محاضرات
فى فيزياء الحرارة ومبادئ الديناميكا الحرارية

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برنامج اللغة الأنجليزية

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Chapter one

1-What is the Heat

Particles of matter are in movement. For example, in gases, molecules in all directions move irregularly and irregularly, and the speed and direction of a molecule changes when that part collides with another. In solids, the motion of their molecules is a fluctuating motion around its equilibrium position.

In the liquid state, the movement of molecules is a compromise between the movement of molecules in gaseous and solid matter. In all cases, the molecules are in motion. This means that each molecule has kinetic energy.

$$KE = \frac{1}{2} mv^2$$

"It should be noted that we mean the motion of the molecule is the kinetic energy of the molecules of the substance.

Each body has kinetic energy of the molecules of the substance and this is equivalent to what it contains of the amount of heat It means that the heat is only the energy of the of the molecules motion of the material

Heat is the energy that causes the transition sensation of heat or cold.

2-Thermal effects

- **Physiological effects**: such as feeling warm and alerting blood circulation and burns.
- **Chemical effects:** such as chemical reactions caused by heating, for example, the sulfur union with iron by heating and produces iron sulfate.
- **Physical effects:** expansion - changing the state from hardness (solid) to liquidity and from liquid to gaseous - increasing electrical resistance - increasing water vapor pressure - generating electric power when heating point of contact of two different metals (Copper and Iron for example

3- Temperature

If we touch a hot object, we feel that we have feelings with a certain feeling. We assume that we divided this body into parts and touched its parts individually. We feel the same feeling as in the first case.

It has because that the sense of touch does not indicate the amount of heat in the body, but it shows us a fixed characteristic of the characteristics of the temperature, which does not change when the division of any body into small parts this property will know it as the temperature.

What does not change in the body when it is divided into parts is clearly the energy of the movement of its molecules. Therefore,

Temperature is a standard or a measure of this medium kinetic energy of the molecules of matter.

4-Temperature Scale

When the state of the crystalline material changes from solidity to fluidity or from liquid to gaseous, this change occurs at constant temperatures - which can be considered as fixed points in temperature

The most important of these points are : the freezing point (or freezing point) and the boiling point of distilled water under pressure 76 cm / Hg (or the boiling point of water under pressure 76 cm / Hg)

Let us assume that the value of the physical property measured at freezing point is x_0 and x_{100} at boiling point. n = the number of equal sections in between the two fixed points.

The change in the physical property of each section is:

$$\frac{X_{100} - X_0}{n}$$

Assuming that the value of the physical property x_t is at t temperature, then the change in the physical property corresponding to 1 ° C is:

$$\frac{x_t - x_0}{t} = \frac{x_{100} - x_0}{100}$$

$$x_t = x_0 + \left(\frac{x_{100} - x_0}{100}\right)t$$

$$= x_0\left(1 + (\frac{x_{100} - x_0}{100x_0})t\right)$$

$$= x_0\left(1 + \alpha t\right)$$

$$\alpha = \frac{x_{100} - x_0}{100x_0}$$

α is the coefficient of increasing in the physical property by high temperature, ie for example, increasing the length, size or resistance. The temperature obtained by this method may vary depending on the quantity this variation is undesirable and therefore we need to have a calibration process for correction and it is agreed to make the thermometer the fixed-size hydrogen gas a standard thermometer. The most common temperature scales are summarized below:

a- Celsius Scale

The Celsius scale was invented in 1742 by the Swedish astronomer, Anders Celsius. This scale divides the range of temperature between the freezing and boiling temperatures of water into 100 equal parts. You will sometimes find this scale identified as the centigrade scale. Temperatures on the Celsius scale are known as degree Celsius (ºC).

b- Fahrenheit Scale

The Fahrenheit scale was established by the German-Dutch physicist, Gabriel Daniel Fahrenheit, in 1724. While many countries now use the Celsius scale, the Fahrenheit scale is widely used in the United States. It divides the difference between the melting and boiling points of water into 180 equal intervals. Temperatures on the Fahrenheit scale are known as degree Fahrenheit (ºF)

c- Kelvin Scale

The Kelvin scale is named after William Thompson Kelvin, a British physicist who devised it in 1848. It extends the Celsius scale down to absolute zero, a hypothetical temperature characterized by a complete absence of heat energy. Temperatures on this scale are called Kelvins (K)

Converting Temperatures It is sometimes necessary to convert temperature from one scale to another. Here is how to do this**.**

Temperature Conversion Formulas		
Example	Formula	Conversion
$21^oC = 294$ K	K = C + 273	Celsius to Kelvin
313 K = $40\ ^oC$	C = K - 273	Kelvin to Celsius
$89\ ^oF = 31.7\ ^oC$	C = (F - 32) x 5/9	Fahrenheit to Celsius
$50\ ^oC = 122\ ^oF$	F = (C x 9/5) + 32	Celsius to Fahrenheit

Comparison of Temperature Scales

Kelvin	Celsius	Fahrenheit	Set Points
373	100	212	water boils
310	37	98.6	body temperature
273	0	32	water freezes
0	-273	-460	absolute zero

5- Thermometers

What is the principle on which thermometers are made? There are many physical properties that are regularly altered by temperature changes, such as the volume of a certain amount of liquid, the pressure of a certain amount of stationary gas, the electric force at the point of contact of two different metals in a closed circuit.

Note some of the other physical properties that can change regularly by changing the temperature. If we choose one of these qualities those changes regularly by changing the temperature we can measure the temperature by the number that measures this variable.

A thermometer is a device that measures temperature or temperature gradient, using a variety of different principles. The word thermometer is derived from two smaller word fragments: *thermo* from the Greek for heat and *meter* from Greek, meaning to measure. A thermometer has two important elements, the temperature sensor (e.g. the bulb on a mercury thermometer) in which some physical change occurs with temperature, plus some means of converting this physical change into a value (e.g. the scale on a mercury thermometer). Industrial thermometers commonly use electronic means to provide a digital display or input to a computer.

6 Types of Thermometers

a- The Liquid in Glass Thermometer

The Liquid in Glass thermometer utilizes the variation in volume of a liquid in temperature. They use the fact that most fluids expand on heating. The fluid is contained in a glass bulb, and its expansion is measured using a scale etched in the stem of the thermometer Liquid in Glass thermometers have been used in science, medicine, metrology and industry for almost 300 years. Liquids commonly used include Mercury and Alcohol.

Structure:

Two basic parts:

a. The bulb: Acting as a reservoir holding the liquid whose volume changes with temperature. The bulb also acts as a sensor or gauge which is inserted in the body whose temperature is to be measured.

b. **The Stem**: containing the scale that is measuring the temperature and a capillary through which the liquid can accordingly expand and contract

General Properties

Advantages:

1. They are cheap to manufacture
2. Easy to carry and handle.

Disadvantages:

1. They tend to have high heat capacities. They are not sensitive enough, that is they cannot measure rapid temperature changes

General Equation for Temperature calculation using a liquid in glass thermometer:

$$t = \left(\frac{L_t - L_0}{L_{100} - -L_0} \right) \times 100$$

b- The resistance thermometer

It use of the change of resistance in a metal wire with temperature. As electrons move through a metal, they are impeded by the thermal vibrations of the atoms in the crystal lattice. The higher the temperature the greater the impediment to flow thus the higher the resistance. This effect is very marked in pure metals, and for a well-behaved material enables measurements of temperature to be made to better than 0.001 °C.

Usually platinum wire is used in the construction of the thermometer, since it is a noble metal which is un-reactive over a wide range of temperatures. But copper, nickel and rhodium alloy may also be used in various temperature ranges. Usually a coil of the pure wire is wound onto an alumina former or placed in the bores of an alumina tube, and this assembly is mounted in a steel tube.

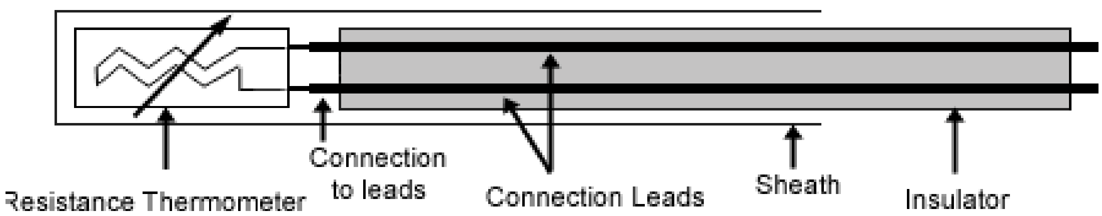
Resistance thermometers are slowly replacing thermocouples in many lower temperature industrial applications (below 600°C). Resistance thermometers come in a number of construction forms and offer greater stability, accuracy and repeatability. The resistance tends to be almost linear with temperature. A small power source is required.

No special extension cables or cold junction compensations are required. The resistance of a conductor is related to its temperature. Platinum is usually used due to its stability with temperature. The Platinum detecting wire needs to be kept free of contamination to remain stable. A Platinum wire or film is created and supported on a former in such a way that it gets minimal differential expansion or other strains from its former, yet is reasonably resistant to vibration.

Resistance thermometers require a small current to be passed through in order to determine the resistance. This can cause self heating and manufacturer's limits should always be followed along with heat path considerations in design.

Care should also be taken to avoid any strains on the resistance thermometer in its application.

