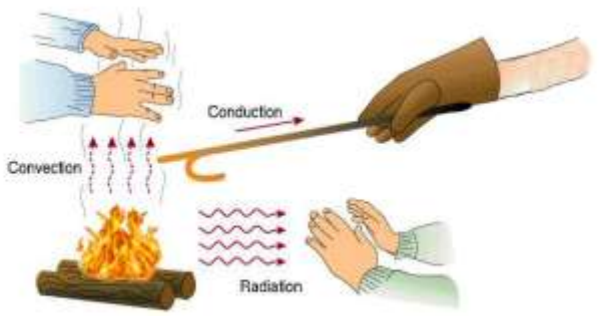
Chapter
15
Transmission of Heat

Heat energy transfers from a body at higher temperature to a body at lower temperature. The transfer of heat from one body to another may take place by one of the following modes.

Conduction, Convection and **Radiation**



Conduction

The process of transmission of heat energy in which the heat is transferred from one particle to other particle without dislocation of the particle from their equilibrium position is called conduction.

(1) Heat flows from hot end to cold end. Particles of the medium simply oscillate but do not leave their place.

(2) Medium is necessary for conduction

(3) It is a slow process

(4) The temperature of the medium increases through which heat flows

Fig. 15.1

(5) Conduction is a process which is possible in all states of matter.

(6) When liquid and gases are heated from the top, they conduct heat from top to bottom.

(7) In solids only conduction takes place

(8) In non-metallic solids and fluids the conduction takes place only due to vibrations of molecules, therefore they are poor conductors.

(9) In metallic solids free electrons carry the heat energy, therefore they are good conductor of heat.

Conduction in Metallic Rod

When one end of a metallic rod is heated, heat flows by conduction from the hot end to the cold end.

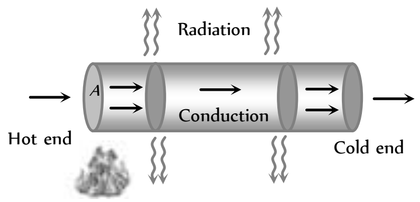


Fig. 15.2

(1) **Variable state :** In this state temperature of every part of the rod increases

Heat received by each cross-section of the rod from hotter end used in three ways.

(i) A part increases temperature of itself.

(ii) Another part transferred to neighbouring cross-section.

(iii) Remaining part radiates.

- $\theta_1 > \theta_2 > \theta_3 > \theta_4 > \theta_5$
- $\theta \rightarrow$ Changing

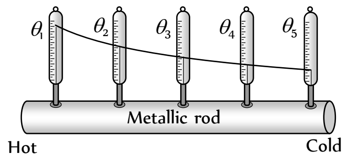
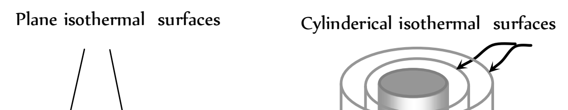


Fig. 15.3

(2) **Steady state :** After sometime, a state is reached when the temperature of every cross-section of the rod becomes constant. In this state, no heat is absorbed by the rod. The heat that reaches any cross-section is transmitted to the next except that a small part of heat is lost to surrounding from the sides by convection & radiation. This state of the rod is called steady state.

(3) **Isothermal surface :** Any surface (within a conductor) having its all points at the same temperature, is called isothermal surface. The direction



of flow of heat through a conductor at any point is perpendicular to the isothermal surface passing through that point.

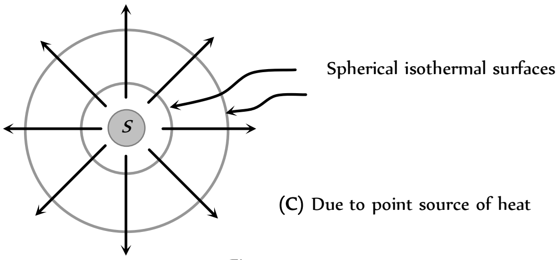


Fig. 15.4

(4) **Temperature gradient (T.G.) :** The rate of change of temperature with distance between two isothermal surfaces is called temperature gradient. Hence

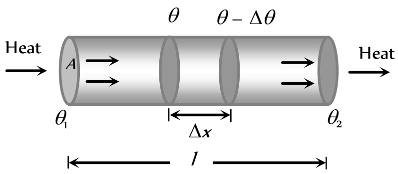


Fig. 15.5

(i) Temperature gradient = $\dfrac{-\Delta\theta}{\Delta x}$

(ii) The negative sign show that temperature θ decreases as the distance x increases in the direction of heat flow.

(iii) For uniform temperature fall $\dfrac{\theta_1 - \theta_2}{l} = \dfrac{\Delta\theta}{\Delta x}$

(iv) Unit : *K/m* or *°C/m* (S.I.) and Dimensions $[L^{-1}\theta]$

(5) **Law of thermal conductivity :** Consider a rod of length l and area of cross-section A whose faces are maintained at temperature θ_1 and θ_2 respectively. The curved surface of rod is kept insulated from surrounding to avoid leakage of heat

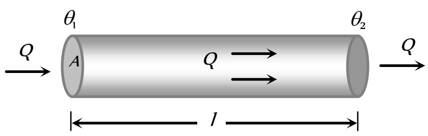


Fig. 15.6

(i) In steady state the amount of heat flowing from one face to the other face in time t is given by $Q = \dfrac{KA(\theta_1 - \theta_2)t}{l}$

where K is coefficient of thermal conductivity of material of rod.

(ii) Rate of flow of heat *i.e.* heat current $\dfrac{Q}{t} = H = \dfrac{KA(\theta_1 - \theta_2)}{l}$

(iii) In case of non-steady state or variable cross-section, a more general equation can be used to solve problems.

$$\frac{dQ}{dt} = -KA\frac{d\theta}{dx}$$

(6) **More about K :** It is the measure of the ability of a substance to conduct heat through it.

(i) Units : *Cal/cm-sec °C* (in C.G.S.), *kcal/m-sec-K* (in M.K.S.) and *W/m- K* (in S.I.). Dimension : $[MLT^{-3}\theta^{-1}]$

(ii) The magnitude of K depends only on nature of the material.

(iii) Substances in which heat flows quickly and easily are known as good conductor of heat. They possesses large thermal conductivity due to large number of free electrons *e.g.* Silver, brass *etc.* For perfect conductors, $K = \infty$.

(iv) Substances which do not permit easy flow of heat are called bad conductors. They possess low thermal conductivity due to very few free electrons *e.g.* Glass, wood *etc.* and for perfect insulators, $K = 0$.

(v) The thermal conductivity of pure metals decreases with rise in temperature but for alloys thermal conductivity increases with increase of temperature.

(vi) Human body is a bad conductor of heat (but it is a good conductor of electricity).

(vii) **Decreasing order of conductivity :** For some special cases it is as follows

(a) $K_{Ag} > K_{Cu} > K_{Al}$

(b) $K_{Solid} > K_{Liquid} > K_{Gas}$

(c) $K_{Metals} > K_{Non-metals}$

Table 15.1 : Thermal conductivity of some material

Substance	Thermal conductivity (*W/m-K*)	Substance	Thermal conductivity (*W/m-K*)
Aluminium	240	Concrete	0.9
Copper	400	Water	0.6
Gold	300	Glass wool	0.04
Iron	80	Air	0.024
Lead	35	Helium	0.14
Glass	0.9	Hydrogen	0.17
Wood	0.1-0.2	Oxygen	0.024

(7) **Relation between temperature gradient and thermal conductivity :** In steady state, rate of flow of heat $\dfrac{dQ}{dt} = -KA\dfrac{d\theta}{dx} = -KA \times$ (T.G.) $\Rightarrow$

(T.G.) $\propto \dfrac{1}{K}$ ($\dfrac{dQ}{dt}$ = constant)

Temperature difference between the hot end and the cold end in steady state is inversely proportional to K, *i.e.* in case of good conductors temperature of the cold end will be very near to hot end.

In ideal conductor where $K = \infty$, temperature difference in steady state will be zero.

(8) **Thermal resistance (*R*) :** The thermal resistance of a body is a measure of its opposition to the flow of heat through it.

It is defined as the ratio of temperature difference to the heat current (= Rate of flow of heat)

(i) Hence $R = \dfrac{\theta_1 - \theta_2}{H} = \dfrac{\theta_1 - \theta_2}{KA(\theta_1 - \theta_2)/l} = \dfrac{l}{KA}$

(ii) **Unit :** $^{o}C \times sec/cal$ or $K \times sec/kcal$ and Dimension : $[M^{-1}L^{-2}T^{3}\theta]$

(9) **Wiedmann-Franz law :** At a given temperature *T*, the ratio of thermal conductivity to electrical conductivity 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.

(10) **Thermometric conductivity or diffusivity :** It is a measure of rate of change of temperature (with time) when the body is not in steady state (*i.e.*, in variable state)

It is defined as the ratio of the coefficient of thermal conductivity to the thermal capacity per unit volume of the material. Thermal capacity per unit volume = $\frac{mc}{V} = \rho c$

(ρ = density of substance) $\Rightarrow$ Diffusivity (*D*) = $\frac{K}{\rho c}$

Unit : *m/sec* and Dimension : $[L^2T^{-1}]$

Table 15.2 : Electrical Analogy for Thermal Conduction

Electrical conduction	Thermal conduction
Electric charge flows from higher potential to lower potential	Heat flows from higher temperature to lower temperature
The rate of flow of charge is called the electric current, *i.e.* $I = \frac{dq}{dt}$	The rate of flow of heat may be called as heat current *i.e.* $H = \frac{dQ}{dt}$
The relation between the electric current and the potential difference is given by Ohm's law, that is $I = \frac{V_1 - V_2}{R}$ where *R* is the electrical resistance of the conductor	Similarly, the heat current may be related with the temperature difference as $H = \frac{\theta_1 - \theta_2}{R}$ where *R* is the thermal resistance of the conductor
The electrical resistance is defined as $R = \frac{\rho l}{A} = \frac{l}{\sigma A}$ where ρ = Resistivity and σ = Electrical conductivity	The thermal resistance may be defined as $R = \frac{l}{KA}$ where *K* = Thermal conductivity of conductor
$\frac{dq}{dt} = I = \frac{V_1 - V_2}{R} = \frac{\sigma A}{l}(V_1 - V_2)$	$\frac{dQ}{dt} = H = \frac{\theta_1 - \theta_2}{R} = \frac{KA}{l}(\theta_1 - \theta_2)$

Applications of Conductivity in Daily Life

(1) Cooking utensils are provided with wooden handles, because wood is a poor conductor of heat. The hot utensils can be easily handled from the wooden handles and our hands are saved from burning.

Fig. 15.7

(2) We feel warmer in a fur coat. The air enclosed in the fur coat being bad conductor heat does not allow the body heat to flow outside. Hence we feel warmer in a fur coat.

(3) Eskimos make double walled houses of the blocks of ice. Air enclosed in between the double walls prevents transmission of heat from the house to the cold surroundings.

Fig. 15.8

For exactly the same reason, two thin blankets are warmer than one blanket of their combined thickness. The layer of air enclosed in between the two blankets makes the difference.

(4) Wire gauze is placed over the flame of Bunsen burner while heating the flask or a beaker so that the flame does not go beyond the gauze and hence there is no direct contact between the flame and the flask. The wire gauze being a good conductor of heat, absorb the heat of the flame and transmit it to the flask.

Fig. 15.9

Davy's safety lamp has been designed on this principle. The gases in the mines burn inside the gauze placed around the flame of the lamp. The temperature outside the gauze is not high, so the gases outside the gauze do not catch fire.

(5) Birds often swell their feathers in winter. By doing so, they enclose more air between their bodies and the feathers. The air, being bad conductor of heat prevents the out flow of their body heat. Thus, birds feel warmer in winter by swelling their feathers.

Combination of Metallic Rods

(1) **Series combination :** Let *n* slabs each of cross-sectional area *A*, lengths $l_1, l_2, l_3, ... l_n$ and conductivities $K_1, K_2, K_3 ...... K_n$ respectively be connected in the series

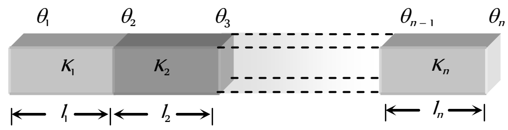


Fig. 15.10

(i) **Heat current :** Heat current is the same in all the conductors.*i.e.*,

$$\frac{Q}{t} = H_1 = H_2 = H_3 .... = H_n$$

$$\frac{K_1A(\theta_1 - \theta_2)}{l_1} = \frac{K_2A(\theta_2 - \theta_3)}{l_2} = \frac{K_nA(\theta_{n-1} - \theta_n)}{l_n}$$

(ii) **Equivalent thermal resistance :** $R = R_1 + R_2 + ... R_n$

(iii) **Equivalent thermal conductivity :** It can be calculated as follows

From $R_S = R_1 + R_2 + R_3 + ...$

$$\frac{l_1 + l_2 + ... l_n}{K_s} = \frac{l_1}{K_1A} + \frac{l_2}{K_2A} + ... + \frac{l_n}{K_nA}$$

$$\Rightarrow K_s = \frac{l_1 + l_2 + ... l_n}{\frac{l_1}{K_1} + \frac{l_2}{K_2} + ... \frac{l_n}{K_n}}$$

(a) For *n* slabs of equal length $K_s = \frac{n}{\frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} + ... \frac{1}{K_n}}$

(b) For two slabs of equal length, $K_s = \frac{2K_1K_2}{K_1 + K_2}$

(iv) **Temperature of interface of composite bar :** Let the two bars are arranged in series as shown in the figure.

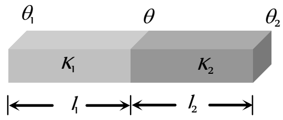


Fig. 15.11

Then heat current is same in the two conductors.

i.e., $\dfrac{Q}{t} = \dfrac{K_1 A(\theta_1 - \theta)}{l_1} = \dfrac{K_2 A(\theta - \theta_2)}{l_2}$

By solving we get $\theta = \dfrac{\dfrac{K_1}{l_1}\theta_1 + \dfrac{K_2}{l_2}\theta_2}{\dfrac{K_1}{l_1} + \dfrac{K_2}{l_2}}$

(a) If $l_1 = l_2$ then $\theta = \dfrac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2}$

(b) If $K_1 = K_2$ and $l_1 = l_2$ then $\theta = \dfrac{\theta_1 + \theta_2}{2}$

(2) **Parallel Combination :** Let n slabs each of length l, areas $A_1, A_2, A_3, ... A_n$ and thermal conductivities $K_1, K_2, K_3, ... K_n$ are connected in parallel then

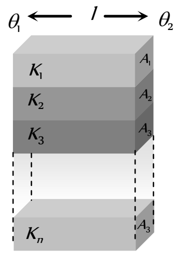


Fig. 15.12

(i) **Equivalent resistance :** $\dfrac{1}{R_s} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + ... \dfrac{1}{R_n}$

For two slabs $R_s = \dfrac{R_1 R_2}{R_1 + R_2}$

(ii) **Temperature gradient :** Same across each slab.

(iii) **Heat current :** in each slab will be different. Net heat current will be the sum of heat currents through individual slabs. *i.e.,* $H = H_1 + H_2 + H_3 + ... H_n$

$$\frac{K(A_1 + A_2 + ... + A_n)(\theta_1 - \theta_2)}{l}$$

$$= \frac{K_1 A_1(\theta_1 - \theta_2)}{l} + \frac{K_2 A_2(\theta_1 - \theta_2)}{l} + ... + \frac{K_n A_n(\theta_1 - \theta_2)}{l}$$

$$\Rightarrow K = \frac{K_1 A_1 + K_2 A_2 + K_3 A_3 + ... K_n A_n}{A_1 + A_2 + A_3 + ... A_n}$$

(a) For n slabs of equal area $K = \dfrac{K_1 + K_2 + K_3 + ... K_n}{n}$

(b) For two slabs of equal area $K = \dfrac{K_1 + K_2}{2}$.

Ingen-Hauz Experiment

It is used to compare thermal conductivities of different materials. If l_1, l_2 and l_3 are the lengths of wax melted on rods as

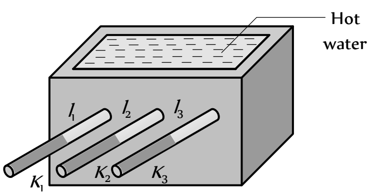


Fig. 15.13

shown in the figure, then the ratio of thermal conductivities is $K_1 : K_2 : K_3 = l_1^2 : l_2^2 : l_3^2$

$\Rightarrow$ Thermal conductivity (K) $\propto$ (Melted length l)^2

Searle's Experiment

It is a method of determination of K of a metallic rod.

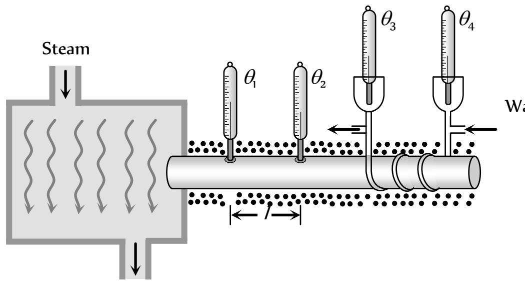


Fig. 15.14

(1) In this experiment a temperature difference $(\theta_1 - \theta_2)$ is maintained across a rod of length l and area of cross section A. If the thermal conductivity of the material of the rod is K, then the amount of heat transmitted by the rod from the hot end to the cold end in time t is given by, $Q = \dfrac{KA(\theta_1 - \theta_2)t}{l}$ ......(i)

(2) In Searle's experiment, this heat reaching the other end is utilized to raise the temperature of certain amount of water flowing through pipes circulating around the other end of the rod. If temperature of the water at the inlet is θ_3 and at the outlet is θ_4, then the amount of heat absorbed by water is given by, $Q = mc(\theta_4 - \theta_3)$ ......(ii)

(3) Where, m is the mass of the water which has absorbed this heat and temperature is raised and c is the specific heat of the water

Equating (i) and (ii), K can be determined *i.e.,* $K = \dfrac{mc(\theta_4 - \theta_3)l}{A(\theta_1 - \theta_2)t}$

(4) In numericals we may have the situation where the amount of heat travelling to the other end may be required to do some other work *e.g.,* it may be required to melt the given amount of ice. In that case equation (i) will have to be equated to mL.

i.e. $mL = \dfrac{KA(\theta_1 - \theta_2)t}{l}$

Growth of Ice on Lake

(1) Water in a lake starts freezing if the atmospheric temperature drops below 0^oC. Let y be the thickness of ice layer in the lake at any instant t and atmospheric temperature is $-\theta^oC$.

(2) The temperature of water in contact with lower surface of ice will be zero.

(3) If A is the area of lake, heat escaping through ice in time dt is $dQ_1 = \dfrac{KA[0 - (-\theta)]dt}{y}$

(4) Suppose the thickness of ice layer increases by dy in time dt, due to escaping of above heat. Then $dQ_2 = mL = \rho(dy\,A)L$

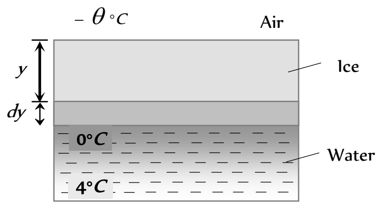


Fig. 15.15

(5) As $dQ_1 = dQ_2$, hence, rate of growth of ice will be $(dy/dt) = (K\theta/\rho L y)$

So, the time taken by ice to grow to a thickness y is

$$t = \frac{\rho L}{K\theta}\int_0^y y\,dy = \frac{\rho L}{2K\theta}y^2$$

(6) If the thickness is increased from y_1 to y_2 then time taken $t = \frac{\rho L}{K\theta}\int_{y_1}^{y_2} y dy = \frac{\rho L}{2K\theta}(y_2^2 - y_1^2)$

(7) Take care and do not apply a negative sign for putting values of temperature in formula and also do not convert it to absolute scale.

(8) Ice is a poor conductor of heat, therefore the rate of increase of thickness of ice on ponds decreases with time.

(9) It follows from the above equation that time taken to double and triple the thickness, will be in the ratio of

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

(10) The time intervals to change the thickness from 0 to y, from y to $2y$ and so on will be in the ratio

$$\Delta t_1 : \Delta t_2 : \Delta t_3 :: (1^2 - 0^2) : (2^2 - 1^2) : (3^2 : 2^2)$$

$$\Rightarrow \Delta t_1 : \Delta t_2 : \Delta t_3 :: 1 : 3 : 5$$

Convection

Mode of transfer of heat by means of migration of material particles of medium is called convection. It is of two types.

(1) **Natural convection :** This arise due to difference of densities at two places and is a consequence of gravity because on account of gravity the hot light particles rise up and cold heavy particles try setting down. It mostly occurs on heating a liquid/fluid.

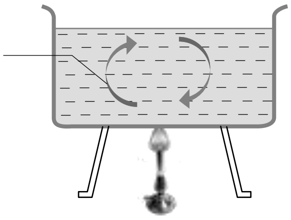


Fig. 15.16

(2) **Forced convection :** If a fluid is forced to move to take up heat from a hot body then the convection process is called forced convection. In this case Newton's law of cooling holds good. According to which rate of loss of heat from a hot body due to moving fluid is directly proportional to the surface area of body and excess temperature of body over its surroundings *i.e.*

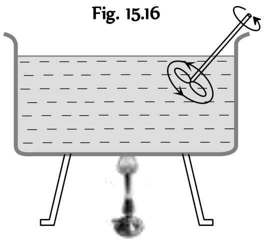


Fig. 15.17

$$\frac{Q}{t} \propto A(T - T_0) \Rightarrow \frac{Q}{t} = h\,A(T - T_0)$$

where h = Constant of proportionality called convection coefficient, T = Temperature of body and T_0 = Temperature of surrounding

Convection coefficient (h) depends on properties of fluid such as density, viscosity, specific heat and thermal conductivity.

(3) Natural convection takes place from bottom to top while forced convection in any direction.

(4) In case of natural convection, convection currents move warm air upwards and cool air downwards. That is why heating is done from base, while cooling from the top.

(5) Natural convection plays an important role in ventilation, in changing climate and weather and in forming land and sea breezes and trade winds.

(6) Natural convection is not possible in a gravity free region such as a free falling lift or an orbiting satellite.

(7) The force of blood in our body by heart helps in keeping the temperature of body constant.

(8) If liquids and gases are heated from the top (so that convection is not possible) they transfer heat (from top to bottom) by conduction.

(9) Mercury though a liquid is heated by conduction and not by convection.

Radiation

(1) The process of the transfer of heat from one place to another place without heating the intervening medium is called radiation.

Fig. 15.18

(2) Precisely it is electromagnetic energy transfer in the form of electromagnetic wave through any medium. It is possible even in vacuum *e.g.* the heat from the sun reaches the earth through radiation.

(3) The wavelength of thermal radiations ranges from $7.8 \times 10^{-7}\,m$ to $4 \times 10^{-4}\,m$. They belong to *infra-red* region of the electromagnetic spectrum. That is why thermal radiations are also called *infra-red* radiations.

(4) Medium is not required for the propagation of these radiations.

(5) They produce sensation of warmth in us but we can't see them.

(6) Every body whose temperature is above zero Kelvin emits thermal radiation.

(7) Their speed is equal to that of light *i.e.* $(= 3 \times 10^8\,m/s)$.

(8) Their intensity is inversely proportional to the square of distance of point of observation from the source (*i.e.* $I \propto 1/d^2$).

(9) Just as light waves, they follow laws of reflection, refraction, interference, diffraction and polarisation.

(10) When these radiations fall on a surface then exert pressure on that surface which is known as radiation pressure.

(11) While travelling these radiations travel just like photons of other electromagnetic waves. They manifest themselves as heat only when they are absorbed by a substance.

(12) Spectrum of these radiations can not be obtained with the help of glass prism because it absorbs heat radiations. It is obtained by quartz or rock salt prism because these materials do not have free electrons and interatomic vibrational frequency is greater than the radiation frequency, hence they do not absorb heat radiations.

(13) **Diathermanous Medium :** A medium which allows heat radiations to pass through it without absorbing them is called diathermanous medium. Thus the temperature of a diathermanous medium does not increase irrespective of the amount of the thermal radiations passing through it *e.g.*, dry air, SO_2, rock salt (*NaCl*).

(i) Dry air does not get heated in summers by absorbing heat radiations from sun. It gets heated through convection by receiving heat from the surface of earth.

(ii) In winters heat from sun is directly absorbed by human flesh while the surrounding air being diathermanous is still cool. This is the reason that sun's warmth in winter season appears very satisfying to us.

(14) **Athermanous medium :** A medium which partly absorbs heat rays is called a thermous medium As a result temperature of an athermanous medium increases when heat radiations pass through it *e.g.*, wood, metal, moist air, simple glass, human flesh *etc.*

Colour of Heated Object

When a body is heated, all radiations having wavelengths from zero to infinity are emitted.

(1) Radiations of longer wavelengths are predominant at lower temperature.

(2) The wavelength corresponding to maximum emission of radiations shifts from longer wavelength to shorter wavelength as the temperature increases. Due to this the colour of a body appears to be changing.

(3) A blue flame is at a higher temperature than a yellow flame

Table 15.3 : Variation of colour of a body on heating

Temperature	Colour
$525°C$	Dull red
$900°C$	Cherry red
$1100°C$	Orange red
$1200°C$	Yellow
$1600°C$	White

Interaction of Radiation with Matter

When thermal radiations (Q) fall on a body, they are partly reflected, partly absorbed and partly transmitted.

