CANTT ACADEMY

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WE OWN OUR STUDENTS

Unit No.08 Thermal properties of matter

TEMPERATURE: - The temperature of a body is the degree of hotness or coldness of the body.

HEAT:- Heat is the energy that is transferred from one body to another body in thermal contact with each other as a result of the difference of temperature between them.

INTERNAL ENERGY: - The sum of kinetic energy and potential energy associated with the atoms, molecules and particles of a body is called its internal energy.

THERMOMETER: - A device that is used to measure temperature of a body is called thermometer.

SCALES OF TEMPERATURE: - Three scales of temperature are in common use.

1) Centigrade or celcius scale 2) Fahranheit scale 3) Kelvin scale

CONVERSION OF TEMPERATURE FROM ONE SCALE TO ANOTHER: -

From celcius to Kelvin scale

$T_K = 273 + T_C$

From Celcius to Fahranheit scale

$T_F = (1.8)\,T_C + 32$

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Example – No - 8.2: What will be the temperature when it is 20 ^{0}C on scale of celcius?

Temperature in centigrade = $T_C = 20\ ^0C$

Temperature in Kelvin scale = T_K =?

We know: -

$T_K = T_C + 273$

$T_K = 20 + 273$

$T_K = 293$ K

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Example – No – 8.2: Change 300K on Kelvin scale into Celcius scale of temperature.

Temperature in Kelvin scale = T_K = 300K

Temperature in Celcius = T_C =?

We know: -

$T_K = T_C + 273$

$300 = T_C + 273$

$300 - 273 = T_C$

$T_C = 27\ ^0C$

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Example – No – 8.3: Convert 50 ^{0}C on Celcius scale in to Fahrenheit scale: -

Temperature in celcius scale = T_C = 50 ^{0}C

Temperature in Fahrenheit scale = T_F =?

We know

$T_F = (1.8)\, T_C + 32$

$T_F = (1.8)\,(50) + 32$

$T_F = 122\ ^0F$

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Example – No – 8.4: Convert 100 ^{0}F into the temperature on celcius scale.

Temperature in Fahrenheit scale = T_F = 100 ^{0}F

Temperature in celcius scale = T_C =?

We know

$T_F = (1.8)\, T_C + 32$

$100 = (1.8)\, T_C + 32$

$100 - 32 + (1.8)\, T_C$

$68 = (1.8)\, T_C$

$\frac{68}{1.8} = T_C$

$T_C = 37.8\ ^0C$

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<u>SPECIFIC HEAT CAPACITY</u>: - The specific heat of a substance is the amount heat required to raise the temperature of 1 kg mass of the substance through 1K.

<u>EXPLANATION</u>: - When a body is heated then its temperature increases. From different experiment it has been found that the amount of (Quantity of) heat absorbed by a body is directly proportional to mass of the body and it is also directly proportional to increase in temperature.

$\Delta Q \propto m \rightarrow (1)$

$\Delta Q \propto \Delta T \rightarrow (2)$

From (1) and (2)

$\Delta Q \propto m\Delta T$

$\Delta Q = (\text{Constant})\, m\Delta T$

Constant = c

$\Delta Q = c\, m\Delta T$

Here “C” is constant and it known as specific heat capacity or specific heat.

$\Delta Q = cm\Delta T$

$c = \frac{\Delta Q}{m\Delta T}$

<u>UNIT</u>: - The unit of specific heat is $JKg^{-1}K^{-1}$

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QUESTION: - Why the temperature of land rises and falls more rapidly than that of the sea?

Answer: - specific heat of water is 4200 JKg^{-1} K^{-1} and specific heat of dry soil 810 JKg^{-1} K^{-1}. Therefore the temperature of soil would increase five times more than the same amount of water. As a result the temperature of the land rises and falls more rapidly than that of the sea.

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QUESTION: - How large specific heat of water is used to maintain the temperature of engine of automobile?

Answer: - Water has large specific heat capacity. Therefore it is very useful in storing and carrying thermal energy the cooling system of automobile uses water to carry away a unwanted thermal energy. In automobile large amount of heat produced by the engine the engine would cease unless it is not cool down water circulating around the engine absorb the heat energy and through it away through its radiator.

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PAGE – NO # 175:- EXAMPLE – NO – 8.5

A Container has 2.5 liter of water is required to boil a water?

Solution:- Volume of water = 2.5 liter.

