بسم الله الرحمن الرحیم

Thermal conductivity

Heat Transfer Methods:

- Conduction,
- Convection
- Radiation

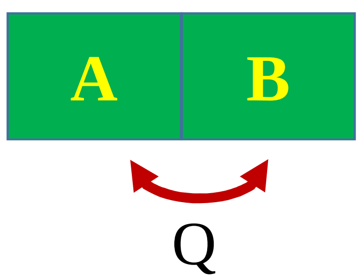
Heat Transfer

Heat always moves from a warmer place to a cooler place.

Hot objects in a cooler room will cool to room temperature.

Cold objects in a warmer room will heat up to room temperature.

$$T_A \neq T_B$$



$$T_A = T_B$$

Heat equilibrium

Conduction

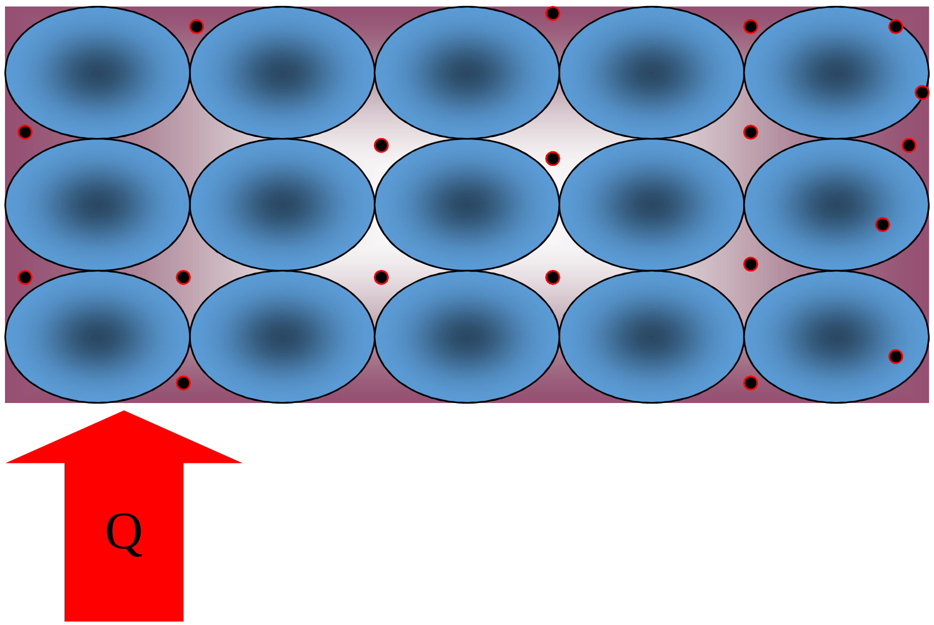
When you heat a metal strip at one end, the heat travels to the other end.

As you heat the metal, the particles vibrate, these vibrations make the adjacent particles vibrate, and so on and so on, the vibrations are passed along the metal and so is the heat. We call this?

Metals are different

The outer electrons of metal atoms drift, and are free to move.

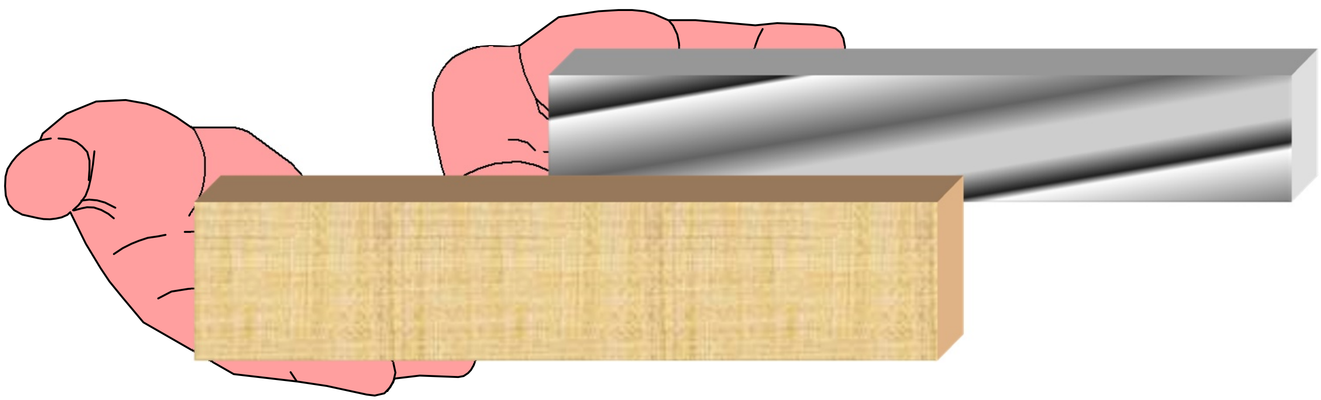
When the metal is heated, this 'sea of electrons' gain kinetic energy and transfer it throughout the metal



Insulators, such as wood and plastic, do not have this 'sea of electrons' which is why they do not conduct heat as well as metals.

Why does metal feel colder than wood, if they are both at the same temperature?

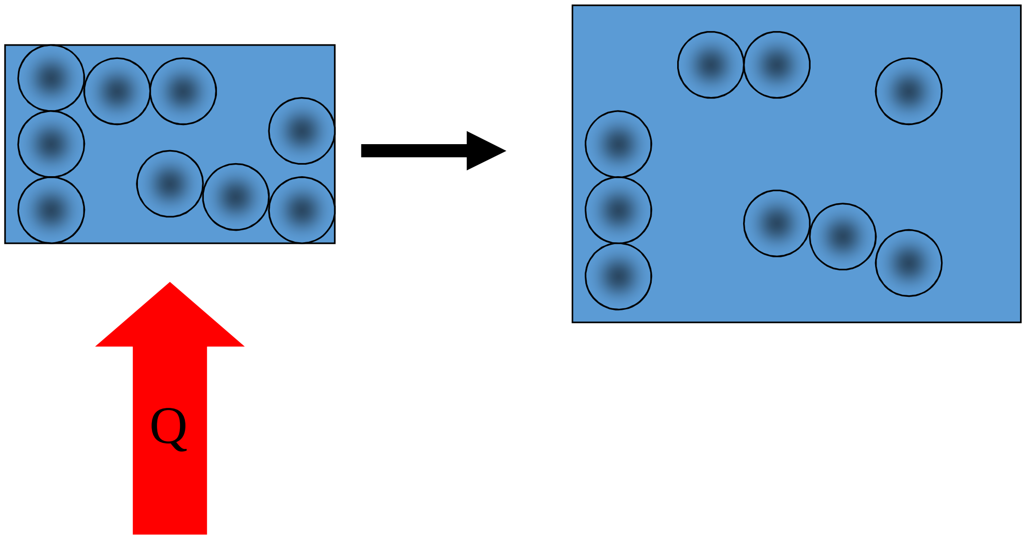
Metal is a conductor, wood is an insulator. Metal conducts the heat away from your hands. Wood does not conduct the heat away from your hands as well as the metal, so the wood feels warmer than the metal.



Convection

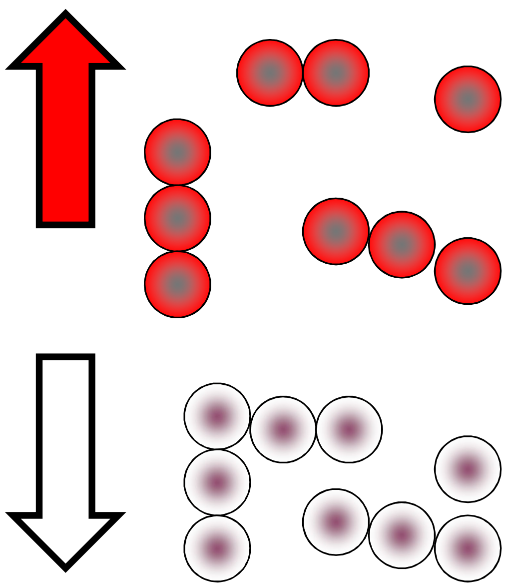
What happens to the particles in a liquid or a gas when you heat them?

