5. HEAT

- **Heat :** Heat is the form of energy which flows between two objects or systems as a result of temperature difference between them. Heat is also called **thermal energy**.
  - **Units of heat :** Its S.I. unit is Joules (J). Other commonly used unit is Calorie (cal).
  - **Calorie** is the amount of heat required to raise the temperature of 1 gram of water by 1℃.

    1 Calorie = 4.18 J ≈ 4.2 J

    1 kilocalorie (kcal) = 1000 calories = 4180 J

    1 kilojoule (kJ) = 1000 J

    1 megajoule (MJ) = 10^6 J
  - Heat naturally flows from high temperature to low temperature.
  - If heat can flow between two objects or systems, the objects or systems are said to be in **thermal contact**.
- **Temperature :** The measure of degree of hotness or coldness of a body is called its temperature.
  - Energy must be either added to or removed from a substance to change its temperature.
  - **Thermal equilibrium :** It is the state in which two bodies in physical contact with each other have identical temperatures.
  - **Zeroth law of thermodynamics :** It two bodies A and B are in thermal equilibrium with a third body C, then A and B must be in thermal equilibrium with each other.
  - **Thermometry :** The branch of physics that deals with measurement of temperature, temperature scales and temperature measuring devices is called **thermometry**.
  - **Thermometer :** It is an instrument used for measuring the temperature of a substance.
  - **Types of thermometers**
    - **Liquid thermometer :** Works on the principle of change in the volume of a liquid with the change in temperature. The temperature range for a mercury thermometer is – 50 ℃ to 357 ℃ but the range can be increased to 550 ℃ by filling nitrogen in the space over mercury column under high pressure. Temperature range for alcohol thermometer is – 80 ℃ to 78 ℃.
    - **Gas thermometer :** Works on the principle of change in pressure or volume of a gas with temperature. Gases used are usually air, hydrogen, helium. A constant volume hydrogen based gas thermometer has a temperature range of – 200 ℃ to 500 ℃.
    - **Resistance thermometer :** Works on the principle of change in resistance with the change in temperature. Using a platinum resistance thermometer range of temperature for a resistance thermometer is – 200 ℃ to 1200 ℃.
    - Some other thermometers are (a) Bimetallic thermometers (b) Thermocouple thermometers (c) Pyrometers
    - Pyrometers are used to measure very high temperatures, usually > 1000 ℃ till 4000 ℃.
  - **Triple point**
    - To measure temperature, two fixed points are taken on thermometers or temperature measuring device. In old thermometry, one fixed point is the melting point of ice (or freezing point of water) called **ice point** (lower fixed point). The other fixed point is the boiling point of water called **steam point** (upper fixed point).
    - In modern thermometry, instead of two fixed points only one point is taken which is 'triple temperature point of water'.
    - It is that condition of temperature and pressure at which all the three states of matter namely, solid, liquid and gas co-exist in equilibrium with each other. This point is unique for every substance i.e., it occurs at a fixed temperature and fixed pressure for a given substance. For example, triple point of water is 0.01 ℃ at a pressure of 4.6 mm of mercury.
- **Temperature scales**
  - **Fahrenheit scale (℉)**
    - **Gabriel Fahrenheit** (1686–1736), a physicist, invented the alcohol thermometer in 1709 and the mercury thermometer in 1714.
    - The upper and lower fixed points of Fahrenheit scale are 212 ℉ and 32 ℉.

- **Centigrade scale (°C) or Celsius scale**
  - **Anders Celsius** (1701–1744), an astronomer, devised the centigrade scale of temperature in 1742.
  - The upper and lower fixed points of Centigrade scale are 100 °C and 0 °C.
- **Kelvin Scale (K)**
  - **Lord Kelvin (Sir William Thomson)** (1824–1907), a mathematician and physicist, developed the absolute temperature scale (now named the Kelvin scale).
  - The upper and lower fixed points of Kelvin scale are 373 K and 273 K.
  - **Absolute zero** is the lowest temperature possible in the universe. At absolute zero, there is no heat and the motion of particles (atoms or molecules) ceases (stops).
  - Absolute zero occurs at – 273 °C or – 459 °F.
  - A temperature in Celsius measures only relative thermal energy, relative to zero Celsius. The Kelvin temperature scale is useful in science because it starts at absolute zero, the minimum possible temperature. A temperature in Kelvin measures the actual energy of atoms relative to zero energy.
  - Kelvin Scale is also called '**thermodynamic scale**' or '**absolute temperature scale**'.
- **Reaumur Scale (°R) :** The upper and lower fixed points of Reaumur scale are 80 °R and 0 °R.
- **Rankine Scale (Ra) :** The upper and lower fixed points on Rankine scale are 672 °Ra and 492 °Ra.
- **Relation between different temperature scales**

$$\frac{C-0}{100-0}=\frac{F-32}{212-32}=\frac{R-0}{80-0}=\frac{K-273}{373-273}=\frac{Ra-492}{672-492}=\frac{T-\text{L.F.P.}}{\text{U.F.P.}-\text{L.F.P}}$$

or $$\frac{C-0}{100}=\frac{F-32}{180}=\frac{R-0}{80}=\frac{K-273}{100}=\frac{Ra-492}{180}=\frac{T-\text{L.F.P.}}{\text{U.F.P.}-\text{L.F.P}}$$

Where, T is temperature of any scale, L.F.P is lower fixed point, U.F.P is upper fixed point.

- Also, $$\boxed{\frac{C}{5}=\frac{F-32}{9}=\frac{R}{4}=\frac{K-273}{5}=\frac{Ra-492}{9}}$$

■ **Thermal expansion :** Increasing the temperature of a substance causes the volume of the substance to increase. This phenomenon is known as **thermal expansion**.

- **Thermal expansion of solids :** Solids expand on heating but their expansion is quite small as compared to liquids or gases. This is because the attractive forces between the particles of the solids are quite strong as compared to liquids or gases. Also, different solids expand by different amounts for the same increase in temperature.
- **Linear expansion :** The change in any linear dimension of a solid such as length, width or thickness is called 'linear expansion'.
  - Let a wire of length L be heated to increase its temperature by ΔT. Let the increase in its length be ΔL. Now,

$$\alpha=\frac{\Delta L}{L\Delta T}$$ where α = coefficient of linear expansion.

  - The '**coefficient of linear expansion**' is defined as the fractional change in length per unit change in temperature.
  - Units of α are $°C^{-1}$ or K^{-1}.
- **Area expansion :** The change in area of a solid due to change in its temperature is called 'area expansion'.
  - Let a solid of surface area A be heated to increase its temperature by ΔT. Let the increase in its area be ΔA. Now,

$$\beta=\frac{\Delta A}{A\Delta T}$$ where β = coefficient of area expansion/superficial expansion.