Mass of water = m = 2.5 kg

Specific heat of water = C = 4200 JKg^{-1} K^{-1}

Initial temperature = t_1 = 20 ^{0}C = 20 + 273 = 293 K

Final temperature = t_2 = 100 ^{0}C = 100 + 273 = 373 K

Increase in temperature = $\Delta T = t_2 - t_1$

$= \Delta T = 373 - 293$

$= \Delta T = 100$ k

Amount of heat = Q =?

we know

$Q = cm\,\Delta T$

Q = (4200) (2.5) (100) = 840,000 J

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HEAT CAPACITY: - The quantity of thermal energy absorbed by a body for one Kelvin increase in its temperature is called heat capacity.

Heat capacity = $\frac{\Delta Q}{\Delta T}$

Putting value of 'ΔQ'

Heat capacity = $\frac{cm\Delta T}{\Delta T}$

Heat capacity = $\frac{cm\Delta T}{c\Delta T}$

Heat capacity = mc

The above relation shows that heat capacity of a body is equal to the product of it's mass and it's specific heat.

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LATENT HEAT OF FUSION: - Heat energy require to change unit mass of a substance from solid to liquid state at it's melting point without change in its temperature is called its latent heat of fusion.

It is denoted by H_F.

$$H_F = \frac{\Delta QF}{m}$$

$$\Delta Q_F = mH_F$$

Latent heat of fusion of ice is 3.36 x 10^5 JKg^{-1}

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LATENT HEAT OF VAPORIZATION: - The quantity of heat that changes unit mass of a liquid completely into gas at its boiling point without any change in its temperature is called its latent heat of vaporization.

It is denoted by H_V.

$$H_V = \frac{\Delta QV}{m} \quad \text{OR} \quad \Delta Q_V = mH_V.$$

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QUESTION: - What is evaporation? Write the factors of affecting evaporation?

EVAPORATION: - It is a process in which a liquid is changes into vapour from the surface of the liquid without heating it. Evaporation takes place at all temperature. The rate of evaporation depends upon four major factors.

i) Temperature ii) Surface area iii) Wind iv) Nature of the liquid

TEMPERATURE: - The rate of evaporation is faster at high temperature and the rate of evaporation is slow at lower temperature.

SURFACE AREA:- If surface area of a liquid is large than greater number of molecules will escape from the surface of liquid. Therefore we can say that the rate of evaporation is faster if a liquid has large surface area.

WIND: **-** If wind is blowing over the surface over the liquid than more molecules will escape from the surface of liquid. As a result the rate of evaporation increases.

NATURE OF LIQUID: **-** Different liquids have different rate of evaporation because the rate of evaporation depends upon nature of liquid. Those liquids which have volatile nature will evaporate much faster than other liquids.

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QUESTION: - Why wet clothes dry up more quickly in summer than in winter?

Answer: - We know that wet clothes dry due to process of evaporation. In summer season the temperature is high. At this higher temperature more molecules of liquid escape from its surface. As a result the rate of evaporation becomes fast. Therefore wet clothes dry up more quickly in summer than in winter.

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Question: **- Spread a few drops of ether or spirit on your palm you feel cold. Why?**

Answer: **-** When we spread few drops of ether or spirit on our palm then both the ether or spirit evaporates by absorbing heat from our palm as a result we feel cold.

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LINEAR THERMAL EXPANSION IN SOLIDS: -

The expansion in length of a solid due to heat is called linear thermal expansion.

EXPLANATION: -

Consider a metal rod of length $\mathbf{L_o}$ at a certain temperature $\mathbf{T_o}$. The length of the rod becomes '**L**' after heating it at a temperature '**T**'

Now,

Change in length = $\Delta L = L - L_o$

Change in temperature = $\Delta T = T - T_o$

From different experiment it has been found that the change in length of a solid is directly proportional to its original length and change in temperature.

Change in length $\propto$ original length

$\Delta L \propto L_o \longrightarrow$ (i)

Change in length $\propto$ Change in temperature

$\Delta L \propto \Delta T \longrightarrow$ (ii)

From (i) and (ii)

$\Delta L \propto L_o \Delta T$

$\Delta L = (\text{Constant}) L_o \Delta T$

Here constant = $\propto$

so $\Delta L = \propto L_o \Delta T$

Putting value of 'ΔL'

$L - L_o = \propto L_o \Delta T$

$L = L_o + \propto L_o \Delta T$

Taking 'L_o' as common

$L = L_o [1 + \propto \Delta T]$

Here '$\propto$' is constant known as coefficient of linear expression.