(1) $Q = Q_a + Q_r + Q_t$

(2) $\dfrac{Q_a}{Q} + \dfrac{Q_r}{Q} + \dfrac{Q_t}{Q} = a + r + t = 1$

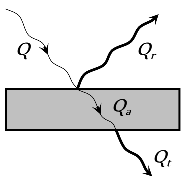


Fig. 15.19

(3) $a = \dfrac{Q_a}{Q}$ = Absorptance or absorbing power

$r = \dfrac{Q_r}{Q}$ = Reflectance or reflecting power

$t = \dfrac{Q_t}{Q}$ = Transmittance or transmitting power

(4) r, a and t all are the pure ratios so they have no unit and dimension.

(5) **Different bodies**

(i) If $a = t = 0$ and $r = 1 \rightarrow$ body is perfect reflector

(ii) If $r = t = 0$ and $a = 1 \rightarrow$ body is perfectly black body

(iii) If, $a = r = 0$ and $t = 1 \rightarrow$ body is perfect transmitter

(iv) If $t = 0 \Rightarrow r + a = 1$ or $a = 1 - r$ *i.e.* good reflectors are bad absorbers.

Emissive Power, Absorptive Power and Emissivity

If temperature of a body is more than it's surrounding then body emits thermal radiation

(1) **Monochromatic Emittance or Spectral emissive power (e_λ) :** For a given surface it is defined as the radiant energy emitted per sec per unit area of the surface with in a unit wavelength around λ *i.e.* lying between $\left(\lambda - \dfrac{1}{2}\right)$ to $\left(\lambda + \dfrac{1}{2}\right)$.

Spectral emissive power $(e_\lambda) = \dfrac{\text{Energy}}{\text{Area} \times \text{time} \times \text{wavelength}}$

Unit : $\dfrac{Joule}{m^2 \times sec \times Å}$ and Dimension : $[ML^{-1}T^{-3}]$

(2) **Total emittance or total emissive power (e) :** It is defined as the total amount of thermal energy emitted per unit time, per unit area of the body for all possible wavelengths.

$$e = \int_0^\infty e_\lambda d\lambda$$

Unit : $\dfrac{Joule}{m^2 \times \sec}$ or $\dfrac{Watt}{m^2}$ and Dimension : $[MT^{-3}]$

(3) **Monochromatic absorptance or spectral absorptive power (a_λ) :** It is defined as the ratio of the amount of the energy absorbed in a certain time to the total heat energy incident upon it in the same time, both in the unit wavelength interval. It is dimensionless and unit less quantity. It is represented by a_λ.

(4) **Total absorptance or total absorpting power (a):** It is defined as the total amount of thermal energy absorbed per unit time, per unit area of the body for all possible wavelengths.

$$a = \int_0^\infty a_\lambda d\lambda$$

(5) **Emissivity (ε) :** Emissivity of a body at a given temperature is defined as the ratio of the total emissive power of the body (e) to the total emissive power of a perfect black body (E) at that temperature *i.e.* $\varepsilon = \dfrac{e}{E}$

($\varepsilon \rightarrow$ read as epsilon)

(i) For perfectly black body $\varepsilon = 1$

(ii) For highly polished body $\varepsilon = 0$

(iii) But for practical bodies emissivity (ε) lies between zero and one ($0 < \varepsilon < 1$).

Perfectly Black Body

(1) A perfectly black body is that which absorbs completely the radiations of all wavelengths incident on it.

(2) As a perfectly black body neither reflects nor transmits any radiation, therefore the absorptance of a perfectly black body is unity *i.e.* $t = 0$ and $r = 0 \Rightarrow a = 1$.

(3) We know that the colour of an opaque body is the colour (wavelength) of radiation reflected by it. As a black body reflects no wavelength so, it appears black, whatever be the colour of radiations incident on it.

(4) When perfectly black body is heated to a suitable high temperature, it emits radiation of all possible wavelengths. For example, temperature of the sun is very high (6000 K approx.) it emits all possible radiation so it is an example of black body.

(5) **Ferry's black body :** A perfectly black body can't be realised in practice. The nearest example of an ideal black body is the Ferry's black body. It is a doubled walled evacuated spherical cavity whose inner wall is blackened. The space between the wall is evacuated to prevent the loss of heat by conduction and radiation. There is a fine hole in it. All the radiations incident upon this hole are absorbed by this black body. If this black body is heated to high temperature then it emits radiations of all wavelengths. It is the hole which is to be regarded as a black body and not the total enclosure

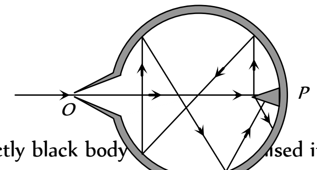
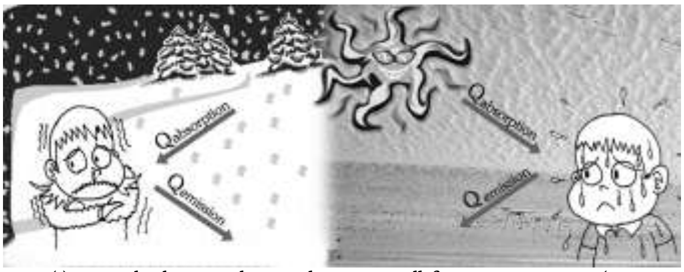


Fig. 15.20

(6) A perfectly black body [illegible]ised in practice but materials like Platinum black or Lamp black come close to being ideal black bodies. Such materials absorbs 96% to 85% of the incident radiations.

Prevost Theory of Heat Exchange



(1) Every body emits heat radiations at all finite temperature (Except 0 K) as well as it absorbs radiations from the surroundings.

(2) Exchange of energy along various bodies takes place via radiation.

(3) The process of heat exchange among various bodies is a continuous phenomenon.

(4) At absolute zero temperature (0 K or $-273°C$) this law is not applicable because at this temperature the heat exchange among various bodies ceases.

(5) If $Q_{emission} > Q_{absorbed} \rightarrow$ temperature of body decreases and consequently the body appears colder.

If $Q_{emission} < Q_{absorbed} \rightarrow$ temperature of body increases and it appears hotter.

If $Q_{emission} = Q_{absorbed} \rightarrow$ temperature of body remains constant (thermal equilibrium)

Kirchoff's Law

According to this 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. Hence $\frac{e_1}{a_1} = \frac{e_2}{a_2} = ... \left(\frac{E}{A}\right)_{\text{Perfectly black body}}$

But for perfectly black body $A = 1$ *i.e.* $\frac{e}{a} = E$

If emissive and absorptive powers are considered for a particular wavelength λ, $\left(\frac{e_\lambda}{a_\lambda}\right) = (E_\lambda)_{\text{black}}$

Now since $(E_\lambda)_{\text{black}}$ is constant at a given temperature, according to this law if a surface is a good absorber of a particular wavelength it is also a good emitter of that wavelength.

This in turn implies that a good absorber is a good emitter (or radiator)

Applications of Kirchoff's Law

(1) Sand is rough black, so it is a good absorber and hence in deserts, days (when radiation from the sun is incident on sand) will be very hot. Now in accordance with Kirchoff's law, good absorber is a good emitter so nights (when sand emits radiation) will be cold. This is why days are hot and nights are cold in desert.

(2) Sodium vapours, on heating, emit two bright yellow lines. These are called D_1, D_2 lines of sodium. When continuos white light from an arc lamp is made to pass through sodium vapours at low temperature, the continuous spectrum is intercepted by two dark lines exactly in the same places as D_1 and D_2 lines. Hence sodium vapours when cold, absorbs the same wavelength, as they emit while hot. This is in accordance with Kirchoff's law.

(3) When a shining metal ball having some black spots on its surface is heated to a high temperature and is seen in dark, the black spots shine brightly and the shining ball becomes dull or invisible. The reason is that the black spots on heating absorb radiation and so emit these in dark while the polished shining part reflects radiations and absorb nothing and so does not emit radiations and becomes invisible in the dark.

(4) When a green glass is heated in furnace and taken out, it is found to glow with red light. This is because red and green are complimentary colours. At ordinary temperatures, a green glass appears green, because it transmits green colour and absorb red colour strongly. According to Kirchoff's law, this green glass, on heating must emit the red colour, which is absorbed strongly. Similarly when a red glass is heated to a high temperature it will glow with green light.

(5) A person with black skin experiences more heat and more cold as compared to a person of white skin because when the outside temperature is greater, the person with black skin absorbs more heat and when the outside temperature is less the person with black skin radiates more energy.

(6) **Kirchoff' law also explains the Fraunhoffer lines :**

(i) Sun's inner most part (photosphere) emits radiation of all wavelength at high temperature.

(ii) When these radiation enters in outer part (chromosphere) of sun, few wavelength are absorbed by some terrestrial elements (present in vapour form at lower temperature)

(iii) These absorbed wavelengths, which are missing appear as dark lines in the spectrum of the sun called **Fraunhoffer lines.**

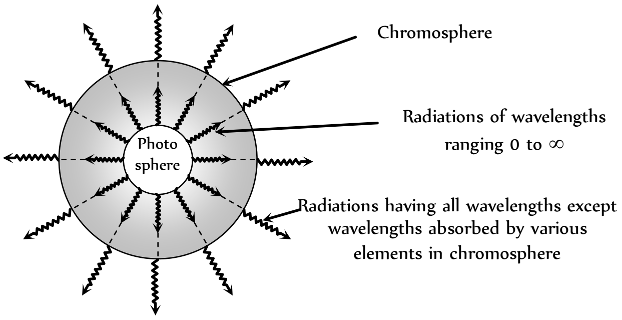


Fig. 15.21

(iv) During total solar eclipse these lines appear bright because the gases and vapour present in the chromosphere start emitting those radiation which they had absorbed.

Stefan's Law

According to it the radiant energy emitted by a perfectly black body per unit area per sec (*i.e.* emissive power of black body) is directly proportional to the fourth power of its absolute temperature, *i.e.* $E \propto T^4$ $\Rightarrow$ $E = \sigma T^4$

where σ is a constant called Stefan's constant having dimension $[MT^{-3}\theta^{-4}]$ and value $5.67 \times 10^{-8}\, W/m^2K^4$.

(i) For ordinary body : $e = \varepsilon E = \varepsilon\sigma T^4$

(ii) Radiant energy : If Q is the total energy radiated by the ordinary body then $e = \dfrac{Q}{A \times t} = \varepsilon\sigma T^4 \;\Rightarrow\; Q = A\,\varepsilon\sigma T^4 t$

(iii) Radiant power (P) : It is defined as energy radiated per unit area *i.e.* $P = \dfrac{Q}{t} = A\varepsilon\sigma T^4$.

(iv) If an ordinary body at temperature T is surrounded by a body at temperature T_0, then Stefan's law may be put as

$$e = \varepsilon\,\sigma(T^4 - T_0^4)$$

Rate of Loss of Heat (R_H) and Rate of Cooling (R_C)

(1) **Rate of loss of heat (or initial rate of loss of heat) :** If an ordinary body at temperature T is placed in an environment of temperature T_0 ($T_0 < T$) then heat loss by radiation is given by

$$\Delta Q = Q_{\text{emission}} - Q_{\text{absorption}} = A\varepsilon\,\sigma(T^4 - T_0^4)$$

(2) Rate of loss of heat $(R_H) = \dfrac{dQ}{dt} = A\varepsilon\,\sigma(T^4 - T_0^4)$

(i) If two bodies are made of same material, have same surface finish and are at the same initial temperature then $\dfrac{dQ}{dt} \propto A \Rightarrow \dfrac{\left(\dfrac{dQ}{dt}\right)_1}{\left(\dfrac{dQ}{dt}\right)_2} = \dfrac{A_1}{A_2}$

(3) **Initial rate of fall in temperature (Rate of cooling):** If m is the body and c is the specific heat then

$$\frac{dQ}{dt} = mc.\frac{dT}{dt} = mc\,\frac{d\theta}{dt} \qquad (\because Q = mc\,\Delta T \text{ and } dT = d\theta)$$

(i) Rate of cooling $(R_c) = \dfrac{d\theta}{dt} = \dfrac{(dQ/dt)}{mc} = \dfrac{A\varepsilon\,\sigma}{mc}(T^4 - T_0^4)$

$= \dfrac{A\varepsilon\,\sigma}{V\rho\,c}(T^4 - T_0^4)$; where m = density (ρ) × volume (V)

(ii) for two bodies of the same material under identical environments, the ratio of their rate of cooling is $\dfrac{(R_c)_1}{(R_c)_2} = \dfrac{A_1}{A_2}.\dfrac{V_2}{V_1}$

(4) **Dependence of rate of cooling :** When a body cools by radiation the rate of cooling depends on

(i) Nature of radiating surface *i.e.* greater the emissivity, faster will be the cooling.

(ii) Area of radiating surface, *i.e.* greater the area of radiating surface, faster will be the cooling.

(iii) Mass of radiating body *i.e.* greater the mass of radiating body slower will be the cooling.

(iv) Specific heat of radiating body *i.e.* greater the specific heat of radiating body slower will be cooling.

(v) Temperature of radiating body *i.e.* greater the temperature of body faster will be cooling.

(vi) Temperature of surrounding *i.e.* greater the temperature of surrounding slower will be cooling.

Table 15.4 : Comparison of rate of heat loss (R_H) and rate of cooling (R_c) for different bodies

Body	Condition	Rate of heat loss $R_H = \dfrac{dQ}{dt}$	Rate of cooling $R_c = \dfrac{dT}{dt}$ or $\dfrac{d\theta}{dt}$
Two solid sphere	T, T_0, c, ρ are same	$R_H \propto A \propto r^2$ $\Rightarrow \dfrac{(R_H)_1}{(R_H)_2} = \dfrac{r_1^2}{r_2^2}$	$R_c \propto \dfrac{A}{V} \propto \dfrac{r^2}{r^3} \propto \dfrac{1}{r}$
Two solid sphere of diff. material	T, T_0 – same	$R_H \propto A \propto r^2$	$R_c \propto \dfrac{A}{V\rho c} \propto \dfrac{1}{r\rho c}$
Different shape bodies like cube, sphere plate	T, T_0, c, ρ - same	$R_H \propto A$ $A_{\max} \rightarrow$ Plate $A_{\min} \rightarrow$ sphere	$R_c \propto \dfrac{A}{V}$
Bodies of different materials	T, T_0, m, A are same but c diff.	$R_H \rightarrow$ same for all. bodies	$R_c \propto \dfrac{1}{c}$

Newton's Law of Cooling

When the temperature difference between the body and its surrounding is not very large *i.e.* $T - T_0 = \Delta T$ then $T^4 - T_0^4$ may be approximated as $4T_0^3 \Delta T$

By Stefan's law, $\frac{dT}{dt} = \frac{A\varepsilon\sigma}{mc}[T^4 - T_0^4]$

Hence $\frac{dT}{dt} = \frac{A\varepsilon\sigma}{mc} 4T_0^3 \Delta T \Rightarrow \frac{dT}{dt} \propto \Delta T$ or $\frac{d\theta}{dt} \propto \theta - \theta_0$

i.e., if the temperature of body is not very different from surrounding, **rate of cooling is proportional to temperature difference** between the body and its surrounding. This law is called Newton's law of cooling.

(1) Greater the temperature difference between body and its surrounding greater will be the rate of cooling.

(2) If $\theta = \theta_0$, $\frac{d\theta}{dt} = 0$ *i.e.* a body can never be cooled to a temperature lesser than its surrounding by radiation.

(3) If a body cools by radiation from $\theta_1^o C$ to $\theta_2^o C$ in time *t*, then $\frac{d\theta}{dt} = \frac{\theta_1 - \theta_2}{t}$ and $\theta = \theta_{av} = \frac{\theta_1 + \theta_2}{2}$. The Newton's law of cooling becomes $\left[\frac{\theta_1 - \theta_2}{t}\right] = K\left[\frac{\theta_1 + \theta_2}{2} - \theta_0\right]$.

This form of law helps in solving numericals.

(4) Practical examples

(i) Hot water loses heat in smaller duration as compared to moderate warm water.

(ii) Adding milk in hot tea reduces the rate of cooling.

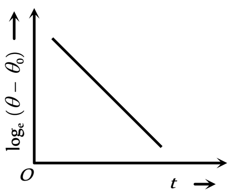
Cooling Curves

(1) **Curve between log(θ – θ_0) and time**

As $\frac{d\theta}{dt} \propto -(\theta - \theta_0) \Rightarrow \frac{d\theta}{(\theta - \theta_0)} = -Kdt$

Integrating $\log_e(\theta - \theta_0) = -Kt + C$

$\log_e(\theta - \theta_0) = -Kt + \log_e A$



This is a straight line with negative slope

Fig. 15.22

(2) **Curve between temperature of body and time**

As $\log_e(\theta - \theta_0) = -Kt + \log_e A \Rightarrow \log_e \frac{\theta - \theta_0}{A} = -Kt$

$\Rightarrow \theta - \theta_0 = Ae^{-kt}$

which indicates temperature decreases exponentially with increasing time.

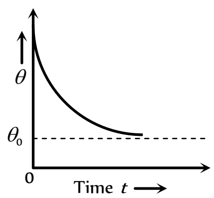


Fig. 15.23

(3) **Curve between the rate of cooling** (R) and body temperature (θ).

$R = K(\theta - \theta_0) = K\theta - K\theta_0$

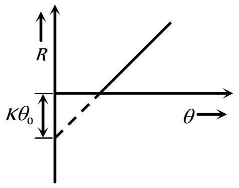


Fig. 15.24

This is a straight line intercept R-axis at $-K\theta_0$

(4) **Curve between rate of cooling (*R*)** and temperature difference between body (θ) and surrounding (θ_0)

$R \propto (\theta - \theta_0)$. This is a straight line passing through origin.

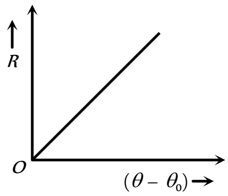


Fig. 15.25

Determination of Specific Heat of Liquid

If volume, radiating surface area, nature of surface, initial temperature and surrounding of water and given liquid are equal and they are allowed to cool down (by radiation) then rate of loss of heat and fall in temperature of both will be same.

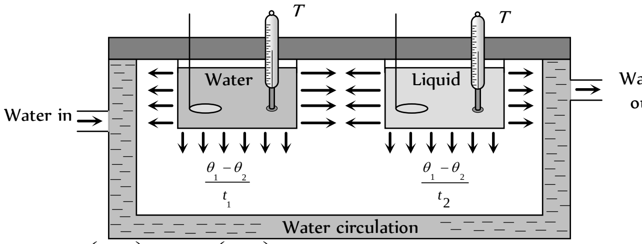


Fig. 15.26

i.e. $\left(\frac{dQ}{dt}\right)_{\text{water}} = \left(\frac{dQ}{dt}\right)_{\text{liquid}}$

$(m_W c_W + W)\frac{(\theta_1 - \theta_2)}{t_1} = (m_l c_l + W)\frac{(\theta_1 - \theta_2)}{t_2}$

or $\left[\frac{m_W c_W + W}{t_1}\right] = \left[\frac{m_l c_l + W}{t_2}\right]$

$W = m_c c_c$ = Water equivalent of calorimeter, where m_c and c_c are mass and specific heat of calorimeter.

If density of water and liquid is ρ and ρ' respectively then $m_W = V\rho_W$ and $m_l = V\rho_l$

Specific heat of liquid $c_l = \frac{1}{m_l}\left[\frac{t_l}{t_W}(m_W c_W + W) - W\right]$

Distribution of Energy in the Spectrum of Black Body

A perfectly black body emits radiation of all possible wavelength.

Langley and later on Lummer and Pringsheim investigated the distribution of energy amongst the different wavelengths in the thermal spectrum of a black body radiation. The results obtained are shown in figure. From these curves it is clear that

(1) At a given temperature energy is not uniformly distributed among different wavelengths.

(2) At a given temperature intensity of heat radiation increases with wavelength, reaches a maximum at a particular wavelength and with further increase in wavelength it decreases.

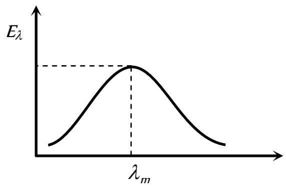


Fig. 15.27

(3) For all wavelengths an increase in temperature causes an increase in intensity.

(4) The area under the curve will represent the total intensity of radiation at a particular temperature *i.e.* Area = $E = \int E_\lambda d\lambda$

From Stefan's law $E = \sigma T \Rightarrow$ Area under E_λ - λ curve $(A) \propto T$

(5) The energy (E_m) emitted corresponding to the wavelength of maximum emission (λ_m) increases with fifth power of the absolute temperature of the black body *i.e.*, $E_{\max} \propto T^5$

Wien's Displacement Law

According to Wien's law the product of wavelength corresponding to maximum intensity of radiation and temperature of body (in Kelvin) is constant, *i.e.* $\lambda_m T = b = \text{constant}$

where b is Wien's constant and has value $2.89 \times 10^{-3}\, m\text{-}K$.

As the temperature of the body increases, the wavelength at which the spectral intensity (E_λ) is maximum shifts towards left. Therefore it is also called Wien's displacement law.

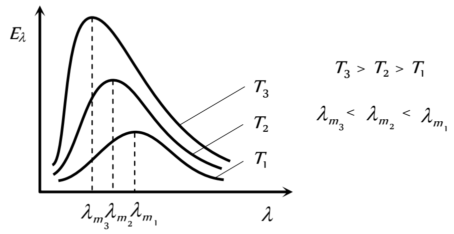


Fig. 15.28

This law is of great importance in 'Astrophysics' as through the analysis of radiations coming from a distant star, by finding λ_m the temperature of the star $T (= b/\lambda_m)$ is determined.

Law of Distribution of Energy (Plank's Hypothesis)

(1) The theoretical explanation of black body radiation was done by Planck.

(2) According to Plank's atoms of the walls of a uniform temperature enclosure behave as oscillators, each with a characteristic frequency of oscillation.

(3) These oscillations emits electromagnetic radiations in the form of photons (The radiation coming out from a small hole in the enclosure are called black body radiation). The energy of each photon is $h\nu$. Where ν is the frequency of oscillator and h is the Plank's constant. Thus emitted energies may be $h\nu$, $2h\nu$, $3h\nu$ ... $nh\nu$ but not in between.

According to Planck's law $E_\lambda d\lambda = \dfrac{8\pi hc}{\lambda^5}\dfrac{1}{[e^{hc/\lambda KT} - 1]} d\lambda$

where c = speed of light and k = Boltzmann's constant. This equation is known as Plank's radiation law. It is correct and complete law of radiation

(4) This law is valid for radiations of all wavelengths ranging from zero to infinite.

(5) For radiations of short wavelength $\left(\lambda << \dfrac{hc}{KT}\right)$ Planck's law reduces to *Wien's energy distribution law* $E_\lambda d\lambda = \dfrac{A}{\lambda^5} e^{-B/\lambda T} d\lambda$

(6) For radiations of long wavelength $\left(\lambda >> \dfrac{hc}{KT}\right)$ Planck's law reduces to *Rayleigh-Jeans energy distribution law* $E_\lambda d\lambda = \dfrac{8\pi KT}{\lambda^4} d\lambda$

Temperature of the Sun and Solar Constant

If R is the radius of the sun and T its temperature, then the energy emitted by the sun per sec through radiation in accordance with Stefan's law will be given by

$$P = A\sigma T^4 = 4\pi R^2 \sigma T^4$$

In reaching earth this energy will spread over a sphere of radius r (= average distance between sun and earth); so the intensity of solar radiation at the surface of earth (called solar constant S) will be given by

$$S = \frac{P}{4\pi r^2} = \frac{4\pi R^2 \sigma T^4}{4\pi r^2}$$

$$i.e.\ T = \left[\left(\frac{r}{R}\right)^2 \frac{S}{\sigma}\right]^{1/4}$$

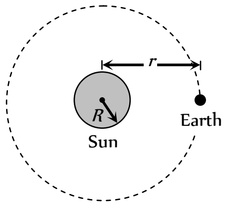


Fig. 15.29

$$= \left[\left(\frac{1.5 \times 10^8}{7 \times 10^5}\right)^2 \times \frac{1.4 \times 10^3}{5.67 \times 10^{-8}}\right]^{1/4} \simeq 5800\, K$$

As $r = 1.5 \times 10^8$ *km*, $R = 7 \times 10^5$ *km*,

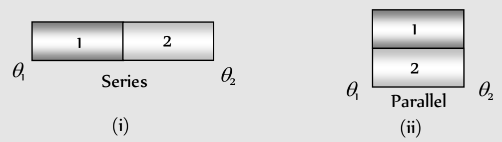
$$S = 2\frac{cal}{cm^2 min} = 1.4\frac{kW}{m^2} \text{ and } \sigma = 5.67 \times 10^{-8}\frac{W}{m^2K^4}$$

This result is in good agreement with the experimental value of temperature of sun, *i.e.*, 6000 *K*.

Tips & Tricks

✍ Glass and water vapours transmit shorter wavelengths through them but reflects longer wavelengths. This concept is utilised in Green house effect. Glass transmits those waves which are emitted by a source at a temperature greater than 100°*C*. So, heat rays emitted from sun are able to enter through glass enclosure but heat emitted by small plants growing in the nursery gets trapped inside the enclosure.

✍ Suppose two metallic rods are first connected in series then in parallel.



