled to 4.8 - 5mm, and cold rolled down to a final gauge of 1mm. It has been demonstrated by various mechanical and corrosion testing that Mg contributes a strong solid solution hardening effect at both the room and elevated temperatures, without damaging the other mechanical properties or corrosion resistance. Hence the alloys with 1 - 2 wt.% Mg are able to maintain high yield strength above 60 MPa at 200 - 300°C, with no reduction in formability and very limited decrease in corrosion resistance. Since the new alloys do not contain expensive alloying elements, there is no significant increase in material or processing costs (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020).

- **Phase transition**

Phase transition or phase change, takes place in a thermodynamic system from one phase or state of matter to another one by heat transfer (Li and Wang, 2020); (Hegde et al., 2020). Phase change examples are the melting of ice or the boiling of water (Khan et al., 2020). The Mason equation explains the growth of a water droplet based on the effects of heat transport on evaporation and condensation (Yokoyama et al., 2020).

Phase transitions involve the four fundamental states of matter:

- **Solid:** Deposition, freezing and solid to solid transformation (Foerst et al., 2020).

- **Gas:** Boiling which is linked with evaporation, recombination/deionization, as well as sublimation (Shahidian et al., 2020).
- **Liquid:** Condensation and fusion (Fisher and Elbaum-Garfinkle, 2020).
- **Plasma:** Ionization (Fisher and Elbaum-Garfinkle, 2020).

Boiling

The boiling point of a substance is the temperature at which the vapor pressure of the liquid equals the pressure surrounding the liquid (Sajjad et al., 2020) and the liquid evaporates resulting in an abrupt change in vapor volume and saturation temperature means boiling point (Fedosov and Bakanov, 2020); (Mahardika and Haryani, 2020); (Chen and Akbarzadeh, 2020); (Ahmed et al., 2020); (Li and Cao, 2020);(Yan et al., 2020). The saturation temperature is the temperature for a corresponding saturation pressure at which a liquid boils into its vapor phase. The liquid can be said to be saturated with thermal energy. Any addition of thermal energy results in a phase transition (Wu et al., 2020).

Figure.1.3. The liquid with thermal energy.

At standard atmospheric pressure and low temperatures, no boiling occurs and the heat transfer rate is controlled by the usual single-phase mechanisms (Polanski and Duszkiewicz, 2020). As the surface temperature is increased (Fedosov and Bakanov, 2020); (Mahardika and Haryani, 2020); (Chen and Akbarzadeh, 2020); (Ahmed et al., 2020); (Li and Cao, 2020);(Yan et al., 2020), local boiling occurs and vapor bubbles nucleate, grow into the surrounding cooler fluid, and collapse (Muhammad and Abo-Elkhier, 2020). This is sub-cooled nucleate boiling, and is a very efficient heat transfer mechanism. At high bubble generation rates, the bubbles begin to interfere and the heat flux no longer increases rapidly with surface temperature which is the departure from nucleate boiling, or DNB (Muhammad and Abo-Elkhier, 2020). At similar standard atmospheric pressure and high temperatures, the hydrodynamically-quieter regime of film boiling is reached. Heat fluxes across the stable vapor layers are low, but rise slowly with temperature (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020). Any contact between fluid and the surface that may be seen probably leads to the extremely rapid nucleation of a fresh vapor layer ("spontaneous nucleation") (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020). At higher temperatures still, a maximum in the heat flux is reached the critical heat flux, or (CHF). The Leidenfrost Effect demonstrates how nucleate boiling slows heat transfer due to gas bubbles on the heater's surface. As mentioned, gas-phase thermal conductivity is much lower than liquid-phase thermal conductivity, so the outcome is a kind of "gas thermal barrier" (Muhammad and Abo-Elkhier, 2020).

- **Condensation**

Condensation occurs when a vapor is cooled and changes its phase to a liquid. During condensation, the latent heat of vaporization must be released. The amount of the heat is the same as that absorbed during vaporization at the same fluid pressure (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020).

There are several types of condensation:

- Homogeneous condensation, as during a formation of fog.
- Condensation in direct contact with sub-cooled liquid.
- Condensation on direct contact with a cooling wall of a heat exchanger: This is the most common mode used in industry:
- Film wise condensation is when a liquid film is formed on the sub-cooled surface, and usually occurs when the liquid wets the surface.
- Drop-wise condensation is when liquid drops are formed on the sub-cooled surface, and usually occurs when the liquid does not wet the surface.
- Drop-wise condensation is difficult to sustain reliably; therefore, industrial equipment is normally designed to operate in film-wise condensation mode.
- **Melting**

Melting is a thermal process that results in the phase transition of a substance from a solid to a liquid. The internal energy of a substance is increased, typically with heat or pressure, resulting in a rise of its temperature to the melting point, at which the ordering of ionic or molecular entities in the solid breaks down to a less ordered state and the solid liquefies (Misyura, 2020); (Taghilou and Khavasi, 2020); (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020). Molten substances generally have reduced viscosity with elevated temperature; an exception to this maxim is the element sulfur, whose viscosity increases to a point due to polymerization and then decreases with higher temperatures in its molten state (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020).

Modeling approaches

Heat transfer can be modeled in various ways.