The particles spread out and become less dense.



Fluid movement

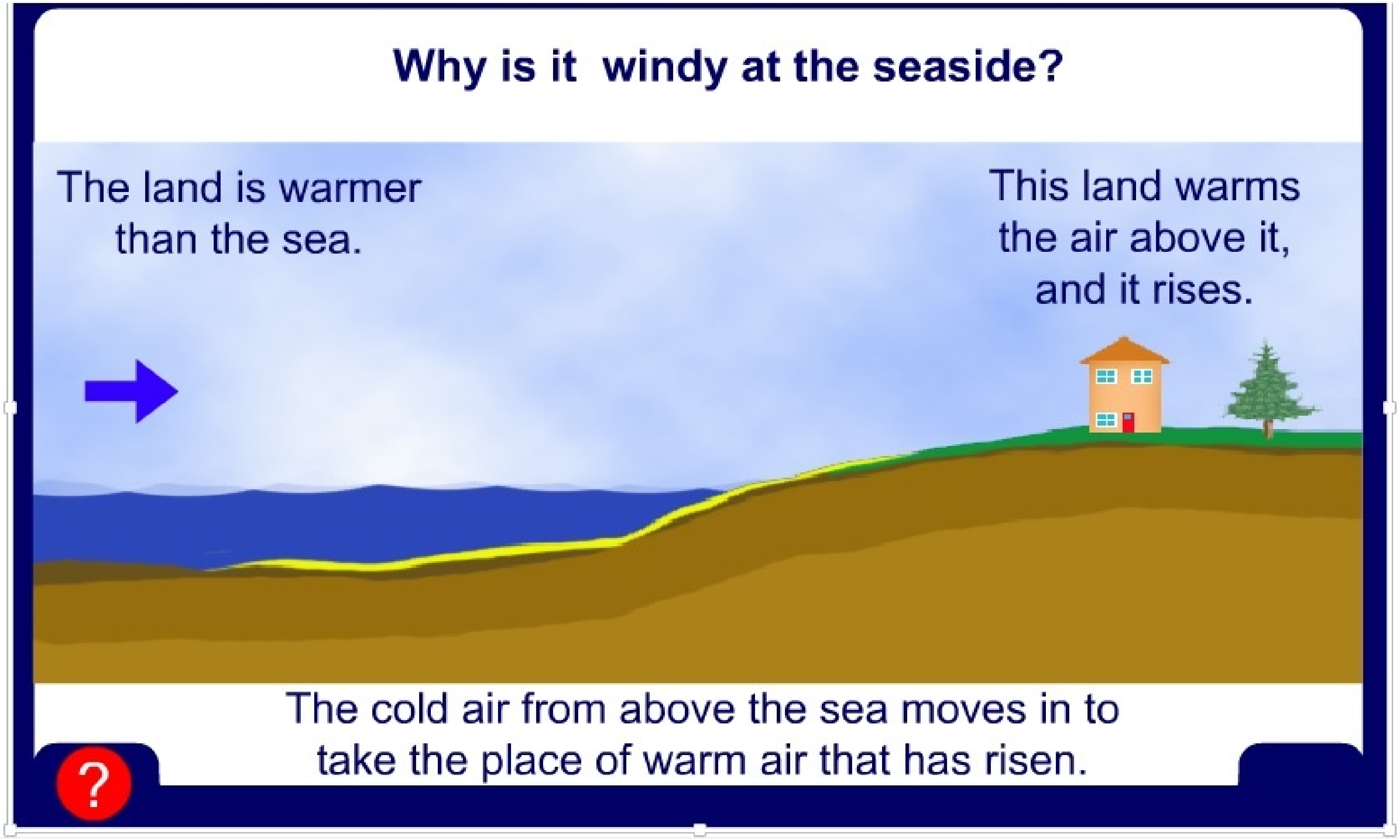
Cooler, more dense, fluids sink through warmer, less dense fluids.



In effect, warmer liquids and gases rise up.

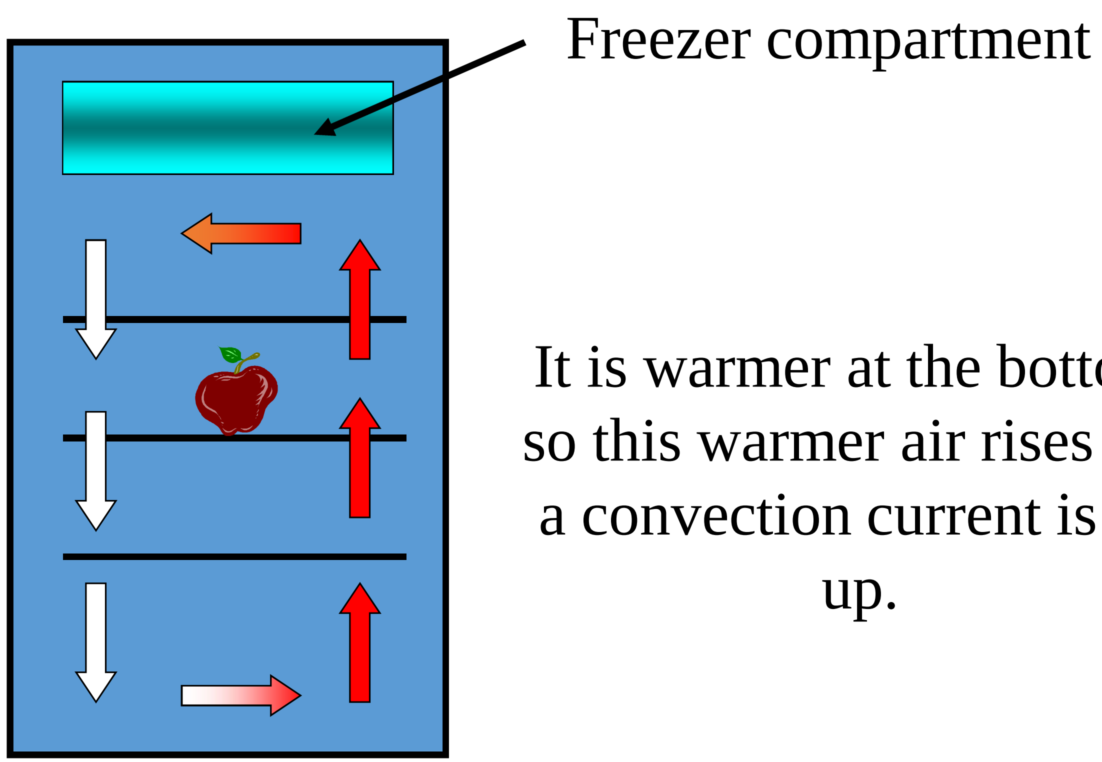
Cooler liquids and gases sink

Why is it windy at the seaside?



Cold air sinks

Where is the freezer compartment put in a fridge?

