BASICS OF HMT-1

This subject is always fun to teach/study in winters 😛

#1

What is heat?

Heat is a form of thermal energy which is defined ONLY when it moves from one place to other. Otherwise, the thermal energy at rest is known as internal energy (as we know from our knowledge of Thermodynamics).

And why does it move and get transferred from one place to another? What causes this flow?
It is the temperature difference.
It is just like other gradient which induce some flow. Difference of electric potential causes electric current. Difference of elevation causes rivers to flow. In a similar way, difference of temperature causes heat to flow.

#2

How is heat transfer different from Thermodynamics? Why a different subject altogether on this? Why it cannot be studied with Thermodynamics?

Thermodynamics deals with the amount of heat transfer as a system undergoes a process from one equilibrium state to another. We are not really concerned about the rate at which that energy is transferred, whereas heat transfer deals not only with the amount but also with the rate at energy is being transferred.

This makes the analysis completely different as we will witness in this subject.

Thermodynamics --------- Qty of heat
HMT ------------------------- Rate of HEAT
TRANSFER & Net Amount

#3

There are various modes of transport available to us. Some are slow, some are fast. Some are available most of the time, some are less frequent. Some are affordable to everyone with no constraint, some are affordable just to particular people. In a similar way, there are various modes through which heat can flow. As we will get to know each of these modes, we will see why I used the above reference of mode of transport.

There are three modes of heat transfer
1. Conduction
2. Convection
3. Radiation

Though all these modes are different, there are two things which are common to all
1. They all require a temperature difference for heat to flow.
2. Heat flow in each of them is from higher temperature to a lower temperature.

4

Interview question:

Heat always from higher to lower temperature then how does refrigerator not follow this rule (if it doesn't) ?

Ans.: The heat flows from higher to lower temp in refrigerator too.. Refrigerant is lower in temperature than refrigerator cabin..

Refrigerator follows this rule as in condendor and evaporator heat flows from high to low temp.

#5

I will discuss each of the method upto a certain extent and explain some basics of each. It greatly helps to avoid any confusion when I will handle them separately.

#6

CONDUCTION-

Every matter is made up of different small constituents known as atoms, molecules, some free electrons, etc.
In conduction, the energy is transferred from more energetic particles of a substance to the adjacent less energetic ones.

Some important point to note:
1. Since it requires a medium (constituent particles), conduction is not possible in vacuum.
2. In liquids and gases, conduction is due to collisions and diffusion of molecules during their random motion.

#7

How to the heat gets conducted in solids?

In solids, it is due to the contribution of these two factors:

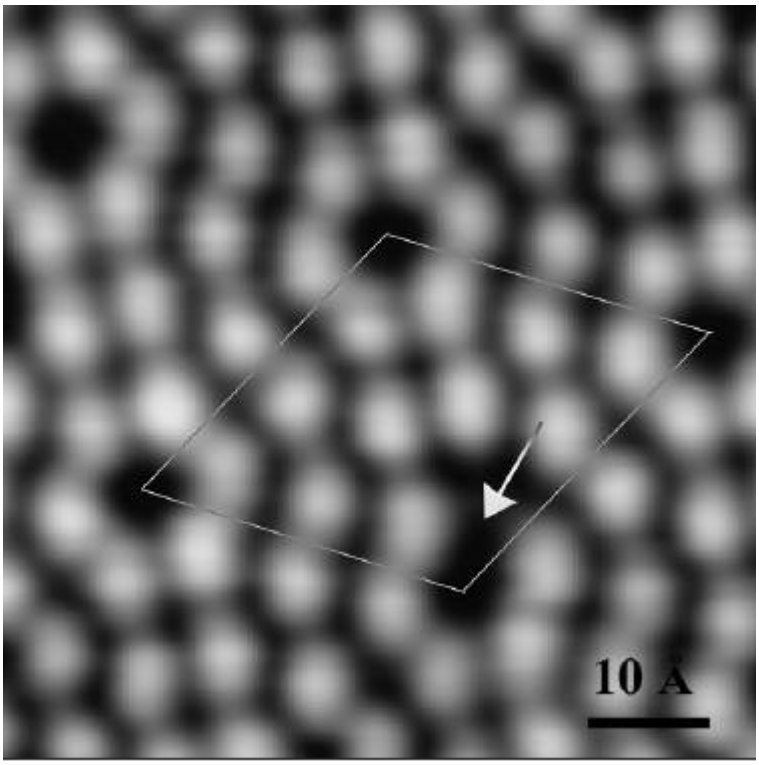
1. Vibrations of the molecule in their lattice (is everyone aware of what is lattice? Those who don't comment below)