Resistance thermometers elements are available in a number of forms. The most common are: Wire Wound in a ceramic insulator - High temperatures to 850 °C Wires encapsulated in glass - Resists the highest vibration and offers most protection to the Pt Thin film with Pt film on a ceramic substrate - Inexpensive mass production



Advantages

1. Depending on the metal being used resistance, thermometers are able to cover extensive temperature ranges. Maximum values are generally related to the melting points of the metal used.
2. Variation of resistance with temperature is stable over an extensive temperature range.
3. Very accurate

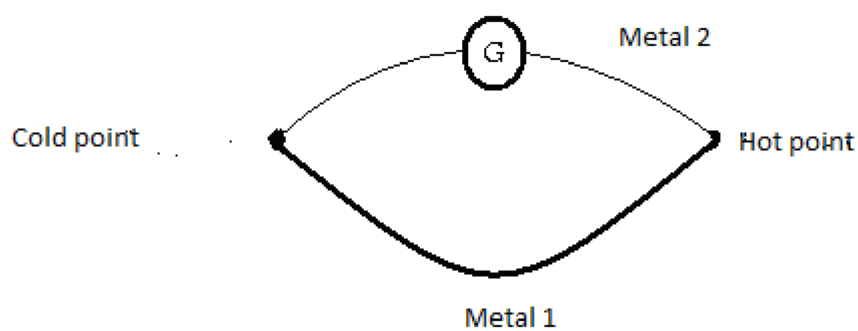
Disadvantages

1. Compared to liquid in glass thermometers, they tend to be expensive.
2. Require other equipment to measure temperature.
3. They exhibit high heat capacities thus they are not sensitive to temperature change meaning that they can not be used to measure rapid temperature changes.

$$t = \left(\frac{R_t - R_0}{R_{100} - R_0} \right) \times 100$$

C- Thermocouples

As a Thermometric, property thermocouples utilize the variation of EMF generated at a bimetallic junction with temperature. In1821, the German-Estonian physicist Thomas Johann Seebeck discovered that when any conductor (such as a metal) is subjected to a thermal gradient, it would generate a voltage. This is now known as the thermoelectric effect or Seebck effect



Unknown temperature is found according to the relation:

$$t = \left(\frac{E_t - E_0}{E_{100} - E_0} \right) \times 100$$

Many different thermocouple combinations have been used, but only 8 are standardized. These include 3 noble metal thermocouples using platinum and platinum-rhodium alloys, widely used for temperature measurement up to 1600 °C. The remaining 5 mainly use nickel-based alloys, which are cheaper and more suitable for industrial use up to about 1200 °C. Other refractory alloys can be used up to and beyond 2000 °C.

Advantages:

1. Cheap to manufacture.
2. The simplicity, ruggedness, low cost, small size and wide temperature range of thermocouples make them the most common type of temperature sensor in industrial use.
3. Low heat capacities making it capable of measuring rapid temperature changes.

Disadvantages:

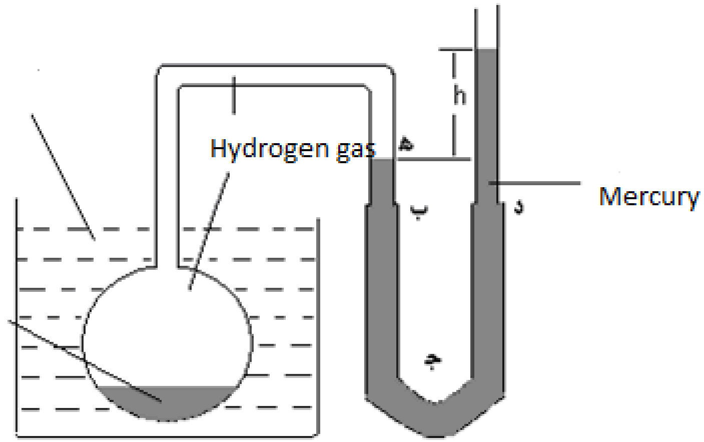
1. Sensitivity reduces accuracy

C -The Constant Volume Gas Thermometer

As a thermometric property it uses the variation of pressure of a gas with temperature. Usually air is used as a gas. For better accuracy other gases like helium that tend to have very low melting points close to absolute zero are used.

Advantages:

1. It is very accurate. In fact its accuracy allows it to be utilized to calibrate other thermometers.



Disadvantages:

1. It is not easy to handle and read.
2. It tends to be highly sensitive to temperature change, and mechanical vibrations. In fact to give a reading it usually entails a lot of time.
3. Expensive to manufacture and keep

Unknown temperature is found according to the relation:

$$t = \left(\frac{p_t - p_0}{p_{100} - p_0} \right) \times 100$$

EX 1 Calculate the temperature of an object where its value is measured by a Fahrenheit temperature equal to twice its value measured by a centigrade, then calculate the temperature at which the readings are equal

Solution:

$$C = (F - 32)5l9$$

And F=2C, then

C=160^0 c

And F=C

F= -40 f

Ex2 Platinum thermometer Its resistance at the ice melting point is 6.5 ohm and at boiling water point of water 11.5 ohm Find the temperature when the resistance is 14 ohm and then calculate the resistance of the thermometer at 60 ° C

Solution:

$$t = \left(\frac{R_t - R_0}{R_{100} - R_0} \right) \times 100$$

$$= \left(\frac{14-6.5}{11.5-6.5}\right).\times 100$$
$$= 150$$

$$60 = \left(\frac{R_t - 6.5}{11.5-6.5}\right)\times 100$$

$$R_t = 9.5 \quad \text{ohm}$$

Ex3 Using the thermometer gas thermometer for the measurement of the temperature of the chamber, the gas pressures were 80cm, 109.3cm at temperature 0 C ^{0}, 100C ^{0} ,respectively. If the pressure is 83cm at room temperature and 100cm in hot water. Find a hot degree both from the room and hot water

Solution

$$t = \left(\frac{p_t - p_0}{p_{100} - p_0}\right)\times 100$$

$$= \left(\frac{83-80}{109.3-80}\right)\times 100$$
$$= 10.239\,\text{C}$$

$$= \left(\frac{100-80}{109.3-80}\right)\times 100$$
$$68.26\,\text{C}$$

Ex

1- if the length of the mercury column in the thermometer's leg at freezing and boiling point, respectively is 15 and 25 cm, calculate the temperature at which the length of the column is equal to 22 cm.

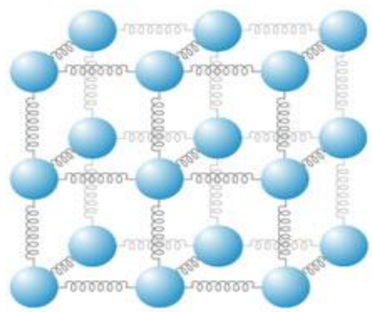
2. Platinum thermometer resistances at 0 ° C and water boiling point respectively are 200 and 400 ohm Calculate the temperature that makes it resist 300 ohm

Chapter Two

Thermal Expansion

When the temperature of the material (solid, liquid or gaseous) is raised, the energy of its molecules increases and thus its vibration, also, is increased around its position (see Figure). This increases the average distance between each molecules and neighboring molecules. The water shrinks when raising the temperature in the range 0: 4 degrees Celsius

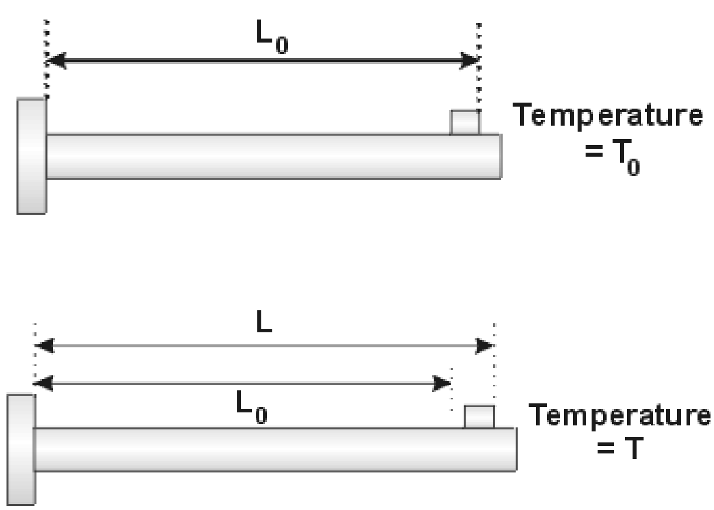
The thermal expansion of the material is a result of the change occurring to the distances between molecules and atoms of matter. To understand more precisely what we have to look at the figure below shows the crystalline structure of a solid state material that contains a matrix of ordered atoms connected to each other by electrical forces



There are three types of expansion: Longitudinal (linear) expansion, surface expansion, and volumetric expansion. The following sections will be summarized them briefly:

1-Longitudinal expansion for solid material:

For a rod of solid copper, its length at zero C is L_0 and by raising the temperature of Δt. The increase in length is ΔL is depend upon the temperature raising Δt and the initial length L_o



$$\Delta L \; \alpha \; L_o$$
$$\Delta L \; \alpha \; \Delta T$$
$$\Delta L \; \alpha \; \Delta T \; L_o$$
$$\Delta L = \sigma \; \Delta T \; L_o$$

Where σ is a fixed amount depends on the type of body material and called the coefficient of longitudinal expansion and thus be

$$\sigma = \frac{\Delta L / L_0}{\Delta T} \quad :$$

According to the previous equation, we can know the coefficient of the longitudinal expansion of the material

As follows: The increase in the unit length of the material by raising the temperature of one degree Celsius. The unit according to the previous equation is / C°.

