Thermal Expansion, Thermometry, Heat Transfer

GUPTA CLASSES

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HEAT TRANSFER

Transmission of heat

Heat can be transmitted from one place to another by three different mechanisms:

1. **Conduction** is the process of transmission of heat in a body from the hotter part to the colder part without any bodily movement of constituent atoms or molecules of the body.
2. **Convection** is the process of transmission of heat in a body from hotter part to the colder part through the actual bodily movement of constituent atoms or molecules of the body.
3. **Radiation** is the process of transmission of heat from one body to another body through electromagnetic waves even through vacuum, irrespective of their temperatures. Heat from the sun reaches the earth by radiation.

Conduction

In steady state the amount Q of heat flowing in t seconds is given by: $Q = \frac{KA(\theta_1 - \theta_2)t}{d}$, where $(\theta_1 - \theta_2)$ is the temperature difference across a rod of length d and cross-section area A. K is thermal conductivity of rod.

Steady state: When one end of a rod is heated, then initially the temperature of various points of the rod changes continuously and the rod is said to exist in a variable state. After some time, a state is reached, when the temperature of each cross-section becomes steady. This state is known as steady state. In this state, no heat is absorbed by the cross-section

Coefficient of thermal conductivity (*K*): For a perfect conductor of heat K is infinite and for a perfect insulator K is zero. In general, solids are better conductors than liquids and liquids are better conductors than gases. Metals are much better conductors than non-metal.

Thermal Resistance : It is the property by virtue of which a conducting body oppose the thermal conduction through it. It is given by $R = \frac{L}{KA}$

Similar to current effective thermal resistance of series combination is given by $R = R_1 + R_2$

For parallel combination effective thermal resistance $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

Wiedmann-Franz law

At a given temperature T, the ratio of thermal conductivity (K), to electrical conductivity (σ) is constant, i.e., $(K/\sigma T)$ = constant, i.e., a substance which is a good conductor of heat (e.g., silver) is also a good conductor of electricity. Mica is an exception to above law.

Ingen Hauz's experiment

If a no. of identical rods of different metals are coated with wax and one of their end is put in boiling water, then in steady state the square of length of the bar over which wax melts is directly proportional to thermal conductivity of metal i.e. $K \propto L^2$

Growth of ice on lakes

Water in a lake starts freezing if the atmospheric temperature drops below 0°C. Let y be the thickness of ice layer formed in the lake at any instant t and atmospheric temperature is $-\theta$°C. Then time taken by ice to grow a thickness y is $t = \frac{\rho L}{2K\theta} y^2$, where L = latent heat of ice; K = thermal conductivity of ice and ρ = density of ice.

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1. It follows from the above equation that time taken to double, triple the thickness will be in the ratio of

$$t_1 : t_2 : t_3 : : 1^2 : 2^2 : 3^2, \quad \text{i.e.,} \quad t_1 : t_2 : t_3 :: 1 : 4 : 9$$

2. And the time intervals to change the thickness from 0 to y, from y to 2y and so on will be in the ratio

$$\Delta t_1 : \Delta t_2 : \Delta t_3 : : (1^2-0^2) : (2^2-1^2) : (3^2-2^2), \quad \text{i.e.,} \quad \Delta t_1 : \Delta t_2 : \Delta t_3 :: 1 : 3 : 5$$

Convection

Convection requires a medium and is the process in which heat is transferred from one place to other by actual movement of heated substance (usually fluid).

The type of convection which results from difference in densities is called natural convection (for example, a fluid in a container heated through its bottom). However, if a heated fluid is forced to move by a blower, fan or pump, the process is called forced convection.

1. In case of natural convection, convection currents move warm substance upwards and cool substance downwards. This is why heating is done from base, while cooling from the top.
2. Natural convection is not possible in a gravity free region such as a freely falling lift or an orbiting satellite.