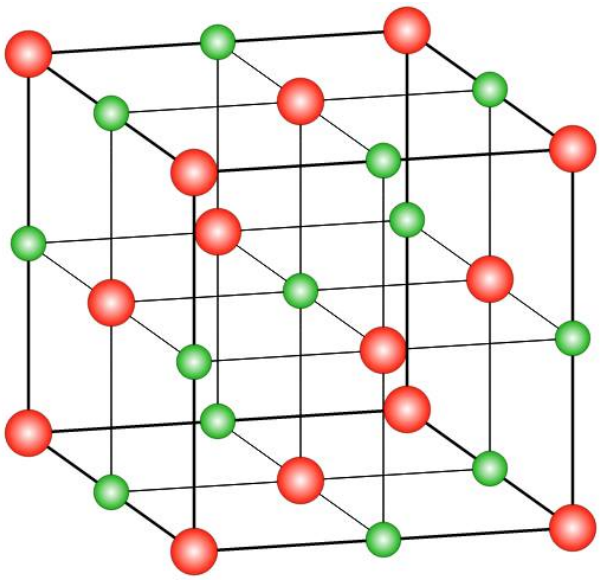
2. Energy transport by free electrons (electrons which are not bound to any atom)

The net effect depends upon the combined effect of these two.

lattice vibrations.

The atoms in crystalline solids are arranged in a definite pattern and sequence. That arrangement is known as crystal lattice.
It looks like this





When one of these atoms vibrate, it transfers its vibration to adjacent atoms and this chain spreads the energy.

Free electrons conduction:

The energetic free electrons (electrons which are not bound to any atom), will get heated up on the heated side of a body. They will diffuse towards the side which is low in energy (cooler side), collide with the electrons there and increase their energy. In this manner, the heat is propagated.

#8

There is one important thing to keep in mind while defining conduction. As I said that it involves transfer by diffusion as well then remember that this is the diffusion of atoms happening at atomic level, there is no BULK motion in the medium, medium is at rest. Atoms are not!

Conduction = diffusion + collision

#9

As I told how conduction occurs in solids, so those solids which have abundant free electrons will conduct heat better. The energetic free electrons (electrons which are not bound to any atom), will get heated up on the heated side of a body. They will diffuse towards the side which is low in energy (cooler side), collide with the electrons there and increase their energy. In this manner, the heat is propagated.

Hence, as a thumb of rule, good electricity conductor solids are good heat conductors too (both require free electrons).

Free electrons are generally those which are at a farther distance from nucleus such that nucleus does not have a control on its movement. They move freely forming positive ions

Metals are generally lattice inside a pool of free electrons roaming around

#10

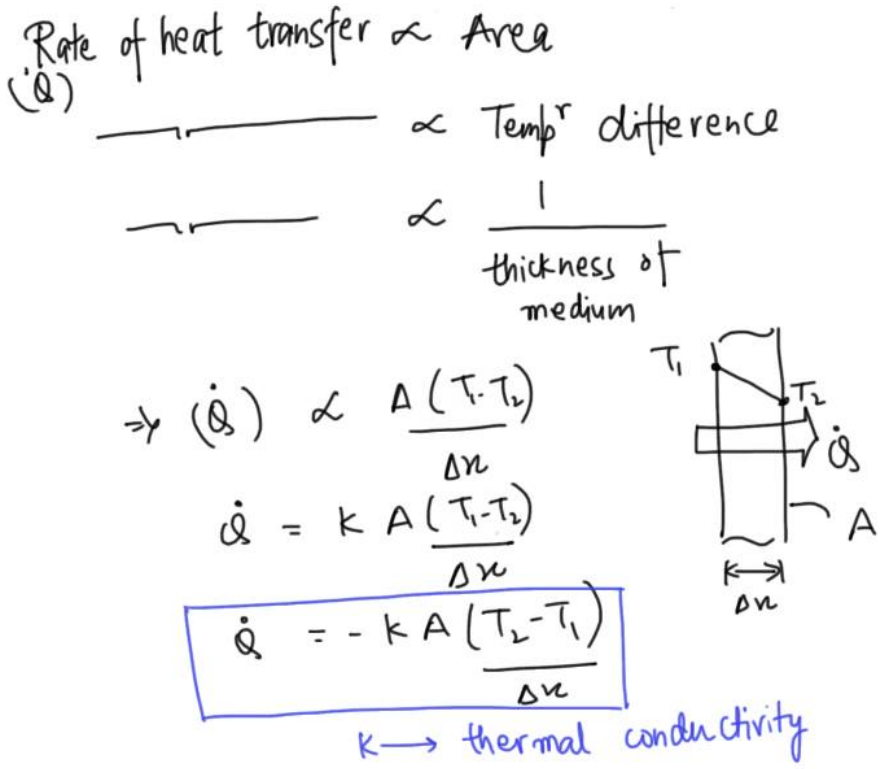
However, the above theory of free electrons in #9 is not always true. Diamond is a HIGHLY good conductor. One of the best natural conductor so far, yet it has no free electrons! Then how come is it such a good conductor? Any views?