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COEFFICIENT OF LINEAR EXPRESSION: - Fractional increase in length of a solid per Kelvin rise in its temperature is called coefficient of linear expansion.

$\Delta L = \propto L_o \Delta T$

$\frac{\Delta L}{L_o \Delta T} = \propto$

$\propto = \frac{\Delta L}{L_o \Delta T}$

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<u>VOLUME THERMAL EXPANSION</u>: - The expansion in volume of a body due to heat is called volume thermal expansion.

EXPLANATION: **-** Consider a solid of initial volume V_o at a certain temperature T_o. The volume of the solid becomes "V" after heating it at temperature T.

Now, Change in volume = $\Delta V = V - V_o$

Change in temperature = $\Delta T = T - T_o$

From different experiments it has been found that the change in volume of a solid is directly proportional to its original volume and change in temperature.

Change in volume $\propto$ original volume

$\Delta V \propto V_o \longrightarrow (1)$

Change in volume $\propto$ Change in temperature

$\Delta V \propto \Delta T \longrightarrow (2)$

From (1) and (2)

$\Delta V \propto V_o\Delta T$

$\Delta V = (\text{Constant})\, V_o\Delta T$

Here constant = β

$\Delta V = \beta\, V_o\, \Delta T$

Putting value of 'ΔV'

$V - V_o = \beta\, V_o\, \Delta T$

$V = V_o + \beta\, V_o\, \Delta T$

Taking (V_o) as common

$V = V_o\, [1 + \beta\Delta T]$

Here β is a constant known as coefficient of volume expansion.

COEFFICIENT OF VALUE EXPANSION: - Fractional change in volume per Kelvin rise in temperature is called coefficient of volume expansion. $\Delta V = \beta V_o\Delta T$

$$\beta = \frac{\Delta V}{V\Delta T}$$

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QUESTION: - 1) Why gaps are left in railways tracks?

Ans: - We know that solid expand on heating this expansion of solid can damage railway tracks in hot summer season. During day time in hot summer season due to increase in temperature the length of railway track increases. This increase in length can damage railway track. To avoid this damage gaps are left in railway tracks.

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QUESTION: - 2) Why one end of bridges made of steel girders is placed on rollers?

Ans: - Bridges made of steel girders expend during the day time and contract during night. If both ends of these girders are fixed then these girders bend and damage the structure of the bridge. To avoid this damage one end of these girders is fixed and the other end is placed on rollers.

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QUESTION: - 3) How we can open the cap of bottle that is very tite?

Ans: - To open the cap of a bottle that is very tite we immerse that bottle in hot water for some time. Due to heat of hot water the matle cap expand and become loose. Now we can easily open the cap of the bottle.

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QUESTION: - 4) What is bi metal strip? Write its uses.

Ans: - A bi metal strip consist of two thin strips of different metals such as brass and iron joined together. When a bi metal strip is heated then brass expands more than iron. This unequal expansion causes bending of the strip. This bending property is used for different purposes.

USES: -

1) Bi metal strips are used to measure the temperature in furnances and ovens.
2) Bi metal strips are used in thermostats. These thermostats are used to control the temperature of heater coil in an electric iron.

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QUESTIONS: - 5) what is anomalous expansion of water?

Ans: - Water on cooling below 4^0C begins to expand until it reaches 0^0C. On further cooling it changes in to ice. On the other hand when ice is cooled below 0^0C then its volume decreases. This unequal expansion of water is called anomalous expansion of water.