- **Heat equation**

The heat equation is an important partial differential equation that describes the distribution of heat (or variation in temperature) in a given region over time. In some cases, exact solutions of the equation are available (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020) in other cases the equation must be solved numerically using computational methods such as DEM-based models for thermal/reacting particulate systems (as critically reviewed by Peng et al. (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020).

- **Lumped system analysis**

Lumped system analysis often reduces the complexity of the equations to one first-order linear differential equation, in which case heating and cooling are described by a simple exponential solution, often referred to as Newton's law of cooling. System analysis by the lumped capacitance model is a common approximation in transient conduction that may be used whenever heat conduction within an object is much faster than heat conduction across the boundary of the object (Misyura, 2020); (Taghilou and Khavasi, 2020); (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020). This is a method of approximation that reduces one aspect of the transient conduction system that within the object to an equivalent steady state system. That is, the method assumes that the temperature within the object is completely uniform, although its value may be changing in time. In this method, the ratio of the conductive heat resistance within the object to the convective heat transfer resistance across the object's boundary (Taghilou and Khavasi, 2020); (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020), known as the Biot number, is calculated. For small Biot numbers, the approximation of spatially uniform temperature within the object can be used: it can be presumed that heat transferred into the object has time to uniformly distribute itself, due to the lower resistance to doing so, as compared with the resistance to heat entering the object (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020).

- **Climate models**

Climate models study the radiant heat transfer by using quantitative methods to simulate the interactions of the atmosphere, oceans, land surface, and ice (Misyura, 2020); (Taghilou and Khavasi, 2020); (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020).

- **Engineering**

Heat transfer has broad application to the functioning of numerous devices and systems. Heat-transfer principles may be used to preserve, increase, or decrease temperature in a wide variety of circumstances (Misyura, 2020); (Taghilou and Khavasi, 2020); (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020). Heat transfer methods are used in numerous disciplines, such as automotive engineering, thermal management of electronic devices and systems, climate control, insulation, materials processing, and power station engineering.

Figure.1.4. The automotive engineering, thermal management of electronic devices and systems, climate control, insulation, materials processing, and power station engineering.

Insulation, radiance and resistance

Thermal insulators are materials specifically designed to reduce the flow of heat by limiting conduction, convection, or both. Thermal resistance is a heat property and the measurement by which an object or material resists towards heat flow to temperature difference (Misyura, 2020); (Taghilou and Khavasi, 2020); (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020). Radiance or spectral radiance are measures of the quantity of radiation that passes through or is emitted. Radiant barriers are materials that reflect radiation, and therefore reduce the flow of heat from radiation sources. Good insulators are not necessarily good radiant barriers, and vice versa. Metal, for instance, is an excellent reflector and a poor insulator (Misyura, 2020); (Taghilou and Khavasi, 2020); (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020).
The effectiveness of a radiant barrier is indicated by its reflectivity, which is the fraction of radiation reflected (Taghilou and Khavasi, 2020); (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020). A material with a high reflectivity (at a given wavelength) has a low emissivity at that same wavelength, as well as vice versa. At any specific wavelength, reflectivity=1 - emissivity. An ideal radiant barrier would have a reflectivity of 1, and would therefore reflect 100 percent of incoming radiation. In the vacuum of space, satellites use multi-layer insulation, which consists of many layers of aluminized Mylar to greatly reduce radiation heat transfer and control satellite temperature (Kong, 2020).

Devices

- A heat engine is a system that performs the conversion of a flow of thermal energy (heat) to mechanical energy to perform mechanical work (Kong, 2020).
- A thermocouple is a temperature-measuring device and widely used type of temperature sensor for measurement and control, and can also be used to convert heat into electric power (Misyura, 2020); (Taghilou and Khavasi, 2020); (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020).
- A thermoelectric cooler is a solid state electronic device that pumps transfers heat from one side of the device to the other when electric current is passed through it. It is based on the Peltier effect (Kong, 2020).
- A thermal diode or thermal rectifier is a device that causes heat to flow preferentially in one direction.

- **Heat exchangers**

A heat exchanger is used for more efficient heat transfer or to dissipate heat. Heat exchangers are widely used in refrigeration, air conditioning, space heating, power generation, and chemical processing (Kong, 2020). One common example of a heat exchanger is a car's radiator, in which the hot coolant fluid is cooled by the flow of air over the radiator's surface (Misyura, 2020); (Taghilou and Khavasi, 2020); (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020).

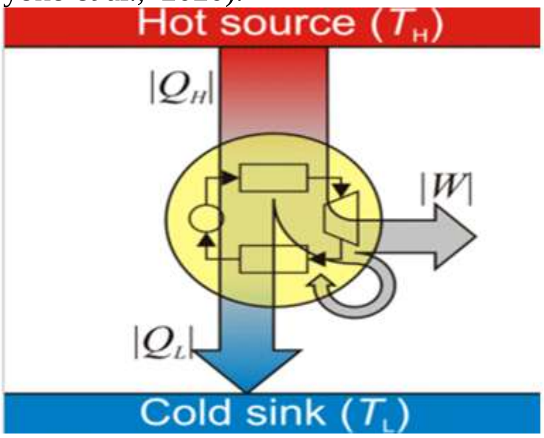

Figure.1.5. Schematic flow of energy in a heat engine.