We can drive the law of longitudinal expansion in another way: Assuming that L_0 L_1 L_2 is the length of a metal rod at zero temperatures, T_1 and T_2 temperature. Also, assuming that the coefficient of height increase by raising the temperature (longitudinal expansion coefficient) is constant and has the same value between the temperatures T_1 and T_2 and by applying Equation 1 (see chapter 1)

$$\boldsymbol{L_1 = L_0(1+\sigma T_1)} \qquad (3)$$

$$\boldsymbol{L_2 = L_0(1+\sigma T_2)} \qquad (4)$$

$$\frac{L_2}{L_1} = \frac{1+\sigma T_2}{1+\sigma T_1}$$

$$\boldsymbol{\frac{L_2}{L_1} = (1+\sigma T_2)(1+\sigma T_1)^{-1}} \qquad (5)$$

$$(1+\sigma T_1)^{-1} = (1-\sigma T_1 + \sigma^2 T^2{}_1 - \sigma^3 T^3{}_1) + \dots\dots\dots + \dots.$$

Consider only the two second terms and neglect the other for simplification then,

$$L_2 = L_1(1+\sigma T_2)(1-\sigma T_1)$$

$$L_2 = L_1\left[1+\sigma(T_2 - T_1)\right]$$

$$\frac{L_2 - L_1}{L_1} = \sigma(T_2 - T_1)$$

Ex1

A length of lead piping is 50.0 m long at a temperature of 16°C. When hot water flows through it the temperature of the pipe rises to 80°C. Determine the length of the hot pipe if the coefficient of linear expansion of lead is 29×10^{-6} C^{-1}

Solution

Length L_1= 50.0 m, temperature T_1= 16°C, T_2 = 80°C and $\sigma = 29 \times 10^{-6}$ K^{-1}
Length of pipe at 80°C is given by:

$$L_2 = L_1[1 + \sigma(T_2 - T_1)]$$

$= 50.0[1 + (29 \times 10^{-6})(80 - 16)]$

$= 50.0[1 + 0.001856]$

$= 50.0[1.001856] =$ **50.0928 m**

i.e. an increase in length of 0.0928 m or 92.28 mm

Ex2

A rod of metal is measured at 285 K and is 3.521 m long. At 373 K the rod is 3.523 m long. Determine the value of the coefficient of linear expansion for the metal.

Length L_1= 3.521 m, L_2= 3.523 m, temperature T_1= 285 K and temperature T_2= 373 K 1212

$$L_2 = L_1\left[1 + \sigma(T_2 - T_1)\right]$$

i.e. 3.523 = 3.521[1 + σ (373 - 285)]

3.523 = 3.521 + (3.521)(σ)(88)

i.e. 3.523 – 3.521 = (3.521)(σ)(88)

Hence, the coefficient of linear expansion = 0.00000645

Ex3

A copper overhead transmission line has a length of 40.0 m between its supports at 20°C. Determine the increase in length at 50°C if the coefficient of linear expansion of copper is 17×10^{-6} K^{-1}

Solution

$$L_2 = L_1\left[1 + \sigma(T_2 - T_1)\right]$$

$$L_2 = L_1 + L_1\sigma(T_2 - T_1)$$

$$L_2 - L_1 = L_1\sigma(T_2 - T_1)$$

= (40.0)(17 × 10^{-6})(50 – 20

= (40.0)(17 × 10^{-6})(30)

= 0.0204 m or 20.4 mm

Ex4

A brass measuring tape measures 2.10 m at a temperature of 15°C. Determine :

(a) the increase in length when the temperature has increased to 40°C

(b) the percentage error in measurement at 40°C. Assume the coefficient of linear expansion of brass to be 18 × 10^{-6} K^{-1}

Solution

Length L_1= 2.10 m, temperature T_1= 15°C, T_2= 40°C

and σ = 18 × 10^{-6} K^{-1}

$$L_2 = L_1\left[1 + \sigma(T_2 - T_1)\right]$$

$$L_2 = L_1 + L_1\sigma(T_2 - T_1)$$

$$L_2 - L_1 = L_1\sigma(T_2 - T_1)$$

Hence, **increase in length**

= (2.10)(18 × 10^{-6})(40 – 15)

= (2.10)(18 × 10^{-6})(25)

= **0.000945 m** or **0.945 mm**

(b) **Percentage error in measurement at 40°C**

$$= \frac{\text{increase in length}}{\text{original length}}$$

$$= \frac{0.000945}{2.1} \times 100\%$$

Ex 5

A pendulum of a 'grandfather' clock is 2.0 m long and made of steel. Determine the change in length of the pendulum if the temperature rises by 15 K. Assume the coefficient of linear expansion of steel to be $15 \times 10^{-6}\ K^{-1}$

Solution

Hence, increase in length = $L_1 \sigma\ (T_2 - T_1)$

$= (2.0)(15 \times 10^{-6})(15)$

$= (2.0)(15 \times 10^{-6})(15)$

= 0.00045 m or 0.45 mm

Ex 6

A temperature control system is operated by the expansion of a zinc rod which is 200 mm long at 15°C. If the system is set so that the source of heat supply is cut off when the rod has expanded by 0.20 mm, determine the temperature to which the system is limited. Assume the coefficient of linear expansion of zinc to be $31 \times 10^{-6}\ K^{-1}$

Solution

Length L_1= 200 mm = 0.20 m, L_2= 200 + 0.20 mm = 200.2 mm = 0.2002, temperatureT_1= 15°C

Hence, increase in length = $L_1 \sigma\ (T_2 - T_1)$

$0.2002 - 0.20 = (0.20)(31 \times 10^{-6})(T_2 - 15)$

$0.0002 = (0.20)(31 \times 10^{-6})(T_2 - 15)$

$$T_2 - 15 = \frac{0.0002}{0.2 \times 31 \times 10^{-6}}$$

$=32.26\ ^0C$

i.e. **the temperature to which the system is limited,**

T_2= 32.26 + 15 **= 47.26**°**C2**

Answer the following:

1- A length of steel railway line is 30.0 m long when the temperature is 288 K. Determine the increase in length of the line when the temperature is raised to 303 K.

Assume the coefficient of linear expansion of steel to be 15 × 10^{-6} K^{-1}

2- A brass shaft is 15.02 mm in diameter and has to be inserted in a hole of diameter 15.0 mm. Determine by how much the shaft must be cooled to make this possible, without using force. Take the coefficient of linear expansion of brass as 18 × 10^{-6} K^{-1}

3- Surface expansion:

The surface expansion coefficient of the material is known as the increase in the unit area due to the increase of one degree Celsius.

We assume that a square metal plate with an area at 0 ° C is L_0^2 and its temperature will expand in all directions then increase its area. If the increase in temperature is equal to T_1 ° the length of both sides is

$$\boldsymbol{L = L_0(1+\sigma T_1)}$$

Then the area:

$$L^2 = L_0{}^2(1+\sigma T_1)^2$$
$$L^2 = L_0{}^2(1+2\sigma T_1+\sigma^2 T_1)$$
$$L^2 = L_0{}^2(1+2\sigma T)$$

By neglecting the last term then the last equation becomes in the following picture:

$$S = S_0 (1 + \beta T_1)$$

Where S_0 represents the area at 0 $^\circ$ C and S is the area at T_1 and by comparing the equation of longitudinal and surface expansion we find that:

$$\beta = 2\sigma$$

i.e the coefficient of surface expansion is twice the value of the longitudinal expansion coefficient

By the same way, it can be shown that the volume expansion coefficient of Φ a solid body is three times the value of the longitudinal expansion coefficient

$$\Phi = 3\sigma$$

$$\Phi = \frac{V - V_0}{V_0 T_1}$$

V_0 is the size at zero degrees Celsius and V is the size at T_1

In addition to the above effect of raising the temperature in the physical properties of the change in length, area and size, the changing of the density of materials as well as flexibility due to thermal effect will be discussed :

1- Density :

We know that the density is the mass of the unit volume of the material, ie the density of the material in the degree of zero percent is :

$$\rho_0 = \frac{M}{V_0}$$

For temperature raising to T_1 the density becomes ρ :

$$\rho = \frac{M}{V}$$

$$\frac{\rho_0}{\rho} = \frac{V}{V_0}$$

By substituting

$$V = V_0(1 + \Phi T_1)$$

$$\rho_0 = \rho(1 + \Phi T_1)$$

For two temperature T_1 and T_2 the density is

$$\rho_0 = \rho\left[(1 + \Phi(T_2 - T_1)\right]$$

2- Elasticity

The scientific experiments have shown that the Elasticity of objects changes with their high temperature. It was found that the young coefficient (Y) of the material is slightly less with high temperature and by more increasing of temperature; its value is missing at the melting point of the material.

For more understand of the effect of temperature on the elasticity of objects in a mathematical way we assume that we have a hot metal rod L_2 at the temperature of T_2 and assume that we fixed the ends of this hot rod and let it cool until it reaches the temperature to room temperature T_1 The cold metal rod will tighten. If it is not fixed at the ends then reduce to to L_1

$$L_2 - L_1 = \sigma L_1 (T_2 - T_1)$$

The fixed metal rod which is hot and then cooled to room temperature, generates a state of tensile force to increases its length from L_1 to L_2. The definition of the Young coefficient, which expresses the elasticity of objects:

$$Y = \frac{Stress}{Strain}$$

$$Y = \frac{F/A}{(L_2 - L_1)/L_1}$$

From the mentioned equations we can deduced the following formula for Young coefficient

$$Y = \frac{F}{A}\frac{1}{\sigma(T_2 - T_1)}$$

This equation shows the effect of temperature on the elastic coefficient Y. Where it is clear that as the temperature increases the elastic coefficient decreased

Applications on the expansion of solid objects

1- **Bimetallic strip**

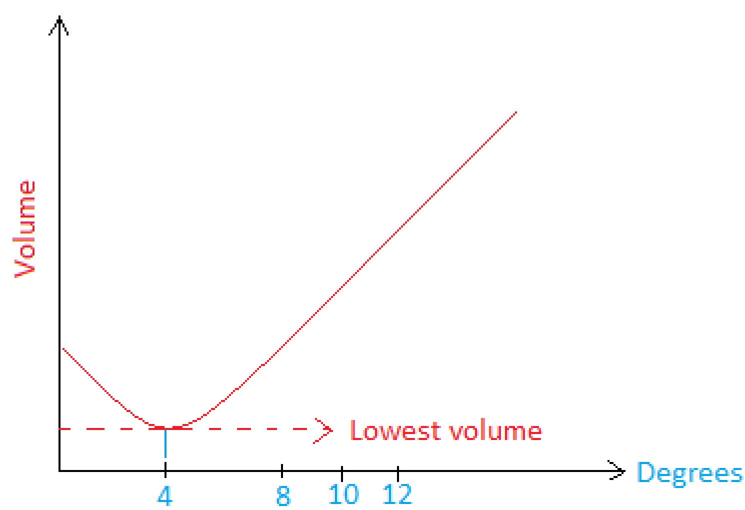
A **bimetallic strip** is used to convert a temperature change into mechanical displacement. The strip consists of two strips of different metals (see the figure) which expand at different rates as they are heated, usually steel and copper, or in some cases steel and brass.