  - The '**coefficient of area expansion**' is defined as the fractional change in area per unit change in temperature.
  - Units of β are $°C^{-1}$ or K^{-1}.
- **Volumetric expansion :** The change in volume of a substance due to change in its temperature is called 'volumetric expansion'. The substance here may be solid, liquid or gas.

- Let a substance of volume V be heated to increase its temperature by ΔT. Let the increase in its volume be ΔV. Now,

$$\gamma = \frac{\Delta V}{V \Delta T} \qquad \text{where } \gamma = \text{coefficient of volumetric expansion.}$$

- The '**coefficient of volumetric expansion**' is defined as the fractional change in volume per unit change in temperature.
- Units of γ are $°C^{-1}$ or K^{-1}.

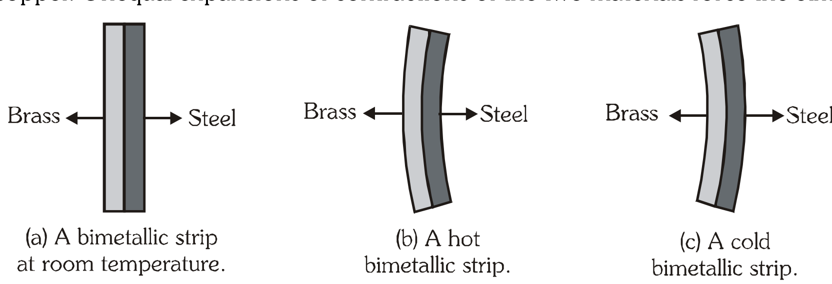
- **Relationship between α, β, γ :** $\boxed{\frac{\alpha}{1} = \frac{\beta}{2} = \frac{\gamma}{3}}$
- **Thermal expansion of liquids :** The attractive forces between the particles in liquids are usually weaker than the forces between the particles in a solid. As a result, the same temperature increase usually causes liquids to expand much more than solids. For example, the liquid in the thermometer expands as its temperature increases. However, the size of the glass tube containing the liquid hardly changes at all.
- **Thermal expansion of gases** : In a gas, the attractive forces between particles are much weaker than they are in liquids. As a result, gases expand even more than liquids for the same increase in temperature.
- **Change in the density of a material on changing temperature :** When a material is heated, thermal expansion occurs, the volume of the material increases. Because the material's volume has increased, but its mass hasn't changed, the density of the material decreases. Similarly, on cooling, the material contracts i.e., volume of material decreases, thus, the density of material increases.

■ **The unusual behaviour of water :** Liquids generally increase in volume with increasing temperature and have average coefficients of volume expansion about ten times greater than those of solids. Water is an exception to this rule.

- As the temperature increases from 0°C to 4°C, water contracts and thus its density increases.
- Above 4°C, water expands with increasing temperature, and so its density decreases.
- The density of water reaches a maximum value of 1000 kg/m^3 at 4°C.
- Due to this, water in a pond begins freezing at the surface rather than at the bottom. When the atmospheric temperature drops from, say, 7°C to 6°C, the surface water also cools and consequently decreases in volume. The surface water is denser than the water below it, which has not cooled and decreased in volume. As a result, the surface water sinks, and warmer water from below is forced to the surface to be cooled. When the atmospheric temperature is between 4°C and 0°C, however, the surface water expands as it cools, becoming less dense than the water below it. The mixing process stops, and eventually the surface water freezes. As the water freezes, the ice remains on the surface because ice is less dense than water. The ice continues to build up at the surface, while water near the bottom remains at 4°C. If this were not the case, then fish and other forms of marine life would not survive.

■ **Applications of thermal expansion**

- **Bimetallic strip :** When two strips of same length made of different metals are joined together and then heated, one expands more than the other. This is called '**differential (unequal) expansion**'. The joined strips when heated (or cooled) bend into a curve, allowing one strip to expand (or contract) more than the other. The bimetallic strip is made by joining a less expanding material (having smaller linear expansion coefficient) such as steel or iron with a more expanding material (having larger linear expansion coefficient) such as brass or copper. Unequal expansions or contractions of the two materials force the bimetallic strip to bend.



A bimetallic strip.

- **Thermostat :** It keeps the temperature of a room or a device constant. The bending of the bimetallic strip closes or opens an electrical switch in the thermostat that turns the air conditioner or any other electric device on or off.

- **Fire alarm :** It also utilises bimetallic strip in its working. Heat from the fire makes the bimetallic strip bend and completes the electrical circuit, hence ringing the alarm bell.
- **Expansion joints in rails :** The railway tracks over which trains run are made of iron. During summer, the iron expands. To allow this expansion, space has to be left between two sections of the rail tracks. If this is not done, expansion of the tracks can cause them to bend. This can cause serious accidents.
- **Sagging and tightening of electric cables :** In summer, electric cables between two poles expand and sag. In winter, they contract and get tightened. If cables are fixed in summer, they must be left a little loose to allow for contraction during winter. If this is not done, they may break on contraction in winter. Similarly, in winter they should be fixed tight such that they will sag only a little in summer.
- **Roller for expansion or contraction in steel bridges :** Bridges are usually put on rollers so that they can expand and contract without any damage. One end of the steel bridges is made to rest on rollers with enough space provided for expansion during summer.
- **Loops in the metal pipeline :** Pipelines carrying liquids often have loops to allow for expansion and contraction due to temperature changes. Without the loops, the pipes could buckle and burst. During changes in temperature, the loops register only a slight change in their curvature and the overall pipeline is not disturbed.
- **Fitting the steel rim on wheels of train :** The steel rim is made smaller than the wheel. The steel rim is heated till its diameter becomes slightly more than the wheel. The rim is then slipped over the wheel. On cooling, the rim contracts and makes a tight fit on the wheel.
- **Riveting :** For joining the two steel plates, they are placed one above the other and holes are drilled in them. The rivets (small cylindrical steel rods) are made hot and inserted in the holes of the plate. The ends of the rivet are hammered into the spherical heads. This can be done easily in heated condition as heating of rivets makes them soft. When the rivets cool, they force plates to come closer and firmly grip them together.

■ **Calorimetry :** The branch of physics that deals with determination of specific heats, heat absorbed or released during a process, calorific values of combustible substances is called calorimetry.

- **Specific heat (c) :** The amount of heat required for a unit increase in the temperature of unit mass of a substance is called its specific heat.

  Heat absorbed or released by a substance, $\mathbf{Q = m\ c\ \Delta t}$

  where, m = mass of the substance ; c = specific heat of the substance ;

  Δt = change in temperature of the substance.

  - **Unit of specific heat :** J/kg/K or J/kg/°C
  - Specific heat depends on the state of substance i.e., solid, liquid or gas. For example, specific heats of water, ice and steam are different.