Common types of heat exchanger flows include parallel flow, counter flow, and cross flow. In parallel flow, both fluids move in the same direction while transferring heat; in counter flow, the fluids move in opposite directions; and in cross flow, the fluids move at right angles to each other. Common types of heat exchangers include shell and tube, double pipe, extruded finned pipe, spiral fin pipe, u-tube, and stacked plate. Each type has certain advantages and disadvantages over other types. A heat sink is a component that transfers heat generated within a solid material to a fluid medium (Misyura, 2020); (Taghilou and Khavasi, 2020); (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020), such as air or a liquid. Examples of heat sinks are the heat exchangers used in refrigeration and air conditioning systems or the radiator in a car. A heat pipe is another heat-transfer device that combines thermal conductivity and phase transition to efficiently transfer heat between two solid interfaces (Misyura, 2020); (Taghilou and Khavasi, 2020); (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020).

Conduction occurs in stationary materials as a result of the vibrations of atoms or molecules in the materials. It is governed by Fourier's law of heat conduction, which in one dimension is written as

$$Q_x = -kA\frac{\partial T}{\partial x} \quad \text{Btu/h} \quad \text{or} \quad \text{W} \tag{8.1a}$$

or

$$q_x = \frac{Q_x}{A} = -k\frac{\partial T}{\partial x} \quad \text{Btu/h/ft}^2 \quad \text{or} \quad \text{W/m}^2 \tag{8.1b}$$

Simply stated the heat flow per unit area is proportional to the negative of the temperature gradient. The proportionality constant is called the thermal conductivity, and it has units of Watts/meter/K or Btus/ft/ R (Misyura, 2020); (Taghilou and Khavasi, 2020); (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020). The thermal conductivities of typical materials vary widely by material, and it also depends on the temperature of the materials. Some typical values are given in the Appendices A, B, and C for solids, liquids, and gases (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020). There are different techniques available to solve the energy equation for conduction heat transfer: shell balance, conformal mapping, numerical methods, and graphical methods. The more complete version of version of heat conduction equation can be written as Eq.8.1c, whereαis the thermal diffusivity, kis the thermal conductivity, and _qis the heat flux.

$$\nabla^2 T + \frac{\dot{q}}{k} = \frac{1}{\alpha}\frac{\partial T}{\partial x} \tag{8.1c}$$

The term $\nabla^2 T \equiv \nabla \cdot \nabla T$ is called the *Laplacian*. In Cartesian coordinate system, this is given as

$$\nabla \cdot \nabla T = \left(\hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}\right) \cdot \left(\hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}\right) \tag{8.1d}$$

or

$$\nabla^2 T = \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} \tag{8.1e}$$

The Laplacian can also be expressed in cylindrical or spherical coordinates.

8.2 Basic Heat Conduction Equations of all three coordinates, for instance, Rectangular, Cylindrical, as well as Spherical; systems heat conduction equations in case of one-dimensional heat transfer is presented here, by expanding on Eqs.8.1aor8.1b. We assume all the used parameters to be described as follows:

Cp= specific heat of materials, J/(kg ^{0}C)

G= energy generation rate per unit volume, W/m^3

Q=conduction heat flux in the given coordinate direction, W/m^2

T= time, s

K= thermal conductivity of materials, where heat transferring through, W/(mC)

P = density of materials, kg/m^3

1. Rectangular Coordinates:

The heat transfer area A does not vary with variable x; hence, it is taken as constant and cancels. Then, Eqs.8.1aor8.1breduces to

$$\frac{\partial}{\partial x}\left(k\frac{\partial T(x,t)}{\partial x}\right)+g=\rho c_{\mathrm{p}}\frac{\partial T(x,t)}{\partial x} \qquad (8.2a)$$

which is the one-dimensional, time-dependent heat conduction relation in the rectangular coordinate system.

2. Cylindrical Coordinates: the variable x with radial variable thus Eq.8.2aconverts to a new form as

$$\frac{1}{r}\frac{\partial}{\partial r}\left(rk\frac{\partial T(r,t)}{\partial r}\right)+g=\rho c_{\mathrm{p}}\frac{\partial T(r,t)}{\partial t} \qquad (8.2b)$$

which is the one-dimensional, time-dependent heat conduction relation in the spherical coordinate system.

- **A Compact Form of Basic Heat Conduction Equations**

The compact version of Eq. 8.2 can be established using Rectangular, Cylindrical, and Spherical coordinates systems for one-dimensional, time-dependent heat conduction as

$$\frac{1}{r^n}\frac{\partial}{\partial r}\left(r^n k\frac{\partial T}{\partial r}\right)+g=\rho c_{\mathrm{p}}\frac{\partial T}{\partial t} \qquad (8.3)$$

where

$$n=\begin{cases}0 & \text{for rectangular coordinates}\\ 1 & \text{for cylindrical coordinates}\\ 2 & \text{for spherical coordinates}\end{cases}$$

- **Special Cases of Heat Conduction Equations**

Eq.8.3are of practical interest in usage of thermalhydraulic subject (Misyura, 2020); (Taghilou and Khavasi, 2020); (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020). For constant thermal conductivityk,Eq.8.3. reduces to a simplified form as

$$\frac{1}{r^n}\frac{\partial}{\partial r}\left(r^n\frac{\partial T}{\partial r}\right)+\frac{1}{k}g=\frac{1}{\alpha}\frac{\partial T}{\partial t} \quad (8.4a)$$

where

$$\alpha\equiv\frac{k}{\rho c_p}=\text{thermal diffusivity of material, m}^2/\text{s} \quad (8.4b)$$