The strips are joined together throughout their length by riveting, brazing or welding. The different expansions force the flat strip to bend one way if heated, and in the opposite direction if cooled below its initial temperature. The metal with the higher coefficient of thermal expansion is on the outer side of the curve when the strip is heated and on the inner side when cooled

Liquid Expansion

The liquids expand and increase in size by increasing the temperature, and their volumetric expansion coefficient is large compared to the solids. Water is different from other liquids as the water density increases by increasing the temperature from 0 to 4 degrees Celsius.

The thermal expansion of water is different from most other liquids. With the exception of water, almost all liquids will expand with an increase in temperature. However take a look at the graph below to see how water behaves as the temperature increases from 0 degree to 4 degrees Celsius. Keep in mind that at zero degree, water is in its solid form.



As the temperature increases from 0 degree to 4 degrees, we notice that the volume is decreasing.

At 4 degrees Celsius, a given amount of water has the smallest volume. Since that amount of water has the smallest volume, it has the greatest density.

Liquids take the shape of the vessel, which is contained. Therefore, when talking about the expansion of liquids, we must consider the expansion of the vessel Φ_c and the observed expansion of the fluid is not in fact the extension of the dilution of the liquid only between the real expansion of the fluid and the expansion of the vessel. That is, the liquid has a real expansion Φ_r and an apparent expansion Φ_a

$$\phi_r = \phi_a + \phi_c$$

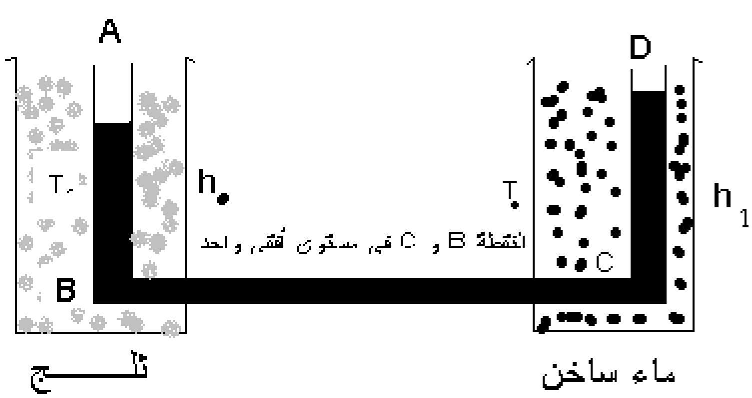
Real expansion of the liquid Φ_r: is the actual increase in the size of the volume unit of liquid if the temperature increased of one degree Celsius

Apparent expansion of the liquid Φ_a: is the apparent increase in the size of the volume unit of liquid if the temperature increased of one degree Celsius

Measurement of volumetric expansion coefficient of liquid Φ:

With out the need to take into account the expansion of the container containing the liquid, **Dwing Dabti** invented a simple method to measure the volumetric expansion coefficient of the liquid.

The device used (see the figure) as the form is composed of two vertical tubes AB DC connected to a horizontal tube with a small BC section and the AB tube is surrounded by fused ice. The CD tube is surrounded by a water bath that can be heated to different temperature



Assume that the water bath temperature is T and the temperature of the melting ice is T_0. When the liquid surface is stable in the two tubes, the liquid pressure at point B equals liquid pressure at point C.

Where **$T > T_0$**, the density of the liquid in the CD is less than the value in AB. This is resulting the rise of the liquid in the CD h_1 becomes greater than the equivalent in AB h_o:

$$P_C = P_B$$

$$p + h_0 \rho_0 g = P + h_1 \rho g$$

$$\frac{\rho_0}{\rho} = \frac{h_1}{h_0}$$

From the equation that shows the relationship between the two liquid densities at two different temperatures.

$$\rho_0 = \rho\left[(1 + \Phi(T - T_0)\right]$$

$$\frac{h_1}{h_0} = \left[(1 + \Phi(T - T_0)\right]$$

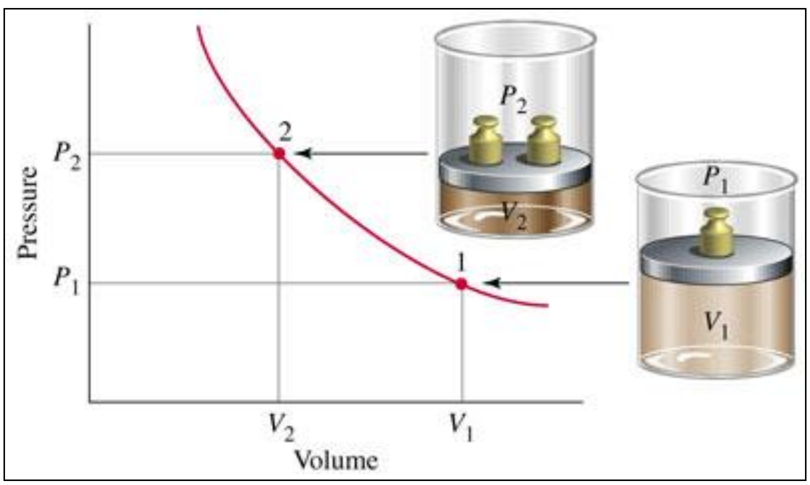
$$\frac{h_1 - h_0}{h_0} = \left[\Phi(T - T_0)\right]$$

$$\frac{h_1 - h_0}{h_0\left(T - T_0\right)} = \Phi$$

Gas expansion:

Gases are expanded when heated and raised temperature, and since the sizes depend upon the pressure, it is necessary to save pressure when studying the increase in size with temperature. On the other hand, if the objective is to study the increase of pressure with temperature, it proves the size.

Boyle's Law :When gas is kept at constant temperature its pressure is inversely proportional to the volume.



$$V \alpha \frac{1}{P}$$

$$PV = cons\tan$$

$$P_1V_1 = P_2V_2$$

Charle's Law

When the pressure of the gas kept constant the volume directly proportional to the temperature

$$V = V_0(1 + \Phi T) \qquad \textbf{(1)}$$

Φ is the Coefficient of increase in volume when pressure is confirmed .

Law of Pressure:

When the volume of the gas kept constant the pressure directly proportional to the temperature

$$\boldsymbol{P = P_0(1 + \beta T)} \qquad \textbf{(2)}$$

Where **β** is the coefficient of pressure increase when the volume is confirmed

Prove that the : Φ = β :

Multiply the equation representing the coefficient of increase in size in P_0 and multiply the equation, which represents the coefficient of pressure increase in V_0

$$P_0 V = P_0 V_0 (1 + \Phi T)$$

$$V_0 P = V_0 P_0 (1 + \beta T)$$

$$\frac{P_0 V}{P V_0} = \frac{(1 + \Phi T)}{(1 + \beta T)}$$

From **Boyle's Law**

$$V = \frac{C}{P} \qquad V_0 = \frac{C}{P_0}$$

$$\frac{P_0^{\,2}}{P^2} = \frac{(1 + \Phi T)}{(1 + \beta T)}$$

$$\frac{P_0^{\,2}}{P_0^{\,2}(1 + \beta T)^2} = \frac{(1 + \Phi T)}{(1 + \beta T)}$$

$$(1 + \beta T)(1 + \Phi T) = 1$$

By neglecting the amount of $\Phi \beta$ **T^2**, and with the insignificance of the sign,

$$\boxed{\beta = \phi}$$

Ex1. A silver plate has an area of 800 mm^2 at 15°C. Determine the increase in the area of the plate when the temperature is raised to 100°C. Assume the coefficient of linear expansion of silver to
be 19×10^{-6} K^{-1}

Chapter Three

Heat Transfer

Heat transfer from the hot body to the cold body in one of three ways:

- Thermal Conduction
- Thermal convection
- Thermal Radiation

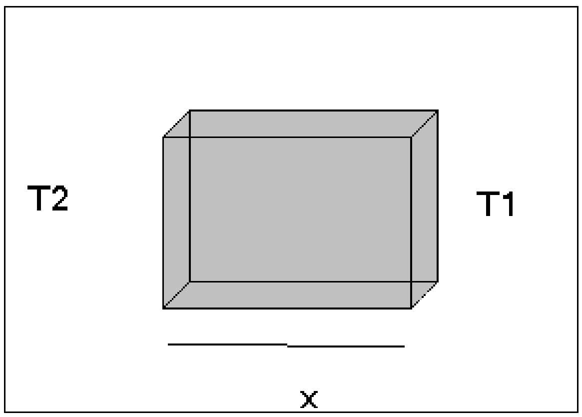
In this chapter we will discuss the above three methods of heat transfer and explanation with accompanied by equations and graphs.