	Cal g^{-1} °C^{-1}	J kg^{-1} °C^{-1}
Specific heat of ice	0.5	2100
Specific heat of water	1.0	4200
Specific heat of steam	0.47	1970

  - Specific heat signifies the resistance (opposition) of a substance to a change in its temperature.
  - Sand heats up (or cools down) faster than water because the sand on a beach has a lower specific heat than water.
  - The tendency on the part of water to resist changes in temperature improves the climate in many locations.

- **Thermal capacity (heat capacity) :** Amount of heat needed to increase the temperature of a substance of any mass by 1°C is called thermal capacity of that substance.

  Thermal capacity = (mass of body) × (specific heat) or $\mathbf{H_c = mc}$

  - **Unit of heat capacity** : J/K or J/°C.
  - Water has a much higher capacity for storing energy than most of the common materials hence water is a very useful cooling agent used in the cooling systems of automobiles and other engines.

- **Molar heat capacity (molar specific heat)**

  $C = M_0c$ where, M_0 = molar mass (in kg) ; c = specific heat in J/kg/°C

  $Q = \mu C \Delta t$ where, Q = heat absorbed or released ; μ = number of moles.

  or $C = \frac{Q}{\mu \Delta t}$

  - **Unit of molar heat capacity :** J/mol/K or J/mol/°C.

■ **Principle of calorimetry :** When one body is kept in contact with another body, the body at higher temperature loses heat and the body at lower temperature gains heat such that finally both of them have same temperature. Such a temperature is called **equilibrium temperature**.

- According to principle of calorimetry, when two bodies at different temperatures are mixed together or kept in direct contact, heat will be transferred from body at higher temperature to the body at lower temperature till they acquire same temperature; heat lost by hot body is equal to the heat gained by the cold body.
- Let two substances of specific heats c_1, c_2 ; temperatures t_1, t_2 and masses m_1, m_2 respectively are kept in contact with each other. Let $t_1 > t_2$, after some time both the substances attain a final temperature t_e, then $t_1 > t_e > t_2$. According to principle of calorimetry,

  heat gained by cold body = heat lost by hot body

  $$m_2c_2(t_e - t_2) = m_1c_1(t_1 - t_e)$$

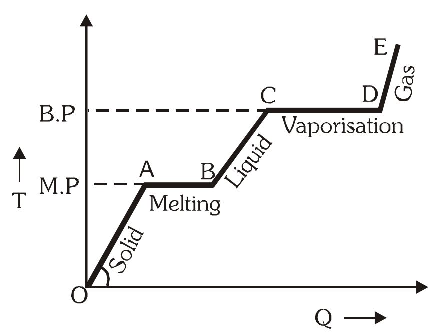
  On solving, we get, $$\boxed{t_e = \frac{m_1c_1t_1 + m_2c_2t_2}{m_1c_1 + m_2c_2}}$$

■ **Change of phase :** A substance changes its phase i.e. from solid to liquid or liquid to gas at constant temperature. A substance changes its state from solid to liquid at its '**melting point**'. Similarly, a substance changes its state from liquid to gas at its '**boiling point**'.

- **Latent heat :** It is the amount of heat absorbed or released per unit mass of a body during the change of state at constant temperature. There are two types of latent heat :
  - **Latent heat of fusion :** The heat per unit mass for the solid-liquid phase change is called the latent heat of fusion. Latent heat of fusion of ice is 80 Cal/g or 3.36×10^5 J/kg.
  - **Latent heat of vaporisation :** The heat per unit mass for the liquid-gas phase change is called the latent heat of vaporisation. The latent heat of vaporisation of water is 540 Cal/g or 2.27×10^6 J/kg.
  - Formula for latent heat : **Q = m L**

    Where, m = mass of the substance undergoing phase change and L is the latent heat.

- **Melting :** Melting occurs when a solid changes into a liquid. The **melting point** of a material is the temperature at which the material changes from a solid to a liquid.
- **Freezing :** Freezing occurs when a liquid changes into a solid. The **freezing point** is the temperature at which the liquid changes to a solid.
- **Vaporisation :** The change from a liquid to a gas is called '**vaporization**'. Vaporization can occur within a liquid and at the surface of a liquid. Vaporization that occurs within a liquid is called '**boiling**'.
- **Condensation :** The change from a gas to a liquid is called '**condensation**'. The **condensation point** is the temperature at which the gas changes to a liquid.

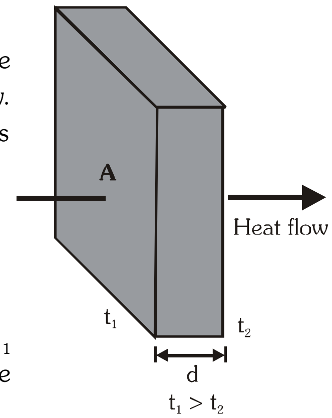


Conversion of a solid into vapour

- **Evaporation :** Vaporisation that occurs at the surface of a liquid is called '**evaporation**'. Evaporation occurs during boiling and at temperatures below the boiling point. During evaporation, the fastest particles leave the surface of the liquid. The particles that remain have less speeds. The liquid cools as evaporation occurs. You experience this cooling effect when perspiration evaporates from your skin.

■ **Methods of heat transfer :** Heat transfer can occur in three ways—by conduction, radiation, or convection.

- **Conduction :** The transfer of heat by the direct contact or collision of particles of matter.
  - Conduction usually occurs most easily in solids and liquids, where atoms and molecules are close together. So, atoms and molecules need to move only a short distance before they bump into one another and transfer energy. As a result, heat is transferred more rapidly by conductions in solids and liquids than in gases.



Heat conduction

  - Heat flow rate is given by, $$H = \frac{Q}{t} = kA\frac{(t_1 - t_2)}{d}$$

    where, H = heat flow rate, J/s; A is the area of heat transfer, m^2; k is a constant called **thermal conductivity**, J $m^{-1}K^{-1}s^{-1}$ or W $m^{-1}K^{-1}$; t_1 and t_2 are the temperatures, $t_1 > t_2$; d is the length or thickness of the material along which heat is transferred.
  - **Heat conductor :** It is any material that easily transfers heat. Metals are particularly good conductors because their atoms have very mobile (free) electrons that easily transfer the thermal energy that is applied to the metal.
  - **Heat insulator :** It is a material in which heat doesn't flow easily. Liquids and gases are usually better insulators than solids. Wood, plastics, wool, cork, etc. are insulators or poor conductors of heat. E.g. :

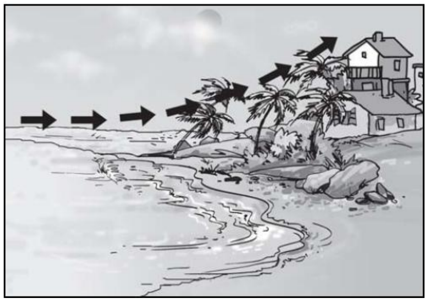
    (1) In the winter, we use woolen clothes. Wool is a poor conductor of heat i.e., it is a heat insulator. Moreover, there is air trapped in between the wool fibres. Since air is also a heat insulator, it prevents the flow of heat from our body to the cold surroundings. So, we feel warm.