Radiation

The process through which heat is transferred directly from one body to another, without requiring any medium is called radiation. Heat from the sun reaches the earth by radiation. Radiation is the fastest mode of heat transfer from one place to another as in this mode heat energy is propagated at speed of light.

1. All the bodies radiate energy at all temperatures and at all times. Radiation from a body can never be stopped but can be minimised.
2. Radiation does not affect the medium through which it passes.
3. Rough and dark (i.e., black) surfaces are good absorbers while shining and smooth surfaces are good reflectors of heat radiations.
4. Glass and water vapours have the property of transmitting shorter wavelength heat radiations through them while reflecting longer ones.

Prevost's Theory : It predicts that all body's absorb and radiate simultaneously to their environment irrespective of temperature.

Black body: A body that absorbs the entire radiations incident on it is called a perfectly black body.

Absorptive power (a) : Absorptive power of a surface is defined as the ratio of the radiant energy absorbed by it in a given time to the total radiant energy incident on it in the same time. It has no units and dimensions.

1. For a perfectly black body, absorptive power is maximum and unity.
2. Spectral absorptive power is defined as the ratio of the radiant energy of a given wave absorbed by a given surface in a given time to the total radiant energy of that wave incident in the same time on the same surface within a unit length range. It is represented by a_λ.

Emissive power (e) : For a given surface it is defined as the radiant energy emitted per sec per unit area surface. It has units W/m^2.

1. If we consider emissive power of a surface for a particular wavelength instead wavelengths, it is called spectral emissive power and is represented by e_λ.
2. Emissive power of a surface depends on its nature and temperature.
3. It is maximum for a perfectly black body and minimum for a smooth shining body.

Kirchhoff's law : According to Kirchhoff's law, the ratio of emissive power to absorptive power is same for all surfaces at the same temperature and is equal to the emissive power of a perfectly black body at that temperature.

1. If a and e represent absorptive and emissive power of a given surface while A and E perfectly black body, then $e/a = E/A$. For a perfectly black body, $A = 1$, $e/a = E$.

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2. For a particular wavelength, $e_\lambda / a_\lambda = E_\lambda$, Since, E_λ, is constant at a given temperature, hence according to this law, if a surface is a good absorber of a particular wavelength, it is also a good emitter of that wavelength
3. Sand is rough and black, so it is a good absorber and hence in deserts, days will be very hot. Now in accordance with Kirchhoff's law, nights (when sand emits radiation) will be cold.
4. Fraunhofer lines are dark lines in the spectrum of the sun. When white light emitted from the central core of the sun (photosphere) passes through its atmosphere (chromosphere) radiations of those wavelengths will be absorbed by the gases present there which they usually emit (as a good emitter is a good absorber) resulting in dark lines in the spectrum of sun,
5. A red piece of glass appears red as it reflects red and absorbs all other radiations incident on it. So, if a piece of red glass is heated to incandescence, it will reflect red end and will absorb all others. Hence, when seen in dark it will glow with emission of radiations, which it has absorbed, i.e., it will glow with emission of radiations complementary to red (or white deficient in red), i.e., cyan (or bluish).

Stefan's law: According to it, the radiant energy emitted by a perfectly black body per unit area per sec i.e; emissive power or radiancy or intensity of black body radiation) is directly proportional to the fourth power of its absolute temperature, i.e., $R \propto T^4$ or $R = \sigma T^4$, where σ is called Stefan's constant having and value 5.67×10^{-8} W/m^{2}K^4.

If a body is not a perfectly black body, then $R = \varepsilon\sigma T^4$, where ε is called emissivity or relative emittance and has value $0 < \varepsilon < 1$ depending on the nature of surface. It has no units and dimensions.

Newton's law of cooling: According to Newton's law of cooling, $\frac{d\theta}{dt} = K(\theta - \theta_0)$ with $\left[K = \frac{\varepsilon A\sigma}{mc} 4T_0^3\right]$

i.e., rate of cooling of a hot body is directly proportional to temperature difference between the body and its surroundings provided the temperature of the body is not much higher than the surroundings.