1- Thermal Conduction;

Thermal conduction is the direct microscopic exchange of kinetic energy of particles through the boundary between two systems without bulk motion of the matter.

When an object is at a different temperature from another 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.

Assume a cube with X length and its area of one of the sides is **A.** The temperature of the opposite sides is T_2 and T_1 where $T_2 > T_1$ so a connection occurs in the direction of the lower temperature.



The amount of heat transferred through the sides of the cube (H) is proportional to:

$$H \alpha T_2 - T_1$$

$$H \alpha A$$

$$H \alpha \frac{1}{x}$$

$$H \alpha t$$

$$H \alpha \frac{T_2 - T_1}{x} At$$

$$H = \lambda \frac{T_2 - T_1}{x} At$$

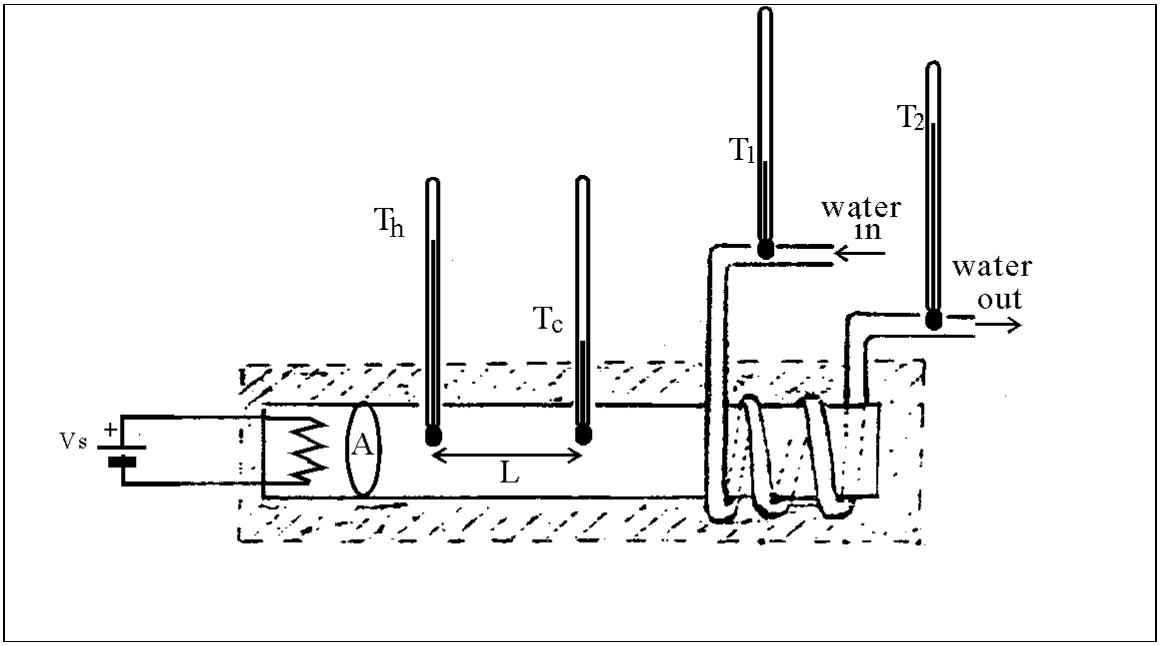
$$\frac{dH}{dt} = -\lambda A \frac{dT}{dx}$$

The proportionality coefficient (λ) is the thermal conductivity coefficient which is a characteristic of the material in terms of its thermal nature

$$\lambda = \frac{\boldsymbol{H}}{\boldsymbol{A}\frac{\boldsymbol{T}_2 - \boldsymbol{T}_1}{\boldsymbol{x}}\boldsymbol{t}}$$

Searle's method for thermal conductivity measurement:

Searle's apparatus are shown below to measure the thermal conductivity of copper. We input heat at one end of the bar by means of an electrical power supply. The other end of the bar we cool by wrapping tubing around it through which water flows at constant rate. The flowing water will carry off the heat reaching the cold end of the copper bar. In this way we eventually get a balance between the heat input on one end, and the heat carried away at the other end. As a result the temperature at each position of the bar becomes constant in time; we have reached what is called a dynamic equilibrium. The adjective "dynamic" is used since heating and cooling goes on continuously, and there is equilibrium because their net effect is to produce no change)



$$m(T_2 - T_1) = -\lambda \pi r^2 \left(\frac{T_h - T_c}{l}\right).t$$

Measurement of Thermal Conductivity by Lee's method

Aim: To determine thermal conductivity of a bad conductor (glass) in form of a disc using Lee's method.

Requisites:

(1) Lee's apparatus and the experimental specimen in the form of a disc.

(2) Two thermometers,

(3) Stop watch,

(4) Weighing balance,

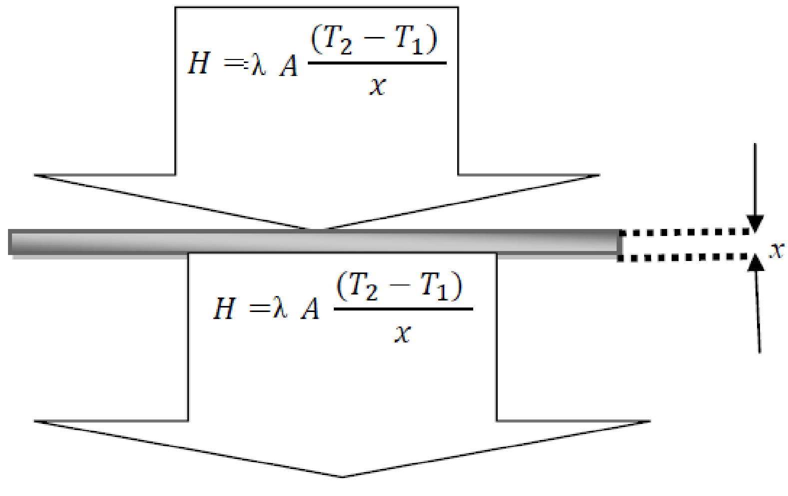
(5) Special clamp stand

(6) Boiler and Heater

Theory:

Thermal conductivity, λ, is the property of a material that indicates its ability to conduct heat. Conduction will take place if there exists a temperature gradient in a solid (or stationary fluid) medium. Energy is transferred from more energetic to less energetic molecules when neighboring molecules collide. Conductive heat flow occurs in direction of the decreasing temperature because higher temperature is associated with higher molecular energy. Fourier's Law expresses conductive heat transfer for one unit time as :

$$H = -\lambda A \frac{T_2 - T_1}{x}$$

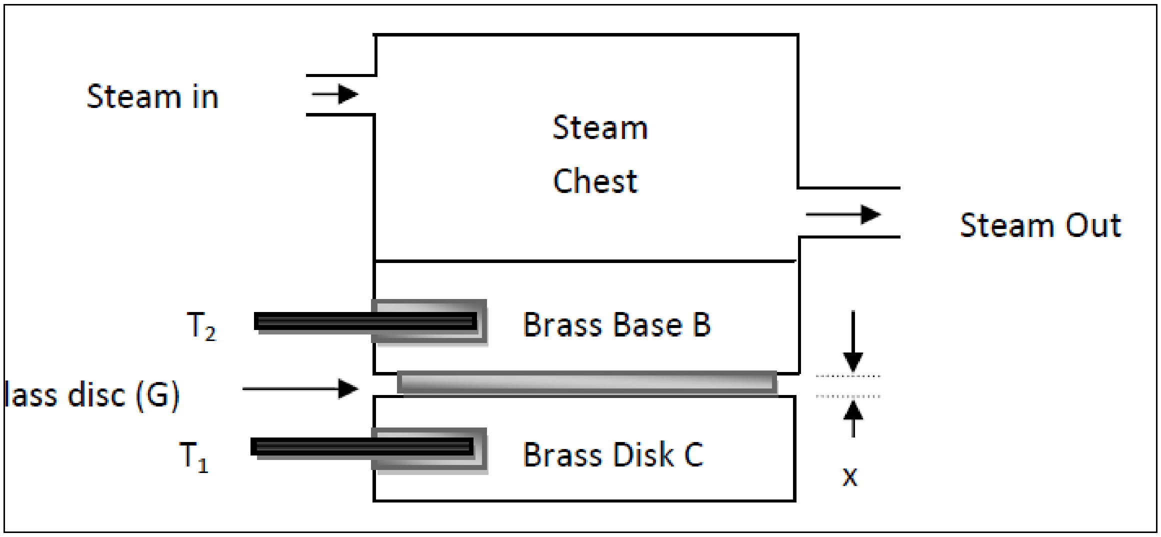


where **H** is the steady state rate of heat transfer, λ is the thermal conductivity of the sample, **A** is the cross sectional area and $(T_2 - T_1)$ is the temperature difference across the sample thickness 'x' (see Figure), assuming that the heat loss from the sides of the sample is negligible. To keep the loss from the sides small, the sample is made in form of a thin disk with a large cross sectional area compared to the area exposed at the edge. Keeping '**A**' large and '**x**' small produces a large rate of energy transfer across the sample. Keeping **x** small also means that the apparatus reaches a steady state (when temperature T_1 and T_2 are constant) more quickly

Generally speaking, there are a number of possibilities to measure thermal conductivity, each of them being suitable for a limited range of materials, depending on the thermal properties and the medium temperature. The most commonly used methods are Searle’s method and Lee’s disc method, for good and bad conductors of heat, respectively. In the experiment, we will use Lee’s disc method to determine the thermal conductivity of a bad conductor, e.g. Glass

Description of Lee’s apparatus:

The apparatus shown in Figure consists of two parts. The lower part **C** is circular metal disc. The experimental specimen **G**, usually rubber, glass or ebonite (here it is glass) is placed on it. The diameter of **G** is equal to that of **C** and thickness is uniform throughout. A steam chamber is placed on **C**. The lower part of the steam chamber, **B** is made of a thick metal plate of the same diameter as of **C**. The upper part is a hollow chamber in which two side tubes are provided for inflow and outflow of steam. Two thermometers T_1 and T_2 are inserted into two holes in **C** and **B**, respectively. There are three hooks attached to **C**. The complete setup is suspended from a clamp stand by attaching threads to these hooks.