For steady-state heat conduction with energy sources within the medium, Eq. 8.3 becomes

$$\frac{1}{r^n}\frac{\partial}{\partial r}\left(r^n k\frac{\partial T}{\partial r}\right)+g=0 \quad (8.5a)$$

and for the case of constant thermal conductivity, this result reduces to

$$\frac{1}{r^n}\frac{\partial}{\partial r}\left(r^n\frac{\partial T}{\partial r}\right)+\frac{1}{k}g=0 \quad (8.5b)$$

For steady-state heat conduction with no energy sources within the medium, Eq. 8.3, forms a more simplified version as

$$\frac{d}{dr}\left(r^n k\frac{\partial T}{\partial r}\right)=0 \quad (8.6a)$$

and for constant k, this result reduces to

$$\frac{d}{dr}\left(r^n\frac{\partial T}{\partial r}\right)=0 \quad (8.6b)$$

In all the equations from Eqs. 8.4 to 8.6, the exponent variable is defined as before

$$n=\begin{cases}0 & \text{for rectangular coordinates}\\ 1 & \text{for cylindrical coordinates}\\ 2 & \text{for spherical coordinates}\end{cases}$$

And for rectangular coordinate again, Radial variables replaced by Cartesian variable x.

1.5. Heat transfer in the human body

The principles of heat transfer in engineering systems can be applied to the human body in order to determine how the body transfers heat. Heat is produced in the body by the continuous metabolism of nutrients which provides energy for the systems of the body. The human body must maintain a consistent internal temperature in order to maintain healthy bodily functions. Therefore, excess heat must be dissipated from the body to keep it from overheating. When a person engages in elevated levels of physical activity, the body requires additional fuel which increases the metabolic rate and the rate of heat production. The body must then use additional methods to remove the additional heat produced in order to keep the internal temperature at a healthy level. Heat transfer by convection is driven by the movement of fluids over the surface of the body. This convective fluid can be either a liquid or a gas (Hurskainen and Ihonen, 2020). For heat transfer from the outer surface of the body, the convection mechanism is dependent on the surface area of the body, the velocity of the air, and the temperature gradient between the surface of the skin and the ambient air (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020). The normal temperature of the body is approximately 37 °C (Hurskainen and Ihonen, 2020). Heat transfer occurs more readily when the temperature of the surroundings is significantly less than the normal body temperature. This concept explains why a person feels cold when not enough covering is worn when exposed to a cold environment (Misyura, 2020); (Taghilou and Khavasi, 2020); (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020). Clothing can be considered an insulator which provides thermal resistance to heat flow over the covered portion of the body (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020). This thermal resistance causes the temperature on the surface of the clothing to be less than the temperature on the surface of the skin. This smaller temperature gradient between the surface temperature and the ambient temperature will cause a lower rate of heat transfer than if the skin were not covered (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020).

In order to ensure that one portion of the body is not significantly hotter than another portion, heat must be distributed evenly through the bodily tissues. Blood flowing through blood vessels acts as a convective fluid and helps to prevent any buildup of excess heat inside the tissues of the body. This flow of blood through the vessels can be modeled as pipe flow in an engineering system. The heat carried by the blood is determined by the temperature of the surrounding tissue, the diameter of the blood vessel, the thickness of the fluid, velocity of the flow, and the heat transfer coefficient of the blood. The velocity, blood vessel diameter, and the fluid thickness can all be related with the Reynolds Number, a dimensionless number used in fluid mechanics to characterize the flow of fluids.

Latent heat loss, also known as evaporative heat loss, accounts for a large fraction of heat loss from the body. When the core temperature of the body increases, the body triggers sweat glands in the skin to bring additional moisture to the surface of the skin. The liquid is then transformed into vapor which removes heat from the surface of the body (Tajadodi, 2020); (Li and Wu, 2020); (Kaur and Goyal, 2020); (Simonis et al., 2020); (Mirkoohi et al., 2020); (Костюк, 2020). The rate of evaporation heat loss is directly related to the vapor pressure at the skin surface and the amount of moisture present on the skin (Baird et al., 2020). Therefore, the maximum of heat transfer will occur when the skin is completely wet. The body continuously loses water by evaporation but the most significant amount of heat loss occurs during periods of increased physical activity (Taghilou and Khavasi, 2020); (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020).

Cooling techniques

- **Evaporative cooling** Latent heat describes the amount of heat that is needed to evaporate the liquid; this heat comes from the liquid itself and the surrounding gas and surfaces. The greater the difference between the two temperatures, the greater the evaporative cooling effect. When the temperatures are the same, no net evaporation of water in air occurs; thus, there is no cooling effect (Taghavifar, 2020); (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020).
- **Laser cooling** is used to achieve temperatures of near absolute zero (−273.15 °C, −459.67 °F) of atomic and molecular samples to observe unique quantum effects that

can only occur at this heat level. Doppler cooling is the most common method of laser cooling. This technique allows cooling of ions and atoms that cannot be laser cooled directly (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020).