If $\theta = \theta_0$, $(d\theta/dt) = 0$, i.e., a body can never be cooled to a temperature lesser than its surroundings by radiation.

If a body cools by radiation from θ_1 to θ_2°C in time t, then taking $d\theta/dt = (\theta_1 - \theta_2)/t$ and $\theta = \theta_{av} = (\theta_1 + \theta_2)/2$ Newton's law of cooling takes the form $\left[\frac{\theta_1 - \theta_2}{t}\right] = K\left[\frac{\theta_1 + \theta_2}{2} - \theta_0\right]$

Newton's law of cooling can be used to compare the specific heats of two liquids as: if equal masses of two liquids having same surface area and finish cool from same initial temperature θ_1 to same final temperature θ_2 with same temperature of surroundings, i.e., θ_0, in time intervals t_1 and t_2 respectively,

$$\frac{t_1}{t_2} = \frac{K_1}{K_2} \quad \text{or} \quad \frac{c_1}{c_2} = \frac{t_1}{t_2}\left(\because K \propto \frac{1}{c}\right)$$

Wien's displacement law: The quantity of energy radiated out by a body is not uniformly distributed over all the wavelengths emitted by it. It is maximum for a particular wavelength (λ), which is different for different temperatures. As the temperature is increased, the value of the wavelength which carries maximum energy is decreased.

According to this law, wavelength corresponding to maximum energy is inversely proportional to the absolute temperature of the body, i.e., $\lambda_m \propto 1/T$ or $\lambda_m T$ = constant.

Thermometry and Thermal Expansion

Temperature

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Temperature is measure of degree of hotness or coldness of a body. Temperature of a body is directly proportional to the kinetic energy of the random motion of the molecules or atoms of the substance. The natural flow of heat is from higher temperature to lower temperature.

1. Two bodies are said to be in thermal equilibrium with each other when no heat flows from one body to the other, i.e., when both the bodies are at the same temperature.
2. Temperature of a body cannot be lowered up to any extent while it can be raised up to any value. Theoretical lowest temperature is considered to be absolute zero. Highest possible temperature achieved in laboratory is about 10^8 K while lowest possible temperature attained is 10^{-8} K.
3. Branch of physics dealing with production and measurement of temperatures close to 0 K, is known as cryogenics while that dealing with the measurement of very high temperatures is called as pyrometry.

Different types of temperature scales

The SI unit of temperature is the Kelvin. The Kelvin temperature scale is also known as thermodynamic scale. In addition to Kelvin temperature scale, there are other temperature scales also like Celsius, Fahrenheit, Reaumer, Rankine, etc. Temperature on one scale can be converted into other scale by using the following identity:

$$\frac{\text{Reading - Lower Fixed Point}}{\text{Upper Fixed Point - Lower Fixed Point}} = \text{Constant}$$

Thermometry

In thermometry, two arbitrary fixed points, ice and steam points (i.e., FP and BP of water at 1 atmosphere) are taken to define the temperature scale, e.g., in Celsius scale, FP of water is assumed to be 0°C while BP of water 100°C, and the temperature interval between them is divided into 100 equal parts. So, if the thermometric properties at temperatures 0°C, 100°C and t_C°C are x_0, x_{100} and x respectively then.

$$\frac{t_C - 0}{100 - 0} = \frac{x - x_0}{x_{100} - x_0} \quad \text{or} \quad t_C = \frac{x - x_0}{x_{100} - x_0} \times 100^{\circ}\text{C}$$

The thermometric property x may be (a) length of liquid in a capillary (b) pressure of gas at constant volume; (c) volume of gas at constant pressure; (d) resistance of a given platinum wire etc.

Thermal expansion

When heat is supplied to matter and its state does not change then it usually gets expanded. There are also some such substances, which contract on heating. Rubber is a very good example of it. The basic reason for thermal expansion is asymmetry in potential energy curve.