Photograph of thermal conductivity measurement setup

When steam flows for some time, the temperatures recorded (T_1 and T_2) gradually remain steady.

This is the steady state.

Let at the steady state, temperature of C = T_1.

Temperature of B = T_2.

Surface area of G = A

Conductivity of G = λ

Thickness of G = x

Hence amount of heat flowing through G per second, H is given by

$$H = -\lambda A \frac{T_2 - T_1}{x} \qquad (1)$$

When the apparatus is in steady state (temperatures $\mathbf{T_1}$ and $\mathbf{T_2}$ constant), the rate of heat conduction into the brass disc **C** is equal to the rate of heat loss from the bottom of it. The rate of heat loss can be determined by measuring how fast the disc **C** cools at the previous (steady state) temperature T_1 (with the top of the brass disk covered with insulation). If the mass and specific heat of the lower disc are **m** and **S**, respectively and the rate of cooling at T_1 is dT/dt then the amount of heat radiated per second is,

$$H = mS \frac{dT}{dt} \qquad (2)$$

Equating (1) and (2) and simplifying, k can be determined as,

$$\lambda = \frac{mS\left(\frac{dT}{dt}\right)x}{A\left(T_2 - T_1\right)}$$

Procedure:

1. Fill the boiler with water to nearly half and heat it to produce steam.
2. In the mean time, take weight of **C** by a weighing balance. Note its specific heat from a constant table. Measure the diameter of the specimen by a scale or slide calipers, if possible. Calculate the surface area, $A = \pi r^2$.
3. Measure the thickness of the specimen by screw gauge. Take observations at 5 spots and take the mean value.
4. Put the specimen, steam chamber etc. in position and suspend it from the clamp stand. Insert the

thermometers. Check if both of them are displaying readings at room temperature. If not, note the difference θ, is to be added to ($T_2 - T_1$) later.

5. Now stem is ready. Connect the boiler outlet with the inlet of the steam chamber by a rubber tube.
6. Temperatures recorded in the thermometers will show a rise and finally will be steady at T_1 and T_2.
7. Wait for 10 minutes and note the steady temperature. Stop the inflow of steam.
8. Remove the steam chamber and the specimen G. C is still suspended. Heat **C** directly by the steam chamber till its temperature is about $T_1 + 7°$.
9. Remove the steam chamber and wait for 2 – 3 minutes so that heat is uniformly distributed over the disc **C**.
10. Place the insulating material on **C**. Start recording the temperature at ½ minute intervals. Continue till the temperature falls by 10 degree from T_1

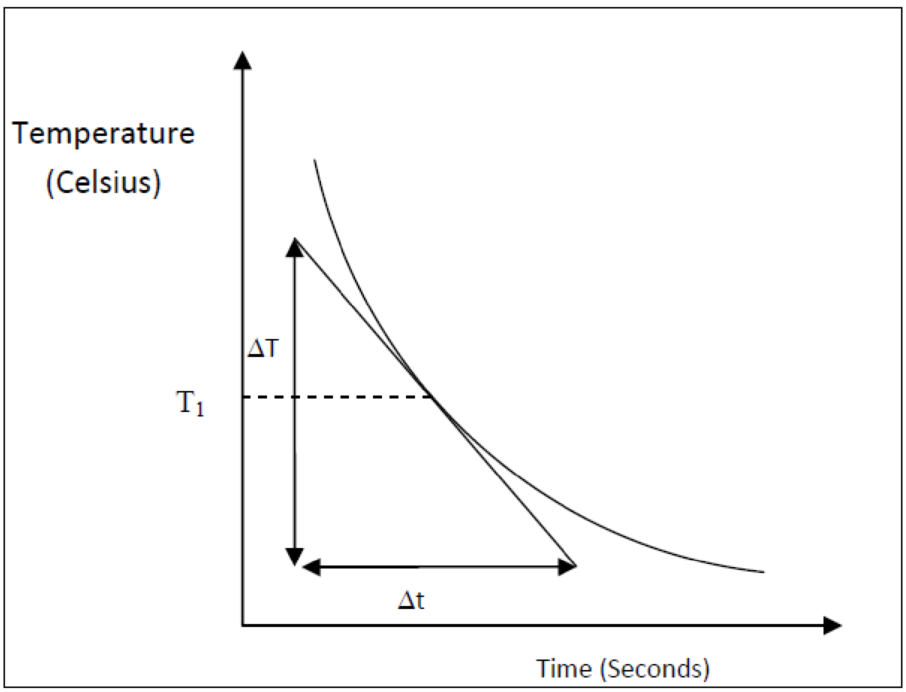
Graph:

Using the data according to step 10, plot the cooling curve (time versus Temperature) and determine the slope $dT/dt = \Delta T/\Delta t$ at the steady temperature T_1 (see the figure below).

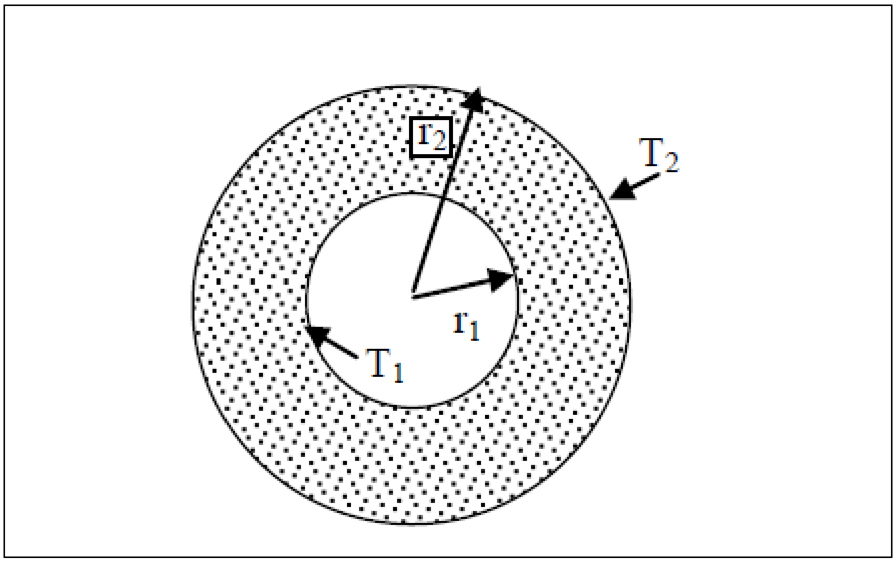
Probable errors and precautions

1. Don't record T_1 and T_2 unless they have remained steady for at least 10 minutes.

2. The tangent to the cooling curve should be done very carefully. An error in dT/dt will result in a wrong result for λ



1- Heat Conduction between two balls united in center:



Consider the above diagram we are interested in determining the rate of heat transfer through the peel. Heat flow, per unit time, is along radial direction outwards

$$H = -\lambda A \frac{dT}{dr}$$

$$A = 4\pi r^2$$

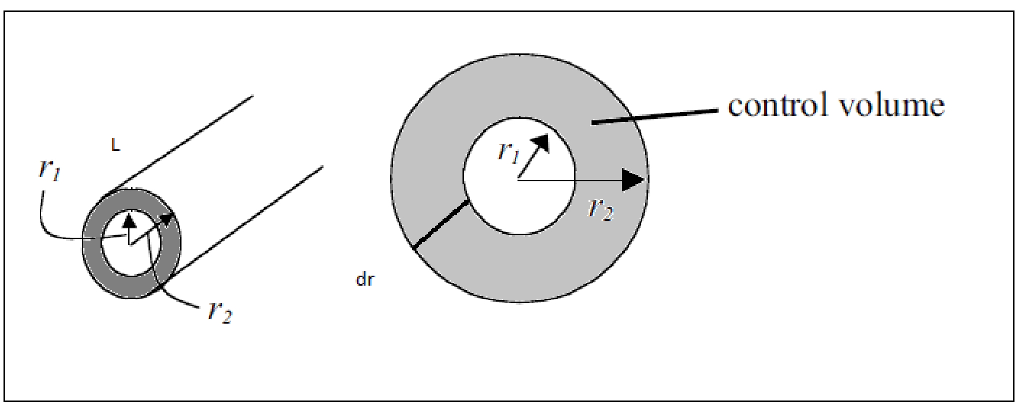
$$\frac{dr}{r^2} = -\frac{4\lambda\pi}{H} dT$$

$$\int_{r_1}^{r_2} \frac{dr}{r^2} = -\frac{4\lambda\pi}{H} \int_{T_1}^{T_2} dT$$

$$\left[\frac{1}{r}\right]_{r_1}^{r_2} = -\frac{4\lambda\pi}{H} [T]_{T_1}^{T_2}$$

$$H = \frac{4\pi\lambda r_1 r_2 (T_1 - T_2)}{r_2 - r_1}$$

2- Heat conduction through hollow Cylinder:



We consider a hollow cylinder (see the figure) with inner and outer diameter are **r_1, r_2** . The inner and outer temperature of the are **T_2** and T_1 respectively where **$T_1 > T_2$** . Assume that cylinder length .

Let's take a small shell thickened **dr**. Since the crust is very small, we can consider that the crust is as if it is the same as the inner and outer surfaces.