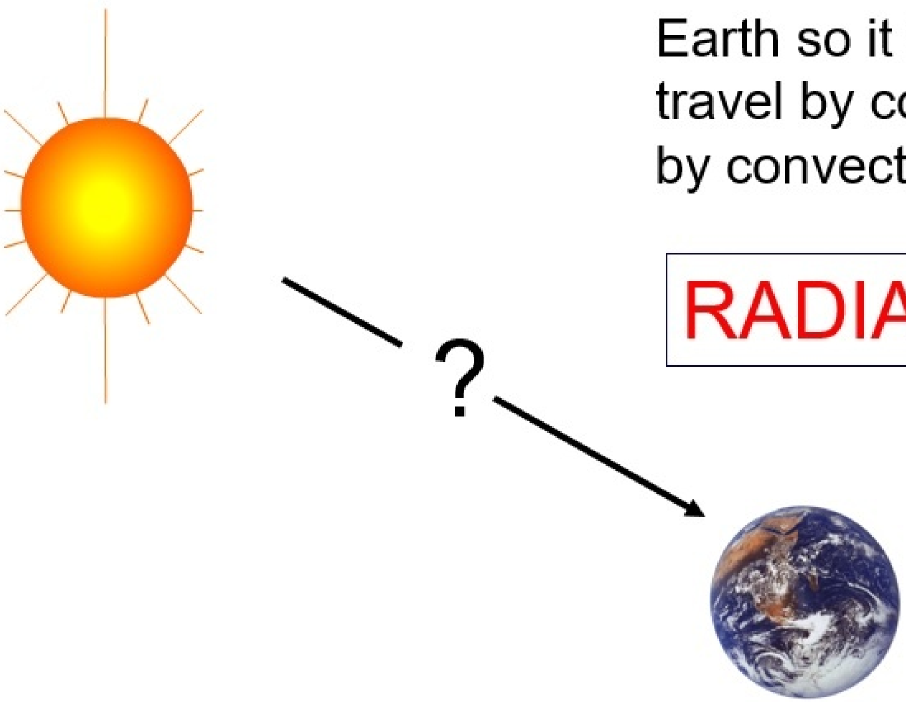


It is put at the top, because cool air sinks, so it cools the food on the way down.

It is warmer at the bottom, so this warmer air rises and a convection current is set up.

The third method of heat transfer

How does heat energy get from the Sun to the Earth?



Earth so it CANNOT travel by conduction or by convection.