1. Thermal expansion is minimum in case of solids but maximum in case of gases because intermolecular force is maximum in solids but minimum in gases.
2. Solids can have all the three types of thermal expansion, i.e., one–dimensional (linear expansion), two–dimensional (superficial expansion) and three–dimensional (volume expansion) while liquids and gases usually possess only volume expansion.

Coefficient of linear expansion

Coefficient of linear expansion α is defined as the increase in length per unit length per unit degree rise in temperature.

$$\alpha = \frac{L_t - L_0}{L_0 t}, \quad \text{hence} \quad L_t = L_0(1 + \alpha t),$$

Although α is defined with respect to L_0, it is usually very small and hence may be expressed without much error by the equation $\alpha = \dfrac{L_2 - L_1}{L_1(t_2 - t_1)}$

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Coefficient of superficial expansion

Coefficient of superficial expansion β is defined as the increase in area per unit area per unit degree rise in temperature.

$$\beta = \frac{A_t - A_0}{A_0 t}, \quad \text{hence} \quad A_t = A_0(1 + \beta t)$$

Although β is defined with respect to A_0, it is usually very small and hence may be expressed without much error by the equation $\beta = \dfrac{A_2 - A_1}{A_1(t_2 - t_1)}$

Coefficient of cubical expansion

Coefficient of cubical expansion γ is defined as the increase in volume per unit volume per unit degree rise in temperature. $\gamma = \dfrac{V_t - V_0}{V_0 t}$, hence $V_t = V_0(1 + \gamma t)$

Although γ is defined with respect to V_0, it is usually very small and hence may be expressed without much error by the equation $\gamma = \dfrac{V_2 - V_1}{V_1(t_2 - t_1)}$

Variation of density with temperature

If d_0 and d_t, be the densities of the material of a body at 0°C and t°C then

$d_0/d_t = (1 + \gamma t)$, where γ is the mean coefficient of cubical expansion of the material of the body.

Expansion of liquids

Liquids also expand on heating just like solids. Since liquids have no shape of their own they suffer only volume expansion. A liquid is always taken in a vessel for heating. So, if a liquid is heated, the vessel also gets heated and hence both liquid and vessel expand. But expansion of liquid is much greater than that of vessel, still the observed expansion is less than the actual expansion it had. Hence, there are two coefficients of expansion in case of liquids: Coefficient of real expansion, γ_r. and Coefficient of apparent expansion γ_a are given by

$$\gamma_r = \frac{\text{real increase in volume}}{\text{original volume} \times \text{rise in temperature}}$$

$$\gamma_a = \frac{\text{apparent increase in volume}}{\text{original volume} \times \text{rise in temperature}}$$

1. **Relation between γ_a and γ_r:** $\gamma_a = \gamma_r - \gamma_s$,where γ_s is the coefficient of cubical expansion of the solid of the vessel.
2. If $\gamma_r > \gamma_s$, level of the liquid in vessel will rise on heating
3. If $\gamma_r < \gamma_s$, level of the liquid in vessel will fall on heating
4. If $\gamma_r = \gamma_s$, level of the liquid in vessel will remain same

Some points

1. $\alpha : \beta : \gamma = 1 : 2 : 3$. , Hence, for same rise in temperature,

   percentage change in area = 2 × percentage change in length and

   percentage change in volume = 3 × percentage change in length.
2. The three coefficients of expansion are not constant for a given solid. Their values depend on temperature range in which they are measured.
3. The values of α, β and γ are independent of units of length, area and volume respectively.

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4. For anisotropic solids, $\gamma = \alpha_x + \alpha_y + \alpha_z$ where α_x , α_y , α_z represent the mean coefficients of linear expansion along three mutually perpendicular directions.
5. If there is a hole in a plate (or cavity in a block), the area of hole (or volume of cavity) will increase when plate (or body) expands on heating, just as if the hole (or cavity) were solids of the same material.
6. If coefficients of linear expansion of the materials of two rods are in the inverse ratio of their initial lengths, then the difference between lengths of two rods remains constant at all temperatures, i.e., $(\alpha_1/\alpha_2) = (L_2/L_1)$.