- **Magnetic cooling** is a process for lowering the temperature of a group of atoms, after pre-cooled by methods such as laser cooling. Magnetic refrigeration cools below 0.3K, by making use of the magnetocaloric effect (Misyura, 2020); (Rahim et al., 2020); (Haryoko et al., 2020).
- **Radiative cooling** Outgoing energy is an important effect in the Earth's energy budget. In the case of the Earth-atmosphere system (Rahim et al., 2020); (Haryoko et al., 2020), the process by which long-wave (infrared) radiation is emitted to balance the absorption of short-wave energy from the Sun. Convective transport of heat and evaporative transport of latent heat both remove heat from the surface and redistribute it in the atmosphere.
- **Thermal energy storage** includes techies for collecting and storing energy for later use. It may be employed to balance energy demand between day and nighttime (Костюк, 2020); (Zhao et al., 2020); (Yokoyama et al., 2020); (Yan et al., 2020); (Xu et al., 2020). The thermal reservoir may be maintained at a temperature that of the ambient environment. Applications include space heating, domestic or process hot water systems, or generating electricity.

Heat Transfer Mechanisms

Enclosure cooling involves a combination of heat transfer mechanisms. The primary mechanisms used for cooling electrical enclosures are as follows:

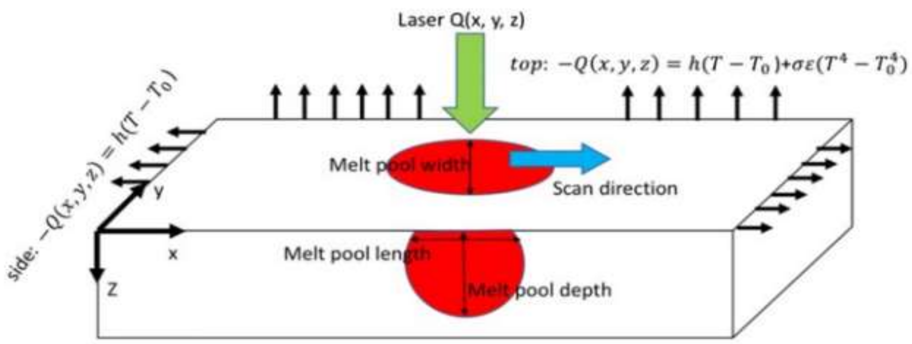

Figure.1.6. Heat transfer mechanisms in Direct metal deposition (DMD) is an additive manufacturing adapted from (Mirkoohi et al., 2020).

- **Conduction:** This is the transfer of heat through a solid. For example, heat generated inside an emclosure is transferred to the outer surface by means of conduction.
- **Convection:** Convection is the transfer of heat from a surface by means of a fluid such as air (Костюк, 2020); (Zhao et al., 2020); (Yokoyama et al., 2020); (Yan et al., 2020); (Xu et al., 2020). Natural convection occurs as air is heated: it expands, rises, and is replaced by cooler air. The amount of convection may be increased by using a fan to increase the flow of air (Mirkoohi et al., 2020).
- **Radiation:** This is a process where energy is radiated through the air by means of electromagnetic radiation. Although effective for high temperature sources such as the sun (Костюк, 2020); (Zhao et al., 2020); (Yokoyama et al., 2020); (Yan et al., 2020); (Xu et al., 2020), it's less effective at ambient temperatures on earth (Mirkoohi et al., 2020).

- **Evaporation:** The latent heat of a fluid can be used to transfer heat by absorbing the energy required to evaporate that fluid. The heat absorbed is released by allowing the fluid to condense outside the enclosure. These forms of heat transfer are used to cool electrical enclosures in several ways.