    (2) Cooking pans are made of metals while their handles are made of plastics.

    (3) A metal block feels colder to the touch than a wooden block, even though the two blocks may have the same temperature. This is because metals conduct heat energy more rapidly than a wooden block.
- **Convection :** The transfer of heat through the motion of matter such as air and water. The circular movement of currents that is set up in liquids and gases is called **convection currents**. Convection can be of two types :
  (i) natural convection (ii) forced convection.
  - **Natural convection :** It is a mode of heat transfer in which the fluid motion is not generated by any external source like a pump or a fan. The heat flows only due to the difference of densities within the fluid that occurs because of the temperature differences in the different regions of the fluid. In natural convection, fluid surrounding a heat source receives heat, becomes less dense and rises. The surrounding, cooler fluid then moves to replace it. This cooler fluid is then heated and the process continues, forming a convection current. Natural convection occurs when a warmer, less dense fluid is pushed away by a cooler, denser fluid. Some examples of natural convection are :

    (1) **Sea breeze :** During the day, the water is cooler than the land. Air above the warm land is heated by conduction. When the air gets hotter, its particles move faster and get farther from each other, making the air less dense. The cooler, denser air from over the lake flows in over the land, pushing the less dense air upward. The cooler air then is heated by the land and also begins to rise. The air from the sea is called the **sea breeze**.

    (2) **Land breeze :** During the night, the water is hotter than the land. Air above the warm water is heated by conduction. When the air gets hotter, its particles move faster and get farther from each other, making the air less dense. The cooler, denser air from over the land flows in over the water, pushing the less dense air upward. The cooler air is then heated by the water and it also begins to rise. The air from the land is called the **land breeze**.



(a) Day time

(b) Night time

Sea breeze and land breeze

- **Forced convection :** It is a mode of heat transfer in which fluid motion is generated by an external source like a pump, fan, blower, etc. It is one of the main methods of transferring heat efficiently. Forced convection is found very commonly in everyday life. It includes following applications :

  (1) Central heating systems.

  (2) Central cooling systems, air conditioning.

  (3) Electric heat convectors or blowers used for room heating at home.

  (4) Heat exchangers used in industries like condensers, heaters, coolers, etc.

  (5) Car, truck or bus engines are cooled by convection current in the water pipes.

- **Radiation :** It is the mode in which a no material medium is required.
  - It occurs when energy is transferred in the form of electromagnetic waves.
  - The waves which mainly carry heat from Sun to Earth are infrared rays. These waves are also called **heat waves** or **thermal radiation**. Heat waves are just like light but unlike light, they are invisible. When heat falls on some object, a part of it is reflected, a part is absorbed and a part may be transmitted.
  - It can occur in vacuum, as well as in solids, liquids, and gases.
  - The Sun is not the only source of radiation. All objects emit heat waves, although warm objects emit more radiation than cool objects.
  - Some common examples of radiation are :

    (1) The warmth you feel when you sit next to a fireplace is due to heat transferred by radiation from the fire to your skin.

    (2) When we sit in front of a room heater, we get heat by radiation.

    (3) A hot utensil kept away from the flame cools down as it transfers heat to the surroundings by radiation.

    (4) Our body too, gives heat to the surroundings and receives heat from it by radiation.
  - A silvered mirror surface reflects most thermal radiation, absorbing very little. A good absorber of heat is also good a emitter of heat. This means dark surfaces or black surfaces are good emitters of heat as they are good absorbers of heat. A dull black surface is a better absorber of heat than a shiny black surface. Similarly, a dull black surface is a better emitter of heat than a shiny black surface.

    (1) The outer base of a cooking utensil is painted black so that it absorbs more heat, so that cooking can be done in less time.

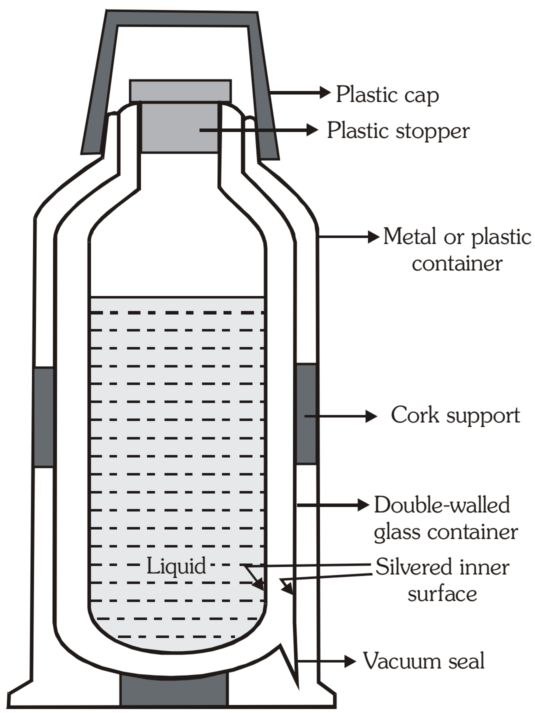
    (2) Light coloured clothes reflect most of the heat that falls on them and, therefore, we feel more comfortable wearing them in the summer. Dark surfaces absorb more heat and, therefore, we feel comfortable with dark coloured clothes in the winter.

(3) The tubes on the back of refrigerators are coloured dull black to radiate (emit) heat more effectively in order to cool down the refrigerator pipes.

(4) Electric room heaters are provided with a polished metal surface behind the heating element. This surface reflects almost all the radiated heat from the heating element that falls on it and makes the room heater more effective.

- **Vacuum flask or thermos flask :** A vacuum flask or thermos flask keeps hot things hot or cold things cold for a long time. It is very difficult for heat to travel into or out of the flask.

  - Transfer by conduction and convection is minimised by making the flask a double walled glass vessel with a vacuum between the walls. This is because both conduction and convection need molecules of a medium for transfer of heat.
  - Radiation is reduced by silvering inner surfaces of both the walls. The silvered surfaces reflect the heat back, thus, reducing radiation.
  - The slight heat loss that occurs is by conduction up the glass walls and through the stopper.