Anomalous expansion of water

Generally matter expands on heating and contracts on cooling. In case of water, it expands on heating if its temperature is greater than 4°C. In the range 0°C to 4°C, water contracts on heating and expands on cooling. This behaviour of water in the range from 0°C to 4°C is called anomalous expansion.

The anomalous behaviour of water arises due to the fact that water has three types of molecules, viz., H_2O, $(H_2O)_2$ and $(H_2O)_3$ having different volume per unit mass and at different temperatures their properties in water are different.

1. At 4°C, density of water is maximum while its specific volume is minimum.

Effect of linear expansion on pendulum clocks

Suppose a pendulum clock gives proper time at temperature θ. If temperature is increased to θ′, then due to linear expansion, length of pendulum and hence its time period will increase. In a time ‘t’ a clock will lose time by: $\Delta t = \frac{1}{2}\alpha\Delta\theta t$, where α = coefficient of linear expansion of pendulum

(a) Hence, time lost by the clock in a day (= 86,400 sec) = (½) α Δθ (86,400) = 43200 α Δθ sec

(b) Clock will gain time, i.e., clock will become fast if θ' < θ

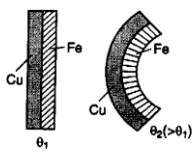
(c) Since α for invar is very small, hence pendulums are made of invar to show the correct time in all seasons.

Generation of thermal stress in a clamped rod due to its linear expansion

When a rod, whose ends are rigidly fixed such as to prevent expansion or contraction, undergoes a change in temperature, due to thermal expansion or contraction, a compressive or tensile stress is developed in it. These stresses are called thermal stresses.

If Δθ°C be the change in temperature of a rod of length L, then thermal strain = (ΔL/l) = α Δθ

So, thermal stress = strain x Y= Yα Δθ and thermal force = YAα Δθ



Effect of linear expansion on a bimetallic strip

A bimetallic strip consists of two strips of equal length but of different metals, riveted together keeping one over the other. When such a bimetallic strip is heated, it bends with metal of greater α on outer side, i.e., convex side.

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Thermal Expansion, Thermometry, Heat Transfer Assignment