If Q_s heat flows in time t_s in series combination and Q_p heat flows in time t_p in parallel combine, then $\dfrac{Q_p}{Q_s} = \dfrac{t_p}{t_s} \times \dfrac{R_s}{R_p}$

If Rods are identical then $R_S = \frac{R}{2}$ and $R_p = 2R \Rightarrow \frac{Q_p}{Q_s} = 4\left(\frac{t_p}{t_s}\right)$

✍ If temperature of a body becomes θ_1 to θ_2 in t time and it becomes θ_2 to θ_3 in next time then use

$$\frac{\theta_2 - \theta_0}{\theta_1 - \theta_0} = \frac{\theta_3 - \theta_0}{\theta_2 - \theta_0}$$ (θ_0 = temperature of enviroment)

✍ Newton's law of cooling can be used to compare the specific heat of the two liquids.

If equal masses of two liquids having same surface are and finish cools from same initial temperature to same final temperature with same surrounding then $\frac{t_1}{t_2} = \frac{K_2}{K_1} = \frac{C_1}{C_2}$

✍ Radiations from sun take 8 *min* and 20 *sec* to reach earth.

✍ Suppose temperature of a body decreases $\theta_1°C$ to $\theta_2°C$ in time t_1 and $\theta_2°C$ to $\theta_3°C$ in time t_2 in the same invirment

If $(\theta_1 - \theta_2) \geq (\theta_2 - \theta_3)$ then $t_2 > t_1$

✍ Green glass is a good absorber of red light and a good reflector of green light. Consequently at lower temperature it is a good emitter of red light.

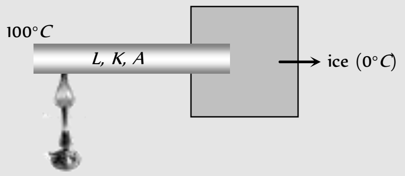
Hence Green $\rightleftharpoons$ Red

Also Yellow $\rightleftharpoons$ Blue

✍ While solving the problems of heat flow, remember the following equation

e.g. If we are interested in finding the mass of ice which transfoms into water in unit time. For this we will take

$$\frac{T.D.}{R} = L_f.\frac{dm}{dt}$$



$$\Rightarrow \frac{dm}{dt} = \frac{T.D.}{(L_f)(R)}$$

✍ **Confusion**

The rate of cooling has been used in many books, with double meanings. At some places. Rate of cooling $= \frac{dQ}{dt}$ and at other places, rate of cooling $= \frac{d\theta}{dt}$. Our suggestion is that look for the units, if the rate of cooling is in *cal/m* in or *J/sec etc.*, then it is $\frac{dQ}{dt}$. But if rate of cooling is in °*C/min* it means $\frac{d\theta}{dt}$.

Ordinary Thinking

Objective Questions

Conduction

1. In which case the thermal conductivity increases from left to right[NCERT 1974

(a) *Al, Cu, Ag* (b) *Ag, Cu, Al*

(c) *Cu, Ag, Al* (d) *Al, Ag, Cu*

2. Which of the following cylindrical rods will conduct most heat, when their ends are maintained at the same steady temperature [CPMT 1981; NCERT 1

MP PMT 1987; CBSE PMT 1995]

(a) Length 1 *m*; radius 1 *cm*

(b) Length 2 *m*; radius 1 *cm*

(c) Length 2 *m*; radius 2 *cm*

(d) Length 1 *m*; radius 2 *cm*

3. The heat is flowing through two cylindrical rods of same material. The diameters of the rods are in the ratio 1 : 2 and their lengths are in the ratio 2 : 1. If the temperature difference between their ends is the same, the ratio of rate of flow of heat through them will be

[NCERT 1982; CBSE PMT 1995; EAMCET 1997]

(a) 1 : 1 (b) 2 : 1

(c) 1 : 4 (d) 1 : 8

4. Two identical square rods of metal are welded end to end as shown in figure (i), 20 calories of heat flows through it in 4 minutes. If the rods are welded as shown in figure (ii), the same amount of heat will flow through the rods in

[NCERT 1982]

(i) (ii)

(a) 1 minute (b) 2 minutes

(c) 4 minutes (d) 16 minutes

5. For cooking the food, which of the following type of utensil is most suitable

[MNR 1986; MP PET 1990; CPMT 1991;

SCRA 1998; MP PMT/PET 1998, 2000; RPET 2001]

(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

6. Under steady state, the temperature of a body [CPMT 1978]

(a) Increases with time
(b) Decreases with time
(c) Does not change with time and is same at all the points of the body
(d) Does not change with time but is different at different points of the body

7. The coefficient of thermal conductivity depends upon [MP PET/PMT 1984; AFMC 1996; Orissa JEE 2005]

(a) Temperature difference of two surfaces
(b) Area of the plate
(c) Thickness of the plate
(d) Material of the plate

8. When two ends of a rod wrapped with cotton are maintained at different temperatures and after some time every point of the rod attains a constant temperature, then [MP PET/PMT 1988]

(a) Conduction of heat at different points of the rod stops because the temperature is not increasing
(b) Rod is bad conductor of heat
(c) Heat is being radiated from each point of the rod
(d) Each point of the rod is giving heat to its neighbour at the same rate at which it is receiving heat

9. The length of the two rods made up of the same metal and having the same area of cross-section are 0.6 m and 0.8 m respectively. The temperature between the ends of first rod is 90^oC and 60^oC and that for the other rod is 150 and 110^oC. For which rod the rate of conduction will be greater

(a) First (b) Second
(c) Same for both (d) None of the above

10. The ratio of thermal conductivity of two rods of different material is 5 : 4. The two rods of same area of cross-section and same thermal resistance will have the lengths in the ratio

(a) 4 : 5 (b) 9 : 1
(c) 1 : 9 (d) 5 : 4

11. The thermal conductivity of a material in CGS system is 0.4. In steady state, the rate of flow of heat 10 *cal/sec-cm*, then the thermal gradient will be [MP PMT 1989]

(a) $10°C/cm$ (b) $12°C/cm$
(c) $25°C/cm$ (d) $20°C/cm$

12. Two rectangular blocks A and B of different metals have same length and same area of cross-section. They are kept in such a way that their cross-sectional area touch each other. The temperature at one end of A is 100°C and that of B at the other end is 0°C. If the ratio of their thermal conductivity is 1 : 3, then under steady state, the temperature of the junction in contact will be

(a) 25°C (b) 50°C
(c) 75°C (d) 100°C

13. Two vessels of different materials are similar in size in every respect. The same quantity of ice filled in them gets melted in 20 minutes and 30 minutes. The ratio of their thermal conductivities will be [MP PMT 1989; CMEET Bihar 1995]

(a) 1.5 (b) 1
(c) 2/3 (d) 4

14. Two rods A and B are of equal lengths. Their ends are kept between the same temperature and their area of cross-sections are A_1 and A_2 and thermal conductivities K_1 and K_2. The rate of heat transmission in the two rods will be equal, if [MP PMT 1991; CBSE PMT 2002]

(a) $K_1A_2 = K_2A_1$ (b) $K_1A_1 = K_2A_2$
(c) $K_1 = K_2$ (d) $K_1A_1^2 = K_2A_2^2$

15. In variable state, the rate of flow of heat is controlled by

(a) Density of material (b) Specific heat
(c) Thermal conductivity (d) All the above factors

16. If the ratio of coefficient of thermal conductivity of silver and copper is 10 : 9, then the ratio of the lengths upto which wax will melt in Ingen Hausz experiment will be [DPMT 2001]

(a) 6 : 10 (b) $\sqrt{10}:3$
(c) 100 : 81 (d) 81 : 100

17. The thickness of a metallic plate is 0.4 cm. The temperature between its two surfaces is 20^oC. The quantity of heat flowing per second is 50 calories from $5cm^2$ area. In CGS system, the coefficient of thermal conductivity will be

(a) 0.4 (b) 0.6
(c) 0.2 (d) 0.5

18. In Searle's method for finding conductivity of metals, the temperature gradient along the bar [MP PMT 1984]

(a) Is greater nearer the hot end
(b) Is greater nearer to the cold end
(c) Is the same at all points along the bar
(d) Increases as we go from hot end to cold end

19. The dimensions of thermal resistance are [MP PET 1984; BVP 2003]

(a) $M^{-1}L^{-2}T^3K$ (b) $ML^2T^{-2}K^{-1}$
(c) $ML^2T^{-3}K$ (d) $ML^2T^{-2}K^{-2}$

20. A piece of glass is heated to a high temperature and then allowed to cool. If it cracks, a probable reason for this is the following property of glass [CPMT 1985]

(a) Low thermal conductivity
(b) High thermal conductivity
(c) High specific heat
(d) High melting point

21. Two walls of thicknesses d_1 and d_2 and thermal conductivities k_1 and k_2 are in contact. In the steady state, if the temperatures at the outer surfaces are T_1 and T_2, the temperature at the common wall is [MP PMT 1985] [MP PMT 1990; CBSE PMT 1999]

(a) $\frac{k_1T_1d_2+k_2T_2d_1}{k_1d_2+k_2d_1}$ (b) $\frac{k_1T_1+k_2d_2}{d_1+d_2}$
(c) $\left(\frac{k_1d_1+k_2d_2}{T_1+T_2}\right)T_1T_2$ (d) $\frac{k_1d_1T_1+k_2d_2T_2}{k_1d_1+k_2d_2}$

22. A slab consists of two parallel layers of copper and brass of the same thickness and having thermal conductivities in the ratio 1 : 4. If

the free face of brass is at $100^o C$ and that of copper at $0^o C$, the temperature of interface is

[IIT 1981; MP PMT 1987, 2001]

(a) $80°C$ (b) $20°C$

(c) $60°C$ (d) $40°C$

23. The temperature gradient in a rod of 0.5 m long is $80^o C/m$. If the temperature of hotter end of the rod is $30^o C$, then the temperature of the cooler end is

(a) $40^o C$ (b) $-10^o C$

(c) $10^o C$ (d) $0^o C$

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

(a) $K = 1$ (b) $K = 0$

(c) $K = 100$ (d) $K = \infty$

25. Snow is more heat insulating than ice, because

(a) Air is filled in porous of snow

(b) Ice is more bad conductor than snow

(c) Air is filled in porous of ice

(d) Density of ice is more

26. Two thin blankets keep more hotness than one blanket of thickness equal to these two. The reason is

(a) Their surface area increases

(b) A layer of air is formed between these two blankets, which is bad conductor

(c) These have more wool

(d) They absorb more heat from outside

27. Ice formed over lakes has

(a) Very high thermal conductivity and helps in further ice formation

(b) Very low conductivity and retards further formation of ice

(c) It permits quick convection and retards further formation of ice

(d) It is very good radiator

28. Two rods of same length and material transfer a given amount of heat in 12 seconds, when they are joined end to end. But when they are joined lengthwise, then they will transfer same heat in same conditions in

[BHU 1998; UPSEAT 2002]

(a) 24 s (b) 3 s

(c) 1.5 s (d) 48 s

29. Wires A and B have identical lengths and have circular cross-sections. The radius of A is twice the radius of B *i.e.* $r_A = 2r_B$. For a given temperature difference between the two ends, both wires conduct heat at the same rate. The relation between the thermal conductivities is given by

(a) $K_A = 4K_B$ (b) $K_A = 2K_B$

(c) $K_A = K_B/2$ (d) $K_A = K_B/4$

30. Two identical plates of different metals are joined to form a single plate whose thickness is double the thickness of each plate. If the coefficients of conductivity of each plate are 2 and 3 respectively, then the conductivity of composite plate will be

(a) 5 (b) 2.4

(c) 1.5 (d) 1.2

31. If the radius and length of a copper rod are both doubled, the rate of flow of heat along the rod increases

(a) 4 times (b) 2 times

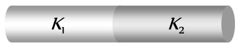
(c) 8 times (d) 16 times

32. The coefficients of thermal conductivity of copper, mercury and glass are respectively K_c, K_m and K_g such that $K_c > K_m > K_g$. If the same quantity of heat is to flow per second per unit area of each and corresponding temperature gradients are X_c, X_m and X_g, then

(a) $X_c = X_m = X_g$ (b) $X_c > X_m > X_g$

(c) $X_c < X_m < X_g$ (d) $X_m < X_c < X_g$

33. If two metallic plates of equal thicknesses and thermal conductivities K_1 and K_2 are put together face to face and a common plate is constructed, then the equivalent thermal conductivity of this plate will be [MP PMT 1991]



(a) $\frac{K_1K_2}{K_1 + K_2}$ (b) $\frac{2K_1K_2}{K_1 + K_2}$

(c) $\frac{(K_1^2 + K_2^2)^{3/2}}{K_1K_2}$ (d) $\frac{(K_1^2 + K_2^2)^{3/2}}{2K_1K_2}$

34. The quantity of heat which crosses unit area of a metal plate during conduction depends upon

[MP PMT 1992; JIPMER 1997]

(a) The density of the metal

(b) The temperature gradient perpendicular to the area

(c) The temperature to which the metal is heated

(d) The area of the metal plate

35. The ends of two rods of different materials with their thermal conductivities, radii of cross-sections and lengths all are 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 $4\ cal/\sec$, that in the shorter rod in $cal/\sec$ will be

[EAMCET 1986]

(a) 1 (b) 2

(c) 8 (d) 16

36. Two spheres of different materials one with double the radius and one-fourth wall thickness of the other, are filled with ice. If the time taken for complete melting ice in the large radius one is 25 *minutes* and that for smaller one is 16 *minutes*, the ratio of thermal conductivities of the materials of larger sphere to the smaller sphere is [EAMCET 1991]

(a) 4 : 5 (b) 5 : 4

(c) 25 : 1 (d) 1 : 25

37. The ratio of the diameters of two metallic rods of the same material is 2 : 1 and their lengths are in the ratio 1 : 4. If the temperature difference between their ends are equal, the rate of flow of heat in them will be in the ratio [MP PET 1994]

(a) 2 : 1 (b) 4 : 1

(c) $8:1$ (d) 16 : 1

38. Two cylinders P and Q have the same length and diameter and are made of different materials having thermal conductivities in the ratio 2 : 3. These two cylinders are combined to make a cylinder. One end of P is kept at $100°C$ and another end of Q at $0°C$. The temperature at the interface of P and Q is [MP PMT 1994; EAMCET 2000]

(a) $30^o C$ (b) $40^o C$

(c) $50^o C$ (d) $60^o C$

39. Two identical rods of copper and iron are coated with wax uniformly. When one end of each is kept at temperature of boiling water, the length upto which wax melts are $8.4 cm$ and $4.2 cm$ respectively. If thermal conductivity of copper is 0.92, then thermal conductivity of iron is [MP PET 1995]

(a) 0.23 (b) 0.46

(c) 0.115 (d) 0.69

40. Mud houses are cooler in summer and warmer in winter because[BVP 2003]

(a) Mud is superconductor of heat

(b) Mud is good conductor of heat

(c) Mud is bad conductor of heat

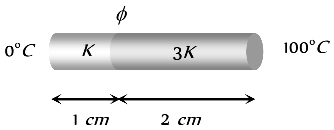
(d) None of these

41. The temperature of hot and cold end of a $20 cm$ long rod in thermal steady state are at $100^o C$ and $20^o C$ respectively. Temperature at the centre of the rod is[MP PMT 1996]

(a) $50^o C$ (b) $60^o C$

(c) $40^o C$ (d) $30^o C$

42. Two bars of thermal conductivities K and $3K$ and lengths $1 cm$ and $2 cm$ respectively have equal cross-sectional area, they are joined lengths wise as shown in the figure. If the temperature at the ends of this composite bar is $0^o C$ and $100^o C$ respectively (see figure), then the temperature ϕ of the interface is



(a) $50^o C$ (b) $\frac{100}{3}\,^o C$

(c) $60^o C$ (d) $\frac{200}{3}\,^o C$

43. A heat flux of $4000\ J/s$ is to be passed through a copper rod of length $10\ cm$ and area of cross-section $100\ cm^2$. The thermal conductivity of copper is $400\ W/m\ ^o C$. The two ends of this rod must be kept at a temperature difference of

(a) $1^o C$ (b) $10^o C$

(c) $100^o C$ (d) $1000^o C$

44. On a cold morning, a metal surface will feel colder to touch than a wooden surface because [AIIMS 1998]

(a) Metal has high specific heat

(b) Metal has high thermal conductivity

(c) Metal has low specific heat

(d) Metal has low thermal conductivity

45. In order that the heat flows from one part of a solid to another part, what is required

[Pb. PMT 1999; EAMCET 1998]

(a) Uniform density (b) Density gradient

(c) Temperature gradient (d) Uniform temperature

46. At a common temperature, a block of wood and a block of metal feel equally cold or hot. The temperatures of block of wood and block of metal are [AIIMS 1999]

(a) Equal to temperature of the body

(b) Less than the temperature of the body

(c) Greater than temperature of the body

(d) Either (b) or (c)

47. According to the experiment of Ingen Hausz the relation between the thermal conductivity of a metal rod is K and the length of the rod whenever the wax melts is

[UPSEAT 1999]

(a) K/l = constant (b) K^2/l = constant

(c) K/l^2 = constant (d) Kl = constant

48. Temperature of water at the surface of lake is $-20^o C$. Then temperature of water just below the lower surface of ice layer is

(a) $-4^o C$ (b) $0^o C$

(c) $4^o C$ (d) $-20^o C$

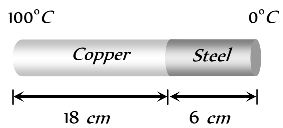
49. One end of a metal rod of length 1.0 m and area of cross section $100 cm^2$ is maintained at $100^o C$. If the other end of the rod is maintained at $0^o C$, the quantity of heat transmitted through the rod per minute is (Coefficient of thermal conductivity of material of rod =100 W/m-K)

[EAMCET (Engg.) 2000]

(a) $3 \times 10^3 J$ (b) $6 \times 10^3 J$

(c) $9 \times 10^3 J$ (d) $12 \times 10^3 J$

50. The coefficient of thermal conductivity of copper is nine times that of steel. In the composite cylindrical bar shown in the figure. What will be the temperature at the junction of copper and steel



(a) $75^o C$

(b) $67^o C$

(c) $33^o C$

(d) $25^o C$

51. The lengths and radii of two rods made of same material are in the ratios 1 : 2 and 2 : 3 [MP PMT 1999] respectively. If the temperature difference between the ends for the two rods be the same, then in the steady state, the amount of heat flowing per second through them will be in the ratio [MP PET 2000]

(a) 1: 3 (b) 4 : 3

(c) 8 : 9 (d) 3 : 2

52. A slab consists of two parallel layers of two different materials of same thickness having thermal conductivities K_1 and K_2. The equivalent conductivity of the combination is

[BHU 2001]

(a) $K_1 + K_2$ (b) $\frac{K_1 + K_2}{2}$

(c) $\frac{2K_1K_2}{K_1 + K_2}$ (d) $\frac{K_1 + K_2}{2K_1K_2}$

53. There are two identical vessels filled with equal amounts of ice. The vessels are of different metals., If the ice melts in the two vessels in 20 and 35 minutes respectively, the ratio of the coefficients of thermal conductivity of the two metals is

[AFMC 1998; MP PET 2001]

(a) 4 : 7 (b) 7 : 4

(c) 16 :49 (d) 49 : 16

54. Surface of the lake is at $2°C$. Find the temperature of the bottom of the lake [Orissa JEE 2002]

(a) $2^o C$ (b) $3^o C$

(c) $4^o C$ (d) $1^o C$

55. The heat is flowing through a rod of length 50 *cm* and area of cross-section $5cm^2$. Its ends are respectively at $25^o C$ and $125^o C$. The coefficient of thermal conductivity of the material of the rod is 0.092 *kcal/m×s×C*. The temperature gradient in the rod is [MP PET 2002]

(a) $2^o C/cm$ (b) $2^o C/m$

(c) $20^o C/cm$ (d) $20^o C/m$

56. In the Ingen Hauz's experiment the wax melts up to lengths 10 and 25 *cm* on two identical rods of different materials. The ratio of thermal conductivities of the two materials is

[MP PET 2002]

(a) $1:6.25$ (b) 6.25 : 1

(c) $1:\sqrt{2.5}$ (d) 1 : 2.5

57. Heat current is maximum in which of the following (rods are of identical dimension) [Orissa JEE 2003]

(a) 

(b) 

(c) 

(d) 

58. Two rods of same length and cross section are joined along the length. Thermal conductivities of first and second rod are K_1 and K_2. The temperature of the free ends of the first and second rods are maintained at θ_1 and θ_2 respectively. The temperature of the common junction is

[MP PET 2003]

(a) $\frac{\theta_1 + \theta_2}{2}$ (b) $\frac{K_2K_2}{K_1 + K_2}(\theta_1 + \theta_2)$

(c) $\frac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2}$ (d) $\frac{K_2\theta_1 + K_1\theta_2}{K_1 + K_2}$

59. Consider a compound slab consisting of two different materials having equal thickness and thermal conductivities K and $2K$ respectively. The equivalent thermal conductivity of the slab is

(a) $\sqrt{2K}$ (b) $3K$

(c) $\frac{4}{3}K$ (d) $\frac{2}{3}K$

60. Two rods having thermal conductivity in the ratio of 5 : 3 having equal lengths and equal cross-sectional area are joined by face to face. If the temperature of the free end of the first rod is $100^\circ C$ and free end of the second rod is $20^\circ C$. Then temperature of the junction is

[CPMT 1996; DPMT 1997, 03; BVP 2004]

(a) $70^\circ C$ (b) $50^\circ C$

(c) $50^\circ C$ (d) $90^\circ C$

61. Woollen clothes are used in winter season because woolen clothes[EAMCET 197

(a) Are good sources for producing heat

(b) Absorb heat from surroundings

(c) Are bad conductors of heat

(d) Provide heat to body continuously

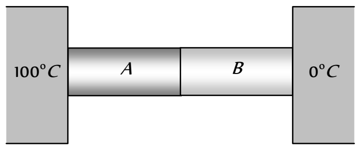
62. Two metal cubes A and B of same size are arranged as shown in the figure. The extreme ends of the combination are maintained at the indicated temperatures. The arrangement is thermally insulated. The coefficients of thermal conductivity of A and B are $300\,W/m\,^oC$ and $200\,W/m\,^oC$, respectively. After steady state is reached, the temperature of the interface will be [IIT 1996]

(a) $45^o C$

(b) $90^o C$

(c) $30^o C$

(d) $60^o C$



63. A cylindrical rod having temperature T_1 and T_2 at its ends. The rate of flow of heat is Q_1 *cal/sec*. If all the linear dimensions are doubled keeping temperature constant then rate of flow of heat Q_2 will be [CBSE PMT 2001]

(a) $4Q_1$ (b) $2Q_1$

(c) $\frac{Q_1}{4}$ (d) $\frac{Q_1}{2}$

64. A body of length 1*m* having cross sectional area 0.75*m* has heat flow through it at the rate of 6000 *Joule/sec*. Then find the temperature difference if $K = 200Jm^{-1}K^{-1}$

[CPMT 2001]

(a) $20°C$ (b) $40°C$

(c) $80°C$ (d) $100°C$

65. A wall has two layers *A* and *B* made of different materials. The thickness of both the layers is the same. The thermal conductivity of *A* and *B* are *K* and *K* such that *K* = 3*K*. The temperature across the wall is $20°C$. In thermal equilibrium

(a) The temperature difference across $A = 15°C$

(b) The temperature difference across $A = 5°C$

(c) The temperature difference across *A* is $10°C$

(d) The rate of transfer of heat through *A* is more than that through *B*.