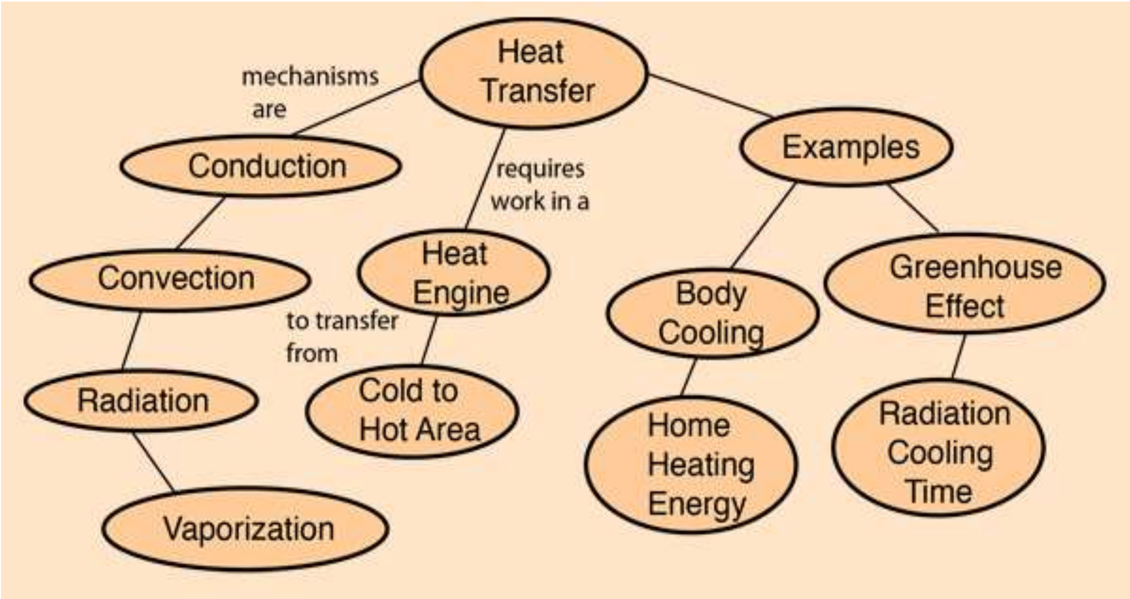

Figure.1.7. Heat Transfer

Zhao et al., (2020) has reported that waste heat is generated in solar cells during the daytime because they operate with a limited electrical efficiency. Moreover, the generated heat increases the solar cells' operating temperature, and this has an adverse effect on their electrical efficiency. Therefore, numerous cooling methods have been developed to cool solar cells, such as forced air/water flow (Костюк, 2020); (Zhao et al., 2020); (Yokoyama et al., 2020); (Yan et al., 2020); (Xu et al., 2020), hybrid photovoltaic/thermal system, and phase change material based photovoltaic application. Recently, a novel concept of changing the solar cells' spectral response to both sunlight and thermal radiation has been proposed and developed to provide a passive cooling method for solar cells, which has drawn much attention from materials science to engineering fields. In this paper, the recent advancements of such a spectrally selective approach to passively cool solar cells, including radioactive cooling of solar cells and full-spectrum thermal management of solar cells are reviewed, analyzed, and discussed from fundamental principles to detailed demonstration. Furthermore, the technical challenges involved in developing this new cooling techy which are discussed in Table.1.1. The fundamental modes of heat transfer.

1.6. The research discussion methods

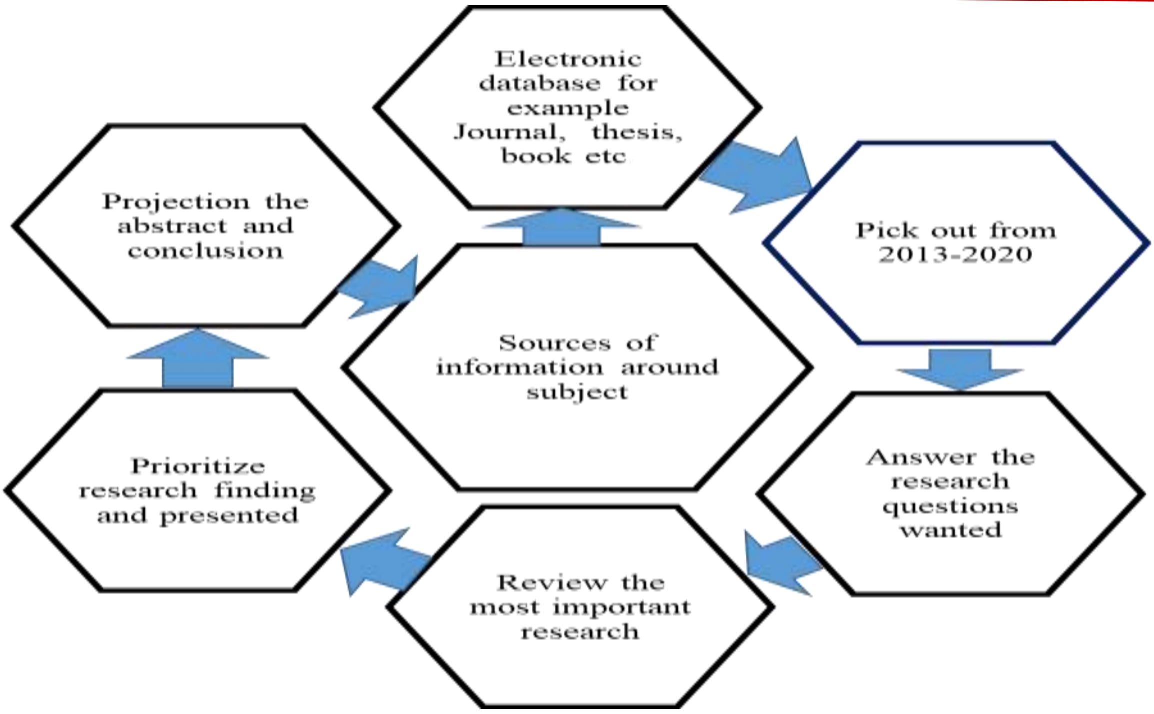

Figure. 1. 8. The research methods that used in this research adapted from (Llahm et al., 2020); (Dalla, 2020).

1.7. Conclusion

This research deals with fundamental concepts in heat transfer overview and dynamic equation in terms of the process and the movement of energy based on the temperature difference theory and outlines some basics of numerical modeling. Thus, the research starts with The relationship between classical simulation of thermal convection in the Earth's mantle. Heat transfer physics, phase transition, phase transitions involve the four fundamental states of matter. There are several types of condensation and Insulation, radiance and resistance with decreasing temperatures. Furthermore, enclosure cooling involves a combination of heat transfer mechanisms. Heat transfer mechanisms in Direct metal deposition (DMD) is an additive manufacturing, for instance, conduction as a heat generated inside an emclosure is transferred to the outer surface by means of conduction. Convection: as a heat from a surface by means of a fluid such as air. Natural convection occurs as air is heated: it expands, rises, and is replaced by cooler air. The amount of convection may be increased by using a fan to increase the flow of air. Radiation where energy is radiated through the air by means of electromagnetic radiation. Although effective for high temperature sources such as the sun, it's less effective at ambient temperatures on earth. Evaporation. The second part of the research yields some introductory aspects of Table.1.1. The fundamental modes of heat transfer theory methods and represents the equations. A brief description ha has been presented in Table.1.2. Applications of Heal transfer and numerical solution of integral equations examples are given, as well.