A vacuum flask or thermos flask

1. Heat is

(1) energy transferred by virtue of a temperature difference

(2) energy transferred by mechanical work

(3) energy content of an object

(4) a temperature difference

2. The temperature of water at the bottom of a large waterfall is higher than that of the water at the top, because

(1) The falling water absorbs heat from the sun

(2) The KE of the falling water is converted into heat

(3) The water at the bottom has greater PE

(4) Rocks on the bed of the river give out heat

3. Which of the following pairs has the same unit?

(1) Heat and Specific Heat

(2) Thermal Capacity and Water Equivalent

(3) Specific Heat and Thermal Capacity

(4) Heat and Work

4. The natural direction of heat flow between two reservoirs depends on their

(1) Temperature (2) Volume

(3) Pressure (4) Mass

5. Two bodies A and B are said to be in thermal equilibrium with each other, if

(1) Heat flows from A to B

(2) Heat flows from B to A

(3) Both the bodies lose equal amounts of heat to the atmosphere

(4) Heat does not flow from either A or B

6. Triple point of water is

(1) 273.16 °F (2) 273.16 K

(3) 273.16 °C (4) 273.16 R

7. In constructing a thermometer, it is NECESSARY to use a substance that

(1) undergoes some change when heated or cooled

(2) expands with rising temperature

(3) expands linearly with rising temperature

(4) will not freeze

8. A thermometer indicates 98.6 °C. It may be

(1) outdoors on a cold day

(2) in a comfortable room

(3) in a cup of hot tea

(4) in a normal person's mouth

9. If room temperature is about 25 degrees, it must be on the

(1) Kelvin scale (2) Celsius scale

(3) Fahrenheit scale (4) Absolute scale

10. A new liquid is tested to decide whether it is suitable for use in a liquid-in-glass thermometer. It is found that the liquid does not expand uniformly with temperature. What will be the effect of this on the scale of the thermometer ?

(1) It has a short range

(2) It is not linear

(3) The markings are too close together

(4) The markings are too far apart

11. An instrument used to measure high temperature is

(1) Pyrheliometer (2) Pyrometer

(3) Technometer (4) Pyknometer

12. On the Celsius scale, the absolute zero of temperature is at

(1) 0 °C (2) –32 °C

(3) 100 °C (4) –273.15 °C

13. At what temperature, the centigrade (Celsius) and Fahrenheit readings are the same ?

(1) –40° (2) +40°

(3) 54° (4) none of these

14. On which of the following scales of temperature, the temperature is never negative ?

(1) Celsius (2) Fahrenheit

(3) Reaumer (4) Kelvin

15. Absolute zero is the condition at which

(1) molecular motion ceases

(2) gas becomes liquid

(3) matter becomes massless

(4) random motion of molecules occur

16. There is a temperature at which the reading on the Kelvin scale is numerically

(1) equal to that on the Celsius scale

(2) lower than that on the Celsius scale

(3) equal to that on the Fahrenheit scale

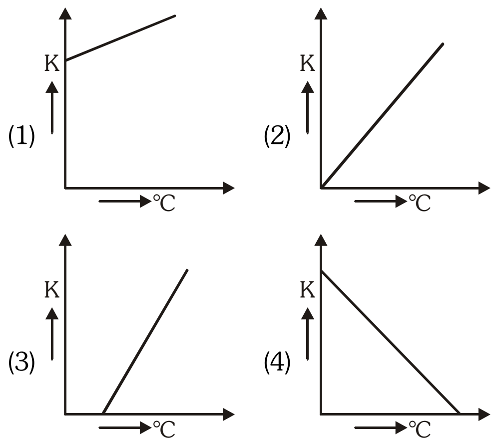
(4) less than zero

17. The temperature of a substance increases by 27 °C. On the Kelvin scale, this increase is equal to

(1) 300 K (2) 2.46 K

(3) 27 K (4) 7 K

18. A graph was plotted taking the temperature in °C along the X-axis and the corresponding temperature in Kelvin along the Y-axis. Which of the curves in fig. most correctly represents this behaviour ?



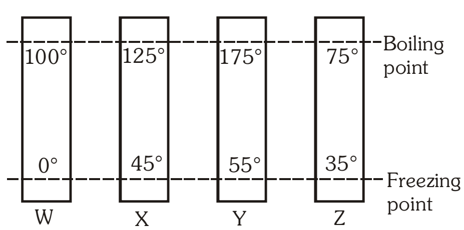
19. If a graph is plotted taking the temperature in Fahrenheit along the Y-axis, and the corresponding temperature in Celsius along the X-axis, then the graph will be a straight line,

(1) Having a positive intercept on the Y-axis
(2) Having a positive intercept on the X-axis
(3) Passing through the origin
(4) Having negative intercepts on the X and Y axes

20. Fahrenheit and Kelvin scales agree numerically at a reading of

(1) – 40 (2) 0 (3) 273 (4) 574.25

21. The diagram shows four thermometers, labelled W, X, Y, and Z. The freezing and boiling points of water are indicated. Rank the thermometers according to the size of a degree on their scales, largest to smallest.



(1) Z, Y, X, W (2) Z, Y, W, X
(3) Z, X, W, Y (4) W, Y, Z, X

22. When a metal rod is heated, it expands because

(1) The size of its atoms increases
(2) The distance among its atoms increases
(3) Atmospheric air rushes into it
(4) The actual cause is still unknown

23. Expansion during heating

(1) Occurs only in solids
(2) Increases the weight of material
(3) Decreases the density of a material
(4) Occurs at the same rate for all solids and liquids

24. Coefficient of linear expansion always ______ with the increase in temperature.

(1) Increases (2) Decreases
(3) Remains the same (4) Doubles itself

25. If a substance contracts on heating, its coefficient of linear expansion is

(1) Positive (2) Negative
(3) Zero (4) Infinity

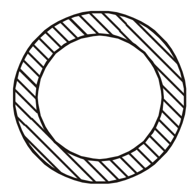
26. The mercury column in an ordinary medical thermometer doubles in length when its temperature changes from 95 °F to 105 °F. Then, coefficient of linear expansion of mercury is

(1) 0.1 per °F (2) 0.3 per °F
(3) 0.25 per °F (4) 1 per °F

27. The diameters of steel rods A and B having the same length are 2 cm and 4 cm respectively. They are heated through 100 °C. The ratio of increase of length of rod A to that of the rod B is

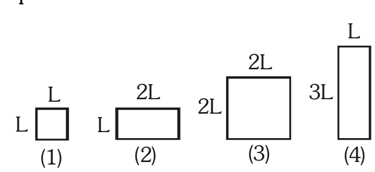
(1) 1 (2) 1/2 (3) 2 (4) 4

28. An annular ring of aluminium is cut from an aluminium sheet as shown. When this ring is heated



(1) the aluminium expands outward and the hole remains the same in size
(2) the hole decreases in diameter
(3) the area of the hole expands the same percent as any area of the aluminium
(4) the area of the hole expands a greater percent than any area of the aluminium

29. The diagram shows four rectangular plates and their dimensions. All are made of the same material. The temperature now increases. Of these plates,



(1) the vertical dimension of plate 1 increases the most and the area of plate 1 increases the most.
(2) the vertical dimension of plate 2 increases the most and the area of plate 4 increases the most.
(3) the vertical dimension of plate 3 increases the most and the area of plate 1 increases the most.
(4) the vertical dimension of plate 4 increases the most and the area of plate 3 increases the most.