66. A metal rod of length 2*m* has cross sectional areas 2*A* and *A* as shown in figure. The ends are maintained at temperatures $100°C$ and $70°C$. The temperature at middle point *C* is

[CPMT 2000]

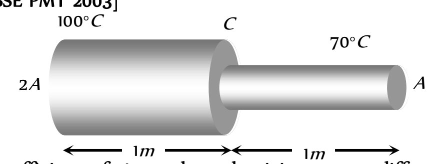
[CBSE PMT 2003]

(a) $80°C$

(b) $85°C$

(c) $90°C$

(d) $95°C$



67. The ratio of the coefficient of thermal conductivity of two different materials is 5 : 3. If the thermal resistance of the rod of same thickness resistance of the rods of same thickness of these materials is same, then the ratio of the length of these rods will be

(a) 3 : 5 (b) 5 : 3

(c) 3 : 4 (d) 3 : 2

68. Which of the following circular rods. (given radius r and length l) each made of the same material as whose ends are maintained at the same temperature will conduct most heat [CBSE PMT 2005]

(a) $r = 2r_0 ; l = 2l_0$ (b) $r = 2r_0 ; l = l_0$

(c) $r = r_0 ; l = l_0$ (d) $r = r_0 ; l = 2l_0$

Convection

1. It is hotter for the same distance over the top of a fire than it is in the side of it, mainly because [NCERT 1976, 79, 80; AIIMS 2000]

(a) Air conducts heat upwards

(b) Heat is radiated upwards

(c) Convection takes more heat upwards

(d) Convection, conduction and radiation all contribute significantly transferring heat upwards

2. One likes to sit under sunshine in winter season, because

(a) The air surrounding the body is hot by which body gets heat

(b) We get energy by sun

(c) We get heat by conduction by sun

(d) None of the above

3. Air is bad conductor of heat or partly conducts heat, still vacuum is to be placed between the walls of the thermos flask because

(a) It is difficult to fill the air between the walls of thermos flask

(b) Due to more pressure of air, the thermos can get crack

(c) By convection, heat can flow through air

(d) On filling the air, there is no advantage

4. While measuring the thermal conductivity of a liquid, we keep the upper part hot and lower part cool, so that [CPMT 1985; MP PMT/PET 1988]

(a) Convection may be stopped

(b) Radiation may be stopped

(c) Heat conduction is easier downwards

(d) It is easier and more convenient to do so

5. For proper ventilation of building, windows must be open near the bottom and top of the walls so as to let pass

(a) In more air

(b) In cool air near the bottom and hot air out near the roof

(c) In hot air near the roof and cool air out near the bottom

(d) Out hot air near the roof

6. The layers of atmosphere are heated through [MP PET 1986]

(a) Convection (b) Conduction

(c) Radiation (d) (b) and (c) both

7. Mode of transmission of heat, in which heat is carried by the moving particles, is [KCET 1999]

(a) Radiation (b) Conduction

(c) Convection (d) Wave motion

8. In a closed room, heat transfer takes place by [BHU 2000] [BHU 2001]

(a) Conduction (b) Convection

(c) Radiation (d) All of these

9. In heat transfer, which method is based on gravitation [CBSE PMT 2000]

(a) Natural convection (b) Conduction

(c) Radiation (d) Stirring of liquids

10. When fluids are heated from the bottom, convection currents are produced because [UPSEAT 2000]

(a) Molecular motion of fluid becomes aligned

(b) Molecular collisions take place within the fluid

(c) Heated fluid becomes more dense than the cold fluid above it

(d) Heated fluid becomes less dense than the cold fluid above it

11. If a liquid is heated in weightlessness, the heat is transmitted through [RPMT1996]

(a) Conduction

(b) Convection

(c) Radiation

(d) Neither, because the liquid cannot be heated in weightlessness

12. The rate of loss of heat from a body cooling under conditions of forced convection is proportional to its (A) heat capacity (B) surface area (C) absolute temperature (D) excess of temperature over that of surrounding : state if [NCERT 1982]

(a) A, B, C are correct (b) Only A and C are correct

(c) Only B and D are correct (d) Only D is correct

13. In which of the following process, convection does not take place primarily [IIT-JEE (Screening) 2005]

(a) Sea and land breeze

(b) Boiling of water

(c) Warming of glass of bulb due to filament

(d) Heating air around a furnace

Radiation (General, Kirchoff's law, Black body)

1. On a clear sunny day, an object at temperature T is placed on the top of a high mountain. An identical object at the same temperature is placed at the foot of mountain. If both the objects are exposed to sun-rays for two hours in an identical manner, the object at the top of the mountain will register a temperature

(a) Higher than the object at the foot

(b) Lower than the object at the foot

(c) Equal to the object at the foot

(d) None of the above

2. The velocity of heat radiation in vacuum is [EAMCET 1982; KCET 1998]

(a) Equal to that of light (b) Less than that of light

(c) Greater than that of light (d) Equal to that of sound

3. In which process, the rate of transfer of heat is maximum [EAMCET 1977; MP PMT 1994; MH CET 2001]

(a) Conduction

(b) Convection

(c) Radiation

(d) In all these, heat is transferred with the same velocity

4. Which of the following is the correct device for the detection of thermal radiation [Manipal MEE 1995, UPSEAT 2000]
(a) Constant volume thermometer
(b) Liquid-in-glass thermometer
(c) Six's maximum and minimum thermometer
(d) Thermopile

5. A thermos flask is polished well [AFMC 1996]
(a) To make attractive
(b) For shining
(c) To absorb all radiations from outside
(d) To reflect all radiations from outside

6. Heat travels through vacuum by [AIIMS 1998; CPMT 2003]
(a) Conduction (b) Convection
(c) Radiation (d) Both (a) and (b)

7. The energy supply being cut-off, an electric heater element cools down to the temperature of its surroundings, but it will not cool further because [CPMT 2001]
(a) Supply is cut off
(b) It is made of metal
(c) Surroundings are radiating
(d) Element & surroundings have same temp.

8. We consider the radiation emitted by the human body. Which of the following statements is true [CBSE PMT 2003]
(a) The radiation is emitted only during the day
(b) The radiation is emitted during the summers and absorbed during the winters
(c) The radiation emitted lies in the ultraviolet region and hence is not visible
(d) The radiation emitted is in the infra-red region

9. The earth radiates in the infra-red region of the spectrum. The spectrum is correctly given by [RPET 2002; AIEEE 2003]
(a) Wien's law (b) Rayleigh jeans law
(c) Planck's law of radiation (d) Stefan's law of radiation

10. Infrared radiation is detected by [AIEEE 2002]
(a) Spectrometer (b) Pyrometer
(c) Nanometer (d) Photometer

11. Pick out the statement which is not true [KCET 2002]
(a) *IR* radiations are used for long distance photography
(b) *IR* radiations arise due to inner electron transitions in atoms
(c) *IR* radiations are detected by using a bolometer
(d) Sun is the natural source of *IR* radiation

12. A hot and a cold body are kept in vacuum separated from each other. Which of the following cause decrease in temperature of the hot body [AFMC 2005]
(a) Radiation
(b) Convection
(c) Conduction
(d) Temperature remains unchanged

13. Good absorbers of heat are [J & K CET 2002]
(a) Poor emitters (b) Non-emitters
(c) Good emitters (d) Highly polished

14. For a perfectly black body, its absorptive power is [MP PMT 1989, 92; RPMT 2001; RPET 2001, 03; AFMC 2003]
(a) 1 (b) 0.5
(c) 0 (d) Infinity

15. Certain substance emits only the wavelengths $\lambda_1, \lambda_2, \lambda_3$ and λ_4 when it is at a high temperature. When this substance is at a colder temperature, it will absorb only the following wavelengths
(a) λ_1 (b) λ_2
(c) λ_1 and λ_2 (d) $\lambda_1, \lambda_2, \lambda_3$ and λ_4

16. As compared to the person with white skin, the person with black skin will experience [CPMT 1988]
(a) Less heat and more cold (b) More heat and more cold
(c) More heat and less cold (d) Less heat and less cold

17. Relation between emissivity e and absorptive power a is (for black body)
(a) $e = a$ (b) $e = \frac{1}{a}$
(c) $e = a^2$ (d) $a = e^2$

18. Which of the following statements is wrong [BCECE 2001]
(a) Rough surfaces are better radiators than smooth surface
(b) Highly polished mirror like surfaces are very good radiators
(c) Black surfaces are better absorbers than white ones
(d) Black surfaces are better radiators than white

19. Half part of ice block is covered with black cloth and rest half is covered with white cloth and then it is kept in sunlight. After some time clothes are removed to see the melted ice. Which of the following statements is correct
(a) Ice covered with white cloth will melt more
(b) Ice covered with black cloth will melt more
(c) Equal ice will melt under both clothes
(d) It will depend on the temperature of surroundings of ice

20. If between wavelength λ and $\lambda + d\lambda$, e_λ and a_λ be the emissive and absorptive powers of a body and E_λ be the emissive power of a perfectly black body, then according to Kirchoff's law, which is true [RPMT 1998; MP PET 1991]
(a) $e_\lambda = a_\lambda = E_\lambda$ (b) $e_\lambda E_\lambda = a_\lambda$
(c) $e_\lambda = a_\lambda E_\lambda$ (d) $e_\lambda a_\lambda E_\lambda$ = constant

21. When p calories of heat is given to a body, it absorbs q calories; then the absorbtion power of body will be
(a) p / q (b) q / p
(c) p^2 / q^2 (d) q^2 / p^2

22. Distribution of energy in the spectrum of a black body can be correctly represented by [MP PMT 1989]
(a) Wien's law (b) Stefan's law
(c) Planck's law (d) Kirchhoff's law

23. In rainy season, on a clear night the black seat of a bicycle becomes wet because

(a) It absorbs water vapour

(b) Black seat is good absorber of heat

(c) Black seat is good radiator of heat energy

(d) None of the above

24. There is a rough black spot on a polished metallic plate. It is heated upto 1400 K approximately and then at once taken in a dark room. Which of the following statements is true [NCERT 1984; CPMT 1998]

(a) In comparison with the plate, the spot will shine more

(b) In camparison with the plate, the spot will appear more black

(c) The spot and the plate will be equally bright

(d) The plate and the black spot can not be seen in the dark room

25. At a certain temperature for given wave length, the ratio of emissive power of a body to emissive power of black body in same circumstances is known as [RPMT 1997]

(a) Relative emissivity (b) Emissivity

(c) Absorption coefficient (d) Coefficient of reflection

26. The cause of Fraunhoffer lines is [RPMT 1996; EAMCET 2001]

(a) Reflection of radiations by chromosphere

(b) Absorption of radiations by chromosphere

(c) Emission of radiations by chromosphere

(d) Transmission of radiations by chromosphere

27. Two thermometers A and B are exposed in sun light. The valve of A is painted black, But that of B is not painted. The correct statement regarding this case is [BHU (Med.) 1999; MH CET 1999]

(a) Temperature of A will rise faster than B but the final temperature will be the same in both

(b) Both A and B show equal rise in beginning

(c) Temperature of A will remain more than B

(d) Temperature of B will rise faster

28. There is a black spot on a body. If the body is heated and carried in dark room then it glows more. This can be explained on the basis of [RPET 2000]

(a) Newton's law of cooling (b) Wien's law

(c) Kirchoff's law (d) Stefan's

29. When red glass is heated in dark room it will seem [RPET 2000]

(a) Green (b) Purple

(c) Black (d) Yellow

30. A hot body will radiate heat most rapidly if its surface is [UPSEAT 1999, 2000]

(a) White & polished (b) White & rough

(c) Black & polished (d) Black & rough

31. A body, which emits radiations of all possible wavelengths, is known as [CPMT 2001; Pb. PET 2002]

(a) Good conductor (b) Partial radiator

(c) Absorber of photons (d) Perfectly black-body

32. Which of the following is the example of ideal black body [AIEEE 2002; CBSE PMT 2002]

(a) Kajal (b) Black board

(c) A pin hole in a box (d) None of these

33. An ideal black body at room temperature is thrown into a furnace. It is observed that [IIT-JEE (Screening) 2002]

(a) Initially it is the darkest body and at later times the brightest

(b) It is the darkest body at all times

(c) It cannot be distinguished at all times

(d) Initially it is the darkest body and at later times it cannot be distinguished

34. Absorption co-efficient of an open window is... [KCET 2004]

(a) Zero (b) 0.5

(c) 1 (d) 0.25

35. Which of the prism is used to see infra-red spectrum of light [RPMT 2000]

(a) Rock-salt (b) Nicol

(c) Flint (d) Crown

36. Which of the following statement is correct [RPMT 2001]

(a) A good absorber is a bad emitter

(b) Every body absorbs and emits radiations at every temperature

(c) The energy of radiations emitted from a black body is same for all wavelengths

(d) The law showing the relation of temperatures with the wavelength of maximum emission from an ideal black body is Plank's law

37. 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 [KCET 2005]

(a) The blue piece will look blue and red will look as usual

(b) Red look brighter red and blue look ordinary blue

(c) Blue shines like brighter red compared to the red piece

(d) Both the pieces will look equally red.

38. Which of the following law states that "good absorbers of heat are good emitters" [Orissa JEE 2005]

(a) Stefan's law (b) Kirchoff's law

(c) Planck's law (d) Wein's law

Radiation (Wein's law)

1. According to Wein's law [DCE 1995, 96; MP PET/PMT 1988 DPMT 1999; AIIMS 2002; CBSE PMT 2004]

(a) $\lambda_m T$ = constant (b) $\frac{\lambda_m}{T}$ = constant

(c) $\frac{T}{\lambda_m}$ = constant (d) $T + \lambda_m$ = constant

2. On investigation of light from three different stars A, B and C, it was found that in the spectrum of A the intensity of red colour is maximum, in B the intensity of blue colour is maximum and in C the intensity of yellow colour is maximum. From these observations it can be concluded that [CPMT 1989]

(a) The temperature of A is maximum, B is minimum and C is intermediate

(b) The temperature of A is maximum, C is minimum and B is intermediate

(c) The temperature of B is maximum, A is minimum and C is intermediate

(d) The temperature of C is maximum, B is minimum and A is intermediate

3. If wavelengths of maximum intensity of radiations emitted by the sun and the moon are $0.5 \times 10^{-6} m$ and $10^{-4} m$ respectively, the ratio of their temperatures is [MP PMT 1990]

(a) 1/100 (b) 1/200

(c) 100 (d) 200

4. The wavelength of radiation emitted by a body depends upon

(a) The nature of its surface

(b) The area of its surface

(c) The temperature of its surface

(d) All the above factors

5. If black wire of platinum is heated, then its colour first appear red, then yellow and finally white. It can be understood on the basis of

(a) Wien's displacement law

(b) Prevost theroy of heat exchange

(c) Newton's law of cooling

(d) None of the above

6. Colour of shining bright star is an indication of its [AIIMS 2001; RPMT 1999; BCECE 2005]

(a) Distance from the earth (b) Size

(c) Temperature (d) Mass

7. The wavelength of maximum emitted energy of a body at 700 K is 4.08 μm. If the temperature of the body is raised to 1400 K, the wavelength of maximum emitted energy will be

(a) $1.02\ \mu m$ (b) 16.32 μm

(c) 8.16 μm (d) 2.04 μm

8. A black body at 200 K is found to exit maximum energy at a wavelength of $14 \mu m$. When its temperature is raised to 1000K, the wavelength at which maximum energy is emitted is[RPMT 1998; MP PET 1991; BVP 2003]

(a) $14 \mu m$ (b) $70 \mu F$

(c) $2.8 \mu m$ (d) $2.8 mm$

9. Two stars emit maximum radiation at wavelength 3600 $\mathring{A}$ and 4800 $\mathring{A}$ respectively. The ratio of their temperatures is [MP PMT 1991]

(a) 1 : 2 (b) 3 : 4

(c) 4 : 3 (d) 2 : 1

10. A black body emits radiations of maximum intensity at a wavelength of $5000 \mathring{A}$, when the temperature of the body is $1227^o C$. If the temperature of the body is increased by $1000^o C$, the maximum intensity of emitted radiation would be observed at

(a) $2754.8 \mathring{A}$ (b) $3000 \mathring{A}$

(c) $3500 \mathring{A}$ (d) $4000 \mathring{A}$

11. Four pieces of iron heated in a furnace to different temperatures show different colours listed below. Which one has the highest temperature [MP PET 1992]

(a) White (b) Yellow

(c) Orange (d) Red

12. If a black body is heated at a high temperature, it seems to be

(a) Blue (b) White

(c) Red (d) Black

13. If the temperature of the sun becomes twice its present temperature, then [MP PET 1989; RPMT 1996]

(a) Radiated energy would be predominantly in infrared

(b) Radiated energy would be predominantly in ultraviolet [MP PMT 1992]

(c) Radiated energy would be predominantly in X-ray region

(d) Radiated energy would become twice the present radiated energy

14. The maximum energy in the thermal radiation from a hot source occurs at a wavelength of $11 \times 10^{-5} cm$. According to Wein's law, the temperature of the source (on Kelvin scale) will be n times the temperature of another source (on Kelvin scale) for which the [MP PMT 1984] wavelength at maximum energy is $5.5 \times 10^{-5} cm$. The value n is [CPMT 1991]

(a) 2 (b) 4

(c) $\frac{1}{2}$ (d) 1

15. The wavelength of maximum energy released during an atomic explosion was $2.93 \times 10^{-10} m$. Given that Wein's constant is $2.93 \times 10^{-3} m-K$, the maximum temperature attained must be of the order of [Haryana CEE 1996; MH CET 2002; Pb. PET 2000]

(a) $10^{-7} K$ [MP PET 1990] (b) $10^{7} K$

(c) $10^{-13} K$ (d) $5.86 \times 10^{7} K$

16. The maximum wavelength of radiation emitted at $2000\, K$ is $4 \mu m$. What will be the maximum wavelength of radiation emitted at [MP PMT/PET 1998; DPMT 2000]

(a) $3.33\ \mu m$ (b) $0.66\ \mu m$

(c) $1\ \mu m$ (d) $1\ m$

17. How is the temperature of stars determined by [BHU 1999, 02; DCE 2000, 03]

(a) Stefan's law (b) Wein's displacement law

(c) Kirchhoff's law (d) Ohm's law

18. On increasing the temperature of a substance gradually, which of the following colours will be noticed by you [Pb. PMT 1995; Pb. PET 1996; CPMT 1995, 98; KCET 2000]

(a) White (b) Yellow

(c) Green (d) Red

19. A black body has maximum wavelength λ_m at temperature 2000 K. Its corr[MP PET 1992]wavelength at temperature 3000 K will be [CBSE PMT 2001; K

(a) $\frac{3}{2} \lambda_m$ (b) $\frac{2}{3} \lambda_m$

(c) $\frac{4}{9} \lambda_m$ (d) $\frac{9}{4} \lambda_m$

20. Relation between the colour and the temperature of a star is given by [Kerala PET 2001]

(a) Wein's displacement law

(b) Planck's law

(c) Hubble's law

(d) Fraunhofer diffraction law

21. A black body at a temperature of 1640 K has the wavelength corresponding to maximum emission equal to 1.75 μ. Assuming the moon to be a perfectly black body, the temperature of the moon, if the wavelength corresponding to maximum emission is 14.35 μ is [Kerala (Med.) 2002]

(a) 100 K (b) 150 K

(c) 200 K (d) 250 K

22. The maximum wavelength of radiations emitted at 900 K is $4\mu m$. What will be the maximum wavelength of radiations emitted at 1200 K [BHU 2002]

(a) $3\mu m$ (b) $0.3\mu m$

(c) $1\mu m$ (d) $1\ m$

23. Solar radiation emitted by sun resembles that emitted by a black body at a temperature of 6000 K. Maximum intensity is emitted at a wavelength of about 4800Å. If the sun were to cool down from 6000 K to 3000 K then the peak intensity would occur at a wavelength [UPSEAT 2002]

(a) 4800$\AA$ (b) 9600$\AA$

(c) 7200$\AA$ (d) 6400$\AA$

24. What will be the ratio of temperatures of sun and moon if the wavelengths of their maximum emission radiations rates are 140 $\AA$ and 4200 $\AA$ respectively [J & K CET 2004]

(a) 1 : 30 (b) 30 : 1

(c) 42 : 14 (d) 14 : 42

25. The radiation energy density per unit wavelength at a temperature T has a maximum at a wavelength λ. At temperature $2T$, it will have a maximum at a wavelength [UPSEAT 2004]

(a) 4λ (b) 2λ

(c) $\lambda/2$ (d) $\lambda/4$

26. The absolute temperatures of two black bodies are 2000 K and 3000 K respectively. The ratio of wavelengths corresponding to maximum emission of radiation by them will be

(a) 2 : 3 (b) 3 : 2

(c) 9 : 4 (d) 4 : 9

27. The temperature of sun is 5500 K and it emits maximum intensity radiation in the yellow region $(5.5\times10^{-7}m)$. The maximum radiation from a furnace occurs at wavelength $11\times10^{-7}m$. The temperature of furnace is [J & K CET 2000]

(a) 1125 K (b) 2750 K

(c) 5500 K (d) 11000 K

28. A particular star (assuming it as a black body) has a surface temperature of about $5\times10^4 K$. The wavelength in nanometers at which its radiation becomes maximum is

(b = 0.0029 mK) [EAMCET (Med.) 2003]

(a) 48 (b) 58

(c) 60 (d) 70

29. The maximum energy in thermal radiation from a source occurs at the wavelength 4000Å. The effective temperature of the source is

(a) $7000 K$ (b) 80000 K

(c) $10^4\ K$ (d) $10^6\ K$

30. The intensity of radiation emitted by the sun has its maximum value at a wavelength of $510\ nm$ and that emitted by the north star has the maximum value at $350\ nm$. If these stars behave like black bodies, then the ratio of the surface temperature of the sun and north star is [IIT 1997 Cancelled; JIPMER 2000; AIIMS 2000]

(a) 1.46 (b) 0.69

(c) 1.21 (d) 0.83

Radiation (Stefan's law)

1. The amount of radiation emitted by a perfectly black body is proportional to [AFMC 1995; Pb. PMT 1997; CPMT 1974, 98, 02; AIIMS 2000; DPMT 1995, 98, 02]

(a) Temperature on ideal gas scale

(b) Fourth root of temperature on ideal gas scale

(c) Fourth power of temperature on ideal gas scale

(d) Source of temperature on ideal gas scale

2. A metal ball of surface area $200\ cm^2$ and temperature 527^oC is surrounded by a vessel at 27^oC. If the emissivity of the metal is 0.4, then the rate of loss of heat from the ball is $(\sigma = 5.67\times10^{-8} J/m^2 - s - k^4)$ [MP PMT/PET 1988]

(a) 108 joules approx. (b) 168 joules approx.

(c) 182 joules approx. (d) 192 joules approx.

3. The rate of radiation of a black body at 0°C is EJ/sec. The rate of radiation of this black body at 273^oC will be [MP PMT 1989; Kerala PET 2002; UPSEAT 2001]

(a) $16\ E$ (b) $8\ E$

(c) $4\ E$ (d) E

4. A black body radiates energy at the rate of E W/m at a high temperature TK. When the temperature is reduced to $\frac{T}{2}K$, the radiant energy will be [RPMT 2003] [CPMT 1988; UPSEAT 1998; MNR 1993; SCRA 1996; MP PMT 1992; DPMT 2001; MH CET 2001]

(a) $\frac{E}{16}$ (b) $\frac{E}{4}$

(c) $4E$ (d) $16E$

5. An object is at a temperature of 400^oC. At what temperature would it radiate energy twice as fast? The temperature of the surroundings may be assumed to be negligible [MP PMT 1990; DPMT 2002]

(a) 200^oC (b) $200\ K$

(c) 800^oC (d) 800 K

6. A black body at a temperature of 227^oC radiates heat energy at the rate of 5 cal/cm-sec. At a temperature of 727^oC, the rate of heat radiated per unit area in cal/cm will be

(a) 80 (b) 160

(c) 250 (d) 500

7. Energy is being emitted from the surface of a black body at 127^oC temperature at the rate of $1.0\times10^6\,J/sec-m^2$. Temperature of the black body at which the rate of energy emission is $16.0\times10^6\,J/sec-m^2$ will be

[MP PMT 1991; AFMC 1998]

(a) 254^oC (b) 508^oC

(c) 527^oC (d) 727^oC

8. In MKS system, Stefan's constant is denoted by σ. In CGS system multiplying factor of σ will be

(a) 1 (b) 10^3

(c) 10^5 (d) 10^2

9. If temperature of a black body increases from 7^oC to 287^oC, then the rate of energy radiation increases by

[AIIMS 1997; Haryana PMT 2000; RPMT 2003]

(a) $\left(\frac{287}{7}\right)^4$ (b) 16

(c) 4 (d) 2

10. The temperature of a piece of iron is 27^oC and it is radiating energy at the rate of $Q\,kWm^{-2}$. If its temperature is raised to 151^oC, the rate of radiation of energy will become approximately

(a) $2Q\,kWm^{-2}$ (b) $4Q\,kWm^{-2}$

(c) $6Q\,kWm^{-2}$ (d) $8Q\,kWm^{-2}$

11. The temperatures of two bodies *A* and *B* are 727^oC and 127^oC. The ratio of rate of emission of radiations will be

[MP PET 1986]

(a) 727/127 (b) 625/16

(c) 1000/400 (d) 100/16

12. The temperature at which a black body of unit area loses its energy at the rate of 1 *joule/second* is

(a) -65^oC (b) 65^oC

(c) 65 *K* (d) None of these

13. The area of a hole of heat furnace is $10^{-4}\,m^2$. It radiates 1.58×10^5 calories of heat per hour. If the emissivity of the furnace is 0.80, then its temperature is

(a) 1500 *K* (b) 2000 *K*

(c) 2500 *K* (d) 3000 *K*

14. Two spheres P and Q, of same colour having radii $8\,cm$ and $2\,cm$ are maintained at temperatures 127^oC and 527^oC respectively. The ratio of energy radiated by P and Q is

(a) 0.054 (b) 0.0034

(c) 1 (d) 2

15. A body radiates energy $5W$ at a temperature of 127^oC. If the temperature is increased to 927^oC, then it radiates energy at the rate of

[MP PET 1994;BHU 1995; CPMT 1998; AFMC 2000]

(a) $410W$ (b) $81\,W$

(c) $405\,W$ (d) $200\,W$

16. A thin square steel plate with each side equal to 10 *cm* is heated by a blacksmith. The rate of radiated energy by the heated plate is 1134 *W*. The temperature of the hot steel plate is (Stefan's constant $\sigma=5.67\times10^{-8}\,watt\,m^{-2}K^{-4}$, emissivity of the plate = 1)

(a) $1000\,K$ (b) $1189\,K$

(c) $2000\,K$ (d) $2378\,K$

17. The temperatures of two bodies A and B are respectively 727^oC and 327^oC. The ratio $H_A:H_B$ of the rates of heat radiated by them is [UPSEAT 1999; MP PET 1999; MH CET 2000; AIIMS 2000]

(a) $727:327$ (b) 5 : 3

(c) 25 : 9 (d) 625 : 81

18. The energy emitted per second by a black body at 27^oC is $10\,J$. If the temperature of the black body is increased to 327^oC, the energy emitted per second will be

[CPMT 1999; DCE 1999]

