HEAT TRANSFER ASSIGNMENT

DADABHOY INSTITUTE OF HIGHER EDUCATION

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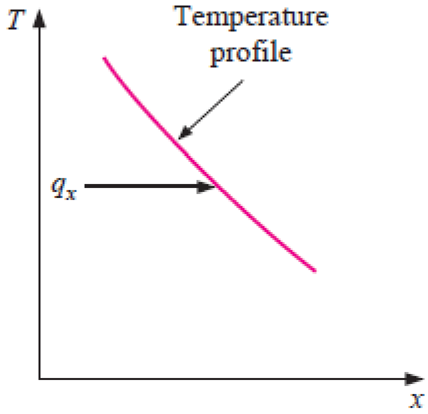
Q1: Explain the sketch shown below:

Figure 1-1 | Sketch showing direction of heat flow.



When a temperature gradient exist in a body, experience has shown that there is an energy transfer from the high temperature region to the low- temperature region. We say that the energy is transferred by conduction and that the heat transfer rates per unit area is proportional to the normal temperature gradient: $qx\ A \sim \partial T\ \partial x$ When the proportionality constant is inserted: $qx=-kA\ \partial T\ \partial x$ Where qx is the heat-transfer rate and $\partial T/\partial x$ is the temperature gradient in the direction of the heat flow. The positive constant k is called the thermal conductivity of the material, and the minus sign is inserted so that the second principle of thermodynamics will be satisfied; i.e heat must flow downhill on the temperature scale, as indicated in the coordinate system is called Fourier's law of heat conduction after the French mathematical physicist Joseph Fourier, who made very significant contributions to the analytical treatment of conduction heat transfer. Energy conducted in left face + heat generated within element = change in internal energy + energy conducted out right face These energy quantities are given as follows: Energy in left face $= qx = -kA\ \partial T\ \partial x$ Energy generated within element $= \dot{q}A\ dx$.

Q2: What do you understand by the term Thermal Conductivity?

Thermal conductivity (often denoted by k, λ, or κ) refers to the intrinsic ability of a material to transfer or conduct heat. It is one of the three methods of heat transfer, the other two being convection and radiation. Heat transfer processes can be quantified in terms of appropriate rate equations. The rate equation in this heat transfer mode is based on Fourier's law of heat conduction.

It is also defined as the amount of heat per unit time per unit area that can be conducted through a plate of unit thickness of a given material, the faces of the plate differing by one unit of temperature.

Thermal conductivity occurs through molecular agitation and contact, and does not result in the bulk movement of the solid itself. Heat moves along a temperature gradient, from an area of high temperature and high molecular energy to an area with a lower temperature and lower molecular energy. This transfer will continue until thermal equilibrium is reached. The rate at which heat is transferred is dependent upon the magnitude of the temperature gradient, and the specific thermal characteristics of the material.

Thermal conductivity is quantified using the International Systems of Unit (SI unit) of W/m•K (Watts per meter per degree Kelvin), and is the reciprocal of thermal resistivity, which measures an objects ability to resist heat transfer. Thermal conductivity equation can be calculated using the following:

k = Q \ast{L / A} (T2-T1)$k=Q\ast L/A(T2-T1)$
Where:
QQ = heat flow (WW)
LL = length or thickness of the material (mm)
AA = surface area of material (m^{2}$m2$)
T2{-}T1$T2-T1$ = temperature gradient (KK)

THERMAL CONDUCTIVITY VARIATION:

The thermal conductivity of a specific material is highly dependent on a number of factors. These include the temperature gradient, the properties of the material, and the path length that the heat follows.

The thermal conductivity of the materials around us varies substantially, from those with low conductivities such as air with a value of 0.024 W/m•K at 0°C to highly conductive metals like copper (385 W/m•K).

The thermal conductivity of materials determines how we use them, for example, those with low thermal conductivities are excellent at insulating our homes and businesses, while high thermal conductivity materials are ideal for applications where heat needs to be moved quickly and efficiently from one area to another, as in cooking utensils and cooling systems in electronic devices. By selecting materials with the thermal conductivity appropriate for the application, we can achieve the best performance possible.

THERMAL CONDUCTIVITY AND TEMPERATURE

Due to the fact that molecular movement is the basis of thermal conductance, the temperature of a material has a large influence on the thermal conductivity. Molecules will move more quickly at higher temperatures, and therefore heat will be transferred through the material at a higher rate. This means that the thermal conductivity of the same sample has the potential to change drastically as the temperature increases or decreases.

The ability to understand the effect that temperature has on thermal conduction is critical to ensuring that products behave as expected when subjected to thermal stress. This is especially important when working with products that generate heat, such as electronics, and developing fire and heat protection materials.

THERMAL CONDUCTIVITY AND STRUCTURE

Thermal conductivity values vary substantially between material and are highly dependent on the structure of each specific material. Some materials will have different thermal conductivity values depending on the direction of heat travel; these are anisotropic materials. In these cases, heat moves more easily in a certain direction due to how the structure is arranged.

When discussing thermal conductivity trends, materials can be divided into three categories; gases, non metallic solids, and metallic solids. The differing abilities of these three categories in terms of heat transfer can be attributed to the differences in their structures and molecular movements.

Gases have lower relative thermal conductivities, as their molecules are not as tightly packed as those in solids, and therefore heat transfer is highly dependent on the free movement of molecules and molecular velocity.

Gases are poor thermal transmitters. In contrast, the molecules in nonmetallic solids are bound into a lattice network, and therefore thermal conductivity primarily occurs through vibrations in these lattices. The close proximity of these molecules in comparison to those of gases means that non metallic solids have the higher thermal conductivities of the two, however within this group there is large variation.

This variation is partially attributable to the amount of air present within the solid, materials with a large number of air pockets are excellent insulators, while those that are more closely packed will have a higher thermal conductivity value.

Thermal conductivity in metallic solids differs yet again from the previous examples. Metals have the highest thermal conductivities of any materials barring graphene, and have the unique combination of possessing both thermal and electrical conductivity. Both of these attributes are transferred by the same molecules, and the relationship between the two is explained by the Wiedemann-Franz Law. This law attests that at a certain temperature electrical conductivity will be proportional to thermal conductivity, however as the temperature increases, the thermal conductivity of the material will grow while the electrical conductivity will shrink.

THERMAL CONDUCTIVITY TESTING AND MEASUREMENT

Thermal conductivity is a crucial component of the relationship between materials, and the ability to understand it enables us to achieve the best performance out of the materials that we use in all aspects of our lives. Effective thermal conductivity testing and measurement are critical to this endeavor. Thermal conductivity testing methods can be classified as either steady state or transient. This delineation is a defining characteristic of how each method works. Steady state methods require that the sample and reference pieces be at thermal equilibrium prior to measurements beginning. Transient methods do not require this rule be fulfilled, and therefore provide results more quickly.

Q3: Write the values for thermal conductivity of the following metals:

Silver, Copper, Aluminum, Nickel, Iron, Carbon Steel, Lead

Thermal Conductivity

Material	Thermal conductivity (cal/sec)/(cm^2 C/cm)	Thermal conductivity (W/m K)*
Silver	1.01	406.0
Copper	0.99	385.0
Aluminum	0.50	205.0
Iron	0.163	79.5
Steel	...	50.2
Lead	0.083	34.7