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Numerical Problems

8.1) Temperature of water in a beaker is 50^0 C. What is its value in Fahrenheit scale? **Data**: Temperature in Centigrade = $T_C = 50^0C$ Temperature in Fahrenheit = T_F =? **Solution**: - We know $T_F = (1.8)\ T_C + 32$ $T_F = (1.8)(50) + 32$ $T_F = 90 + 32$ $T_F = 122^0F$	**8.2) Normal human body temperature is 98.6^0F. Convert into Celsius scale and Kelvin scale?** **Data**: - Temperature in Fahrenheit = $T_F = 98.6\ ^0F$ Temperature in Centigrade = T_c =? Temperature in Kelvin = T_K =? **Solution: -** We know $T_F = (1.8)\ T_C + 32$ $98.6 = (1.8)\ T_C + 32$ $98.6 - 32 = (1.8)\ T_C$ $66.6 = (1.8)\ T_C = \frac{66.6}{1.8} = T_c = 37 = T_c = 37^0C$ Now $T_k = T_C + 273$ $T_k = 37 + 273$ $T_k = 310$ K
8.3) Calculate the increase in the length of a aluminum bar 2 m long when heated from 0^0C to 20^0C. The thermal coefficient of linear expansion of aluminum is linear expansion of aluminum is $2.5 \times 10^{-5} K^{-1}$. **Data**: - Initial length = $L_o = 2$ m Initial Temperature = $T_o = 0^0C = 0 + 273 = 273$ K Final Temperature = T = $20^0C = 20 + 273 = 293$ K Increase in length = ΔL =? Coefficient of linear thermal expansion = $\propto = 2.5 \times 10^{-5} k^{-1}$ **Solution**: - We know $\Delta L = \propto L_o \Delta T$ Here, $\Delta T = T - T_o$ $= 293 - 273 = 20$ K Now, $\Delta L = \propto L_o \Delta T$ $\Delta L = (2.5 \times 10^{-5})\ (2)\ (20)$ $\Delta L = (5 \times 10^{-5})\ (20)$ $\Delta L = 100 \times 10^{-5}$ m	**8.4) A balloon contains 1.2 m^3 air at 15 ^{0}C. Find its volume at 40^0C. Thermal coefficient of volume expansion of air is 3.67×10^{-3} K^{-1}.** **Data**: - Initial volume = $V_o = 1.2\ m^3$ Final Volume = V =? Initial Temperature = $T_o = 15^0C = 15 + 273 = 288$ K Final Temperature = T = $40^0C = 40 + 273 = 313$ k Coefficient of Volume expansion = $\beta = 3.67 \times 10^{-3} K^{-1}$ **Solution**: - We know $V = V_o (1 + \beta \Delta T)$ Here, $\Delta T = T - T_o$ $= 313 - 288 = 25$ K Now, $V = V_o (1 + \beta \Delta T)$ $V = 1.2 \times (1 + 3.67 \times 10^{-3} \times 25)$ $V = 1.2 \times (1 + 91.75 \times 10^{-3}$ $V = 1.2 \times (1 + 0.09175)$ $V = 1.2 \times (1.09175)$ $V = 1.3101\ m^3$
8.5) How much heat is required to increase the temperature of 0.5 Kg of water from 10^0C to 65 ^{0}C. **Data:** Mass = m = 0.5 Kg	**8.6) An electric heater supplies heat at the rate of 1000 joules per second. how much time is required to raise the temperature of 200 g of water from 20^0C to 90^0C?** **Data: -** Power = P = 1000 Js^{-1}

Initial Temperature = T_o = 10^0C = 10 + 273 = 283 K

Final Temperature = T = 65^0C = 65 + 273 = 338 K

Specific heat of water = C = 4200 $JKg^{-1}K^{-1}$

Heat = Q =?

Solution:

We know

Q = cmΔT

Here, $\Delta T = T - T_o$

$= 338 - 283$

$= 55$ K

Now,

Q = cmΔT

Q = 4200 x 0.5 x 55

Q = 2100 (55)

Q = 11500 J

Mass = m = 200 g = $\frac{200}{1000}$ = 0.2 Kg

Initial Temperature = T_o = 20^0C = 20 + 273 = 293 K

Final Temperature = T = 90^0C = 92 + 273 = 363 K

Time = t =?

Specific heat of water = C = 4200 $JKg^{-1}K^{-1}$

Solution:

We know

Power = $\frac{Energy}{Time}$

Energy = Heat = Q

So, P = $\frac{Q}{t}$

First we will find value of Q

We Know

Q = CmΔT

Here, $\Delta T = T - T_o$

$= 363 - 293 = 70$ K

Now, Q = CmΔT

Q = (4200) (0.2) (70)

Q = 58800 J

Now, P = $\frac{Q}{t}$

1000 = $\frac{58800}{t}$

t = $\frac{58800}{1000}$ = 58.8 Sec

8.7) How much ice will melt by 50000 J of heat? Latent heat of fusion of ice = 336000 JKg^{-1}.

Data: -

Mass = m =?