RADIATION

Radiation

Radiation travels in straight lines

True/~~False~~

Radiation can travel through a vacuum

True/~~False~~

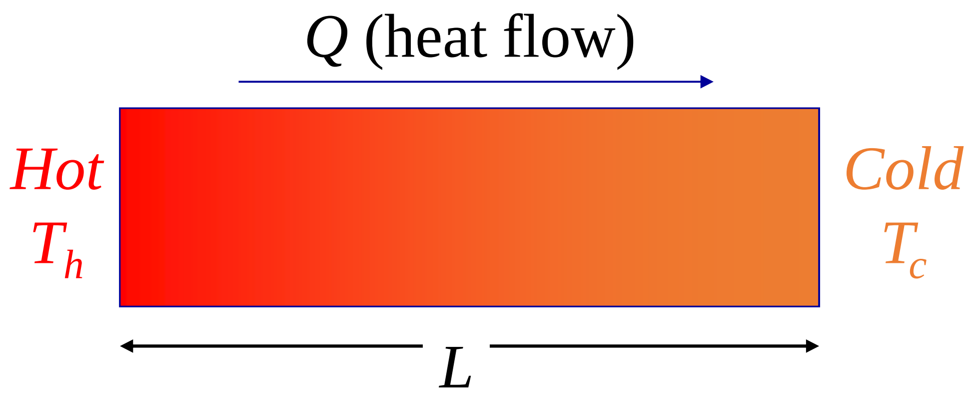
Radiation requires particles to travel

~~True~~/False

Radiation travels at the speed of light

True/~~False~~

Fourier's Law for Heat Conduction

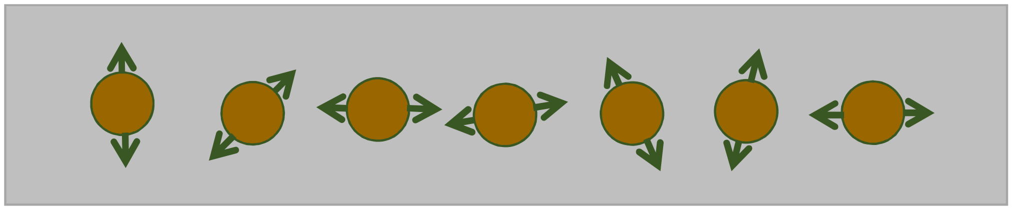


$$Q = kA\frac{T_h - T_c}{L} = kA\frac{dT}{dx}$$

Thermal conductivity

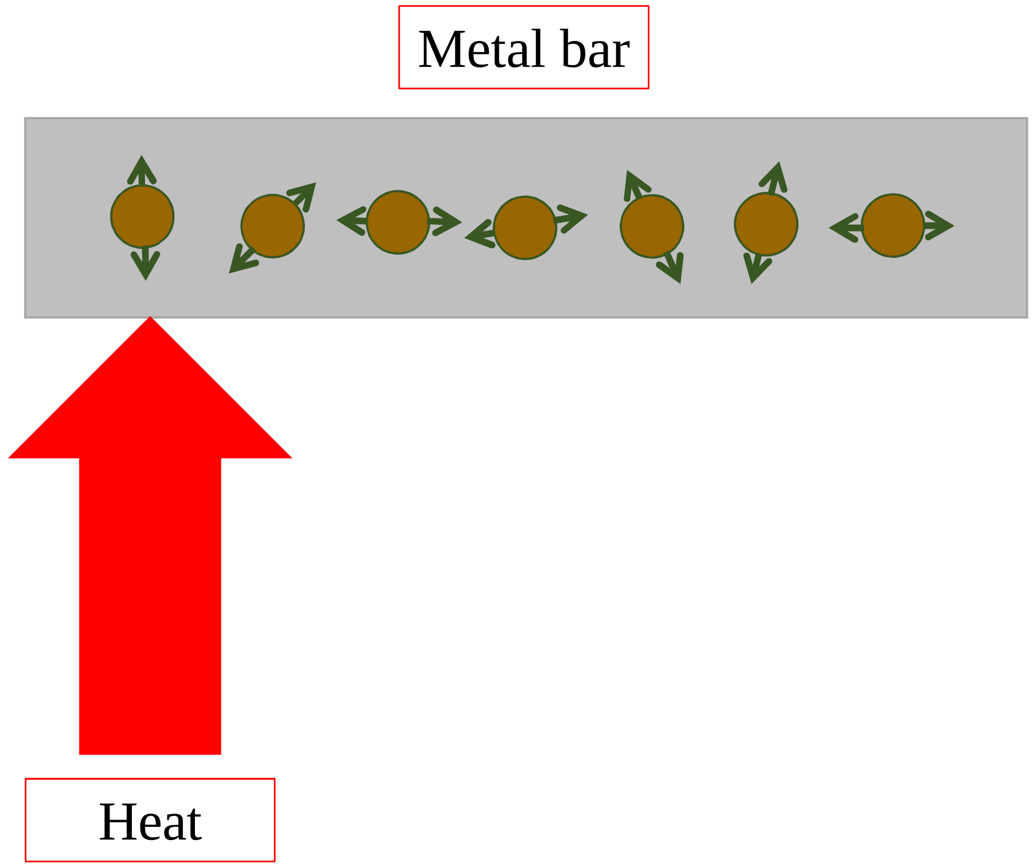
Thermal conduction

Metal bar

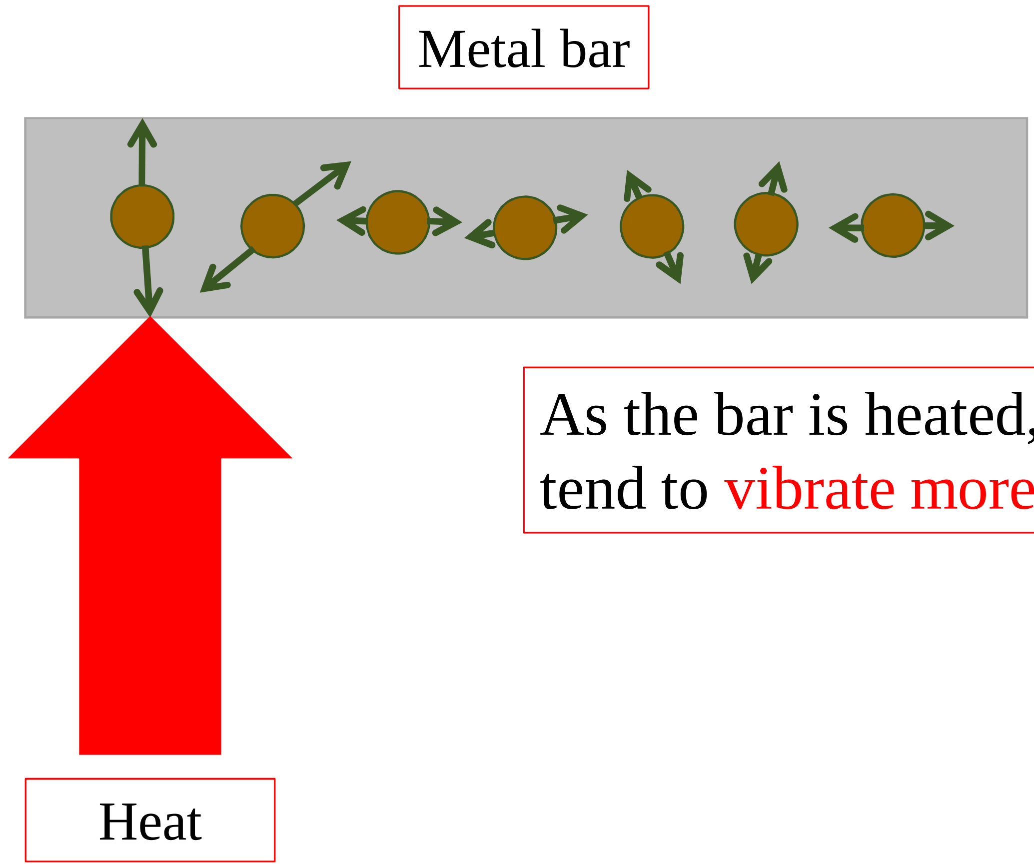


According to kinetic theory, all materials are made up of tiny, moving particles. In a solid these particles tend to vibrate around a fixed spot.

Thermal conduction

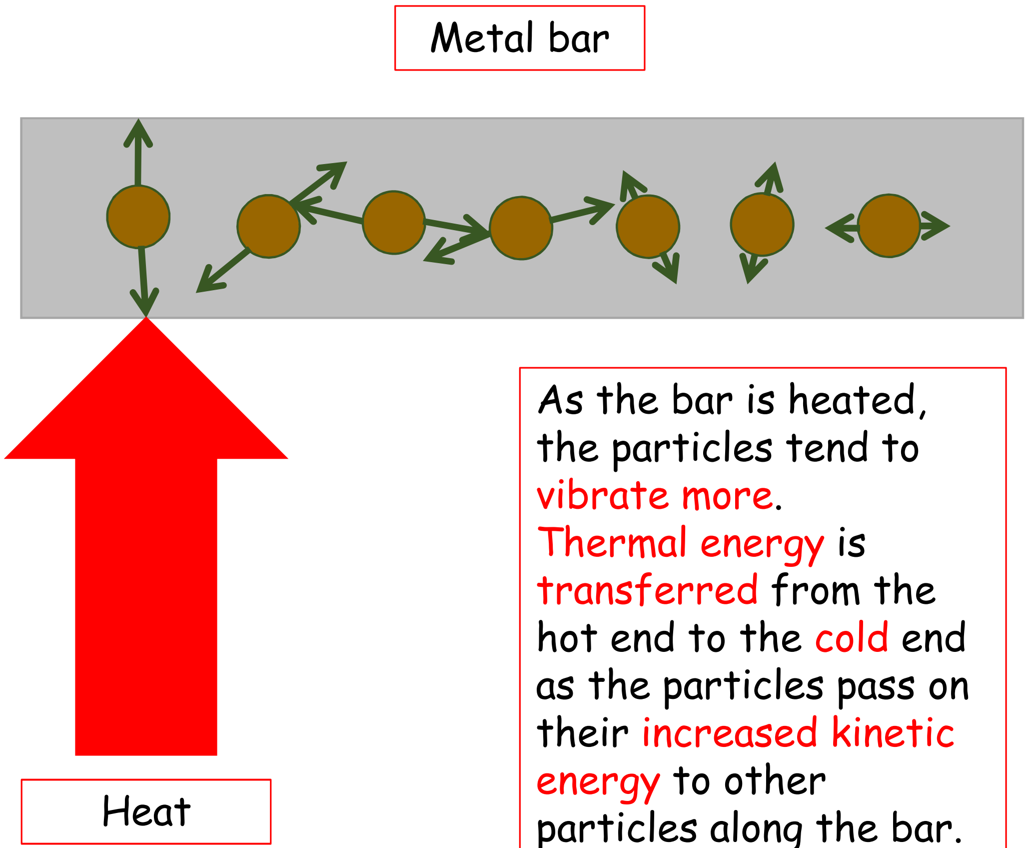


Thermal conduction



As the bar is heated, the particles tend to vibrate more.

Thermal conduction

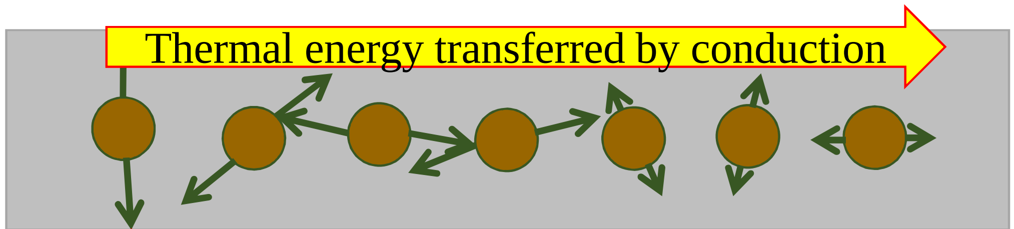


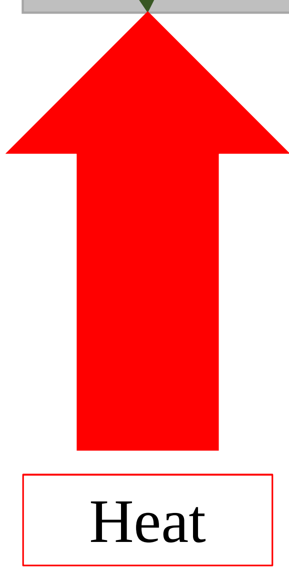
As the bar is heated, the particles tend to vibrate more.
Thermal energy is transferred from the hot end to the cold end as the particles pass on their increased kinetic energy to other particles along the bar.

Thermal conduction

Thermal energy transfer is increased if:

1. **<u>Temperature difference</u>** across ends of bar is **<u>increased</u>**.

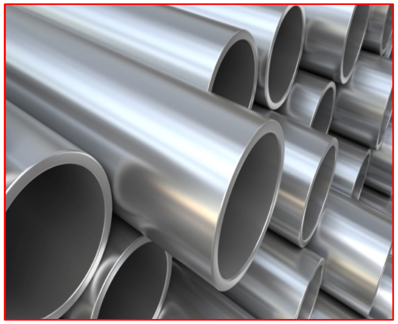




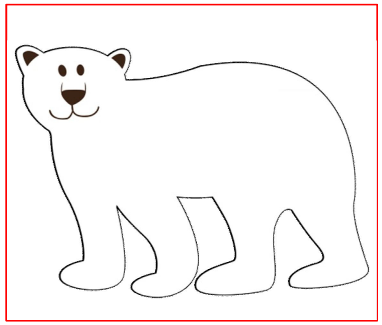
As the bar is heated, the particles tend to vibrate more. Thermal energy is transferred from the hot end to the cold end as the particles pass on their increased kinetic energy to other particles along the bar.

Thermal conduction

Conductors and insulators

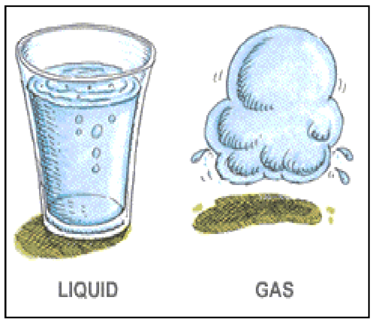


Metals are the best thermal conductors. They feel cold to the touch as heat is quickly conducted away from your hand.



Poor conductors are called insulators.