Authors' contributions

The author has contributed to this study in ways that conform to the iiardpub authorship criteria. The author has read and approved the final version of the manuscript.

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Table.1.1. The fundamental modes of heat transfer

Factors	Description and equation	Limitation	Authors and years
Advection	Advection is the transport mechanism of a fluid from one location to another, and is dependent on motion and momentum of that fluid. $\phi_q = v\rho c_p \Delta T$	By transferring matter, energy including thermal energy is moved by the physical transfer of a hot or cold object from one place to another. This can be as simple as placing hot water in a bottle and heating a bed, or the movement of an iceberg in changing ocean currents. A practical example is thermal hydraulics.This can be described by the formula:	(Tajadodi, 2020) (Li and Wu, 2020). (Kaur and Goyal, 2020) (Simonis et al., 2020) (Mirkoohi et al., 2020) (Костюк, 2020)
Conduction or diffusion	The transfer of energy between objects that are in physical contact. Thermal conductivity is the property of a material to conduct heat and evaluated primarily in terms of Fourier's Law for heat conduction. $\mathrm{Ra} = \mathrm{Gr} \cdot \mathrm{Pr} = \frac{g\Delta\rho L^3}{\mu\alpha} = \frac{g\beta\Delta T L^3}{\nu\alpha}$	On a microscopic scale, heat conduction occurs as hot, rapidly moving or vibrating atoms and molecules interact with neighboring atoms and molecules, transferring some of their energy (heat) to these neighboring particles. In other words, heat is transferred by conduction when adjacent atoms vibrate against one another, or as electrons move from one atom to another. Conduction is the most significant means of heat transfer within a solid or between solid objects in thermal contact. Fluids—especially gases—are less conductive. Thermal contact conductance is the study of heat conduction between solid bodies in contact.[8] The process of heat transfer from one place to another place without the movement of particles is called conduction, such as when placing a hand on a cold glass of water heat is conducted from the warm skin to the cold glass, but if the hand is held a few inches from the glass, little conduction would occur	(Fedosov and Bakanov, 2020) (Mahardika and Haryani, 2020) (Chen and Akbarzadeh, 2020) (Ahmed et al., 2020) (Li and Cao, 2020) (Yan et al., 2020) (Mirkoohi et al., 2020) (Li et al., 2020)

		since air is a poor conductor of heat. Steady state conduction is an idealized model of conduction that happens when the temperature difference driving the conduction is constant, so that after a time, the spatial distribution of temperatures in the conducting object does not change (Fourier's law). In steady state conduction, the amount of heat entering a section is equal to amount of heat coming out, since the change in temperature is zero. An example of steady state conduction is the heat flow through walls of a warm house on a cold inside the house is maintained at a high temperature, and outside the temperature stays low, so the transfer of heat per unit time stays near a constant rate determined by the insulation in the wall, and the spatial distribution of temperature in the walls will be approximately constant over time.	
Convection	The transfer of energy between an object and its environment, due to fluid motion. The average temperature is a reference for evaluating properties related to convective heat transfer. $\mathrm{Ra} = \mathrm{Gr} \cdot \mathrm{Pr} = \frac{g\Delta\rho L^3}{\mu\alpha} = \frac{g\beta\Delta T L^3}{\nu\alpha}$	Convective heat transfer, or convection, is the transfer of heat from one place to another by the movement of fluids, a process that is essentially the transfer of heat via mass transfer. Bulk motion of fluid enhances heat transfer in many physical situations, such as (for example) between a solid surface and the fluid. Convection is usually the dominant form of heat transfer in liquids and gases. Although sometimes discussed as a third method of heat transfer, convection is usually used to describe the combined effects of heat conduction within the fluid and heat transference by bulk fluid flow streaming. The process of transport by fluid streaming is known as advection, but pure advection is a term that is generally associated only with mass transport in fluids, such as advection of pebbles in a river. In the case of heat transfer in fluids,	(Misyura, 2020) (Taghilou and Khavasi, 2020) (Taghavifar, 2020) (Misyura, 2020) (Rahim et al., 2020) (Haryoko et al., 2020)