The lattice of Diamond is very perfect with minimum imperfections. Hence it has a unique property of high heat conductivity but less electrical conductivity.

Diamonds has perfect diamond cubic lattice structure and no free electrons making it great electrical insulator but still good heat conductor.

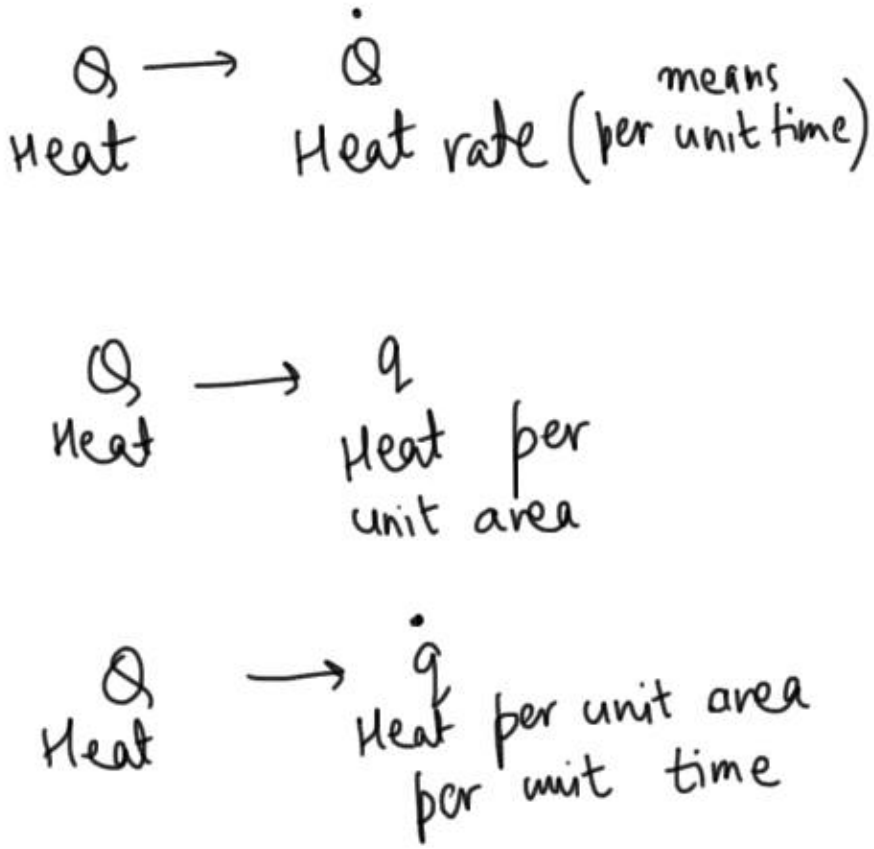
#11

The rule which conduction follows is Fourier's law of conduction. There are a LOT of things and concepts related to this which we will study in conduction. It is just an overview:



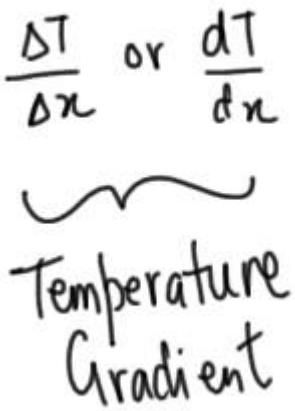
#12

A note regarding notations to follow.
Note the use of small letters and a dot.



#13

Temperature gradient :
slope of the temperature curve of T-x diagram



This is it for today. Next class tomorrow .

HAVE A NICE DAY.....