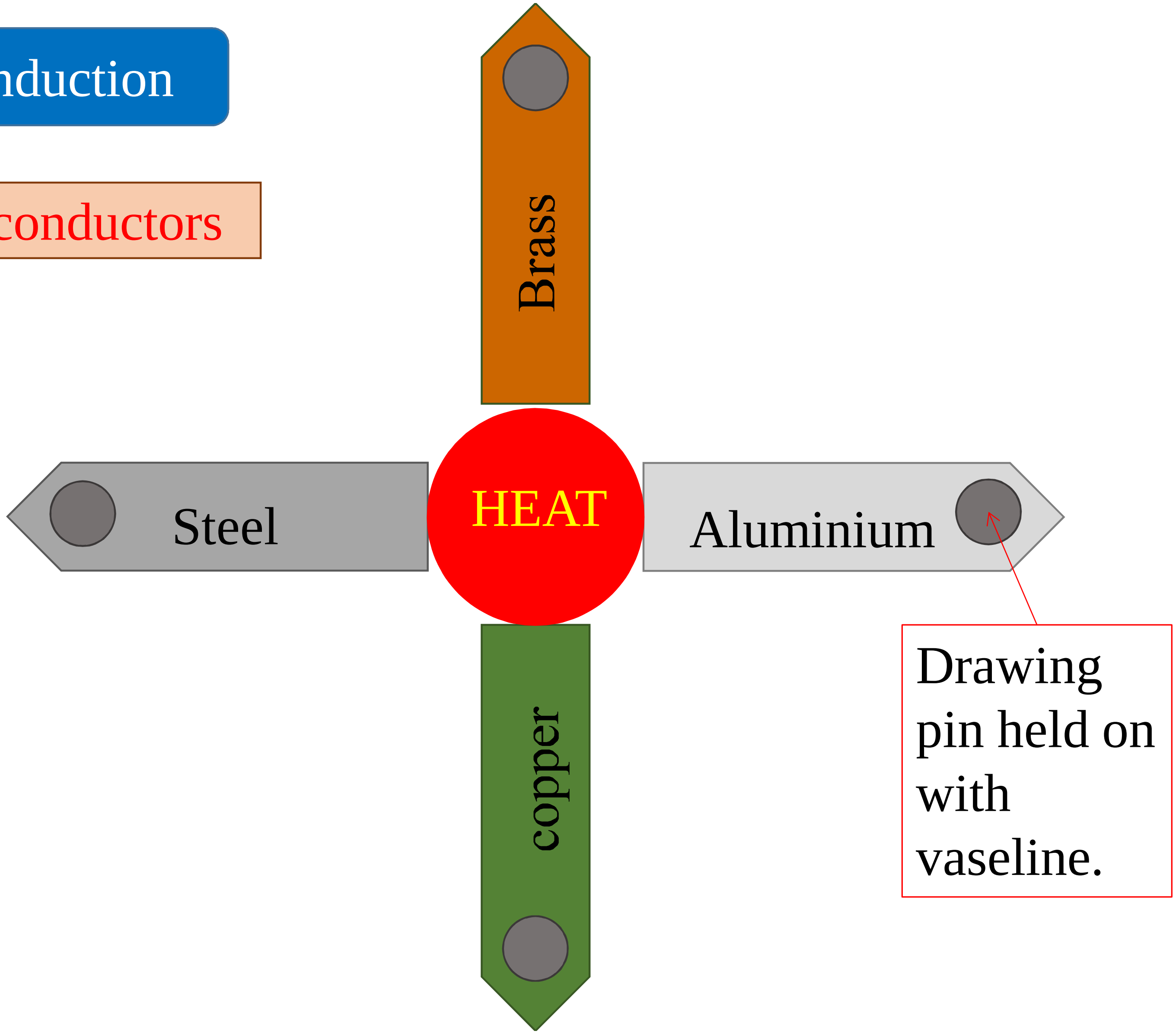
Non-metals tend to be poor conductors. A polystyrene tile feels warm to the touch because it stops your hand from losing thermal energy.



Liquids are poor conductors, and gases are the worst of all. Many insulators have tiny pockets of trapped air.

Thermal conduction

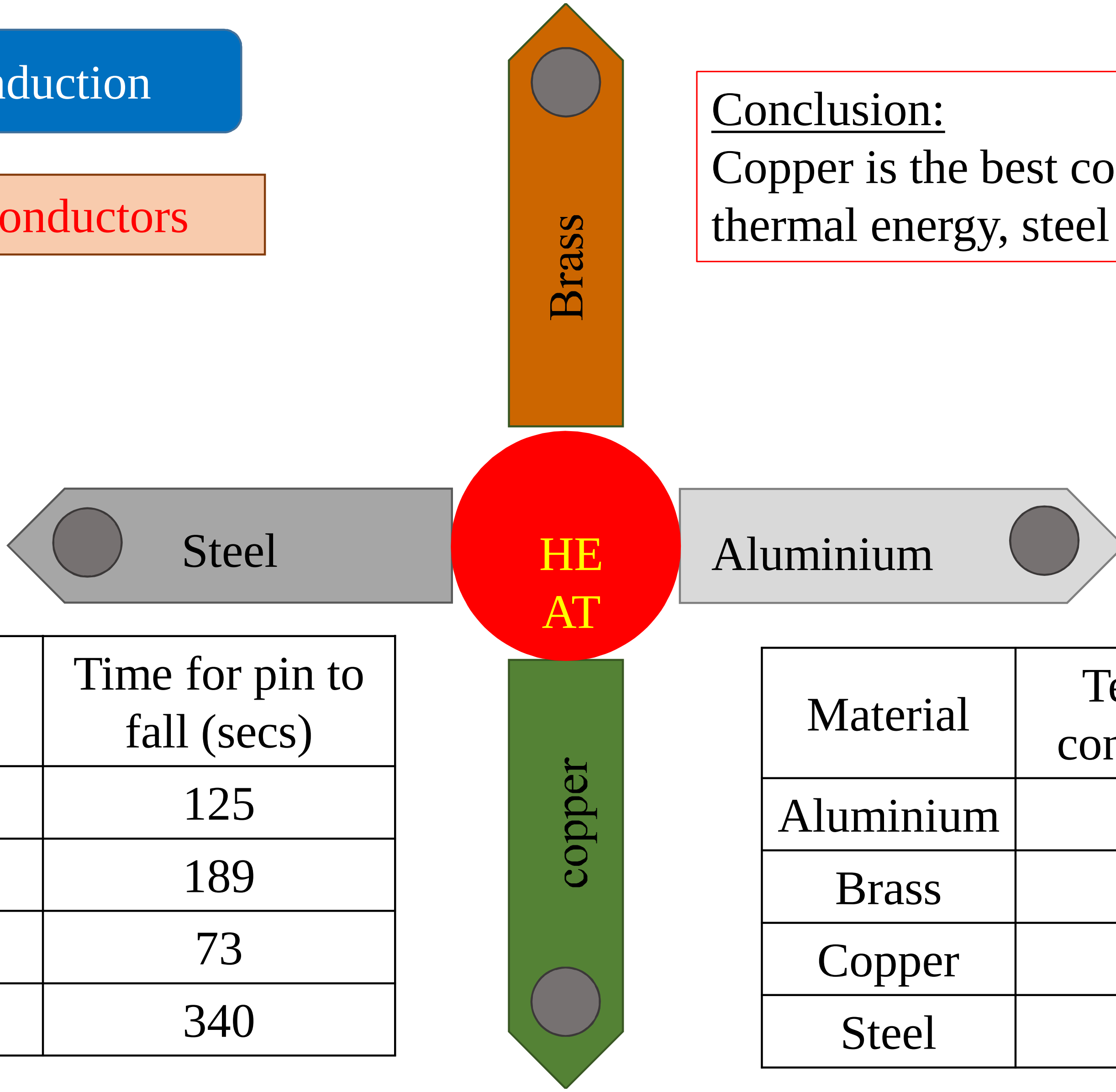
Comparing conductors



Thermal conduction

Comparing conductors

<u>Conclusion:</u>
Copper is the best conductor of thermal energy, steel is the worst.