1. Two spheres of the 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
   (a) both the spheres will expand equally
   (b) the hollow sphere will expand more than the solid one
   (c) the solid sphere will expand more than the hollow one
   (d) no conclusion can be drawn about their relative expansions unless the nature of the material is known.
2. A metal sheet with a circular hole is heated. The hole will
   (a) contract
   (b) expand
   (c) remain unaffected
   (d) contract or expand depending on the value of the linear expansion coefficient.
3. Given coefficient at linear expansion for brass (α_b) = 18 x 10^{-6} /^{o} C and that for iron (α_i) = 12 x 10^{-6}/^{o}C. what lengths of brass (l_b) and iron (l_i) should be taken so that the difference between them may always remain 0.1 m for any variation in temperature ?
   (a) l_b = 0.3m.; l_i = 0.4m
   (b) l_b = 0.4m ; l_i = 0.3m
   (c) l_b = 0.2m ; l_i = 0.3m
   (d) l_b = 0.3m ; l_i = 0.2m.
4. A bimetal made of copper and iron strips welded together is straight at room temperature. It is held vertically with iron strip towards left and copper strip towards right. If this bimetal is heated, it will
   (a) remain straight
   (b) bend towards right
   (c) bend towards left
   (d) bend forward.
5. On heating a liquid of coefficient of cubical expansion α in a container having coefficient of linear expansion $\alpha/3$, the level of liquid in the container will
   (a) rise
   (b) fall
   (c) remain almost the same.
   (d) rise or fall depending on the density of the liquid.
6. The coefficient of apparent expansion of a liquid is C when heated in a copper vessel and is S when heated in a silver vessel. If A is the coefficient of linear expansion of copper, then that of silver is
   (a) $\frac{C+S-3A}{3}$ (b) $\frac{C+3A-S}{3}$
   (c) $\frac{S+3A-C}{3}$ (d) $\frac{C+S+3A}{3}$
7. A block of wood is floating on water at 0°C with a certain volume V above water level. The temperature of water is slowly raised to 20°C. How does the volume V change with the rise of temperature'?
   (a) remain unchanged
   (b) decrease continuously
   (c) decrease till 4°C and then increase
   (d) increase till 4°C and then decrease.
8. The volume of a block of a metal changes by 0.12% when it is heated through 20°C. The coefficient of linear expansion of the metal is
   (a) 2.0 x 10^{-5} per ^{o}C
   (b) 4.0 x 10^{-5} per °C
   (c) 6.0 x 10^{-5} per ^{o}C
   (d) 8.0 x 10^{-5} per ^{o}C
9. An iron tyre is to be fitted on a wooden wheel 1.0 m in diameter. The diameter of the tyre is 6 mm smaller than that of the wheel. The tyre should be heated by a temperature of (coefficient of volume expansion of iron is 3.6 x 10^{-5}/^{o}C)
   (a) 167°C (b) 334°C (c) 500°C (d) 1000°C
10. A steel rod of length 25 cm has a cross-sectional area of 0.8 cm^2. The force required to stretch this rod by the same amount as the expansion produced by heating it through 10°C is (coefficient of linear expansion of steel is 10^{-5} /^{o}C and Young's modulus of steel is 2 x $l0^{10}$ N/m^2)
    (a) 40 N (b) 80 N (c) 120 N (d) 160 N
11. A flask is filled up to the 50 cm^3 mark with mercury at temperature 28°C. If the flask and the contents are heated to 48°C, the volume of mercury above the mark will be (coefficient of linear expansion of glass = 9 x 10^{-6} /^{o}C. coefficient of real expansion of mercury = 180 x 10^{-6}/^{o}C)
    (a) 0.15 cm^3 (b) 0.25 cm^3 (c) 0.3 cm^3 (d) 0.5 cm^3
12. A second's pendulum gives correct time at 25°C. The pendulum shaft is thin and is made of steel. How many seconds will it lose per day at 35°C ? (α_{steel} = 11 x 10^{-6} /^{o}C)
    (a) 1.75s (b) 2.5s (c) 3.5s (d) 4.75s
13. On a thermometer, the freezing point of water is marked as 20° and the boiling point of water is marked as 150°. A temperature of 60°C will be read on this thermometer as
    (a) 40° (b) 65° (c) 98° (d) 110°