Using the Fourier,s equation

$$\frac{dH}{dt} = -\lambda A \frac{dT}{dx}$$

$$\boldsymbol{A} = 2\boldsymbol{\pi r L}$$

$$\frac{\boldsymbol{dH}}{\boldsymbol{dt}} = -2\boldsymbol{\pi L r \lambda} \frac{\boldsymbol{dT}}{\boldsymbol{dr}}$$

For the steady state $\frac{dH}{dt}$ is constant then:

$$\boldsymbol{a} = -\boldsymbol{r} \frac{\boldsymbol{dT}}{\boldsymbol{dr}}$$

$$\boldsymbol{a} \int \frac{\boldsymbol{dr}}{\boldsymbol{r}} = \int \boldsymbol{dT}$$

$$\boldsymbol{b} + \boldsymbol{a} \log \boldsymbol{r} = \boldsymbol{T}$$

By applying the boundary condition:

$T=T_1$ when $r=r_1$

$T=T_2$ when $r=r_2$

$$b + a\log r_1 = T_1$$

$$b + \log r_2 = T_2$$

$$T_1 - T_1 = a\log\frac{r_1}{r_2}$$

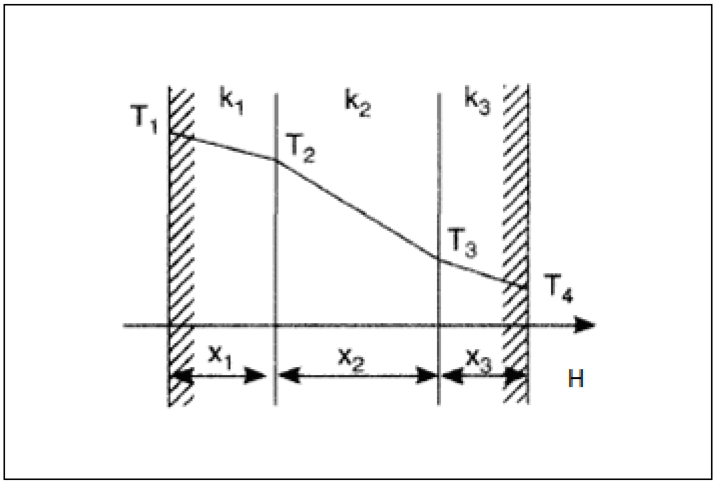
$$a = \frac{T_1 - T}{\log\frac{r_1}{r_2}}$$

$$\frac{dH}{dt} = -2\pi L\lambda\,\frac{T_1 - T_2}{\log(r_1/r_2)}$$

$$H = -2\pi L\lambda\,\frac{T_1 - T_2}{\log(r_1/r_2)}\,t$$

Heat conduction through composite wall:

Assume that a composite wall consist of three layers **(x_1 x_2 x_3)** and their thermal conductivity coefficients are **k_1, k_2** and **k_3**, respectively and their surface area is **A** with temperatures of are **$T_1 > T_2 > T_3 > T_4$**



$$\frac{dH}{dt} = -\lambda_1 A \frac{T_1 - T_2}{x_1}$$

$$\frac{dH}{dt} = -\lambda_2 A \frac{T_2 - T_3}{x_2}$$

$$\frac{dH}{dt} = -\lambda_3 A \frac{T_3 - T_4}{x_3}$$

$$-\frac{dH}{dt}\frac{x_1}{\lambda_1 A} = T_1 - T_2$$

$$-\frac{dH}{dt}\frac{x_2}{\lambda_2 A} = T_2 - T_3$$

$$-\frac{dH}{dt}\frac{x_3}{\lambda_3 A} = T_3 - T_4$$

On addition

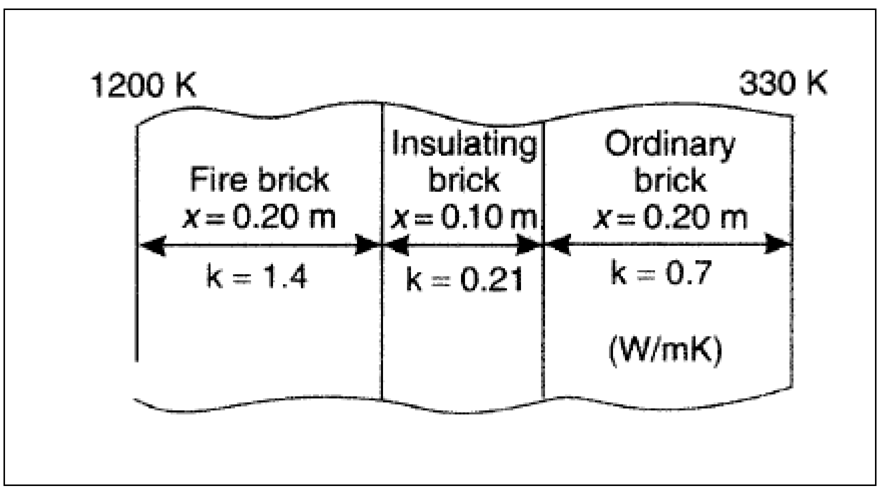
$$T_1 - T_4 = \frac{dH}{dt}\left[\frac{x_1}{\lambda_1 A} + \frac{x_2}{\lambda_2 A} + \frac{x_3}{\lambda_3 A}\right]$$

For one second:

$$T_1 - T_4 = H\left[\frac{x_1}{\lambda_1 A} + \frac{x_2}{\lambda_2 A} + \frac{x_3}{\lambda_3 A}\right]$$

Ex1

A furnace is constructed with 0.20 m of firebrick, 0.10 m of insulating brick, and 0.20 m of building brick. The inside temperature is 1200 K and the outside temperature is 330 K. If the thermal conductivities are as shown in Figure, estimate the heat loss per unit area and the temperature at the junction of the firebrick and the insulating brick



Solution

From equation 9.19:

$$Q = (1200 - 330) \Big/ \left[\left(\frac{0.20}{1.4 \times 1} \right) + \left(\frac{0.10}{0.21 \times 1} \right) + \left(\frac{0.20}{0.7 \times 1} \right) \right]$$

$$= \frac{870}{(0.143 + 0.476 + 0.286)} = \frac{870}{0.905}$$

$$= \underline{\underline{961 \text{ W/m}^2}}$$

The ratio (Temperature drop over firebrick)/(Total temperature drop) = (0.143/0.905)

$\therefore$ Temperature drop over firebrick $= \left(\frac{870 \times 0.143}{0.905} \right) = 137$ deg K

Hence the temperature at the firebrick-insulating brick interface = (1200 − 137) = $\underline{\underline{1063 \text{ K}}}$

Ex2

Wall of a room consist of three parallel layers of cement, bricks and wood their thickness are 2, 23 and 1 cm, respectively. If the air temperature is -5 °C and the room temperature is 20 °C. Calculate the amount of heat transmitted by conduction per minute of each square meter of the wall. The heat conduction coefficients for cement, bricks and wood are: 7×10^{-4} , 6×10^{-3} and 4×10^{-4} respectively.

Solution

$$T_1 - T_4 = \frac{H}{t}\left[\frac{x_1}{\lambda_1 A} + \frac{x_2}{\lambda_2 A} + \frac{x_3}{\lambda_3 A}\right]$$

$$20 + 5 \ = \frac{H}{60}\left[\frac{2}{0.0007\times 10^4} + \frac{23}{0.006\times 10^4} + \frac{1}{0.0004\times 10^4}\right]$$

25 ==H/60[0.286+0.383+0.250]

25 =(H/60)(0.919)

H =1632.2 cal

Ex3

Calculate the amount of heat transferred by the conduction per hour during the material between two balls united in the center. The inside and outside balls have diameters 4 and 6 cm , respectively . If the temperature of the surface of the two balls are 100 and 40 degrees Celsius, respectively, and the thermal conductivity of its material is equal to 3×10^{-4} .

Solution

The amount of heat transfer by conduction per second is :

$$H = 4\pi r r_2 r_1 \lambda \frac{T_2 - T_1}{(r_2 - r_1)}$$

The amount of heat transfer by conduction per one hour is

$$H = \left[4\times 3.14\times 2\times 3\times 0.0003\times \frac{100-40}{(3 \ -2)}\right]\times 60\times 60$$

H=4885.8 cal.

Radiation Heat Transfer

Heat is transferred by radiation between the objects, surfaces and fluids that are different from each other and are different in their temperature in the form of electromagnetic waves. Electromagnetic waves are approximately equal to the speed of light (3×10^{8} m s^{-1} . Therefore, the transfer of heat by radiation is the fastest method of heat transfer

When studying the process of heat transfer by radiation;

- The properties of Thermal Radiation should be studied
- Boltzmann Law for a Black Bodies

Finally, the process of heat transfer between different objects or surfaces at temperature depends on the shape of the surface or the radiant body and the distance between objects and some of them.