30. Two spheres of same size are made of the same material but one is hollow and the other is solid. They are heated to the same temperature. Then,

(1) both the spheres will expand equally.

(2) hollow sphere will expand more than the solid one.

(3) solid sphere will expand more than the hollow one.

(4) None of the above.

31. Possible unit for the coefficient of volume expansion is

(1) mm/°C (2) mm^3/°C

(3) $(°C)^3$ (4) 1/°C

32. Two glass tumblers have been stuck together (one into the other). They can be separated by

(1) Placing hot water in the inner tumbler

(2) Placing the tumblers in cold water

(3) Placing the outer tumbler in hot water

(4) Hammering them vigorously

33. It is more difficult to measure the coefficient of volume expansion of a liquid than that of a solid because

(1) no relation exists between linear and volume expansion coefficients

(2) a liquid expands too much when heated

(3) a liquid expands too little when heated

(4) the containing vessel also expands

34. Choose the correct statement

(1) $\alpha : \beta : \gamma :: 1 : 3 : 2$ (2) $\alpha : \beta : \gamma :: 2 : 3 : 1$

(3) $\alpha : \beta : \gamma :: 3 : 2 : 1$ (4) $\alpha : \beta : \gamma :: 1 : 2 : 3$

35. The superficial expansion of a metal is β and volume expansion is γ. Then,

(1) $\beta = \frac{\gamma}{2}$ (2) $\beta = \frac{\gamma}{3}$ (3) $\beta = \frac{2\gamma}{3}$ (4) $\beta = \frac{3\gamma}{2}$

36. The coefficient of linear expansion of iron is 1.0×10^{-5} per °C. The surface area of an iron cube, with an edge length of 5.0 cm, will increase by what amount, if it is heated from 10 °C to 60 °C ?

(1) 0.0125 cm^2 (2) 0.025 cm^2

(3) 0.075 cm^2 (4) 0.15 cm^2

37. Water in a container is heated from 0 °C to 10 °C. Its volume

(1) Increases for the full given range (from 0 °C to 10 °C)

(2) Decreases up to 4 °C, then increases

(3) Increases up to 4 °C, then decreases

(4) Decreases for the full range (from 0 °C to 10 °C)

38. The surface water in a lake is just going to freeze. What is the temperature of water at the bottom ?

(1) Less than 0 °C (2) 0 °C

(3) 4 °C (4) More than 4 °C

39. A gram of distilled water at 4 °C

(1) will increase slightly in weight when heated to 6 °C

(2) will decrease slightly in weight when heated to 6 °C

(3) will increase slightly in volume when heated to 6 °C

(4) will decrease slightly in volume when heated to 6 °C

40. Metal pipes, used to carry water, sometimes burst in the winter because

(1) metal contracts more than water

(2) outside of the pipe contracts more than the inside

(3) metal becomes brittle when cold

(4) water expands when it freezes

41. Two metal strips that constitute a thermostat must necessarily differ in their

(1) Length

(2) Mass

(3) Resistivity

(4) Coefficient of linear expansion

42. Thin strips of iron and zinc are riveted together to form a bimetallic strip that bends when heated. The iron is on the inside of the bend because

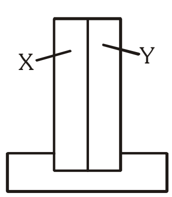
(1) it has a higher coefficient of linear expansion

(2) it has a lower coefficient of linear expansion

(3) it has a higher specific heat

(4) it has a lower specific heat

43. A bimetallic strip consists of metals X and Y. It is mounted rigidly at the base as shown. The metal X has a higher coefficient of expansion to that for metal Y. When bimetallic strip is placed in a cold bath,



(1) It will bend towards the right

(2) It will bend towards the left

(3) It will not bend but shrink

(4) It will neither bend nor shrink

44. The gaps are kept in the railway track so that

(1) The friction is produced and the speed of the train may not increase beyond a limit.

(2) The friction between the wheels and track decreases.

(3) The replacement of the track is easier when there is fault in the track.

(4) The expansion of the track can take place due to friction as well as in summer.

45. When you put a metal key into its metal lock, you find the key is too tight. Which of the following methods will you adopt to make the key fit properly?

(1) heat the key and cool the lock

(2) cool the key and heat the lock

(3) heat the key and the lock

(4) cool the key and the lock

46. The specific heat of a substance is

(1) the amount of heat energy to change the state of one gram of the substance

(2) the amount of heat energy per unit mass emitted by oxidizing the substance

(3) the amount of heat energy per unit mass to raise the substance from its freezing to its boiling point

(4) the amount of heat energy per unit mass to raise the temperature of the substance by 1 ℃

47. The specific heat capacity of a substance depends on its

(1) Nature (2) Mass

(3) Rise in temperature (4) Both (2) and (3)

48. Which of the following has the highest specific heat ?

(1) Water (2) Mercury

(3) Kerosene (4) Copper

49. If specific heat of a substance is infinite, it means

(1) Heat is given out

(2) Heat is taken in

(3) No change in temperature takes place whether heat is taken in or given out

(4) All of the above

50. Heat gained by 1 g of water when heated from 0 ℃ to 100 ℃ is

(1) 4200 cal (2) 4.2 cal

(3) 100 cal (4) 1 cal

51. 420 J of energy supplied to 10 gm of water will raise its temperature by

(1) 1 ℃ (2) 4.2 ℃ (3) 10 ℃ (4) 42 ℃

52. Assuming that no heat is lost to the surroundings, what will be the final temperature when 1 kg of water at 10 ℃ is mixed with 5 kg of water at 80 ℃ ?

(1) 36.8 ℃ (2) 68.3 ℃

(3) 60.8 ℃ (4) 45 ℃

53. A mass of 0.8 kg of water at 25 °C is mixed with 0.2 kg of boiling water. The temperature of the mixture obtained is

(1) 35 ℃ (2) 40 ℃ (3) 55 ℃ (4) 60 ℃

54. If 20 g of water at 50 ℃ is mixed with 60 g of water at 10 ℃, then calculate the final temperature of the mixture.

(1) 20 ℃ (2) 30 ℃ (3) 35 ℃ (4) 40 ℃

55. 40 g of hot water is poured in 100 g of cold water, then temperature of cold water rises by 10 ℃. If the temperature of hot water is 60 ℃, calculate the initial temperature of cold water.