Heat = Q =50,000 J

Latent heat of fusion of ice = H_F = 336000 $JKg^{-1}K^{-1}$

Solution: -

We know

Latent of fusion = $\frac{Qf}{m}$

$H_F = \frac{Q_F}{m}$

336000 = $\frac{50000}{m}$

m = $\frac{50000}{336000}$

m = 0.15

m = 150 Kg

8.8) Fin the quantity of heat needed to melt 100 g of ice at – 10^0C into water at 10^0C.
(Note: specific heat of ice is 2100 $JKg^{-1}K^{-1}$, specific heat of water is 4200 $JKg^{-1}K^{-1}$, Latent heat of fusion of ice is 336000 JKg^{-1}).

Data: -

Mass = m =100g

Mass = m = $\frac{100}{1000}$ = 0.1 Kg

Heat = Q =?

- 10^0 C→ $0^0 C \rightarrow 0^0 C \rightarrow 10^0 C$

Ice Water Water

i) At - 10^0C → 0^0C

Q_1 = mcΔT

Q_1 = (0.1)(2100)(T - T_o)

Q_1 = (210)(0 – (- 10)

Q_1 = (210)(0+10)

Q_1 = (210)(10) = 2100 J

ii) Heat required 0^0C ice to 0^0C water

Q_F = m H_F

Q_F = (0.1) (336000)

Q_F = 33600 J

iii) Heat required 0^0C water into 10^0C water.

Q_2 = mcΔT

Q_2 = (0.1)(4200)(10)

	Q_2 = 4200 j Now $Q = Q_1 + Q_F + Q_2$ Q = 2100 + 33600 + 4200 Q = 39900 J
8.9) How much heat is required to change 100 g of water at 100^0C into steam? (Latent heat of vaporization of water is 2.26×10^6 JKg^{-1}. **Data: -** Heat = Q =? Mass = m = 100g = $\frac{100}{1000}$ = 0.1 Kg Latent heat of vaporization of water = H_V = 2.26×10^6 JKg^{-1} K^{-1} **Solution**: - We know $Q = m H_V$ $Q = (0.1)(2.26 \times 10^6)$ $Q = 0.226 \times 10^6$ $Q = 2.26 \times 10^5$ J **Q) How does a refrigerator work?** **Ans: -** Cooling is produced in refrigerators by evaporation of liquefied gas. This produce cooling effect. Freon, a CFC was used as a refrigerant gas. but CFC cause ozone depletion in atmosphere which results increase in amount of UV rays from the sun. UV rays are from the sun. UV rays are harmful to all living matter. So Freon gas is replaced by ammonia and other substances which are not harmful to us.	**8.10) Find the temperature of water after passing 5 g of steam at 100^0C through 500 g of water at 10^0C. (Note: Specific heat of water is 4200 JKg^{-1}, latent heat of vaporization of water is 2.26×10^6 JKg^{-1}).** **Data: -** Mass of steam = m_1 = 5g = $\frac{5}{1000}$ = 0.005 Kg Temperature of steam = T_1 = 100^0C = 273+100 =383 K Mass of water = m_2 = 500 g = $\frac{500}{1000}$ = 0.5 Kg Temperature of water = T_2 = 10^0C = 273 + 10 = 283 K Specific heat of water = c = 4200 $JKg^{-1}K^{-1}$ Latent heat of vaporization = H_V = 2.26×10^6 JKg^{-1} **Solution: -** Heat lost by steam + heat gained by water = Heat gained by water $Q_1 + Q_2 = Q_3$ First we find heat lost by gained. $Q_1 = m H_V$ $Q_1 = (0.005)(2.25 \times 10^6)$ $Q_1 = 0.0113 \times 10^6$ Q_1 = 11300 J Now heat lost by water from 100^0C to final temperature $Q_2 = Cm_2\Delta T$ $Q_2 = (4200)(0.005)(100 - T_2)$ $Q_2 = 21\ (100 - T_2)$ $Q_2 = 2100 - 21T_2$ Now we find the heat gained by water from 10^0 to final temperature $Q_3 = Cm_1\Delta T$ $Q_3 = 4200 \times 0.5\ (T_2 - 10)$ $Q_3 = 2100\ (T_2 - 10)$ $Q_3 = 2100T_2 - 21000$ $Q_1 + Q_2 = Q_3$ $1300 + 2100 + 21T_2 = 2100T_2 - 2100$ $13400 - 21T_2 = 2100T_2 - 21000$ $13400 + 21T_2 = 2100\ T_2 + 21T_2$ $34400 = 2121T_2$ $\frac{34400}{2121} = T_2$ $16.21 = T_2$ $T_2 = 16.21^0$C