Also, we must know that the thermal radiation that is emitted from an object does not fully reach to the other body that exchanges with it. Heat, but loses part of it, all these factors are governed by a coefficient called Radiation Shape Factor

Properties of Thermal Radiation

When the thermal energy (thermal radiation) hits the surface of any object, a portion of this radiation is **reflected** (**refracted radiation)** and the a part is **absorbed (absorbed radiation) . The last portion is** transmitted **radiation** Therefore, the sum of the previous three parts equal to the correct .

$$\rho + \alpha + \tau = 1$$

where

Reflectivity factor is (ρ)

Absorptivity factor is (α)

Transmissivity factor is (τ)

However, most solid objects do not transmit heat radiation. Therefore, the **Transmissivity factor** of these objects is zero, so the previous equation becomes as follows

$$\rho + \alpha = 1$$

Stefan-Boltzmann Law For a Black Bodies

The total amount of energy emitted from the black surface because (this type of surface, as we know, absorbs the radiation at a very high rate and at the same time sends the radiation that absorbed it at a high rate also. This world found that the total energy emitted from the black surface of the unit of space is directly proportional to the absolute temperature of this body is raised to the fourth

$$\frac{q}{A} \alpha T^{4}$$

$$\frac{q}{A} = \eta T^{4}$$

η is Boltezman constant

Thermodynamics and Energy

Thermodynamics can be defined as the study of energy, energy transformations and its relation to matter. The analysis of thermal systems is achieved through the application of the governing conservation equations, namely Conservation of Mass, Conservation of Energy (1st law of thermodynamics), the 2nd law of thermodynamics and the property relations. Energy can be viewed as the ability to cause changes. First law of thermodynamics: one of the most fundamental laws of nature is the conservation of energy principle. It simply states that during an interaction, energy can change from one form to another but the total amount of energy remains constant. Second law of thermodynamics: energy has quality as well as quantity, and actual processes occur in the direction of decreasing quality of energy. Whenever there is an interaction between energy and matter, thermodynamics is involved. Some examples include heating and air-conditioning systems, refrigerators, water heaters, etc.

Closed and Open Systems

A system is defined as a quantity of matter or a region in space chosen for study. The mass or region outside the system is called the surroundings.

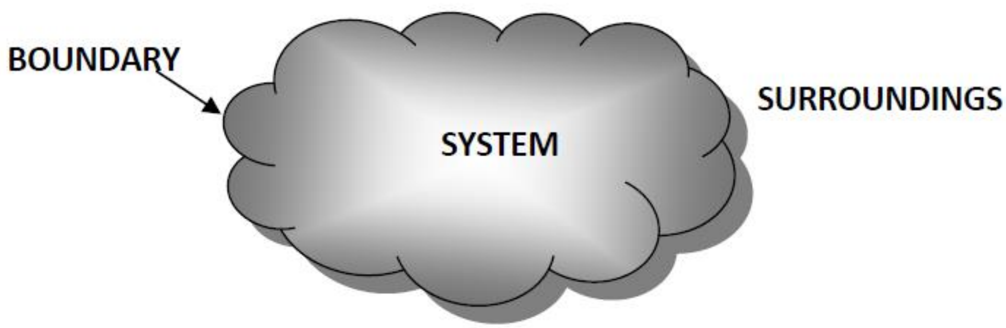


Fig. 1: System, surroundings, and boundary

Boundary: the real or imaginary surface that separates the system from its surroundings. The boundaries of a system can be fixed or movable. Mathematically, the boundary has zero thickness, no mass, and no volume.

Closed system or control mass: consists of a fixed amount of mass, and no mass can cross its boundary. But, energy in the form of heat or work, can cross the boundary, and the volume of a closed system does not have to be fixed.

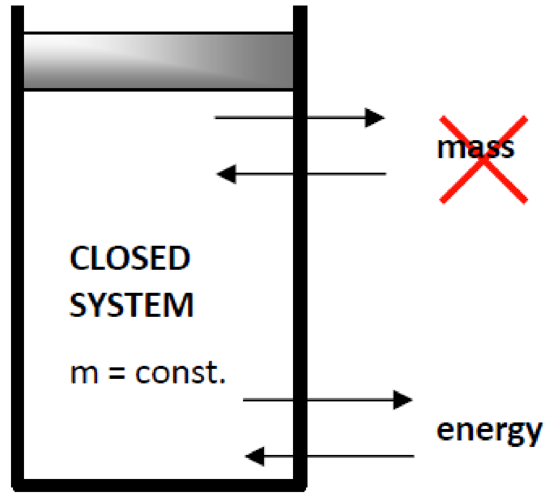
Open system or control volume: is a properly selected region in space. It usually encloses a device that involves mass flow such as a compressor. Both mass and energy can cross the boundary of a control volume.

Important note: some thermodynamics relations that are applicable to closed and open systems are different. Thus, it is extremely important to recognize the type of system we have before start analyzing it.

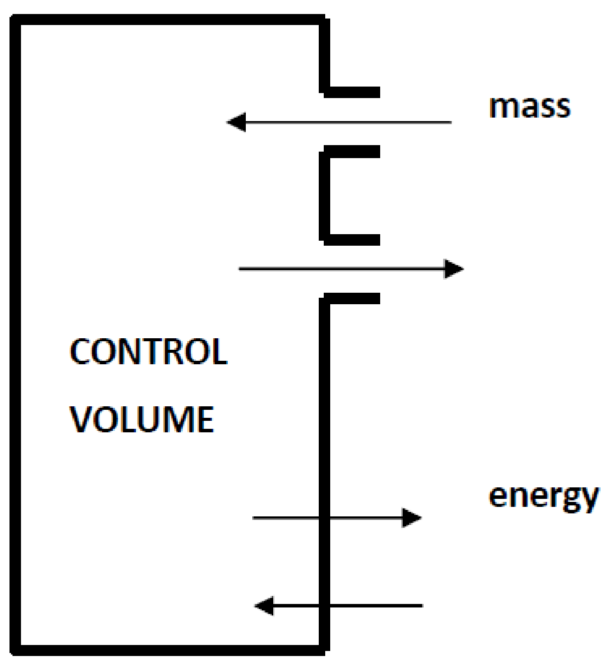
Isolated system: A closed system that does not communicate with the surroundings by any means.

Rigid system: A closed system that communicates with the surroundings by heat only.

Adiabatic system: A closed or open system that does not exchange energy with the surroundings by heat.



. 2: Closed system, mass cannot cross the boundaries, but energy can.



3: Control volume, both mass and energy can cross the boundaries.

Kinetic energy: energy that a system posses as a result of its relative motion relative to some reference frame, KE

$$KE = \frac{mV^2}{2} \qquad (kJ)$$

Where V is the velocity of the system in (m/s)

.

Potential energy: is the energy that a system posses as a result of its elevation in a gravitational field, PE

$$PE = mgz \qquad (kJ)$$

where g is the gravitational acceleration and z is the elevation of the center of gravity of the system relative to some arbitrary reference plane.

Microscopic forms of energy: are those related to molecular structure of a system. They are independent of outside reference frames. The sum of microscopic energy is called the *internal energy, U*.

The total energy of a system consists of the kinetic, potential, and internal energies:

$$E = U + KE + PE = U + \frac{mV^2}{2} + mgz$$

Properties of a System

Any characteristic of a system is called a *property*. In classical thermodynamics, the substance is assumed to be a *continuum*, homogenous matter with no microscopic holes.
This assumption holds as long as the volumes, and length scales are large with respect to the intermolecular spacing.

Intensive properties: are those that are independent of the size (mass) of a system, such as temperature, pressure, and density. They are not additive.

Extensive properties: values that are dependant on size of the system such as mass, volume, and total energy U. They are additive.

- Generally, uppercase letters are used to denote extensive properties (except mass m), and lower case letters are used for intensive properties (except pressure P, temperature T).
- Extensive properties per unit mass are called specific properties, e.g. specific volume (v=V/m).

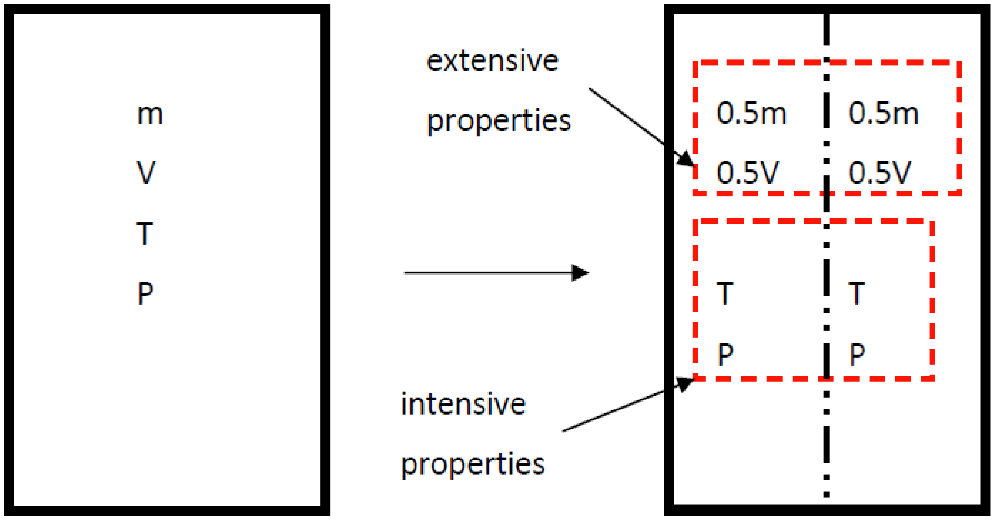


Fig. 1-5: Intensive and extensive properties of a system.

The change in the state of the system occurs at different conditions, summarized in the following;

The adiabatic process: The system does not lose the or acquire heat energy.

The Isothermal Process is the process that occurs at the temperature stability

The isobaric process is the process that occurs at constant pressure.

Isochoric Process is the process that occurs at a fixed size.

Cyclic Process is the process in which the system moves in a circular shape due to its first position (that is, its internal energy does not change)

First law in thermodynamics:

The first law expresses the relationship between work and heat. If a quantity of mechanical energy is converted into thermal energy within an isolated system, there is a correlation between these two quantities called the thermal mechanical equivalent of 4.18 Joules.

Joule was the first to conduct systematic experiments to study this transformation and set the proportionality constant

عزيزى الطالب سوف تدرس فى الفرقة الثانية مقرر كامل سوف يتناول الديناميكا الحرارية ونكتفى هنا ببعض المفاهيم والتعريفات الخاصة والمهمة لمدخل مقرر الديناميكا الحرارية