(1) 5 ℃ (2) 15 ℃ (3) 25 ℃ (4) 35 ℃

56. A liquid of specific heat 0.3 at 90 ℃ is mixed with another liquid of specific heat 0.5 at 15 ℃. If final temperature of the mixture is 60 ℃, then find the ratio of masses of the two liquids mixed.

(1) 1:1 (2) 2:3 (3) 5:2 (4) 2:5

57. A substance of mass m_1 with specific heat c_1 and initial temperature θ_1 is mixed with another substance of mass m_2, specific heat c_2 and initial temperature θ_2 respectively. Then, their equilibrium temperature is _____ (take $\theta_1 > \theta_2$)

(1) $\frac{m_1c_1\theta_1 - m_2c_2\theta_2}{m_1c_1 - m_2c_2}$ (2) $\frac{m_1c_1\theta_1 - m_2c_2\theta_2}{m_1c_1 + m_2c_2}$

(3) $\frac{m_2c_2\theta_2 - m_1c_1\theta_1}{m_1 + m_2}$ (4) $\frac{m_1c_1\theta_1 + m_2c_2\theta_2}{m_1c_1 + m_2c_2}$

58. The energy given off as heat by 300 g of an alloy as it cools through 50 ℃ raises the temperature of 300 g of water from 30 ℃ to 40 ℃. The specific heat of the alloy (in cal/g ℃) is

(1) 0.015 (2) 0.10 (3) 0.15 (4) 0.20

59. The specific heat of lead is 0.030 cal/g ℃. 300 g of lead shot at 100 ℃ is mixed with 100 g of water at 70 ℃ in an insulated container. The final temperature of the mixture is

(1) 100 ℃ (2) 72.5 ℃ (3) 85.5 ℃ (4) 79.5 ℃

60. A 0.01 kg bullet moving at 2000 m/s plunges into 1 kg of paraffin wax (specific heat 2940 J/kg ℃). The wax was initially at 20 ℃. Assuming that all the bullet's energy heats the wax, its final temperature (in ℃) is

(1) 23.1 (2) 26.8 (3) 20.1 (4) 29.1

61. In thermal power stations, steam is preferred to convert heat to electric energy because

(1) Steam is good conductor of heat

(2) Steam is good conductor of electricity

(3) Steam can flow quickly

(4) Every gram of steam can give 2260 J of heat

62. A glass tumbler containing ice shows droplets of water on the outer surface because

(1) The outer surface of the tumbler shows hygroscopic effect.

(2) Water from inside oozes out through the wall of the tumbler.

(3) The moisture in the air on coming in contact with the cold surface of the tumbler condenses in the form of droplets of water.

(4) Both (1) and (2)

63. Steam burns are more painful than those caused by boiling water at the same temperature because

(1) Steam contains more heat than the same amount of water at the same temperature. When steam condenses it gives out this extra latent heat

(2) Hot air is also mixed up with steam

(3) Steam produces some chemical effect on the skin to cause pain

(4) The question is irrelevant as steam burns are equally painful as those caused by boiling water

64. The heat of fusion of water is 80 cal/g. This means 80 cal of energy are required to

(1) raise the temperature of 1 g of water by 1 K

(2) turn 1 g of water to steam

(3) raise the temperature of 1 g of ice by 1 K

(4) melt 1 g of ice

65. Latent heat of ice is 80 cal/g. A man melts 60 g of ice by chewing it in 1 minute. His power is

(1) 4800 W (2) 336 W

(3) 1.33 W (4) 0.75 W

66. The formation of ice from water is accompanied by

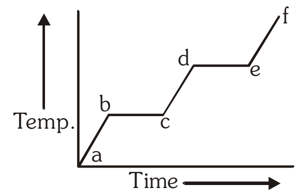
(1) absorption of energy as heat

(2) temperature increase

(3) decrease in volume

(4) an evolution of heat

67. The following figure represents the temperature versus time plot for a given amount of a substance when heat is supplied at a fixed rate and at a constant pressure. Which parts of this plot represent a phase change ?



(1) a to b and e to f (2) d to e and e to f

(3) b to c and c to d (4) b to c and d to e

68. When 'x' grams of steam at 100 °C is mixed with 'y' grams of ice at 100 °C and allowed to attain thermal equilibrium, the final temperature of mixture is

(1) $\frac{80(8x-y)}{x+y}$ (2) $\frac{80(x-8y)}{x+y}$

(3) $\frac{80(8x+y)}{x-y}$ (4) $\frac{80(x+8y)}{x-y}$

69. How many calories are required to change one gram of 0 °C ice to 100 °C steam ? The latent heat of fusion is 80 cal/g and the latent heat of vaporization is 540 cal/g. The specific heat of water is 1 cal/g °C.

(1) 100 (2) 540

(3) 620 (4) 720

70. Ten grams of ice at –20 °C is to be changed to steam at 130 °C. The specific heat of both ice and steam is 0.5 cal/g °C. The heat of fusion is 80 cal/g and the heat of vaporization is 540 cal/g. The entire process requires

(1) 750 cal (2) 1250 cal

(3) 7450 cal (4) 6950 cal

71. Fifty grams of ice at 0 °C is placed in a thermos bottle containing one hundred grams of water at 6 °C. How many grams of ice will melt ? The heat of fusion of ice is 333 kJ/kg and the specific heat is 4190 J/kg °C.

(1) 7.5 (2) 2.0

(3) 8.3 (4) 17

72. The heat capacity of an object is

(1) the amount of heat energy that raises its temperature by 1 ℃

(2) the amount of heat energy that changes its state without changing its temperature

(3) the amount of heat energy per kilogram that raises its temperature by 1 ℃

(4) the ratio of its specific heat to that of water

73. Two different samples have the same mass and temperature. Equal quantities of energy are absorbed as heat by each. Their final temperatures may be different because the samples have different

(1) coefficients of expansion

(2) densities

(3) heat capacities

(4) volumes

74. The same energy Q enters four different substances as heat.

The temperature of 3 g of substance A increases by 10 K.

The temperature of 4 g of substance B increases by 4 K.

The temperature of 6 g of substance C increases by 15 K.

The temperature of 8 g of substance D increases by 6 K.

Which substance has the greatest specific heat ?