		where transport by advection in a fluid is always also accompanied by transport via heat diffusion (also known as heat conduction) the process of heat convection is understood to refer to the sum of heat transport by advection and diffusion/conduction. Convective cooling is sometimes described as Newton's law of cooling: The rate of heat loss of a body is proportional to the temperature difference between the body and its surroundings.	
Radiation	The transfer of energy by the emission of electromagnetic radiation. For radiative transfer between two objects, the equation is as follows: $\phi_q = \epsilon\sigma F(T_a^4 - T_b^4)$,	Thermal radiation occurs through a vacuum or any transparent medium (solid or fluid or gas). It is the transfer of energy by means of photons in electromagnetic waves governed by the same laws. Thermal radiation is energy emitted by matter as electromagnetic waves, due to the pool of thermal energy in all matter with a temperature above absolute zero. Thermal radiation propagates without the presence of matter through the vacuum of space. Thermal radiation is a direct result of the random movements of atoms and molecules in matter. Since these atoms and molecules are composed of charged particles (protons and electrons), their movement results in the emission of electromagnetic radiation, which carries energy away from the surface. The Stefan-Boltzmann equation, which describes the rate of transfer of radiant energy, is as follows for an object in a vacuum :	(Mansuripur and Jakobsen, 2020) (Ganguly et al., 2020) (Churchill et al., 2020) (Binjola, 2020) (de Sousa and Grober, 2020) (Mirkoohi et al., 2020)
Passive Cooling	Reliance on natural conduction, convection and radiation, is suitable for lightly loaded enclosures that have relatively large surface areas and good ventilation.	1.The ambient air temperature must be lower than the enclosure temperature. 2.This method is not suitable for temperature-sensitive components in high ambient temperatures.	(La Roche et al., 2020) (Abo-Zahhad et al., 2020) (Zhao et al., 2020) (Song et al., 2020)

Forced Ventilation	The effectiveness of convection can be increased by the use of fans that increase the flow of air through the enclosure. Cool air is drawn into the bottom of the enclosure and hot air discharged at the top.	1.Fans should be fitted with filters to limit the ingress of dirt that could harm components. 2. To ensure the electrical components do not get too hot. 3. The ambient temperature must be well below the maximum desired enclosure temperature.	(Preet et al., 2020) (Barsim et al., 2020) (Gadeikytė and Barauskas, 2020) (Shimoda and Takahashi, 2020) (Mirkoohi et al., 2020)
Heat Pipe Techy	Heat pipes, first developed in the 1960s, are an almost energy-free method of enclosure cooling. A heat pipe consists of an evacuated copper tube partially filled with a fluid such as alcohol or water.	1.Due to the low pressure, the fluid at the bottom of the pipe boils when it absorbs heat from the air inside an enclosure. 2.The vapor rises to the top of the tube, where it is cooled by the air outside the enclosure and condenses. 3.The condensed fluid then returns to the bottom of the tube and the cycle repeats. 4.Thermal Edge's Air-To-Air Heat Exchangers use this novel technique to cool sealed electrical enclosures. 5.The energy needed is for small fans to circulate air around the hot and cold ends of the heat pipe.	(Brough et al., 2020) (Yan et al., 2020) (Elmas, 2020) (Wang et al., 2020) (Wang et al., 2020) (Sukarno et al., 2020)
Enclosure Air Conditioning	Air conditioning also utilizes evaporation, but in a slightly different way. A refrigerant liquid, under pressure, is passed through an expansion device. The drop in pressure causes the liquid to evaporate in the air conditioner's evaporator coil and absorb heat, cooling the air inside an enclosure.	1.The hot gas is then compressed and passed through a condenser coil, where the gas liquefies, giving up its heat to the air outside the enclosure. 2.An enclosure air conditioner represents an extremely effective method of cooling an enclosure and will work efficiently even if the ambient temperature is much higher than the enclosure's air temperature.	(Freedman, 2020) (Qin et al., 2020) (Xu et al., 2020) (Park and Chang, 2020) (Agnaou 2020) (Schmidt et al., 2020) (Mirkoohi et al., 2020)

Table.1.2. Applications of Heal transfer

Applications	**Description**	**Limitations**	**Authors and years**
Architecture	Efficient energy use is the goal to reduce the amount of energy required in heating or cooling. In architecture, condensation and air currents can cause cosmetic or structural damage. An energy audit can help to assess the implementation of recommended corrective procedures. For instance, insulation improvements, air sealing of structural leaks or the addition of energy-efficient windows and doors.	1. Smart meter is a device that records electric energy consumption in intervals. 2. Thermal transmittance is the rate of transfer of heat through a structure divided by the difference in temperature across the structure. It is expressed in watts per square meter per kelvin, or $W/(m^2K)$. 3. Well-insulated parts of a building have a low thermal transmittance, whereas poorly-insulated parts of a building have a high thermal transmittance. 4. Thermostat is a device to monitor and control temperature.	(Mirkoohi et al., 2020) (Freedman, 2020) (Qin et al., 2020) (Xu et al., 2020) (Park and Chang, 2020) (Agnaou 2020) (Schmidt et al., 2020)
Climate engineering	Climate engineering consists of carbon dioxide removal and solar radiation management.	Since the amount of carbon dioxide determines the radiative balance of Earth atmosphere, carbon dioxide removal techniques can be applied to reduce the radiative forcing. Solar radiation management is the attempt to absorb less solar radiation to offset the effects of greenhouse gases.	(Freedman, 2020) (Qin et al., 2020) (Xu et al., 2020) (Park and Chang, 2020) (Schmidt et al., 2020)
Greenhouse effect	The greenhouse effect is a process by which thermal radiation from a planetary surface is absorbed by atmospheric greenhouse gases, and is re-radiated in all directions.	Since part of this re-radiation is back towards the surface and the lower atmosphere, it results in an elevation of the average surface temperature above what it would be in the absence of the gases.	(Freedman, 2020) (Qin et al., 2020) (Xu et al., 2020) (Park and Chang, 2020) (Agnaou 2020) (Schmidt et al., 2020)