(a) $20\,J$ (b) $40\,J$

(c) $80\,J$ [MP PET 1992] (d) $160\,J$

19. The radiant energy from the sun incident normally at the surface of earth is $20\,kcal/m^2min$. What would have been the radiant energy incident normally on the earth, if the sun had a temperature twice of the present one

[CBSE PMT 1998; Pb. PET 2001]

(a) $160\,kcal/m^2\,min$ (b) $40\,kcal/m^2\,min$

(c) $320\,kcal/m^2\,min$ (d) $80\,kcal/m^2\,min$

20. A spherical black body with a radius of $12\,cm$ radiates $440\,W$ power at $500\,K$. If the radius were halved and the temperature doubled, the power radiated in watt would be

[IIT 1997 Re-Exam]

(a) 225 (b) 450

(c) 900 (d) 1800

21. If the temperature of the sun (black body) is doubled, the rate of energy received on earth will be increased by a factor of [CBSE PMT 1993; BHU 2

(a) 2 (b) 4

(c) 8 (d) 16

22. The ratio of energy of emitted radiation of a black body at 27^oC and 927^oC is [MP PMT 1994] [Pb. PMT 1995; CPMT 1997, 2000; CBSE PMT 2000; DPMT 1998, 02, 03]

(a) 1 : 4 (b) 1 : 16

(c) 1 : 64 (d) 1 : 256

23. If the temperature of a black body be increased from 27^oC to 327^oC the radiation emitted increases by a fraction of

[Pb. PET 1997; JIPMER 1999]

(a) 16 (b) 8

(c) 4 (d) 2

24. The rectangular surface of area 8 $cm \times 4 cm$ of a black body at a temperature of $127^o C$ emits energy at the rate of E per second. If the length and breadth of the surface are each reduced to half of the initial value and the temperature is raised to $327^o C$, the rate of emission of energy will become [MP PET 2000]

(a) $\frac{3}{8}E$ (b) $\frac{81}{16}E$

(c) $\frac{9}{16}E$ (d) $\frac{81}{64}E$

25. At temperature T, the power radiated by a body is Q *watts*. At the temperature $3T$ the power radiated by it will be

[MP PET 2000]

(a) 3 Q (b) 9 Q

(c) 27 Q (d) 81 Q

26. Two spherical black bodies of radii r_1 and r_2 and with surface temperature T_1 and T_2 respectively radiate the same power. Then the ratio of r_1 and r_2 will be

[KCET 2001; UPSEAT 2001]

(a) $\left(\frac{T_2}{T_1}\right)^2$ (b) $\left(\frac{T_2}{T_1}\right)^4$

(c) $\left(\frac{T_1}{T_2}\right)^2$ (d) $\left(\frac{T_1}{T_2}\right)^4$

27. Temperature of a black body increases from $327^o C$ to $927^o C$, the initial energy possessed is 2*KJ*, what is its final energy

(a) 32 *KJ* (b) 320 *KJ*

(c) 1200 *KJ* (d) None of these

28. The original temperature of a black body is $727^o C$. The temperature at which this black body must be raised so as to double the total radiant energy, is [Pb. PMT 2001]

(a) 971 K (b) 1190 K

(c) 2001 K (d) 1458 K

29. Two black metallic spheres of radius 4m, at 2000 K and 1m at 4000 K will have ratio of energy radiation as

[RPET 2000; AIEEE 2002]

(a) 1 : 1 (b) 4 : 1

(c) 1 : 4 (d) 2 : 1

30. The energy spectrum of a black body exhibits a maximum around a wavelength λ_o. The temperature of the black body is now changed such that the energy is maximum around a wavelength $\frac{3\lambda_o}{4}$. The power radiated by the black body will now increase by a factor of [KCET 2002]

(a) 256/81 (b) 64/27

(c) 16/9 (d) 4/3

31. A black body is at a temperature 300 K. It emits energy at a rate, which is proportional to

[Pb. PMT 1998; AIIMS 2002; MH CET 2003]

(a) 300 (b) $(300)^2$

(c) $(300)^3$ (d) $(300)^4$

32. If the temperature of a hot body is increased by 50% then the increase in the quantity of emitted heat radiation will be

[RPET 1998; EAMCET 2001; MP PMT 2003]

(a) 125% (b) 200%

(c) 300% (d) 400%

33. Two identical metal balls at temperature $200^o C$ and $400^o C$ kept in air at $27^o C$. The ratio of net heat loss by these bodies is

(a) 1/4 (b) 1/2

(c) 1/16 (d) $\frac{473^4 - 300^4}{673^4 - 300^4}$

34. Two spheres made of same material have radii in the ratio 1: 2 Both are at same temperature. Ratio of heat radiation energy emitted per second by them is

[MP PMT 2002; MH CET 2004]

(a) 1 : 2 (b) 1 : 8

(c) 1 : 4 (d) 1 : 16

35. A black body at a temperature of 127°C radiates heat at the rate of 1 *cal/cm* × *sec*. At a temperature of 527°C the rate of heat radiation from the body in (*cal/cm* × *sec*) will be

[MP PET 2002]

(a) 16.0 (b) 10.45

(c) 4.0 (d) 2.0

36. A black body radiates 20 W at temperature $227^o C$. If temperature of the black body is changed to $727^o C$ then its radiating power will be [DCE 2001]

[CBSE PMT 2002; DCE 1999, 03; AIIMS 2003]

(a) 120 W (b) 240 W

(c) 320 W (d) 360 W

37. Two spheres of same material have radius 1m and 4 m and temperature 4000K and 2000K respectively. The energy radiated per second by the first sphere is [Pb. PMT 2002]

(a) Greater than that by the second

(b) Less than that by the second

(c) Equal in both cases

(d) The information is incomplete

38. The radiation emitted by a star A is 10,000 times that of the sun. If the surface temperatures of the sun and the star A are 6000 K and 2000 K respectively, the ratio of the radii of the star A and the sun is

(a) 300 : 1 (b) 600 : 1

(c) 900 : 1 (d) 1200 : 1

39. A black body radiates at the rate of W watts at a temperature T. If the temperature of the body is reduced to $T/3$, it will radiate at the rate of (in *Watts*)

[BHU 1998; MP PET 2003]

(a) $\frac{W}{81}$ (b) $\frac{W}{27}$

(c) $\frac{W}{9}$ (d) $\frac{W}{3}$

40. Star A has radius r surface temperature T while star B has radius $4r$ and surface temperature $T/2$. The ratio of the power of two starts, $P_A : P_B$ is [MP PMT 2004]

(a) 16 : 1 (b) 1 : 16

(c) 1 : 1 (d) 1 : 4

41. Suppose the sun expands so that its radius becomes 100 times its present radius and its surface temperature becomes half of its present value. The total energy emitted by it then will increase by a factor of [AIIMS 2004]

(a) 10^4 (b) 625

(c) 256 (d) 16

42. If the temperature of the sun were to be increased from T to $2T$ and its radius from R to $2R$, then the ratio of the radiant energy received on the earth to what it was previously will be

(a) 4 (b) 16

(c) 32 (d) 64

43. At 127° C radiates energy is 2.7×10^3 J/s. At what temperature radiated energy is 4.32×10^6 J/s [BCECE 2004]

(a) 400 K (b) 4000 K

(c) 80000 K (d) 40000 K

44. If the initial temperatures of metallic sphere and disc, of the same mass, radius and nature are equal, then the ratio of their rate of cooling in same environment will be

[J & K CET 2004]

(a) 1 : 4 (b) 4 : 1

(c) 1 : 2 (d) 2 : 1

45. A black body radiates energy at the rate of 1×10^5 $J/s \times m$ at temperature of 227° C. The temperature to which it must be heated so that it radiates energy at rate of 1×10^9 J/sm^2, is

(a) 5000 K (b) 5000°C

(c) 500 K (d) 500°C

46. The temperature of the body is increased from –73° C to 327° C, the ratio of energy emitted per second is :

[CPMT 2001; Pb. PET 2001]

(a) 1 : 3 (b) 1 : 81

(c) 1 : 27 (d) 1 : 9

47. If the temperature of the body is increased by 10%, the percentage increase in the emitted radiation will be

[RPMT 2001, 02]

(a) 46% (b) 40%

(c) 30% (d) 80%

48. If the sun's surface radiates heat at $6.3 \times 10^7 \, Wm^{-2}$. Calculate the temperature of the sun assuming it to be a black body $(\sigma = 5.7 \times 10^{-8} Wm^{-2}K^{-4})$ [BHU (Med.) 2000]

(a) $5.8 \times 10^3 K$ (b) $8.5 \times 10^3 K$

(c) $3.5 \times 10^8 K$ (d) $5.3 \times 10^8 K$

49. A sphere at temperature 600K is placed in an environment of temperature is 200K. Its cooling rate is H. If its temperature reduced to 400K then cooling rate in same environment will become [CBSE PMT 1999; BHU 2001]

(a) (3/16)H (b) (16/3)H

(c) (9/27)H (d) (1/16)H

50. The value of Stefan's constant is [RPMT 2002]

(a) $5.67 \times 10^{-8} W/m^2\text{-}K^4$ (b) $5.67 \times 10^{-5} W/m^2\text{-}K^4$

(c) $5.67 \times 10^{-11} W/m^2\text{-}K^4$ (d) None of these

51. Rate of cooling at 600K, if surrounding temperature is 300K is R. The rate of cooling at 900K is [DPMT 2002]

(a) $\frac{16}{3}R$ (b) $2R$

(c) $3R$ (d) $\frac{2}{3}R$

52. A black body of surface area 10cm is heated to 127°C and is suspended in a room at temperature 27°C. The initial rate of loss of heat from the body at the room temperature will be [AIEEE 2004]

(a) 2.99 W (b) 1.89 W

(c) 1.18 W (d) 0.99 W

53. Two identical objects A and B are at temperatures T_A and T_B respectively. Both objects are placed in a room with perfectly absorbing walls maintained at temperatures T $(T_A > T > T_B)$. The objects A and B attain temperature T eventually which one of the following is correct statement

[CPMT 1997]

(a) 'A' only emits radiations while B only absorbs them until both attain temperature

(b) A loses more radiations than it absorbs while B absorbs more radiations that it emits until temperature T is attained

(c) Both A and B only absorb radiations until they attain temperature T

(d) Both A and B only emit radiations until they attain temperature T

[DPMT 2004]

54. When the body has the same temperature as that of surroundings [UPSEAT 199

(a) It does not radiate heat

(b) It radiates the same quantity of heat as it absorbs

(c) It radiates less quantity of heat as it receives from surroundings

(d) It radiates more quantity of heat as it receives heat from surroundings

55. The ratio of radiant energies radiated per unit surface area by two bodies is 16 : 1, the temperature of hotter body is 1000K, then the temperature of colder body will be

[UPSEAT 2001]

(a) 250 K (b) 500 K

(c) 1000 K (d) 62.5 K

56. The spectral energy distribution of star is maximum at twice temperature as that of sun. The total energy radiated by star is

(a) Twice as that of the sun

(b) Same as that of the sun

(c) Sixteen times as that of the sun

(d) One sixteenth of sun

Radiation (Newton's Law of Cooling)

1. Hot water cools from $60^o C$ to $50^o C$ in the first 10 minutes and to $42^o C$ in the next 10 minutes. The temperature of the surrounding is [MP PET 1993]

(a) $5^o C$ (b) $10^o C$

(c) 15^oC (d) 20^oC

2. A bucket full of hot water cools from 75^oC to 70^0C in time T_1, from 70^oC to 65^oC in time T_2 and from 65^oC to 60^oC in time T_3, then [NCERT 1980; MP PET 1989; CBSE PMT 1995; KCET 2003; MH CET 1999]

(a) $T_1 = T_2 = T_3$ (b) $T_1 > T_2 > T_3$

(c) $T_1 < T_2 < T_3$ (d) $T_1 > T_2 < T_3$

3. Consider two hot bodies B_1 and B_2 which have temperatures 100^oC and 80^oC respectively at $t = 0$. The temperature of the surroundings is 40^oC. The ratio of the respective rates of cooling R_1 and R_2 of these two bodies at $t = 0$ will be

(a) $R_1 : R_2 = 3:2$ (b) $R_1 : R_2 = 5:4$

(c) $R_1 : R_2 = 2:3$ (d) $R_1 : R_2 = 4:5$

4. Newton's law of cooling is a special case of

(a) Stefan's law (b) Kirchhoff's law

(c) Wien's law (d) Planck's law

5. Equal masses of two liquids are filled in two similar calorimeters. The rate of cooling will [MP PMT 1987]

(a) Depend on the nature of the liquids

(b) Depend on the specific heats of liquids

(c) Be same for both the liquids

(d) Depend on the mass of the liquids

6. In Newton's experiment of cooling, the water equivalent of two similar calorimeters is 10 *gm* each. They are filled with 350 *gm* of water and 300 *gm* of a liquid (equal volumes) separately. The time taken by water and liquid to cool from 70^oC to 60^oC is 3 *min* and 95 *sec* respectively. The specific heat of the liquid will be

(a) 0.3 *Cal/gm* $\times$°*C* (b) 0.5 *Cal/gm* $\times$°*C*

(c) 0.6 *Cal/gm* $\times$°*C* (d) 0.8 *Cal/gm* $\times$°*C*

7. Newton's law of cooling is used in laboratory for the determination of the [CPMT 1973; CPMT 2002]

(a) Specific heat of the gases (b) The latent heat of gases

(c) Specific heat of liquids (d) Latent heat of liquids

8. A body cools from 60^oC to 50^oC in 10 *minutes* when kept in air at 30^oC. In the next 10 *minutes* its temperature will be

(a) Below 40^oC (b) 40^oC

(c) Above 40^oC (d) Cannot be predicted

9. Liquid is filled in a vessel which is kept in a room with temperature 20^oC. When the temperature of the liquid is 80^oC, then it loses heat at the rate of $60\ cal/\sec$. What will be the rate of loss of heat when the temperature of the liquid is 40^oC

(a) $180\ cal/\sec$ (b) $40\ cal/\sec$

(c) $30\ cal/\sec$ (d) $20\ cal/\sec$

10. Which of the following statements is true/correct [Manipal MEE 1995]

(a) During clear nights, the temperature rises steadily upward near the ground level

(b) Newton's law of cooling, an approximate form of Stefan's law, is valid only for natural convection

(c) The total energy emitted by a black body per unit time per unit area is proportional to the square of its temperature in the Kelvin scale

(d) Two spheres of the same material have radii $1m$ and $4m$ and temperatures 4000 *K* and 2000 *K* respectively. The energy radiated per second by the first sphere is greater than that radiated per second by the second sphere

11. A body takes 4 *minutes* to cool from 100^oC to 70^oC. To cool from 70^oC to 40^oC it will take (room temperature is 15^oC)

(a) 7 *minutes* (b) 6 *minutes*

(c) 5 *minutes* (d) 4 *minutes*

12. A cup of tea cools from 80^0C to 60^oC in one minute. [MP PET 1990] The ambient temperature is 30^oC. In cooling from 60^oC to 50^oC it will take [MP PMT 1995; UPSEAT 2000; MH CET 2002]

(a) 30 seconds (b) 60 seconds

(c) 90 seconds (d) 50 seconds

13. A liquid cools down from 70^oC to 60^oC in 5 *minutes*. The time taken to cool it from 60^oC to 50^oC will be [MP PET 1992, 2000; MP PMT 1996]

(a) 5 *minutes*

(b) Lesser than 5 *minutes*

(c) Greater than 5 *minutes*

(d) Lesser or greater than 5 *minutes* depending upon the density of the liquid

14. If a metallic sphere gets cooled from 62^oC to 50^oC in 10 minutes and in the next 10 minutes gets cooled to 42^oC, then the temperature of the surroundings is [MP PET 1997]

(a) 30^oC (b) 36^oC

(c) 26^oC (d) 20^oC

15. The rates of cooling of two different liquids put in exactly similar calorimeters and kept in identical surroundings are the same if [MP PET 1994]

(a) The masses of the liquids are equal

(b) Equal masses of the liquids at the same temperature are taken

(c) Different volumes of the liquids at the same temperature are taken

(d) Equal volumes of the liquids at the same temperature are taken

16. A body cools from 60^oC to 50^oC in 10 *minutes*. If the room temperature is 25^oC and assuming Newton's law of cooling to hold good, the temperature of the body at the end of the next 10 *minutes* will be [MP PMT 1994] [MP PMT/PET 1998; BHU 2000; Pb. PMT 2001]

(a) 38.5^oC (b) 40^oC

(c) 42.85^oC (d) 45^oC

17. The temperature of a liquid drops from $365K$ to 361 *K* in 2 *minutes*. Find the time during which temperature of the liquid drops from $344\ K$ to $342K$. Temperature of room is $293\ K$

(a) 84 *sec* (b) 72 *sec*

(c) 66 *sec* (d) 60 *sec*

18. A body cools from $50.0^o C$ to $49.9^o C$ in $5\ s$. How long will it take to cool from $40.0^o C$ to $39.9^o C$? Assume the temperature of surroundings to be $30.0^o C$ and Newton's law of cooling to be valid **[CBSE PMT 1994]**

(a) 2.5 *s* (b) 10 *s*

(c) 20 *s* (d) 5 *s*

19. A container contains hot water at $100^o C$. If in time T_1 temperature falls to $80^o C$ and in time T_2 temperature falls to $60^o C$ from $80^o C$, then **[CPMT 1997]**

(a) $T_1 = T_2$ (b) $T_1 > T_2$

(c) $T_1 < T_2$ (d) None

20. Hot water kept in a beaker placed in a room cools from $70^o C$ to $60^\circ C$ in 4 *minutes*. The time taken by it to cool from $69^o C$ to $59^o C$ will be **[JIPMER 1999]**

(a) The same 4 minutes (b) More than 4 minutes

(c) Less than 4 minutes (d) We cannot say definitely

21. Newton's law of cooling, holds good only if the temperature difference between the body and the surroundings is **[BHU 2000]**

(a) Less than $10^o C$ (b) More than $10^o C$

(c) Less than $100^o C$ (d) More than $100^o C$

22. In a room where the temperature is $30^o C$, a body cools from $61^o C$ to $59^o C$ in 4 minutes. The time (in min.) taken by the body to cool from $51^0 C$ to $49^0 C$ will be **[UPSEAT 2000]**

(a) 4 *min* (b) 6 *min*

(c) 5 *min* (d) 8 *min*

23. According to 'Newton's Law of cooling', the rate of cooling of a body is proportional to the **[MP PET 2001]**

(a) Temperature of the body

(b) Temperature of the surrounding

(c) Fourth power of the temperature of the body

(d) Difference of the temperature of the body and the surroundings

24. A body cools in 7 minutes from $60^o C$ to $40^o C$ What time (in minutes) does it take to cool from $40^o C$ to $28^o C$ if the surrounding temperature is $10^o C$? Assume Newton's Law of cooling holds **[Kerala (Engg.) 2001]**

(a) 3.5 (b) 11

(c) 7 (d) 10

25. A body takes 5 minutes for cooling from $50^o C$ to $40^o C$. Its temperature comes down to $33.33^o C$ in next 5 minutes. Temperature of surroundings is **[MP PMT 2002]**

(a) $15^o C$ (b) $20^o C$

(c) $25^o C$ (d) $10^o C$

26. The temperature of a body falls from $50^o C$ to $40^o C$ in 10 minutes. If the temperature of the surroundings is $20^o C$ Then temperature of the body after another 10 minutes will be

(a) $36.6^o C$ (b) $33.3^o C$

(c) $35^o C$ (d) $30^o C$

27. It takes 10 minutes to cool a liquid from $61^\circ C$ to $59^\circ C$. If room temperature is $30^\circ C$ then time taken in cooling from $51^\circ C$ to $49^\circ C$ is

(a) 10 *min* (b) 11 *min*

(c) 13 *min* (d) 15 *min*

28. A calorimeter of mass 0.2 *kg* and specific heat 900 *J/kg-K*. Containing 0.5 *kg* of a liquid of specific heat 2400*J* /*kg-K*. Its temperature falls from $60^\circ C$ to $55^\circ C$ in one minute. The rate of cooling is **[MP PET 2003]**

(a) 5 *J/s* (b) 15 *J/s*

(c) 100 *J/s* (d) 115 *J/s*

29. According to Newton's law of cooling, the rate of cooling of a body is proportional to $(\Delta\theta)^n$, where $\Delta\theta$ is the difference of the temperature of the body and the surroundings, and *n* is equal to

(a) One (b) Two

(c) Three (d) Four

30. The initial temperature of a body is $80^\circ C$. If its temperature falls to $64^\circ C$ in 5 *minutes* and in 10 *minutes* to $52^\circ C$ then the temperature of surrounding will be **[MP PMT 2003]**

(a) $26^\circ C$ (b) $49^\circ C$

(c) $35^\circ C$ (d) $42^\circ C$

31. A liquid cools from $50^\circ C$ to $45^\circ C$ in 5 minutes and from $45^\circ C$ to $41.5^\circ C$ in the next 5 minutes. The temperature of the surrounding is

(a) $27^\circ C$ (b) $40.3^\circ C$

(c) $23.3^\circ C$ (d) $33.3^\circ C$

32. A cup of tea cools from $65.5^\circ C$ to $62.5^\circ C$ in one minute in a room of $22.5^\circ C$. How long will the same cup of tea take, in............. minutes, to cool from $46.50^\circ C$ to $40.5^\circ C$ in the same room ? (choose nearest value) **[Kerala PMT 2004]**

(a) 1 (b) 2

(c) 3 (d) 4

33. The temperature of a body falls from $62^\circ C$ to $50^\circ C$ in 10 *minutes*. If the temperature of the surroundings is $26^\circ C$, the temperature in next 10 *minutes* will become **[RPMT 2002]**

(a) $42^\circ C$ (b) $40^\circ C$

(c) $56^\circ C$ (d) $55^\circ C$

34. A body takes 5 *minutes* to cool from $90^\circ C$ to $60^\circ C$. If the temperature of the surroundings is $20^\circ C$, the time taken by it to cool from $60^\circ C$ to $30^\circ C$ will be. **[RPMT 2003]**

(a) 5 *min* (b) 8 *min*

(c) 11 *min* (d) 12 *min*

35. An object is cooled from $75^\circ C$ to $65^\circ C$ in 2 minutes in a room at $30^\circ C$. The time taken to cool another object from $55^\circ C$ to $45^\circ C$ in the same room in minutes is **[EAMCET (Med.) 1996]**

(a) 4 (b) 5

(c) 6 (d) 7

36. A body takes 5 minute to cool from 80°C to 50°C. How much time it will take to cool from 60°C to 30°C, if room temperature is 20°C.