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14. The temperature at which both the Fahrenheit and the Centigrade scales have the same value is
(a) 40° (b) - 40° (c) 20° (d) - 20°
15. The gas thermometers are more sensitive than the liquid thermometers because gases
(a) expand more than liquids
(b) do not change their states easily
(c) are much lighter
(d) are easy to obtain.
16. A constant volume gas thermometer shows pressure readings of 50 cm and 90 cm of mercury at 0°C and 100° C, respectively. When the pressure reading is 60 cm of mercury, the temperature is
(a) 25°C (b) 40°C (c) 15°C (d) 12.5°C
17. Of the following thermometers, the one which can be used for measuring a temperature of the order of 5000°C is
(a) constant volume gas thermometer
(b) radiation pyrometer
(c) vapour pressure thermometer
(d) platinum resistance thermometer.
18. Four rods of the same material but different radii (r) and lengths (*l*) are used to connect two reservoirs of heat at different temperatures. The one which will conduct most heat is
(a) r = 2cm, l = 0.5m (b) r = 2cm, l = 2m
(c) r = 1 cm, l = 1 m (d) r = 0.5cm, l = 0.5m
19. Two vessels A and B of different materials are similar in shape and size. The same quantity of ice filled in them melts in times t_1 and t_2, respectively. The ratio of the thermal conductivities of A and B is
(a) $t_1 : t_2$ (b) $t_2 : t_1$ (c) $t_1^2 : t_2^2$ (d) $t_2^2 : t_1^2$
20. One end of a thermally insulated copper rod, 1 m long and having area of cross-section 10 cm^2 is immersed in boiling water (100°C) and the other in ice (0^oC). If thermal conductivity of copper is 0.92 cal/cm/s/ °C and latent heat of ice is 80 cal/g, the amount of ice that will melt per minute is
(a) 5.2g (b) 6.9g (c) 8.4g (d) 9.2g
21. A cooking pot should have
(a) high specific heat and low conductivity
(b) high specific heat and high conductivity
(c) low specific heat and low conductivity
(d) low specific heat and high conductivity,
22. Two rods of the same length and diameter, having thermal conductivities K_1 and K_2, are joined in parallel. The equivalent thermal conductivity of the combination is
(a) K_1K_2/K_1+K_2 (b) $K_1 + K_2$
(c) $(K1 + K_2)/2$ (d) $(K_1K_2)^{1/2}$
23. Two identical rods of the same material are joined in series. Under a temperature difference, a certain quantity of heat flows through the combination in 4 minutes. If the two rods are joined in parallel, the same quantity of heat will flow through the combination under the same temperature difference in
(a) 1 min (b) 2 min (c) 8 min (d) 16 min
24. Two slabs A & B having lengths l_1 and l_2 respectively, and same cross-section have thermal conductivities K_1 and K_2 respectively. They are placed in contact and a constant temperature difference is maintained across the combination. The ratio of the quantities of heat flowing through A and B in a given time is
(a) $\frac{K_1}{l_1} : \frac{K_2}{l_2}$ (b) $\frac{K_1}{l_2} : \frac{K_2}{l_1}$
(c) $K_1l_1 : K_2l_2$ (d) 1 : 1
25. Thermal conductivity of a plate depends on
(a) the temperature difference between the two sides
(b) the thickness of the plate
(c) the area of the plate
(d) none of the above
26. The ends of two rods of different materials, having thermal conductivities, radii of cross-section and lengths in the ratio 1 : 2, are maintained at the same temperature difference. If the rate of flow of heat in the larger rod is 4 cal/s, that in the shorter rod in cal/s will be
(a) 1 (b) 2 (c) 8 (d) 16
27. A glass window conducts out a certain quantity of heat per second when the inside temperature is 10°C and the outside temperature is - 10°C. The same quantity of heat will be conducted in through the window per second when the inside temperature is - 43°C and the outside temperature is
(a) 43°C (b) - 23°C (c) 23°C (d) 0°C
28. A sphere, a cube and a thin circular plate, all having the same mass and made of the same material are heated to the same temperature and then allowed to cool. Which of them cools fastest?
(a) sphere (b) cube
(c) circular plate (d) all at the same rate.
29. A black body at a high temperature T K. radiates energy at the rate of E W/m^2. When the temperature falls to T/2 K, the radiated energy in W/m^2 will be
(a) E/4 (b) E/2 (c) 2E (d) E/16
30. A black body at 227°C radiates heat at the rate of 5 $cal/cm^2/s$. The rate of heat radiated in $cal/cm^2/s$ at 727°C is
(a) 40 (b) 80 (c) 160 (d) 240
31. A piece of blue glass heated to a high temperature and a piece of red glass at room temperature are taken inside a dimly-lit room. Then
(a) the blue piece will look blue and the red piece will look red as usual
(b) both the pieces will look equally red
(c) the blue piece will look brighter red as compared to the red piece
(d) both the pieces will look red but the blue piece will be dimmer
32. A body cools from 85°C to 80°C in 5 minutes. The time taken to cool from 80°C to 75°C is
(a) less than 5 minutes
(b) 5 minutes
(c) more than 5 minutes

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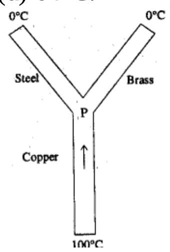
(d) less or more than five minutes depending on the nature of the body.