(1) A (2) B (3) C (4) D

75. A hot body at temperature θ_1 is mixed with a cold body at θ_2 both having the same heat capacity, such that the rise in temperature of the cold body is equal to the fall in temperature of the hot body. The resultant temperature θ is

(1) $\frac{\theta_1+\theta_2}{2}$ (2) $\theta_1+\theta_2$

(3) $\frac{\theta_1-\theta_2}{2}$ (4) $\theta_1-\theta_2$

76. The heat capacity of object B is twice that of object A. Initially A is at 300 K and B is at 450 K. They are placed in thermal contact and the combination is isolated. The final temperature of both objects is

(1) 200 K (2) 300 K

(3) 400 K (4) 450 K

77. Transmission of heat by molecular collisions is called

(1) Conduction (2) Convection

(3) Radiation (4) Scattering

78. Inside a room at a uniform comfortable temperature, metallic objects generally feel cooler to the touch than wooden objects do. This is because

(1) a given mass of wood contains more heat than the same mass of metal

(2) metal conducts heat better than wood

(3) heat tends to flow from metal to wood

(4) the equilibrium temperature of metal in the room is lower than that of wood

79. Under steady state, the temperature of a body

(1) Increases with time

(2) Decreases with time

(3) Does not change with time and is same at all points of the body

(4) Does not change with time but is different at different cross-sections of the body

80. Coefficient of thermal conductivity of a metal plate depends on

(1) Temperature difference between its two sides

(2) Thickness of the metal plate

(3) Area of the plate

(4) Nature of the material

81. Two rods of copper and brass ($K_C > K_B$) of same length and area of corss-section are joined as shown. End A is kept at 100 ℃ and end B at 0 ℃. The temperature at the junction

(1) will be more than 50 ℃

(2) will be less than 50 ℃

(3) will be 50 ℃

(4) may be more or less than 50 ℃ depending upon the size of rods.

82. On heating one end of a rod, the temperature of whole rod will be uniform when thermal conductivity

(1) K = 1 (2) K = 0

(3) K = 100 (4) $K = \infty$

83. An ideal material for making cooking vessels must have

(1) small conductivity and large heat capacity

(2) large conductivity and large heat capacity

(3) large conductivity and small heat capacity

(4) small conductivity and small heat capacity

84. Four rods with different radii r and length l are used to connect two reservoirs of heat at different temperatures. Which one will conduct more heat?

(1) r = 1 cm, l = 1 m

(2) r = 2 cm, l = 2 m

(3) r = 1 cm, l = 0.5 m

(4) r = 2 cm, l = 0.5 m

85. In which of the following, heat loss is primarily not due to convection ?

(1) boiling of water

(2) land and sea breeze

(3) heating of glass surface of a bulb due to current in filament

(4) circulation of air around blast furnace

86. In natural convection, a heated portion of a liquid moves because

(1) its molecular motion becomes aligned

(2) of molecular collisions within it

(3) its density is less than that of the surrounding fluid

(4) of currents of the surrounding fluid

87. Water is usually heated by

(1) Conduction (2) Convection

(3) Radiation (4) All of these

88. In which process, the rate of transfer of heat is maximum ?

(1) Conduction

(2) Convection

(3) Radiation

(4) In all these, heat is transferred at the same rate

89. A hot and a cold body are kept in vacuum separated from each other. Which of the following will cause decrease in temperature of the hot body?

(1) Radiation

(2) Convection

(3) Conduction

(4) Temperature remains unchanged

90. Energy from the Sun reaches the Earth by

(1) scattering (2) conduction

(3) radiation (4) convection

91. Which of the following statements pertaining to a vacuum flask (thermos) is NOT correct ?

(1) Silvering reduces radiation loss

(2) Vacuum reduces conduction loss

(3) Stopper reduces convection loss

(4) Vacuum reduces radiation loss

92. To help keep buildings cool in the summer, dark coloured window shades have been replaced by light coloured shades. This is because light coloured shades

(1) are more pleasing to the eye

(2) absorb more sunlight

(3) reflect more sunlight

(4) transmit more sunlight

93. A sphere, a cube and a thin circular plate of same material and mass, are heated to a temperature of 20 °C and allowed to cool. Then which one of these cools fastest ?

(1) Sphere

(2) Plate

(3) Cube

(4) Rate of cooling will be same in all three

94. The running of fan makes us comfortable during summer, because it

(1) decreases the temperature of air.

(2) increases the thermal conductivity of air.

(3) increases the rate of evaporation of perspiration.

(4) cuts off the thermal radiation reaching us.

95. A person takes hot tea by pouring it into the saucer plate when one is in hurry because he knows that

(1) The latent heat of steam is high and the tea will cool down quickly.

(2) The evaporation increases with the increase in surface area and cooling of tea is faster.

(3) Part of heat will be absorbed by the saucer plate and the tea will cool down quickly.

(4) The high specific heat of water makes the tea cool down quickly.

96. A paper wrapped tightly around the joint of a brass tube and its wooden handle is put in a flame. The paper will

(1) Catch fire immediately

(2) Not burn at any place

(3) Burn around the brass tube

(4) Burn around the wooden handle

97. Two thin blankets piled together are warmer than a single one of the same total thickness as the two because

(1) Air gets enclosed between the two blankets acting as heat insulator.

(2) The distance of the heat transmission increases.

(3) Total surface increases.

(4) It is a wrong statement.

98. A hot body will radiate heat most rapidly, if its surface is

(1) white and polished (2) white and rough

(3) black and polished (4) black and rough

99. Morning sun is not so hot as the mid day sun because

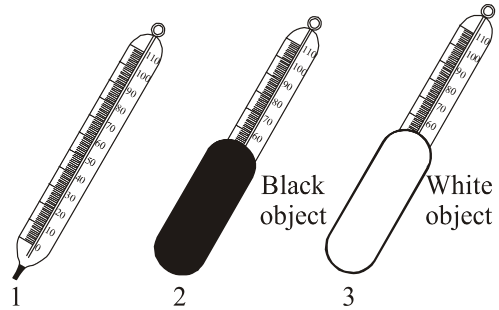
(1) Sun is cooler in the morning

(2) Heat rays travel slowly in the morning

(3) It is God's gift

(4) The Sun's rays travel a longer distance through atmosphere in the morning

100. Rohan wants to test whether a white object or a black object would heat up faster in the Sun. The picture shows you his experiment. These thermometers were left out in the Sun for 30 minutes.



Which of the following statement is true?

(1) Thermometer 1 reads the same as thermometer 3.

(2) Thermometer 2 shows a higher temperature than thermometer 3.

(3) Thermometer 3 shows higher temperature than thermometer 1.

(4) Thermometer 1 reads the same as thermometer 2.

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans.	1	2	4	1	4	2	1	3	2	2	2	4	1	4	1	3	3	1	1	4
Que.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Ans.	3	2	3	3	2	1	1	3	4	1	4	3	4	4	3	2	2	3	3	4
Que.	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Ans.	4	2	2	4	2	4	1	1	3	3	3	2	2	1	3	3	4	4	2	2
Que.	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Ans.	4	3	1	4	2	4	4	1	4	3	1	1	3	2	1	3	1	2	4	4
Que.	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Ans.	1	4	3	4	3	3	2	3	1	3	4	3	2	3	2	4	1	4	4	2