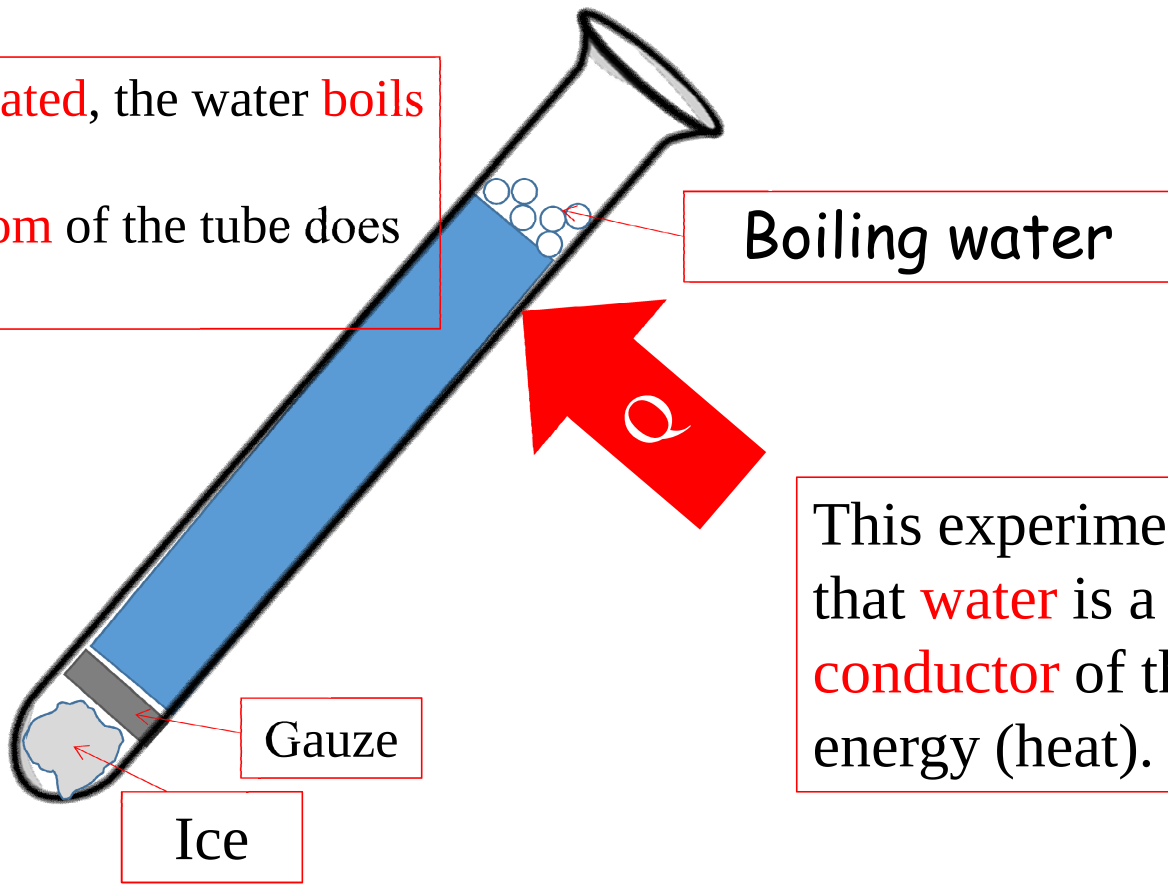
Material	Time for pin to fall (secs)
Aluminium	125
Brass	189
Copper	73
Steel	340

Material	Textbook relative conductivity values.
Aluminium	204
Brass	109
Copper	385
Steel	16

Thermal conduction

Conductivity of water

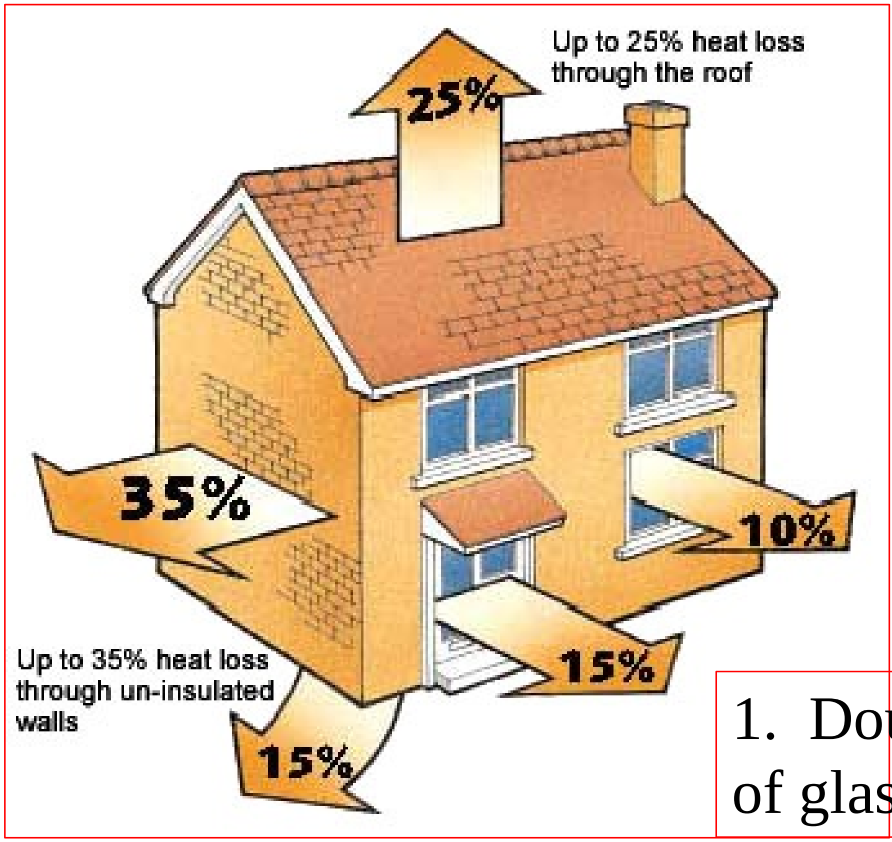
As the top of the tube is heated, the water boils and turns into steam.
The ice trapped at the bottom of the tube does not melt.

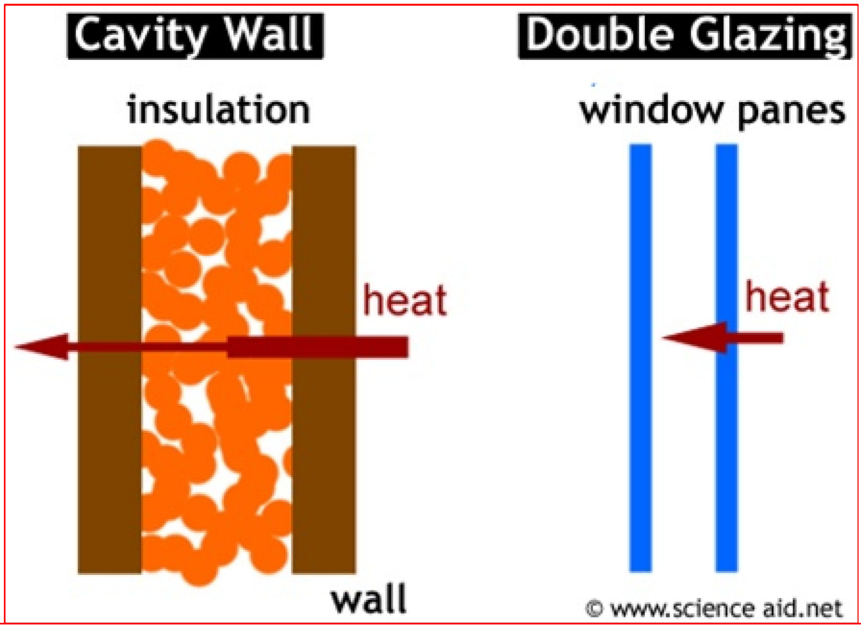


This experiment shows that water is a poor conductor of thermal energy (heat).