33. The end A of a rod AB of length 1m is maintained at 80°C and the end B at 0°C. The temperature at a distance of 60 cm from the end A is
(a)16°C (b) 32°C (c) 48°C (d) 64°C.

34. Rods of copper, brass and steel are welded together to form a Y-shaped figure as shown. The cross-sectional area of each rod is 4 cm^2. The end of the copper rod is maintained at 100°C and the ends of the brass and the steel rods at 0°C. The lengths of the copper, brass and steel rods are 46 cm. 13 cm and 12 cm., respectively. The temperature of the junction point F in steady state is (K_{cu} = 0.92, K_{brass} = 0.26, K_{steel} = 0.12 in cal/s/cm/°C)



(a) 20°C (b) 30°C (c) 40°C (d) 600C.

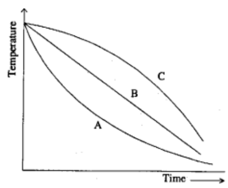
35. A body, having a surface area of 5.0 cm^2, radiates 300 J of energy per minute at a temperature of 727°C. The emissivity of the body is (Stefan's constant = 5.67 x 10^{-8} $W/m^2/K^4$)
(a) 0.09 (b) 0.18 (c) 0.36 (d) 0.54

36. A piece of metal and a piece of wood are kept at a temperature of 45°C. On touching the two with hand
(a) the two will appear equally hot
(b) the piece of wood will appear hotter than the piece of metal
(c) the piece of metal will appear hotter than the piece of wood
(d) the distinction in the hotness will not be possible.

37. A partition wall has two layers A and B, in contact, each made of a different material. They have the same thickness but the thermal conductivity of layer A is twice that of layer B. If the steady state temperature difference across the wall is 60 K, then the corresponding difference across the layer A is
(a) 10 K (b) 20 K (c) 30 K (d) 40 K

38. In a room where the temperature is 30° C, a body cools from 61°C to 59°C in 4 minutes. The time (in minutes) taken by the body to cool from 51°C to 49°C will be
(a) 4 (b) 6 (c) 5 (d) 8

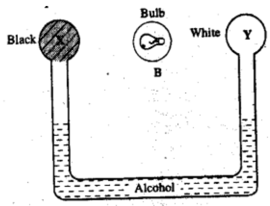
39. A block of steel heated to 100°C is left in a room to cool. Which of the curves shown in the figure represents the decrease of temperature with time ?



(a) A (b) B
(c) C (d) None

40. If the wavelengths of maximum intensity of radiations emitted by the sun and the moon are 0.5 x 10^{-6} m and 10^{-4}m, respectively, the ratio of their temperatures is
(a) 1/100 (b) 1/200 (c) 100 (d) 200

41. The figure shows two air filled bulbs X and Y connected by a U-tube partly filled with alcohol. X is painted black while Y is painted white. An electric bulb B is placed midway between X and Y. When B is lighted the level of alcohol in



(a) X falls and that in Y rises
(b) Y falls and that in X rises
(c) both X and Y falls
(d) both X and Y rises.

42. If the temperature of a hot body is increased by 50%, the amount of radiation emitted by it increases approximately by
(a) 225 % (b) 250 % (c) 400 % (d) 500 %

ANSWERS

1a ,2b ,3c ,4c ,5c ,6b ,7d ,8a ,9c ,10d ,11a ,12d ,13c ,14b ,15a ,16a ,17b ,18a ,19b ,20b ,21d ,22c ,23a ,24d ,25d ,26a ,27b ,28c ,29d ,30b ,31c ,32c ,33b ,34c ,35b ,36c ,37b ,38b ,39a ,40d ,41a, 42c