(a) 40 minute (b) 9 minute

(c) 30 minute (d) 20 minute

37. A cane is taken out from a refrigerator at 0°C. The atmospheric temperature is 25°C. If t_1 is the time taken to heat from 0°C to 5°C and t_2 is the time taken from 10°C to 15°C, then

(a) $t_1 > t_2$ (b) $t_1 < t_2$

(c) $t_1 = t_2$ (d) There is no relation

Critical Thinking

Objective Questions

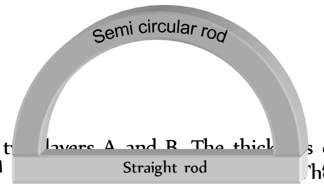
1. Two rods (one semi-circular and other straight) of same material and of same cross-sectional area are joined as shown in the figure. The points A and B are maintained at different temperature. The ratio of the heat transferred through a cross-section of a semi-circular rod to the heat transferred through a cross section of the straight rod in a given time is [UPSEAT 2002]

(a) $2 : \pi$

(b) 1 : 2

(c) $\pi : 2$

(d) 3 : 2



2. A wall is made up of t layers A and B. The thick s of the two layers is the same, he thermal conductivity of A is double than that of B. In thermal equilibrium the temperature difference between the two ends is 36^oC. Then the difference of temperature at the two surfaces of A will be

BHU 1997; MP PET 1996, 99; DPMT 2000]

(a) 6^oC (b) 12^oC

(c) 18^oC (d) 24^oC

3. Ice starts forming in lake with water at 0^oC and when the atmospheric temperature is -10^oC. If the time taken for 1 *cm* of ice be 7 *hours*, then the time taken for the thickness of ice to change from 1 *cm* to 2 *cm* is

[NCERT 1971; MP PMT/PET 1988; UPSEAT 1996]

(a) 7 *hours* (b) 14 *hours*

(c) Less than 7 *hours* (d) More than 7 *hours*

4. A cylinder of radius R made of a material of thermal conductivity K_1 is surrounded by a cylindrical shell of inner radius R and outer radius $2R$ made of material of thermal conductivity K_2. The two ends of the combined system are maintained at two different temperatures. There is no loss of heat across the cylindrical surface and the system is in steady state. The effective thermal conductivity of the system is

(a) $K_1 + K_2$ (b) $\frac{K_1K_2}{K_1 + K_2}$

(c) $\frac{K_1 + 3K_2}{4}$ (d) $\frac{3K_1 + K_2}{4}$

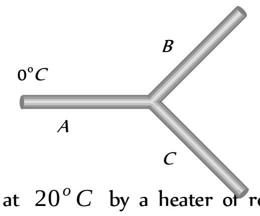
5. Three rods made of the same material and having the same cross section have been joined as shown in the figure. Each rod is of the same length. [RPET 1998] The left and right ends are kept at 0^oC and 90^oC respectively. The temperature of the junction of the three rods will be [IIT-JEE (Screening) 2001]

(a) 45^oC

(b) 60^oC [Orissa JEE 2005]

(c) 30^oC

(d) 20^oC



6. A room is maintained at 20^oC by a heater of resistance 20 *ohm* connected to 200 *volt* mains. The temperature is uniform through out the room and heat is transmitted through a glass window of area $1m^2$ and thickness 0.2 *cm*. What will be the temperature outside? Given that thermal conductivity K for glass is $0.2\ cal/m/^oC/\sec$ and J = 4.2 *J/cal*

[IIT 1978]

(a) 15.24^oC (b) 15.00°C

(c) 24.15^oC (d) None of the above

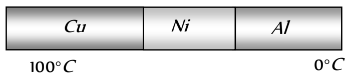
7. There is formation of layer of snow $x\,cm$ thick on water, when the temperature of air is $-\theta^oC$ (less than freezing point). The thickness of layer increases from x to y in the time t, then the value of t is given by

(a) $\frac{(x+y)(x-y)\rho L}{2k\theta}$ (b) $\frac{(x-y)\rho L}{2k\theta}$

[IIT 1980; CPMT 1991;

(c) $\frac{(x+y)(x-y)\rho L}{k\theta}$ (d) $\frac{(x-y)\rho Lk}{2\theta}$

8. A composite metal bar of uniform section is made up of length 25 *cm* of copper, 10 *cm* of nickel and 15 *cm* of aluminium. Each part being in perfect thermal contact with the adjoining part. The copper end of the composite rod is maintained at 100^oC and the aluminium end at 0^oC. The whole rod is covered with belt so that there is no heat loss occurs at the sides. If $K_{Cu} = 2K_{Al}$ and $K_{Al} = 3K_{Ni}$, then what will be the temperatures of $Cu - Ni$ and $Ni - Al$ junctions respectively



(a) 23.33^oC and 78.8^oC (b) 83.33^oC and 20^oC

(c) 50^oC and 30^oC (d) 30^oC and 50^oC

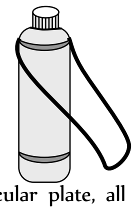
[IIT 1988; MP PMT 1994, 97; SCRA 1998]

9. Three rods of identical area of cross-section and made from the same metal form the sides of an isosceles triangle ABC, right angled at B. The points A and B are maintained at temperatures T and $\sqrt{2}T$ respectively. In the steady state the temperature of the point C is T_C. Assuming that only heat conduction takes place, $\frac{T_C}{T}$ is equal to [IIT 1995]

(a) $\frac{1}{(\sqrt{2}+1)}$ (b) $\frac{3}{(\sqrt{2}+1)}$

(c) $\frac{1}{2(\sqrt{2}-1)}$ (d) $\frac{1}{\sqrt{3}(\sqrt{2}-1)}$

10. The only possibility of heat flow in a thermos flask is through its cork which is 75 cm in area and 5 cm thick. Its thermal conductivity is 0.0075 $cal/cmsec C$. The outside temperature is $40^{\circ}C$ and latent heat of ice is 80 $cal\ g$. Time taken by 500 g of ice at $0^{\circ}C$ in the flask to melt into water at $0^{\circ}C$ is [CPMT 1974, 78; MNR 1983]



(a) 2.47 hr
(b) 4.27 hr
(c) 7.42 hr
(d) 4.72 hr

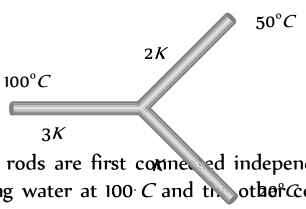
11. A sphere, a cube and a thin circular plate, all made of the same material and having the same mass are initially heated to a temperature of $1000°C$. Which one of these will cool first

J & K CET 2000 MH CET 2000; UPSEAT 2001]

(a) Plate (b) Sphere
(c) Cube (d) None of these

12. Three rods of the same dimension have thermal conductivities $3K$, $2K$ and K. They are arranged as shown in fig. Given below, with their ends at $100^{\circ}C$, $50^{\circ}C$ and $20^{\circ}C$. The temperature of their junction is

(a) $60^{o}\ C$
(b) $70^{o}\ C$
(c) $50^{\circ}\ C$
(d) $35^{\circ}\ C$



13. Two identical conducting rods are first connected independently to two vessels, one containing water at $100^{\circ}\ C$ and the other containing ice at $0^{\circ}C$. In the second case, the rods are joined end to end and connected to the same vessels. Let q_1 and q_2 $g\ /\ s$ be the rate of melting of ice in two cases respectively. The ratio of q_1/q_2 is

[IIT-JEE (Screening) 2004]

(a) $\frac{1}{2}$ (b) $\frac{2}{1}$

(c) $\frac{4}{1}$ (d) $\frac{1}{4}$

14. A solid cube and a solid sphere of the same material have equal surface area. Both are at the same temperature $120^{o}\ C$, then [MP PET 1992, 96; MP PMT 2000]

(a) Both the cube and the sphere cool down at the same rate
(b) The cube cools down faster than the sphere
(c) The sphere cools down faster than the cube
(d) Whichever is having more mass will cool down faster

15. Two bodies A and B have thermal emissivities of 0.01 and 0.81 respectively. The outer surface areas of the two bodies are the same. The two bodies emit total radiant power at the same rate. The wavelength λ_B corresponding to maximum spectral radiancy in the radiation from B is shifted from the wavelength corresponding to maximum spectral radiancy in the radiation from A, by $1.00 \mu m$. If the temperature of A is $5802\ K$

(a) The temperature of B is $1934\ K$
(b) $\lambda_B = 1.5 \mu m$
(c) The temperature of B is $11604\ K$
(d) The temperature of B is $2901\ K$

16. A black body is at a temperature of $2880\ K$. The energy of radiation emitted by this object with wavelength between $499\ nm$ and $500\ nm$ is U_1, between $999\ nm$ and $1000\ nm$ is U_2 and between $1499\ nm$ and $1500\ nm$ is U_3. The Wein's constant $b = 2.88 \times 10^{6}\ nm K$. Then

[IIT 1998]

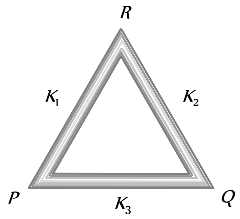
(a) $U_1 = 0$ (b) $U_3 = 0$
(c) $U_1 > U_2$ [IIT 1972; MP PMT 1993; (d) $U_2 > U_1$

17. A black metal foil is warmed by radiation from a small sphere at temperature T and at a distance d. It is found that the power received by the foil is 'P. If both the temperature and the distance are doubled, the power received by the foil will be

(a) $16P$ (b) $4P$
[UPSEAT 2002]
(c) $2P$ (d) P

18. Three rods of same dimensions are arranged as shown in figure they have thermal conductivities K_1, K_2 and K_3 The points P and Q are maintained at different temperatures for the heat to flow at the same rate along PRQ and PQ then which of the following option is correct [KCET 2001]

(a) $K_3 = \frac{1}{2}(K_1 + K_2)$
(b) $K_3 = K_1 + K_2$
(c) $K_3 = \frac{K_1 K_2}{K_1 + K_2}$
(d) $K_3 = 2(K_1 + K_2)$



19. Two metallic spheres S_1 and S_2 are made of the same material and have identical surface finish. The mass of S_1 is three times that of S_2. Both the spheres are heated to the same high temperature and placed in the same room having lower temperature but are thermally insulated from each other. The ratio of the initial rate of cooling of S_1 to that of S_2 is [IIT 1995]

(a) $1/3$ (b) $(1/3)^{1/3}$

(c) $1/\sqrt{3}$ (d) $\sqrt{3}/1$

20. Three discs A, B and C having radii $2m$, $4m$, and $6m$ respectively are coated with carbon black on their other surfaces. The wavelengths corresponding to maximum intensity are 300 nm, 400 nm and 500 nm, respectively. The power radiated by them are Q_a, Q_b and Q_c respectively

[IIT-JEE (Screening) 2004]

(a) Q_a is maximum (b) Q_b is maximum

(c) Q_c is maximum (d) $Q_a = Q_b = Q_c$

21. The total energy radiated from a black body source is collected for one minute and is used to heat a quantity of water. The temperature of water is found to increase form $20^o C$ to $20.5^o C$. If the absolute temperature of the black body is doubled and the experiment is repeated with the same quantity of water at $20^o C$, the temperature of water will be [UPSEAT 2004]

(a) $21^o C$ (b) $22^o C$

(c) $24^o C$ (d) $28^o C$

22. A solid sphere and a hollow sphere of the same material and size are heated to the same temperature and allowed to cool in the same surroundings. If the temperature difference between each sphere and its surroundings is T, then

[Manipal MEE 1995]

(a) The hollow sphere will cool at a faster rate for all values of T

(b) The solid sphere will cool at a faster rate for all values of T

(c) Both spheres will cool at the same rate for all values of T

(d) Both spheres will cool at the same rate only for small values of T

23. A solid copper cube of edges $1\ cm$ is suspended in an evacuated enclosure. Its temperature is found to fall from $100^o C$ to $99^o C$ in $100\ s$. Another solid copper cube of edges $2\ cm$, with similar surface nature, is suspended in a similar manner. The time required for this cube to cool from $100^o C$ to $99^o C$ will be approximately[MP PMT 1997]

(a) $25\ s$ (b) $50\ s$

(c) $200\ s$ (d) $400\ s$

24. A body initially at $80^\circ C$ cools to $64^\circ C$ in 5 *minutes* and to $52^\circ C$ in 10 *minutes*. The temperature of the body after 15 *minutes* will be[UPSEAT 2000; Pb. PET 2004]

(a) $42.7^\circ C$ (b) $35^\circ C$

(c) $47^\circ C$ (d) $40^\circ C$

25. A 5*cm* thick ice block is there on the surface of water in a lake. The temperature of air is $-10^\circ C$; how much time it will take to double the thickness of the block

($L = 80$ *cal/g*, $K_{ice} = 0.004$ *Erg/s-k*, $d_{ice} = 0.92\ g\ cm^{-3}$)

[RPET 1998]

(a) 1 *hour* (b) 191 *hours*

(c) 19.1 *hours* (d) 1.91 *hours*

26. Four identical rods of same material are joined end to end to form a square. If the temperature difference between the ends of a diagonal is $100^o C$, then the temperature difference between the ends of other diagonal will be

[MP PET 1989; RPMT 2002]

(a) $0^o C$

(b) $\frac{100}{l}\ ^o C$; where l is the length of each rod

(c) $\frac{100}{2l}\ ^o C$

(d) $100^o C$

27. A cylindrical rod with one end in a steam chamber and the other end in ice results in melting of 0.1*gm* of ice per second. If the rod is replaced by another with half the length and double the radius of the first and if the thermal conductivity of material of second rod is $\frac{1}{4}$ that of first, the rate at which ice melts in $gm/\sec$ will be [EAMCET 1987]

(a) 3.2 (b) 1.6

(c) 0.2 (d) 0.1

28. One end of a copper rod of length $1.0\ m$ and area of cross-section 10^{-3} is immersed in boiling water and the other end in ice. If the coefficient of thermal conductivity of copper is $92\ cal/m\text{-}s\text{-}^oC$ and the latent heat of ice is $8 \times 10^4\ cal/kg$, then the amount of ice which will melt in one minute is

[MNR 1994]

(a) $9.2 \times 10^{-3}\ kg$ (b) $8 \times 10^{-3}\ kg$

(c) $6.9 \times 10^{-3}\ kg$ (d) $5.4 \times 10^{-3}\ kg$

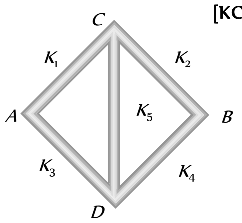
29. An ice box used for keeping eatable cold has a total wall area of $1\ metre^2$ and a wall thickness of $5.0\ cm$. The thermal conductivity of the ice box is $K = 0.01\ joule/metre\text{-}^oC$. It is filled with ice at $0^o C$ along with eatables on a day when the temperature is $30^\circ C$. The latent heat of fusion of ice is $334 \times 10^3\ joules/kg$. The amount of ice melted in one day is ($1\ day = 86{,}400\ seconds$) [MP PMT 1995]

(a) $776\ gms$ (b) $7760\ gms$

(c) $11520\ gms$ (d) $1552\ gms$

30. Five rods of same dimensions are arranged as shown in the figure. They have thermal conductivities K_1, K_2, K_3, K_4 and K_5. When points A and B are maintained at different temperatures, no heat flows through the central rod if

[KCET 2002]



(a) $K_1 = K_4$ and $K_2 = K_3$

(b) $K_1 K_4 = K_2 K_3$

(c) $K_1 K_2 = K_3 K_4$

(d) $\frac{K_1}{K_4} = \frac{K_2}{K_3}$

31. A hot metallic sphere of radius r radiates heat. It's rate of cooling is

(a) Independent of r (b) Proportional to r

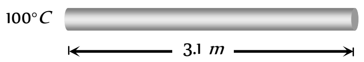
(c) Proportional to r^2 (d) Proportional to $1/r$

32. A solid copper sphere (density ρ and specific heat capacity c) of radius r at an initial temperature $200K$ is suspended inside a chamber whose walls are at almost $0K$. The time required (in μ s) for the temperature of the sphere to drop to 100 K is

(a) $\frac{72}{7}\frac{r\rho c}{\sigma}$ (b) $\frac{7}{72}\frac{r\rho c}{\sigma}$

(c) $\frac{27}{7}\frac{r\rho c}{\sigma}$ (d) $\frac{7}{27}\frac{r\rho c}{\sigma}$

33. One end of a copper rod of uniform cross-section and of length 3.1 m is kept in contact with ice and the other end with water at $100^\circ C$. At what point along it's length should a temperature of $200^\circ C$ be maintained so that in steady state, the mass of ice melting be equal to that of the steam produced in the same interval of time. Assume that the whole system is insulated from the surroundings. Latent heat of fusion of ice and vaporisation of water are 80 *cal/gm* and 540 *cal/gm* respectively



(a) 40 cm from 100°C end (b) 40 cm from 0°C end

(c) 125 cm from 100°C end (d) 125 cm from 0°C end

34. A sphere and a cube of same material and same volume are heated upto same temperature and allowed to cool in the same surroundings. The ratio of the amounts of radiations emitted will be

(a) 1 : 1 (b) $\frac{4\pi}{3} : 1$

(c) $\left(\frac{\pi}{6}\right)^{1/3} : 1$ (d) $\frac{1}{2}\left(\frac{4\pi}{3}\right)^{2/3} : 1$

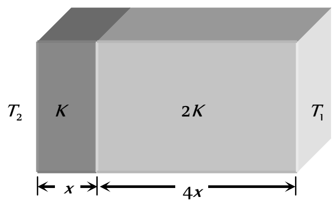
35. The temperature of the two outer surfaces of a composite slab, consisting of two materials having coefficients of thermal conductivity K and $2K$ and thickness x and $4x$, respectively are T_2 and T_1 ($T_2 > T_1$). The rate of heat transfer through the slab, in a steady state is $\left(\frac{A(T_2 - T_1)K}{x}\right)f$, with f which equal to[**AIEEE 2004**]

(a) 1

(b) $\frac{1}{2}$

(c) $\frac{2}{3}$

(d) $\frac{1}{3}$



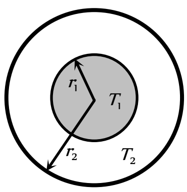
36. The figure shows a system of two concentric spheres of radii r_1 and r_2 and kept at temperatures T_1 and T_2, respectively. The radial rate of flow of heat in a substance between the two concentric spheres is proportional to [**AIEEE 2005**]

(a) $\frac{r_1 r_2}{(r_1 - r_2)}$

(b) $(r_2 - r_1)$

(c) $(r_2 - r_1)(r_1 r_2)$

(d) $\ln\left(\frac{r_2}{r_1}\right)$



37. Four rods of identical cross-sectional area and made from the same metal form the sides of square. The temperature of two diagonally opposite points and T and $\sqrt{2}\,T$ respective in the steady state. Assuming that only heat conduction takes place, what will be the temperature difference between other two points

[**BCECE 2005**]

(a) $\frac{\sqrt{2}+1}{2}T$ (b) $\frac{2}{\sqrt{2}+1}T$

(c) 0 (d) None of these

GQ Graphical Questions

1. The graph. Shown in the adjacent diagram, represents the variation of temperature (T) of two bodies, x and y having same surface area, with time (t) due to the emission of radiation. Find the correct relation between the emissivity (e) and absorptivity (a) of the two bodies

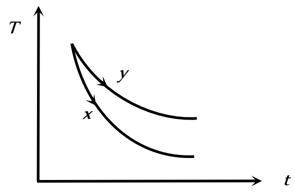
[**IIT-JEE (Screening) 2003**]

(a) $e_x > e_y$ & $a_x < a_y$

(b) $e_x < e_y$ & $a_x > a_y$

(c) $e_x > e_y$ & $a_x > a_y$

(d) $e_x < e_y$ & $a_x < a_y$



2. The plots of intensity versus wavelength for three black bodies at temperatures T_1, T_2 and T_3 respectively are as shown. Their temperature are such that

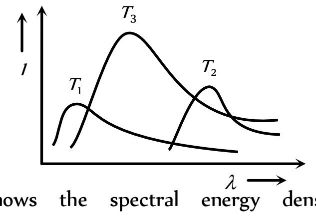
[**IIT-JEE (Screening) 2000**]

(a) $T_1 > T_2 > T_3$

(b) $T_1 > T_3 > T_2$

(c) $T_2 > T_3 > T_1$

(d) $T_3 > T_2 > T_1$



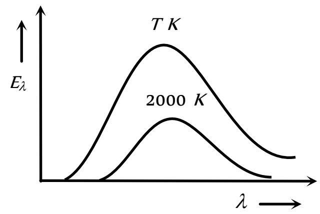
3. The adjoining diagram shows the spectral energy density distribution E_λ of a black body at two different temperatures. If the areas under the curves are in the ratio 16 : 1, the value of temperature T is [**DCE 1999**]

(a) 32,000 K

(b) 16,000 K

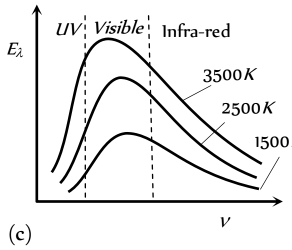
(c) 8,000 K

(d) 4,000 K

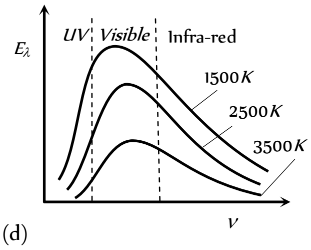


4. Following graph shows the correct variation in intensity of heat radiations by black body and frequency at a fixed temperature

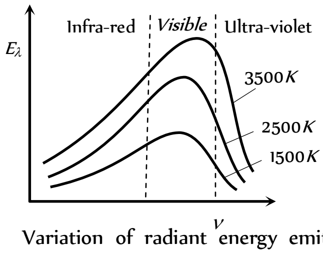
(a)



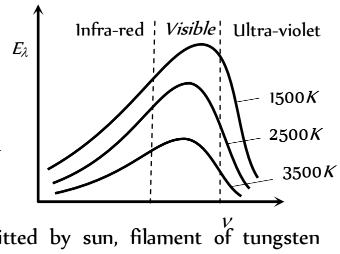
(b)



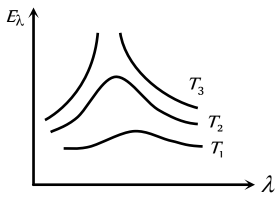
(c)



(d)



5. Variation of radiant energy emitted by sun, filament of tungsten lamp and welding arc as a function of its wavelength is shown in figure. Which of the following option is the correct match



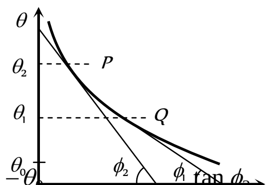
(a) Sun- T_1, tungsten filament $-T_2$, welding arc $-T_3$

(b) Sun $-T_2$, tungsten filament $-T_1$, welding arc $-T_3$

(c) Sun $-T_3$, tungsten filament $-T_2$, welding arc $-T_1$

(d) Sun $-T_1$, tungsten filament $-T_3$, welding arc $-T_2$

6. A body cools in a surrounding which is at a constant temperature of θ_0. Assume that it obeys Newton's law of cooling. Its temperature θ is plotted against time *t*. Tangents are drawn to the curve at the points $P(\theta = \theta_1)$ and $Q(\theta = \theta_2)$. These tangents meet the time axis at angles of ϕ_2 and ϕ_1, as shown



(a) $\dfrac{\tan\phi_2}{\tan\phi_1} = \dfrac{\theta_1 - \theta_0}{\theta_2 - \theta_0}$

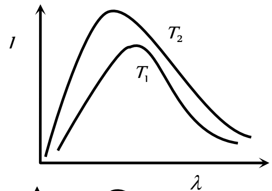
(b) $\dfrac{\tan\phi_2}{\tan\phi_1} = \dfrac{\theta_2 - \theta_0}{\theta_1 - \theta_0}$

(c) $\dfrac{\tan\phi_1}{\tan\phi_2} = \dfrac{\theta_1}{\theta_2}$

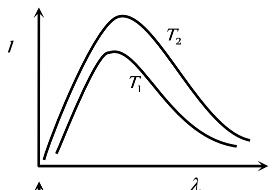
(d) $\dfrac{\tan\phi_1}{\tan\phi_2} = \dfrac{\theta_2}{\theta_1}$

7. Shown below are the black body radiation curves at temperatures T_1 and T_2 ($T_2 > T_1$). Which of the following plots is correct

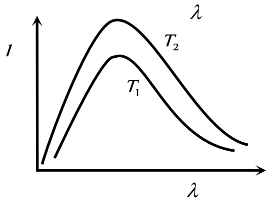
(a)



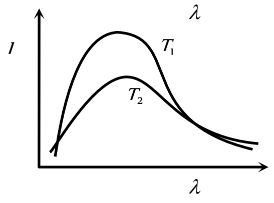
(b)



(c)



(d)



8. The spectrum of a black body at two temperatures 27°C and 327°C is shown in the figure. Let A_1 and A_2 be the areas under the two curves respectively. The value of $\dfrac{A_2}{A_1}$ is

(a) 1 : 16

(b) 4 : 1

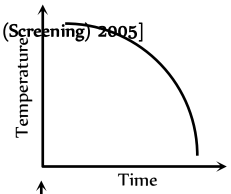
(c) 2 : 1

(d) 16 : 1

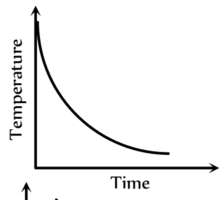
9. A block of metal is heated to a temperature much higher than the room temperature and allowed to cool in a room free from air currents. Which of the following curves correctly represents the rate of cooling [Manipal MEE 1995]

[IIT-JEE (Screening) 2005]

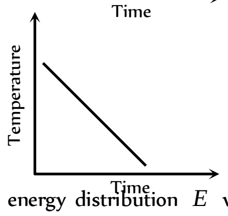
(a)



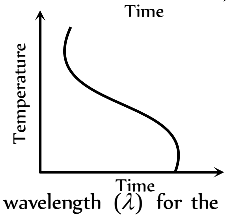
(b)



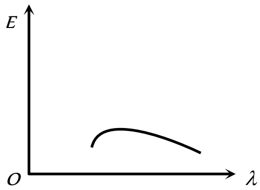
(c)



(d)



10. The energy distribution E with the wavelength (λ) for the black body radiation at temperature $T\ Kelvin$ is shown in the figure. As the temperature is increased the maxima will



(a) Shift towards left and become higher

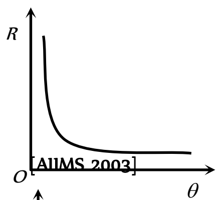
(b) Rise high but will not shift

(c) Shift towards right and become higher

(d) Shift towards left and the curve will become broader

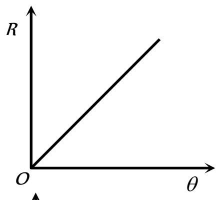
11. For a small temperature difference between the body and the surroundings the relation between the rate of loss heat R and the temperature of the body is depicted by

(a)

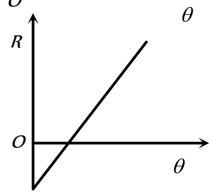


[AIIMS 2003]

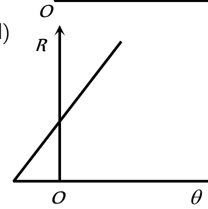
(b)



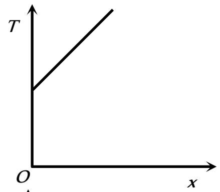
(c)

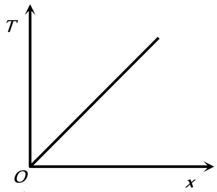


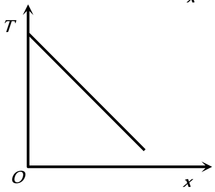
(d)

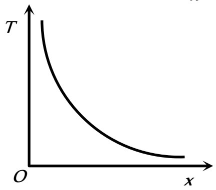


12. Heat is flowing through a conductor of length l from $x = 0$ to $x = l$. If its thermal resistance per unit length is uniform, which of the following graphs is correct

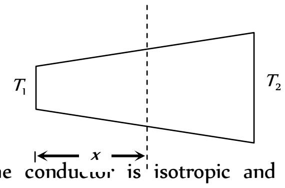
(a) 

(b) 

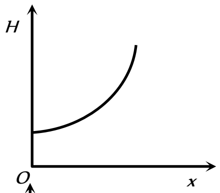
(c) 

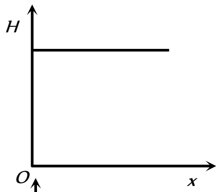
(d) 

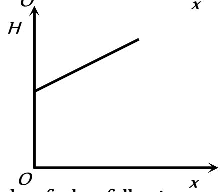
13. Radius of a conductor increases uniformly from left end to right end as shown in fig.