Thermal conduction

Using insulating materials



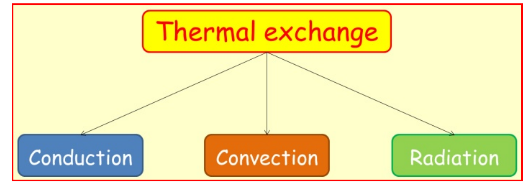


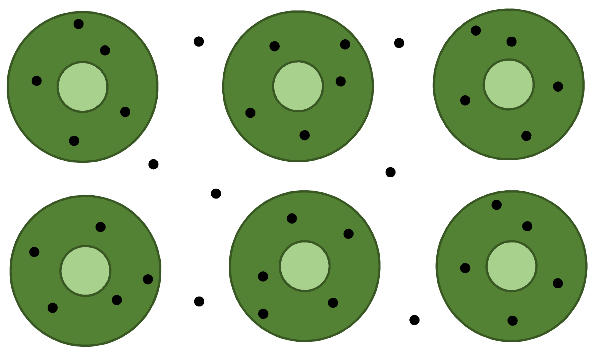
2. Wall cavity filled with plastic foam, beads, or mineral wool.

1. Double-glazed windows; two sheets of glass with air between them.

Thermal conduction

Explaining conduction





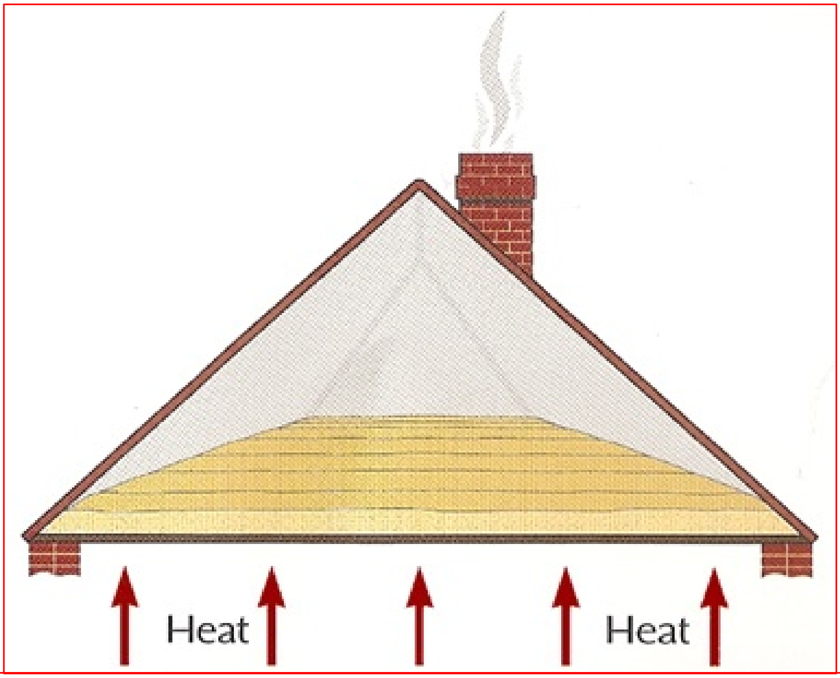
In a metal, there are many tiny electrons fixed inside the atoms. Some, however, are 'loose' and free to drift between the atoms. If the metal is heated then the free electrons begin to move more quickly (they have more kinetic energy).

These free electrons are moving randomly within the metal. They may collide with the atoms and make them vibrate more quickly. This means that the thermal energy is transferred rapidly to all parts, making metals good thermal conductors.

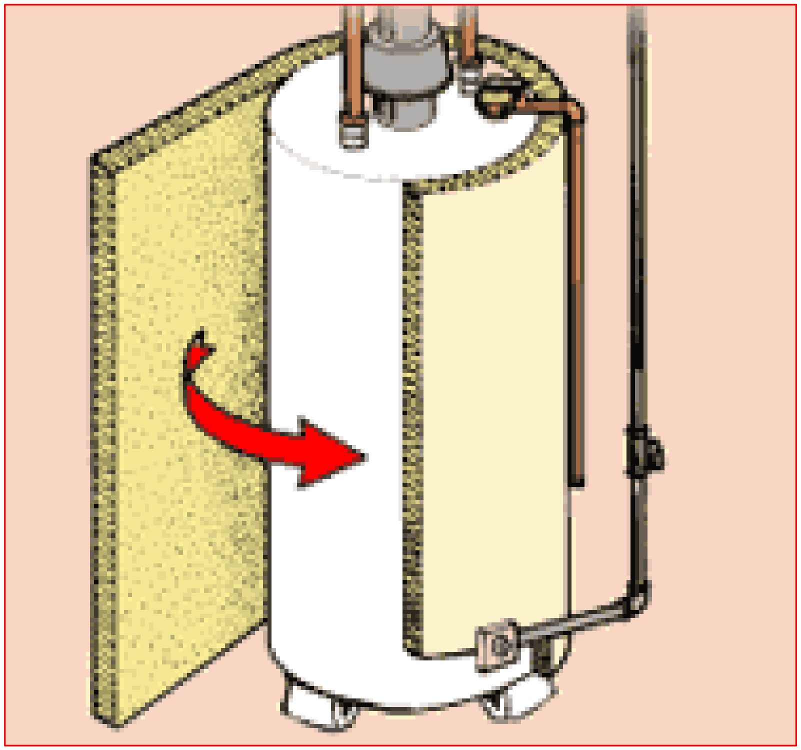
Any material that conducts will have particles vibrating and pushing on neighbouring particles. But in metals, this energy transfer through the movement of free electrons means that they conduct energy much more quickly.

Thermal conduction

Using insulating materials



3. Loft insulation – glass or mineral wool, with air trapped between the fibres.



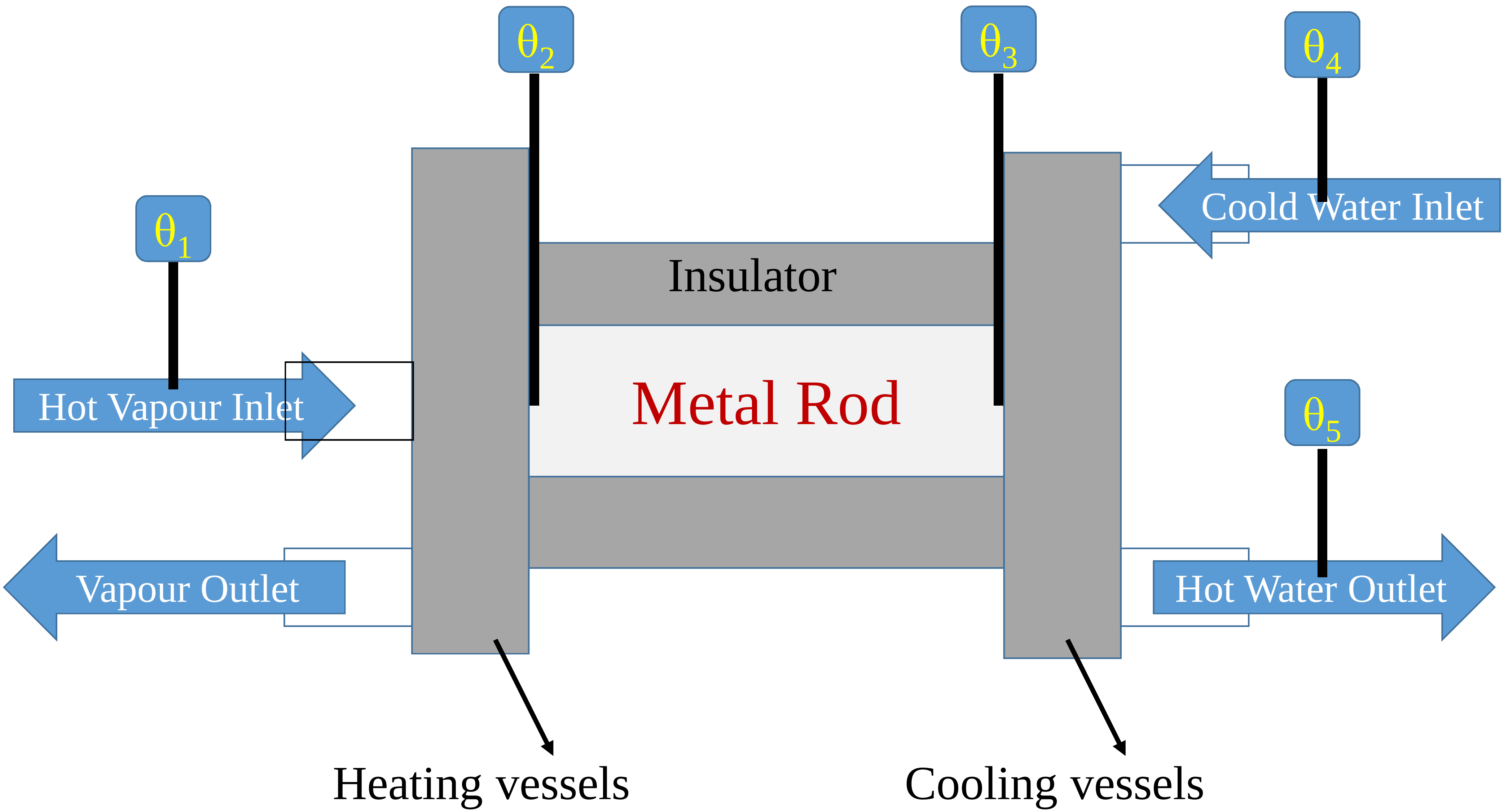
4. Plastic foam lagging around the hot water storage tank.