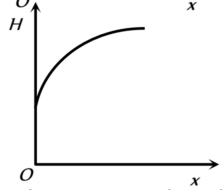


Material of the conductor is isotropic and its curved surface is thermally isolated from surrounding. Its ends are maintained at temperatures T_1 and T_2 ($T_1 > T_2$): If, in steady state, heat flow rate is equal to H, then which of the following graphs is correct

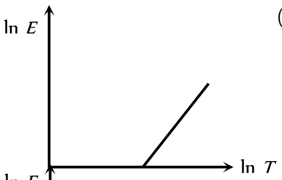
(a) 

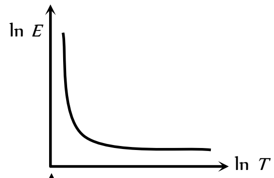
(b) 

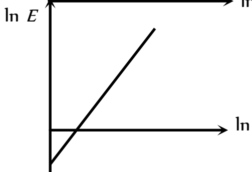
(c) 

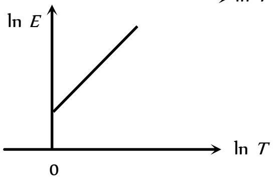
(d) 

14. Which of the following graphs correctly represents the relation between ln E and ln T where E is the amount of radiation emitted per unit time from unit area of a body and T is the absolute temperature **[DCE 2002]**

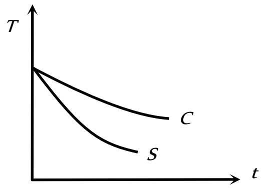
(a) 

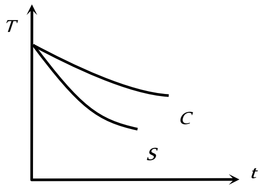
(b) 

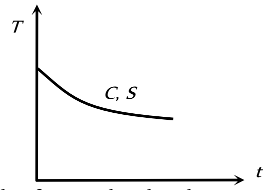
(c) 

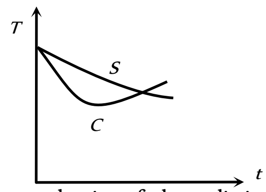
(d) 

15. A hollow copper sphere S and a hollow copper cube C, both of negligible thin walls of same area, are filled with water at 90°C and allowed to cool in the same environment. The graph that correctly represents their cooling is

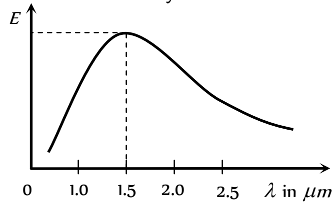
(a) 

(b) 

(c) 

(d) 

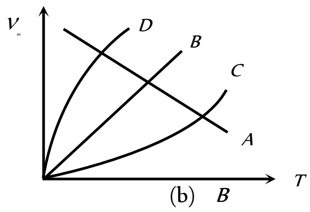
16. In the figure, the distribution of energy density of the radiation emitted by a black body at a given temperature is shown. The possible temperature of the black body is



(a) 1500 K (b) 2000 K

(c) 2500 K (d) 3000 K

17. Which of the following is the $\nu_m - T$ graph for a perfectly black body (ν_m =maximum frequency of radiation) **[RPMT 1996]**



(a) A (b) B

(c) C (d) D

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : A body that is a good radiator is also a good absorber of radiation at a given wavelength.
Reason : According to Kirchoff's law the absorptivity of a body is equal to its emissivity at a given wavelength. [AIIMS 2005]

2. Assertion : For higher temperature, the peak emission wavelength of a black body shifts to lower wavelengths.
Reason : Peak emission wavelength of a blackbody is proportional to the fourth power of temperature. [AIIMS 2005]

3. Assertion : Temperatures near the sea coast are moderate.
Reason : Water has a high thermal conductivity. [AIIMS 2003]

4. Assertion : It is hotter over the top of a fire than at the same distance on the sides.
Reason : Air surrounding the fire conducts more heat upwards. [AIIMS 2003]

5. Assertion : Bodies radiate heat at all temperatures.
Reason : Rate of radiation of heat is proportional to the fourth power of absolute temperature. [AIIMS 1999, 2002]

6. Assertion : Woolen clothes keep the body warm in winter.
Reason : Air is a bad conductor of heat. [AIIMS 2002]

7. Assertion : The equivalent thermal conductivity of two plates of same thickness in contact (series) is less than the smaller value of thermal conductivity.
Reason : For two plates of equal thickness in contact (series) the equivalent thermal conductivity is given by [AIIMS 1997]

$$\frac{1}{K}=\frac{1}{K_1}+\frac{1}{K_2}$$

8. Assertion : A hollow metallic closed container maintained at a uniform temperature can act as a source of black body radiation.
Reason : All metals acts as a black body [AIIMS 1996]

9. Assertion : If the temperature of a star is doubled then the rate of loss of heat from it becomes 16 times.
Reason : Specific heat varies with temperature. [AIIMS 1996]

10. Assertion : The radiation from the sun's surface varies as the fourth power of its absolute temperature.
Reason : The sun is not a black body. [AIIMS 1999]

11. Assertion : Blue star is at high temperature than red star.
Reason : Wein's displacement law states that $T \propto (1/\lambda_m)$. [AIIMS 2002]

12. Assertion : The S.I. unit of thermal conductivity is watt $m^{-1}K^{-1}$.
Reason : Thermal conductivity is a measure of ability of the material to allow the passage of heat through it.

13. Assertion : A brass tumbler feels much colder than a wooden tray on a chilly day.
Reason : The thermal conductivity of brass is less than that of wood.

14. Assertion : Like light radiations, thermal radiations are also electromagnetic radiation.
Reason : The thermal radiations require no medium for propagation.

15. Assertion : Snow is better insulator than ice.
Reason : Snow contain air packet and air is good insulator of heat.

16. Assertion : Water can be boiled inside satellite by convection.
Reason : Convection is the process in which heat is transmitted from a place of higher temperature to a place of lower temperature by means of particles with their migrations from one place to another.

17. Assertion : The absorbance of a perfect black body is unity.
Reason : A perfect black body when heated emits radiations of all possible wavelengths at that temperature.

18. Assertion : A man would feel iron or wooden balls equally hot at $98.4°F$.
Reason : At $98.4°F$ both iron and wood have same thermal conductivity.

19. Assertion : As temperature of a black body is raised, wavelength corresponding to maximum energy reduces.
Reason : Higher temperature would mean higher energy and hence higher wavelength.

20. Assertion : All black coloured objects are considered black bodies.
Reason : Black colour is a good absorber of heat.

21. Assertion : Greater is the coefficient of thermal conductivity of a material, smaller is the thermal resistance of a rod of that material.
Reason : Thermal resistance is the ratio of temperature difference between the ends of the conductor and rate of flow of heat.

22. Assertion : Radiation is the speediest mode of heat transfer.
Reason : Radiation can be transmitted in zig-zag motion.

23. Assertion : Two thin blankets put together are warmer than a single blanket of double the thickness.

Reason : Thickness increases because of air layer enclosed between the two blankets.

24. Assertion : Animals curl into a ball, when they feel very cold.

Reason : Animals by curling their body reduces the surface area.

Answers

Conduction

1	a	2	d	3	d	4	a	5	d
6	d	7	d	8	d	9	c	10	d
11	c	12	a	13	a	14	b	15	d
16	b	17	c	18	c	19	a	20	a
21	a	22	a	23	b	24	d	25	a
26	b	27	b	28	d	29	d	30	b
31	b	32	c	33	b	34	b	35	a
36	d	37	d	38	b	39	a	40	c
41	b	42	c	43	c	44	b	45	c
46	a	47	c	48	b	49	b	50	a
51	c	52	b	53	b	54	c	55	a
56	a	57	a	58	c	59	c	60	a
61	c	62	d	63	b	64	b	65	b
66	c	67	b	68	b				

Convection

1	c	2	a	3	c	4	a	5	b
6	a	7	c	8	b	9	a	10	d
11	a	12	c	13	c				

Radiation (General, Kirchoff's law, Black body)

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

Radiation (Wein's law)

1	a	2	c	3	d	4	c	5	a
6	c	7	d	8	c	9	c	10	b
11	a	12	b	13	b	14	c	15	b
16	a	17	b	18	a	19	b	20	a
21	c	22	a	23	b	24	b	25	c
26	b	27	b	28	b	29	a	30	b

Radiation (Stefan's law)

1	c	2	c	3	a	4	a	5	d
6	a	7	c	8	b	9	b	10	b
11	b	12	c	13	c	14	c	15	c
16	b	17	d	18	d	19	c	20	d
21	d	22	d	23	a	24	d	25	d
26	a	27	a	28	b	29	a	30	a
31	d	32	d	33	d	34	c	35	a
36	c	37	c	38	c	39	a	40	c
41	b	42	d	43	c	44	d	45	a
46	b	47	a	48	a	49	a	50	a
51	a	52	d	53	b	54	b	55	b
56	c								

Radiation (Newton's Law of Cooling)

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

Critical Thinking Questions

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

Graphical Questions

1	c	2	b	3	d	4	c	5	c
6	b	7	a	8	d	9	b	10	a
11	c	12	c	13	b	14	d	15	c
16	b	17	b						

Assertion & Reason

1	a	2	c	3	b	4	c	5	e
6	a	7	d	8	c	9	b	10	c

11	a	12	b	13	c	14	b	15	a
16	e	17	b	18	c	19	c	20	e
21	b	22	c	23	c	24	a		

Answers and Solutions

Conduction

1. (a) Cu is better conductor than Al and Ag is better conductor than Cu. Hence conductivity in increasing order is $Al < Cu < Ag$.

2. (d) $\frac{Q}{t} = \frac{KA\,\Delta\theta}{l} \Rightarrow \frac{Q}{t} \propto \frac{A}{l} \propto \frac{r^2}{l}$

$\because \frac{r^2}{l}$ is maximum in option (d), hence it will conduct more heat.

3. (d) $\frac{Q}{t} = \frac{KA\,\Delta\theta}{l} \Rightarrow \frac{Q}{t} \propto \frac{A}{l} \propto \frac{d^2}{l}$ (d = Diameter of rod)

$$\Rightarrow \frac{(Q/t)_1}{(Q/t)_2} = \left(\frac{d_1}{d_2}\right)^2 \times \frac{l_2}{l_1} = \left(\frac{1}{2}\right)^2 \times \left(\frac{1}{2}\right) = \frac{1}{8}$$

4. (a) $\frac{Q}{t} = \frac{KA\,\Delta\theta}{l} = \frac{\Delta\theta}{(l/KA)} = \frac{\Delta\theta}{R}$ (R = Thermal resistance)

$\Rightarrow t \propto R$ ($\because$ Q and $\Delta\theta$ are same)

$$\Rightarrow \frac{t_P}{t_S} = \frac{R_P}{R_S} = \frac{R/2}{2R} = \frac{1}{4} \Rightarrow t_P = \frac{t_S}{4} = \frac{4}{4} = 1\text{ min}.$$

(Series resistance $R_S = R_1 + R_2$ and parallel resistance $R_P = \frac{R_1 R_2}{R_1 + R_2}$)

5. (d) For cooking utensils, low specific heat is preferred for it's material as it should need less heat to raise it's temperature and it should have high conductivity, because, it should transfer heat quickly.

6. (d) In steady state there is no absorption of heat in any position. Heat passes on or is radiated from it's surface. Therefore, in steady state the temperature of the body does not change with time but can be different at different points of the body.

7. (d) It is the property of material.

8. (d) Because steady state has been reached.

9. (c) $\frac{Q_1}{t} = \frac{KA(90-60)}{0.6} = 50\ KA$

and $\frac{Q_2}{t} = \frac{KA(150-110)}{0.8} = 50\ KA$

10. (d) Given $A_1 = A_2$ and $\frac{K_1}{K_2} = \frac{5}{4}$

$$\because R_1 = R_2 \Rightarrow \frac{l_1}{K_1 A} = \frac{l_2}{K_2 A} \Rightarrow \frac{l_1}{l_2} = \frac{K_1}{K_2} = \frac{5}{4}.$$

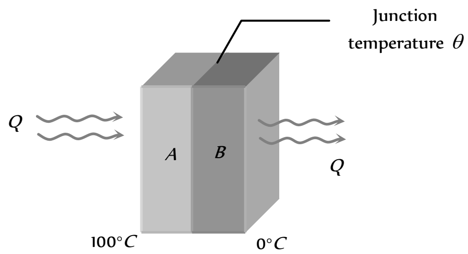
11. (c) $\frac{\Delta Q}{\Delta t} = \frac{KA\,\Delta\theta}{\Delta x} \Rightarrow$ Thermal gradient $\frac{\Delta\theta}{\Delta x}$

$$= \frac{(\Delta Q/\Delta t)}{KA} = \frac{10}{0.4} = 25°C/cm$$

12. (a) It is given that $\frac{K_1}{K_2} = \frac{1}{3} \Rightarrow K_1 = K$ then $K_2 = 3K$

the temperature of the junction in contact

$$\theta = \frac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2} = \frac{1\times 100 + 3\times 0}{1+3} = \frac{100}{4} = 25°C$$



13. (a) $Q = \frac{KA(\theta_1 - \theta_2)t}{l}$; in both the cases, A, l and $(\theta_1 - \theta_2)$ are same so Kt = constant $\Rightarrow \frac{K_1}{K_2} = \frac{t_1}{t_2} = \frac{30}{20} = \frac{3}{2} = 1.5.$

14. (b) $\left(\frac{Q}{t}\right)_1 = \frac{K_1A_1(\theta_1-\theta_2)}{l}$ and $\left(\frac{Q}{t}\right)_2 = \frac{K_2A_2(\theta_1-\theta_2)}{l}$

given $\left(\frac{Q}{t}\right)_1 = \left(\frac{Q}{t}\right)_2 \Rightarrow K_1A_1 = K_2A_2$

15. (d) In variable state $\frac{Q}{t} \propto K$ and $\frac{Q}{t} \propto \frac{1}{\rho c} \Rightarrow \frac{Q}{t} \propto \frac{K}{\rho c}$

(K = thermal conductivity, ρ = density, c = specific heat)

16. (b) $K_1 : K_2 = l_1^2 : l_2^2 \Rightarrow \frac{l_1}{l_2} = \sqrt{\frac{K_1}{K_2}} = \sqrt{\frac{10}{9}} = \frac{\sqrt{10}}{3}$

17. (c) $\frac{Q}{t} = \frac{KA(\Delta\theta)}{l} \Rightarrow 50 = \frac{5\times 20\ K}{0.4} \Rightarrow K = \frac{1}{5} = 0.2$

18. (c)

19. (a) Thermal resistance

$= \frac{l}{KA} = \left[\frac{L}{MLT^{-3}K^{-1}\times L^2}\right] = [M^{-1}L^{-2}T^3K]$

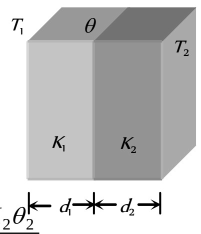
20. (a) When a piece of glass is heated, due to low thermal conductivity it does not conduct heat fast. Hence unequal expansion of it's layers crack the glass.

21. (a) In series both walls have same rate of heat flow. Therefore

$\frac{dQ}{dt} = \frac{K_1A(T_1-\theta)}{d_1} = \frac{K_2A(\theta-T_2)}{d_2}$

$\Rightarrow K_1d_2(T_1-\theta) = K_2d_1(\theta-T_2)$

$\Rightarrow \theta = \frac{K_1d_2T_1 + K_2d_1T_2}{K_1d_2+K_2d_1}$



22. (a) Temperature of interface $\theta = \frac{K_1\theta_1+K_2\theta_2}{K_1+K_2}$

$(\because \frac{K_1}{K_2} = \frac{1}{4} \Rightarrow$ If $K_1 = K$ then $K_2 = 4K)$

$\Rightarrow \theta = \frac{K\times 0 + 4K\times 100}{5\,K} = 80°C$

23. (b) $\frac{\theta_1-\theta_2}{l} = 80 \Rightarrow \frac{30-\theta_2}{0.5} = 80 \Rightarrow \theta_2 = -10^oC$

24. (d) $\frac{dQ}{dt} = -KA\frac{d\theta}{dx}$; when $K=\infty$, $\frac{d\theta}{dx} = 0$

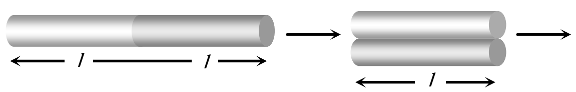
i.e. θ is independent of x *i.e.* constant or uniform.

25. (a) Air is poor conductor of heat.

26. (b)

27. (b)

28. (d) Let the heat transferred be Q.



When rods are joined end to end. Heat transferred by each rod $= Q = \frac{KA\Delta\theta}{l}\times 12$ .....(i)

When rods are joined lengthwise, $Q = \frac{KA\Delta\theta}{2l}t$ .....(ii)

From equation (i) and (ii) we get $t = 48\ s$

29. (d) $\frac{Q}{t} = \frac{KA\Delta\theta}{l} \Rightarrow \frac{K_A}{K_B} = \frac{A_B}{A_A} = \left(\frac{r_B}{r_B}\right)^2 = \frac{1}{4} \Rightarrow K_A = \frac{K_B}{4}$

30. (b) Thermal conductivity of composite plate

$K_{eq} = \frac{2K_1K_2}{K_1+K_2} = \frac{2\times2\times3}{2+3} = \frac{12}{5} = 2.4$

31. (b) $Q \propto \frac{A}{l} \propto \frac{r^2}{l} \Rightarrow \frac{Q_2}{Q_1} = \frac{r_2^2}{r_1^2}\times\frac{l_1}{l_2}$

$\Rightarrow \frac{Q_2}{Q_1} = \frac{4}{1}\times\frac{1}{2} \Rightarrow Q_2 = 2Q_1$

32. (c) $\frac{Q}{At} = K\frac{\Delta\theta}{l} \Rightarrow K\frac{\Delta\theta}{l}$ = constant $\Rightarrow \frac{\Delta\theta}{l} \propto \frac{1}{K}$

Hence If $K_c > K_m > K_g$, then

$\left(\frac{\Delta\theta}{l}\right)_c < \left(\frac{\Delta\theta}{l}\right)_m < \left(\frac{\Delta\theta}{l}\right)_g \Rightarrow X_c < X_m < X_g$

because higher K implies lower value of the temperature gradient.

33. (b) In series $R_{eq} = R_1 + R_2 \Rightarrow \frac{2l}{K_{eq}A} = \frac{l}{K_1A} + \frac{l}{K_2A}$

$\Rightarrow \frac{2}{K_{eq}} = \frac{1}{K_1} + \frac{1}{K_2} \Rightarrow K_{eq} = \frac{2K_1K_2}{K_1+K_2}$

34. (b) $\frac{dQ}{dt} = KA\frac{d\theta}{dl} \Rightarrow \frac{dQ}{dt} \propto \frac{d\theta}{dl}$ (Temperature gradient)

35. (a) $\frac{dQ}{dt} = \frac{K(\pi r^2)d\theta}{dl} \Rightarrow \frac{\left(\frac{dQ}{dt}\right)_s}{\left(\frac{dQ}{dt}\right)_l} = \frac{K_s\times r_s^2\times l_l}{K_l\times r_l^2\times l_s} = \frac{1}{2}\times\frac{1}{4}\times\frac{2}{1}$

$\Rightarrow \left(\frac{dQ}{dt}\right)_s = \frac{\left(\frac{dQ}{dt}\right)_l}{4} = \frac{4}{4} = 1$

36. (d) $Q = \frac{KA\,(\Delta\theta)t}{l}$

$\because$ Q and $\Delta\theta$ are same for both spheres hence

$K \propto \frac{l}{At} \propto \frac{l}{r^2t} \Rightarrow \frac{K_{\text{larger}}}{K_{\text{smaller}}} = \frac{l_l}{l_s}\times\left(\frac{r_s}{r_l}\right)^2\times\frac{t_s}{t_l}$. It is given that $r_l = 2r_s$, $l_l = \frac{1}{4}l_s$ and $t_1 = 25$ *min*, $t_s = 16$ *min.*

$\Rightarrow \frac{K_{\text{larger}}}{K_{\text{smaller}}} = \left(\frac{1}{4}\right)\left(\frac{1}{2}\right)^2\times\frac{16}{25} = \frac{1}{25}$

37. (d) $\frac{Q}{t} = \frac{KA(\Delta\theta)}{l} \Rightarrow \frac{Q}{t} \propto \frac{A}{l} \propto \frac{r^2}{l}$

$\Rightarrow \frac{(Q/t)_1}{(Q/t)_2} = \left(\frac{r_1}{r_2}\right)^2\times\frac{l_2}{l_1} = \left(\frac{2}{1}\right)^2\times\left(\frac{4}{1}\right) = \frac{16}{1}$

38. (b) Temperature of interface $\theta = \frac{K_1\theta_1+K_2\theta_2}{K_1+K_2}$

where $K_1 = 2K$ and $K_2 = 3K$ $\left(\because \frac{K_1}{K_2} = \frac{2}{3}\right)$

$\Rightarrow \theta = \frac{2K\times100+3K\times0}{2K+3K} = \frac{200K}{5K} = 40°C$

39. (a) $\frac{K_1}{K_2} = \frac{l_1^2}{l_2^2}$ $\therefore K_2 = \frac{K_1 l_2^2}{l_1^2} = \frac{0.92 \times (4.2)^2}{(8.4)^2} = 0.23$

40. (c) Mud is bad conductor of heat. So it prevents the flow of heat between surroundings and inside.

41. (b) Temperature gradient $= \frac{100 - 20}{20} = 4°C/cm$

temperature at centre $= 100 - 4 \times 10 = 60°C$

42. (c) Temperature of interface

$$\theta = \frac{K_1\theta_1 l_2 + K_2\theta_2 l_1}{K_1 l_2 + K_2 l_1} = \frac{K \times 0 \times 2 + 3K \times 100 \times 1}{K \times 2 + 3K \times 1}$$

$$= \frac{300K}{5K} = 60°C$$

43. (c) $\Delta\theta = \frac{Q \times l}{KAt} = \frac{4000 \times 0.1}{400 \times 10^{-2}} = 100^o C$

44. (b) Heat passes quickly from the body into the metal which leads to a cold feeling.

45. (c) Heat energy always flow from higher temperature to lower temperature. Hence, temperature difference *w.r.t.* length (temperature gradient) is required to flow heat from one part of a solid to other part.

46. (a) When the temperature of an object is equal to that of human body, no heat is transferred from the object to body and vice versa, Therefore block of wood and block of metal feel equally cold and hot if they have same temperature as human body.

47. (c)

48. (b) Temperature of water just below the lower surface of ice layer is $0°C$.

49. (b) $\frac{Q}{t} = \frac{KA(\theta_1 - \theta_2)}{l} = \frac{100 \times 100 \times 10^{-4}(100 - 0)}{1}$

$$\Rightarrow \frac{Q}{t} = 100\ Joule/sec = 6 \times 10^3\ Joule/min$$

50. (a) Temperature of interface $\theta = \frac{K_1\theta_1 l_2 + K_2\theta_2 l_1}{K_1 l_2 + K_2 l_1}$

It is given that $K_{Cu} = 9K_S$. So if $K_S = K_1 = K$ then $K_{Cu} = K_2 = 9K$

$$\Rightarrow \theta = \frac{9K \times 100 \times 6 + K \times 0 \times 18}{9K \times 6 + K \times 18} = \frac{5400K}{72K} = 75°C$$

51. (c) $\frac{Q}{t} = \frac{KA(\theta_1 - \theta_2)}{l} \Rightarrow \frac{Q}{t} \propto \frac{A}{l} \propto \frac{r^2}{l}$

[As $(\theta_1 - \theta_2)$ and K are constants]

$$\Rightarrow \frac{\left(\frac{Q}{t}\right)_1}{\left(\frac{Q}{t}\right)_2} = \frac{r_1^2}{r_2^2} \times \frac{l_2}{l_1} = \frac{4}{9} \times \frac{2}{1} = \frac{8}{9}$$

52. (b) In parallel combination equivalent conductivity

$$K = \frac{K_1 A_1 + K_2 A_2}{A_1 + A_2} = \frac{K_1 + K_2}{2} \text{ (As } A_1 = A_2)$$

53. (b) $Q = \frac{KA(\theta_1 - \theta_2)}{l} t \Rightarrow K_1 t_1 = K_2 t_2 \Rightarrow \frac{K_1}{K_2} = \frac{t_2}{t_1} = \frac{35}{20} = \frac{7}{4}$

(As Q, l, A and $(\theta_1 - \theta_2)$ are same)

54. (c) A lake cools from the surface down. Above $4°C$, the cooled water at the surface flows to the bottom because of it's greater density. But when the surface temperature drops below $4°C$ (here it is $2°C$), the water near the surface is less dense than the warmer water below. Hence the downward flow ceases, the water at the bottom remains at $4°C$ until nearly the entire lake, is frozen.