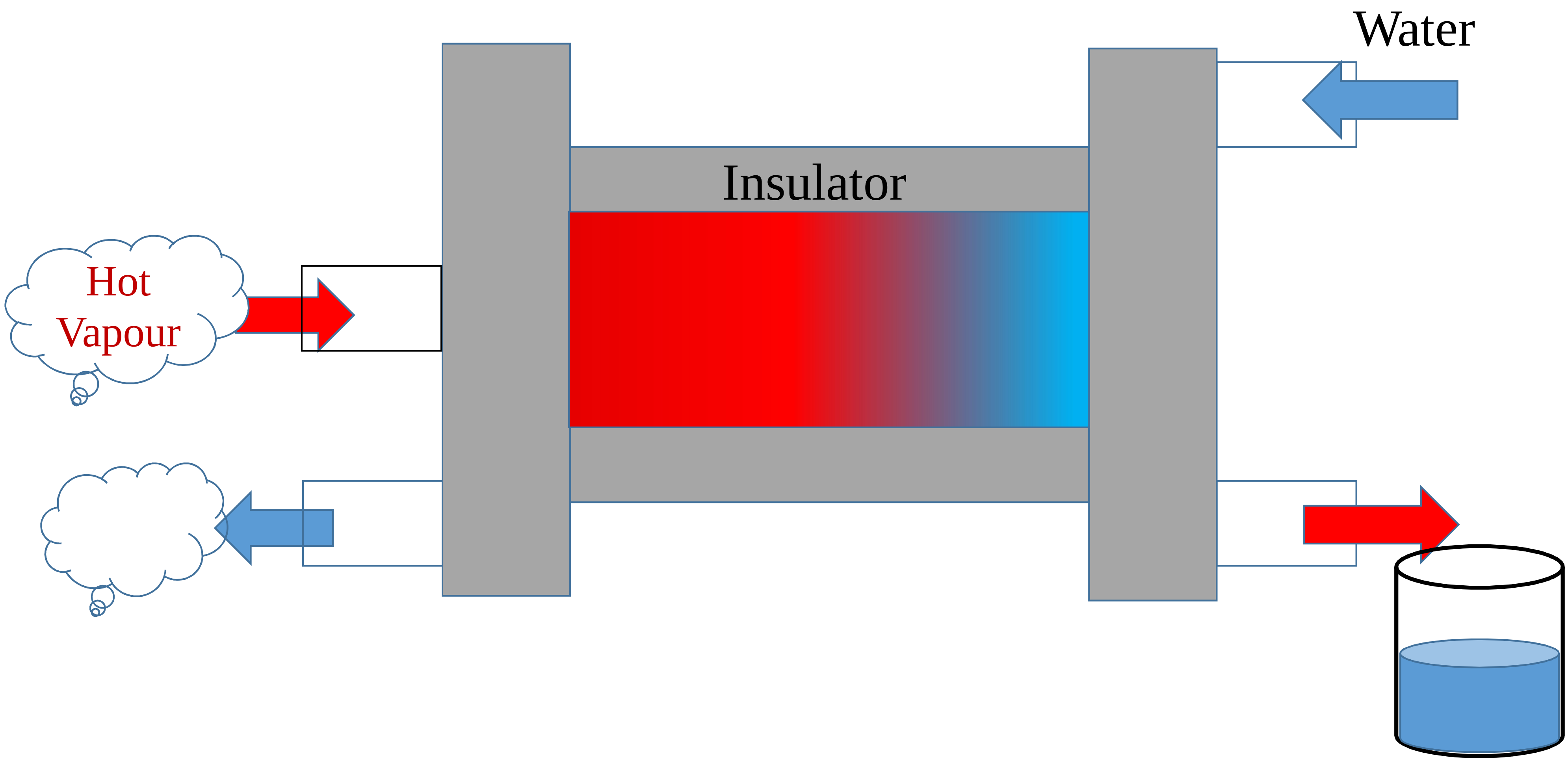
Material	Thermal conductivity W/(m·K)
Silica Aerogel	0.004 - 0.04
Air	0.025
Wood	0.04 - 0.4
Hollow Fill Fibre Insulation	0.042
Alcohols and oils	0.1 - 0.21
Polypropylene	0.25 [14]
Mineral oil	0.138
Rubber	0.16
LPG	0.23 - 0.26
Cement, Portland	0.29
Epoxy (silica-filled)	0.30
Epoxy (unfilled)	0.59
Water (liquid)	0.6
Thermal grease	0.7 - 3
Thermal epoxy	1 - 7
Glass	1.1
Soil	1.5
Concrete, stone	1.7
Ice	2
Sandstone	2.4
Stainless steel	12.11 ~ 45.0
Lead	35.3
Aluminium	237 (pure) 120—180 (alloys)
Gold	318
Copper	401
Silver	429
Diamond	900 - 2320
Graphene	(4840±440) - (5300±480)

Thermal conductivity measurement

Apparatus

process


θ2
θ3
θ4
θ1
Coold Water Inlet
Insulator
Hot Vapour Inlet
Metal Rod
θ5
Vapour Outlet
Hot Water Outlet
Heating vessels
Cooling vessels


Water
Insulator
Hot
Vapour

مراحل آزمایش اندازه گیری ضریب رسانش یک میله:

تزریق بخار آب به یک طرف میله با نرخ ثابت

تزریق آب سرد به سمت دیگر با نرخ ثابت

یادداشت مقادیر دماها در بازه های زمانی ثابت

هرگاه دماهای یادداشت شده دیگر تغییر نکرد به حالت مانا رسیده ایم

نوشتن دماهای نشان داده شده توسط دماسنج ها

جمع آوری آب خروجی از سمت راست در یک بازه زمانی مشخص مثلا ۶۰ ثانیه (m)

$$P = kA\frac{\Delta\theta}{L} = kA\frac{(\theta_3 - \theta_2)}{L}$$

$$P = \frac{Q}{t} = \frac{mc\Delta\theta}{t} = \frac{mc(\theta_5 - \theta_4)}{t}$$

$$kA\frac{(\theta_3 - \theta_2)}{L} = \frac{mc(\theta_5 - \theta_4)}{t}$$

$$k = Thermal Conductivity$$