55. (a) Temperature gradient $\frac{d\theta}{dx} = \frac{(125 - 25)^o C}{50\ cm} = 2°C/cm$

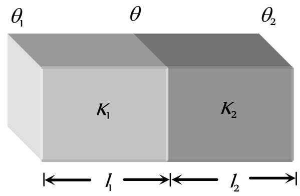
56. (a) $K \propto l^2 \Rightarrow \frac{K_1}{K_2} = \frac{l_1^2}{l_2^2} = \left(\frac{10}{25}\right)^2 = \frac{1}{6.25}$

57. (a) Thermal resistance of Cu is lesser than the thermal resistance of steel. Hence only in option (a) thermal resistance is minimum so heat current is maximum.

58. (c) At steady state, rate of heat flow for both blocks will be same

i.e., $\frac{K_1 A(\theta_1 - \theta)}{l_1} = \frac{K_2 A(\theta - \theta_2)}{l_2}$ (given $l_1 = l_2$)

$$\Rightarrow K_1 A(\theta_1 - \theta) = K_2 A(\theta - \theta_2) \Rightarrow \theta = \frac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2}$$



59. (c) $K = \frac{2K_1 K_2}{K_1 + K_2} = \frac{2.K.2K}{K + 2K} = \frac{4}{3}K$

60. (a) Temperature of interface $\theta = \frac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2}$

It is given that $\frac{K_1}{K_2} = \frac{5}{3} \Rightarrow K_1 = 5K$ and $K_2 = 3K$

$$\theta = \frac{5K \times 100 + 3K \times 20}{5K + 3K} = \frac{560K}{8K} = 70°C$$

61. (c) In winter, the temperature of surrounding is low compared to the body temperature $(37.4°C)$. Since woolen clothes are bad conductors of heat, so they keep the body warm.

62. (d) Temperature of interface $T = \frac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2}$

$$= \frac{300 \times 100 + 200 \times 0}{300 + 200} = 60°C$$

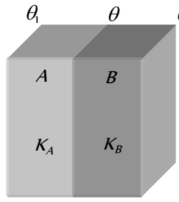
63. (b) Rate of heat flow $\left(\frac{Q}{t}\right) = \frac{k\pi r^2(\theta_1 - \theta_2)}{L} \propto \frac{r^2}{L}$

$$\therefore \frac{Q_1}{Q_2} = \left(\frac{r_1}{r_2}\right)^2 \left(\frac{l_2}{l_1}\right) = \left(\frac{1}{2}\right)^2 \times \left(\frac{2}{1}\right) = \frac{1}{2} \Rightarrow Q_2 = 2Q_1$$

64. (b) $\frac{Q}{t} = \frac{KA\Delta\theta}{l} \Rightarrow 6000 = \frac{200 \times 0.75 \times \Delta\theta}{1}$

$$\therefore \Delta\theta = \frac{6000 \times 1}{200 \times 0.75} = 40°C$$

65. (b) In series rate of flow of heat is same



$$\Rightarrow \frac{K_A A(\theta_1-\theta)}{l}=\frac{K_B A(\theta-\theta_2)}{l}$$

$$\Rightarrow 3K_B(\theta_1-\theta)=K_B(\theta-\theta_2)$$

$$\Rightarrow 3(\theta_1-\theta)=(\theta-\theta_2)$$

$$\Rightarrow 3\theta_1-3\theta=\theta-\theta_2 \Rightarrow 4\theta_1-4\theta=\theta_1-\theta_2$$

$$\Rightarrow 4(\theta_1-\theta)=(\theta_1-\theta_2)$$

$$\Rightarrow 4(\theta_1-\theta)=20 \Rightarrow (\theta_1-\theta)=5°C$$

66. (c) Let θ be temperature middle point C and in series rate of heat flow is same $\Rightarrow K(2A)(100-\theta)=KA(\theta-70)$

$$\Rightarrow 200-2\theta=\theta-70 \Rightarrow 3\theta=270 \Rightarrow \theta=90°C$$

67. (b) Thermal resistances are same

$$\Rightarrow \frac{l_1}{K_1A_1}=\frac{l_2}{K_2A_2} \Rightarrow \frac{l_1}{K_1}=\frac{l_2}{K_2} \;(\because A_1=A_2)$$

$$\Rightarrow \frac{l_1}{l_2}=\frac{K_1}{K_2}=\frac{5}{3}$$

68. (b) $\frac{Q}{t}\propto\frac{r^2}{l}$; from the given options, option (b) has higher value of $\frac{r^2}{l}$.

Convection

1. (c) Convection significantly transferring heat upwards (Gravity effect).

2. (a) Heat flows from hot air to cold body so person feels comfort.

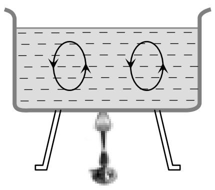
3. (c) No flow of heat by convection in vacuum.

4. (a)

5. (b) Density of hot air is lesser than the density of cold air so hot air rises up.

6. (a)

7. (c) In convection hot particles moves up ward (due to low density) and light particle moves downward (due to high density).



8. (b)

9. (a) Natural convection arises due to difference of density at two places and is a consequence of gravity.

10. (d)

11. (a) Convection is not possible in weightlessness. So the liquid will be heated through conduction.

12. (c) In forced convection rate of loss of heat $\frac{Q}{t}\propto A(T-T_0)$

13. (c)

Radiation (General, Kirchoff's law, Black body)

1. (b) Because of uneven surfaces of mountains, most of it's parts remain under shadow. So, most of the mountains. Land is not heated up by sun rays. Besides this, sun rays fall slanting on the mountains and are spread over a larger area. So, the heat received by the mountains top per unit area is less and they are less heated compared to planes (Foot).

2. (a) The velocity of heat radiation in vacuum is equal to that of light.

3. (c) Radiation is the fastest mode of heat transfer.

4. (d) A thermopile is a sensitive instrument, used for detection of heat radiation and measurement of their intensity.

5. (d) The polished surface reflects all the radiation.

6. (c) Heat radiations are electromagnetic waves of high wavelength.

7. (d) When element and surrounding have same temperature. There will be no temperature difference, hence heat will not flow from the filament and it's temperature remains constant.

8. (d) Every body at all time, at all temperatures emits radiation (except at $T=0$). The radiation emitted by the human body is in the infra-red region.

9. (c)

10. (b) Infrared radiations are detected by pyrometer.

11. (b)

12. (a) In vacuum heat flows by the radiation mode only.

13. (c) Good absorbers are always good emitters of heat.

14. (a) A perfectly black body is a good absorber of radiations falls on it. So it's absorptive power is 1.

15. (d) According to Kirchoff's law in spectroscopy. If a substance emit certain wavelengths at high temperature, it absorbs the same wavelength at comparatively lower temperature.

16. (b) A person with dark skin absorbs more heat radiation and feels more heat. It also radiates more heat and feels more cold.

17. (a) For a black body emissivity = absorptive power.

18. (b) Highly polished mirror like surfaces are good reflectors, but not good radiators.

19. (b) Black cloth is a good absorber of heat, therefore ice covered by black cloth melts more as compared to that covered by white cloth.

20. (c) According to Kirchoff's law, the ratio of emissive power to absorptive power is same for all bodies is equal to the emissive power of a perfectly black body *i.e.,*

$$\left(\frac{e}{a}\right)_{body}=E_{\text{Blackbody}} \text{ for a particular wave length}$$

$$\left(\frac{e_\lambda}{a_\lambda}\right)_{\text{body}}=(E_\lambda)_{\text{Blackbody}} \Rightarrow e_\lambda=a_\lambda E_\lambda$$

21. (b) Absorption power $=\frac{\text{Heat absorbed}}{\text{Total heat given}}$

22. (c) Because Planck's law explains the distribution of energy correctly at low temperature as well as at high temperature.

23. (c)

24. (a) The black spot on heating absorbs radiations and so emits them in the dark room while the polished shining part reflects radiation and absorbs nothing and so does not emit radiations and becomes invisible in the dark.

25. (b)

26. (b) When the light emitted from the sun's photosphere passes through it's outer part Chromosphere, certain wave lengths are absorbed. In the spectrum of sunlight, a large number of dark lines are seen called Fraunhoffer lines.

27. (a) As for a black body rate of absorption of heat is more. Hence thermometer A shows faster rise in temperature but finally both will acquire the atmospheric temperature.

28. (c) According to Kirchoff's law, a good emitter is also a good absorber.

29. (a) Red and green colours are complementary to each other. When red glass is heated it absorbs green light strongly, hence according to Kirchoff's law, the emissive power of red glass should be maximum for green light. That's why when this heated red glass is taken in dark room it strongly emits green light and looks greenish.

30. (d) Black and rough surfaces are good absorber that's why they emit well. (Kirchoff's law).

31. (d)

32. (c) When light incident on pin hole, enters into the box and suffers successive reflection at the inner wall. At each reflection some energy is absorbed. Hence the ray once it enters the box can never come out and pin hole acts like a perfect black body.

33. (a) Initially black body absorbs all the radiant energy incident on it, So it is the darkest one. Black body radiates maximum energy if all other condition are same. So when the temperature of the black body becomes equal to the temperature of furnace it will be brightest of all.

34. (c) Open window behaves like a perfectly black body.

35. (a) Ordinary glass prism (crown, flint) absorbs the infrared radiation but rock salt prism transmit them. Hence it is used to obtain the spectrum of infrared radiation.

36. (d) A good absorber is a good emitter hence option (a) is wrong. Every body stops absorbing and emitting radiation at 0 K hence option (b) is wrong.

The energy of radiation emitted from a black body is not same for all wavelength hence option (c) is wrong.

Plank's law relates the wavelength (λ) and temperature (T) according to the relation $E_\lambda d_\lambda = \dfrac{8\pi hc}{\lambda^5}\dfrac{1}{[e^{hc/kT}-1]}d_\lambda$. Hence option (d) is correct.

37. (c) When blue glass is heated at high temperature, it absorbs all the radiation of, higher wavelength except blue. If it is taken inside a dark room, it emits all the radiation of higher wavelength, hence it looks brighter red as compared to the red piece.

38. (b)

Radiation (Wein's law)

1. (a)

2. (c) According to Wein's law, $\lambda_m T$ = constant

$\lambda_r > \lambda_y > \lambda_b \Rightarrow T_r < T_y < T_b$ or $T_A < T_C < T_B$

3. (d) $\lambda_m T$ =constant $\Rightarrow \dfrac{T_1}{T_2} = \dfrac{\lambda_2}{\lambda_1} \Rightarrow \dfrac{10^{-4}}{0.5\times 10^{-5}}$ =200.

4. (c) $\lambda_m T$ = constant

5. (a) According to Wein's law $\lambda_m T$ = constant, on heating up to ordinary temperatures, only long wavelength (red) radiation is emitted. As the temperature rises, shorter wavelengths are also emitted in more and more quantity. Hence the colour of radiation emitted by the hot wire shifts from red to yellow, then to blue and finally to white.

6. (c) According to Wein's displacement law.

7. (d) $\lambda_{m_1}T_1 = \lambda_{m_2}T_2 \Rightarrow \lambda_{m_2} = \dfrac{\lambda_{m_1}T_1}{T_2} = 4.08\times\dfrac{700}{1400} = 2.04\,m$

8. (c) $\lambda_{m_1}T_1 = \lambda_{m_2}T_2 \Rightarrow \lambda_{m_2} = \dfrac{\lambda_{m_1}T_1}{T_2} = \dfrac{14\times 200}{1000} = 2.8\ \mu m$

9. (c) $\dfrac{T_1}{T_2} = \dfrac{\lambda_{m_2}}{\lambda_{m_1}} = \dfrac{4800}{3600} \Rightarrow \dfrac{48}{36} = \dfrac{4}{3}$

10. (b) $\lambda_{m_2} = \dfrac{T_1}{T_2}\times\lambda_{m_1} = \dfrac{1500}{2500}\times 5000 = 3000\text{Å}$

11. (a) At low temperature short wavelength radiation is emitted. As the temperature rise colour of emitted radiation are in the following order

Red→Yellow→Blue→White (at highest temperature)

12. (b) Similar to Q. 11

13. (b) The wavelength corresponding to maximum emission of radiation from the sun is $\lambda_{\max} = 4753\text{Å}$ (close to the wavelength of violet colour of visible region). Hence if temperature is doubled λ is decreased $\left(\lambda_m \propto \dfrac{1}{T}\right)$ *i.e.* mostly ultraviolet radiations emits.

14. (c) $\dfrac{T_1}{T_2} = \dfrac{\lambda_{m_2}}{\lambda_{m_1}} = \dfrac{5.5\times 10^5}{11\times 10^5} = \dfrac{1}{2} \Rightarrow n = \dfrac{1}{2}$.

15. (b) $\therefore T = \dfrac{b}{\lambda_m} = \dfrac{2.93\times 10^{-3}}{2.93\times 10^{-10}} = 10^7\ K$

16. (a) $\therefore \dfrac{\lambda_{m_2}}{\lambda_{m_1}} = \dfrac{T_1}{T_2} \Rightarrow \lambda_{m_2} = \dfrac{2000}{2400}\times 4 = 3.33\ \mu m$

17. (b)

18. (a)

19. (b) $\lambda_{m_2} = \dfrac{T_1}{T_2}\times\lambda_{m_1} = \dfrac{2000}{3000}\times\lambda_{m_1} = \dfrac{2}{3}\lambda_{m_1} = \dfrac{2}{3}\lambda_m$

20. (a)

21. (c) $\dfrac{T_2}{T_1} = \dfrac{\lambda_{m_1}}{\lambda_{m_2}} = \dfrac{1.75}{14.35} \Rightarrow T_2 = \dfrac{1.75}{14.35}\times 1640 = 200\ K$

22. (a) $\dfrac{\lambda_2}{\lambda_1} = \dfrac{T_1}{T_2} \Rightarrow \lambda_2 = \dfrac{T_1}{T_2}\times\lambda_1 = \dfrac{900}{1200}\times 4 = 3\mu m$

23. (b) $\lambda_{m_2} = \dfrac{\lambda_{m_1}T_1}{T_2} = \dfrac{4800\times 6000}{3000} = 9600\text{Å}$

24. (b) $\dfrac{T_1}{T_2} = \dfrac{\lambda_{m_2}}{\lambda_{m_1}} = \dfrac{4200}{140} = \dfrac{30}{1}$

25. (c) $\because \lambda_m T = \lambda'_m T' \Rightarrow \lambda_0 T = \lambda'\times 2T \Rightarrow \lambda' = \dfrac{\lambda_0}{2}$

26. (b) $\lambda_m T = \lambda'_m T' \Rightarrow \dfrac{\lambda_m}{\lambda'_m} = \dfrac{T'}{T} = \dfrac{3000}{2000} = \dfrac{3}{2}$

27. (b) $\lambda_{m_1}T = \lambda_{m_2}T_2 \Rightarrow 5.5\times 10^{-7}\times 5500 = 11\times 10^{-7}T$

$T = 550\times 5K = 2750K$

28. (b) According to Wein's displacement law

$\lambda_m T = b$ or $\lambda_m = \dfrac{b}{T} = \dfrac{0.0029}{5\times 10^4} = 58\times 10^{-9}m = 58nm$

29. (a) $\lambda_m = \dfrac{b}{T} \Rightarrow T = \dfrac{b}{\lambda_m} = \dfrac{2.93\times 10^{-3}}{4000\times 10^{-10}} = 7325\ K$

30. (b) $\dfrac{T_S}{T_N} = \dfrac{(\lambda_N)_{\max}}{(\lambda_S)_{\max}} = \dfrac{350}{510} = 0.69$

Radiation (Stefan's law)

1. (c) $E \propto T^4$ (Stefan's law)

2. (c) Rate of heat loss $E = \sigma eA(T^4 - T_0^4)$

$= 5.67\times10^{-8}\times0.4\times200\times10^{-4}\times[(273+527)^4-(273+27)^4]$

$= 5.67\times10^{-8}\times0.4\times200\times10^{-4}\times(800)^4-(300)^4 = 182 J/sec$

3. (a) $\frac{E_1}{E_2} = \left(\frac{T_1}{T_2}\right)^4 \Rightarrow \frac{E}{E_2} = \left(\frac{273+0}{273+273}\right)^4 \Rightarrow E_2 = 16\ E.$

4. (a) $E \propto T^4 \Rightarrow \frac{E_1}{E_2} = \frac{T^4}{T^4}\times2^4 \Rightarrow E_2 = \frac{E}{16}$

5. (d) $\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{2}{1} = \left(\frac{420+273}{T}\right)^4 = \left(\frac{673}{T}\right)^4$

$\Rightarrow T = 2^{1/4}\times673 = 800K.$

6. (a) $\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4 = \left(\frac{273+727}{237+227}\right) = \frac{(1000)^4}{(500)^4} = 16 \Rightarrow E_2 = 80$

7. (c) $\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow T_2 = \left(\frac{E_2}{E_1}\right)^{1/4}\times T_1 = (16)^{1/4}\times(273+127)$

$\Rightarrow T = 800\ K = 527^oC$

8. (b) In M.K.S. system unit of σ is $\frac{J}{m^2\times sec\times K^4}$

$\Rightarrow 1\frac{J}{m^2\times sec\times K^4} = \frac{10^7 erg}{10^4 cm^2\times sec\times K^4}$

$= 10^3\frac{erg}{cm^2\times sec\times K^4}$

9. (b) For a block body rate of energy $\frac{Q}{t} = P = A\sigma T^4$

$\Rightarrow P \propto T^4 \Rightarrow \frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^4 = \left\{\frac{(273+7)}{(273+287)}\right\}^4 = \frac{1}{16}$

10. (b) $E_2 = E_1\frac{T_2^4}{T_1^4} = Q\times\frac{(273+151)^4}{(273+27)^4} = \left(\frac{424}{300}\right)^4 = 3.99Q \approx 4Q$

11. (b) $\frac{E_1}{E_2} = \left(\frac{T_1}{T_2}\right)^4 = \left(\frac{727+273}{127+273}\right)^4 = \frac{(1000)^4}{(400)^4} = \frac{10^4}{4^4} = \frac{625}{16}$

12. (c) $E = \sigma T^4 \Rightarrow 5.6\times10^{-8}\times T^4 = 1$

$\Rightarrow T = \left[\frac{1}{5.6\times10^{-8}}\right]^{1/4} = 65\ K$

13. (c) According to Stefen's law $E = \sigma\varepsilon AT^4$

$\Rightarrow \frac{1.58\times10^5\times4.2}{60\times60} = 5.6\times10^{-8}\times10^{-4}\times0.8\times T^4$

$T \approx 2500\ K$

14. (c) Total energy radiated from a body $Q = A\varepsilon\sigma T^4t$

$\Rightarrow Q \propto AT^4 \propto r^2T^4 \quad (\because\ A = 4\pi r^2)$

$\Rightarrow \frac{Q_P}{Q_Q} = \left(\frac{r_P}{r_Q}\right)^2\left(\frac{T_P}{T_Q}\right)^4 = \left(\frac{8}{2}\right)^2\left\{\frac{(273+127)}{(273+527)}\right\}^4 = 1$

15. (c) Rate of energy $\frac{Q}{t} = P = A\varepsilon\sigma T^4 \Rightarrow P \propto T^4$

$\Rightarrow \frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^4 = \left(\frac{927+273}{127+273}\right)^4 \Rightarrow P_1 = 405\ W$

16. (b) The rate of radiated energy $\frac{Q}{t} = P = A\varepsilon\sigma T^4$

$\Rightarrow 1134 = 5.67\times10^{-8}\times(0.1)^2T^4 \Rightarrow T = 1189\ K$

17. (d) $Q \propto T^4 \Rightarrow \frac{H_A}{H_B} = \left(\frac{273+727}{273+327}\right)^4 = \left(\frac{10}{6}\right)^4 = \left(\frac{5}{3}\right)^4 = \frac{625}{81}$

18. (d) $(Q)_{Blackbody} = A\sigma T^4t \Rightarrow Q \propto T^4$

$\Rightarrow Q_2 = Q_1\left(\frac{T_2}{T_1}\right)^4 = 10\left(\frac{273+327}{273+27}\right)^4 = 10\left(\frac{600}{300}\right)^4 = 160J$

19. (c) $\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{E_2}{20} = \left(\frac{2T}{T}\right)^4 = 16 \Rightarrow E_2 = 320\ kcal/m^2\ min.$

20. (d) Radiated power by blackbody $P = \frac{Q}{t} = A\sigma T^4$

$\Rightarrow P \propto AT^4 \propto r^2T^4 \Rightarrow \frac{P_1}{P_2} = \left(\frac{r_1}{r_2}\right)^2\left(\frac{T_1}{T_2}\right)^4$

$\Rightarrow \frac{440}{P_2} = \left(\frac{12}{6}\right)^2\left(\frac{500}{1000}\right)^4 \Rightarrow P_2 = 1760\ W \approx 1800\ W$

21. (d) Amount of energy radiated $\propto$ (Temperature)^4.

22. (d) $\frac{Q_1}{Q_2} = \left(\frac{T_1}{T_2}\right)^4 = \left(\frac{273+27}{273+927}\right)^4 = \left(\frac{1}{4}\right)^4 = \frac{1}{256}$

23. (a) $\frac{E_2}{E_1} = \frac{T_2^4}{T_1^4} = \left(\frac{237+227}{273+27}\right)^4 = \left(\frac{600}{300}\right)^4 = 16$

24. (d) $(Q)_{Blackbody} = A\sigma T^4t \Rightarrow \frac{Q}{t} \propto P = A\sigma T^4$

Breadth are halved so area becomes one fourth.

$\Rightarrow \frac{P_1}{P_2} = \frac{A_1}{A_2}\times\left(\frac{T_1}{T_2}\right)^4 \Rightarrow \frac{A_1}{(A_1/4)}\times\left(\frac{273+327}{273+127}\right)$

$\Rightarrow P_2 = \frac{81}{64}E$

25. (d) Power radiated $P \propto T^4 \Rightarrow \frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^4$

$\Rightarrow \frac{Q}{P_2} = \left(\frac{T}{3T}\right)^4 \Rightarrow P_2 = 81Q$

26. (a) For black body, $P = A\varepsilon\sigma T^4$. For same power $A \propto \frac{1}{T^4}$

$\Rightarrow \left(\frac{r_1}{r_2}\right)^2 = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{r_1}{r_2} = \left(\frac{T_2}{T_1}\right)^2$

27. (a) $\frac{Q_2}{Q_1} = \left(\frac{T_2}{T_1}\right)^4 = \left(\frac{273+927}{273+327}\right)^4 = \left(\frac{1200}{600}\right)^4 = 16$

$\Rightarrow Q = 32\ KJ$

28. (b) $\frac{Q_2}{Q_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{2}{1} = \left(\frac{T_2}{T_1}\right)^4$

$\Rightarrow T_2^4 = 2 \times T_1^4 = 2 \times (273+727)^4 \Rightarrow T_2 = 1190K$.

29. (a) $\frac{Q_1}{Q_2} = \frac{r_1^2 T_1^4}{r_2^2 T_2^4} = \frac{4^2}{1^2} \times \left(\frac{2000}{4000}\right)^4 = 1$

30. (a) According to Wein's law $\lambda_m T$ = constant

$\Rightarrow \lambda_{m_1} T_1 = \lambda_{m_2} T_2 \Rightarrow T_2 = \frac{\lambda_{m_1}}{\lambda_{m_2}} T_1 = \frac{\lambda_0}{3\lambda_0/4} \times T_1 = \frac{4}{3} T_1$

Now $P \propto T^4 \Rightarrow \frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{P_2}{P_1} = \left(\frac{4/3\ T_1}{T_1}\right)^4 = \frac{256}{81}$

31. (d) $E \propto T^4$

32. (d) $Q \propto T^4 \Rightarrow \frac{Q_1}{Q_2} = \left(\frac{T_1}{T_2}\right)^4$

$\Rightarrow \frac{Q_1}{Q_2} = \left(\frac{T}{T+T/2}\right)^4 = \frac{16}{81} \Rightarrow Q_2 = \frac{81}{16} Q_1$

% increase in energy $= \frac{Q_2 - Q_1}{Q_1} \times 100 = 400\%$

33. (d) If temperature of surrounding is considered then net loss of energy of a body by radiation

$Q = A\varepsilon\sigma(T^4 - T_0^4)t \Rightarrow Q \propto (T^4 - T_0^4) \Rightarrow \frac{Q_1}{Q_2} = \frac{T_1^4 - T_0^4}{T_2^4 - T_0^4}$

$= \frac{(273+200)^4 - (273+27)^4}{(273+400)^4 - (273+27)^4} = \frac{(473)^4 - (300)^4}{(673)^4 - (300)^4}$

34. (c) $Q = A\varepsilon\sigma T^4 \Rightarrow Q \propto A \propto r^2$ ($\because T$ = constant)

$\Rightarrow \frac{Q_1}{Q_2} = \frac{r_1^2}{r_2^2} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$

35. (a) $\frac{Q_2}{Q_1} = \frac{T_2^4}{T_1^4} = \left(\frac{273+527}{273+127}\right)^4 = \left(\frac{800}{400}\right)^4 \Rightarrow Q_2 = 16 \frac{cal}{cm^2 \times s}$

36. (c) For a black body $\frac{Q}{t} = P = A\sigma T^4$

$\Rightarrow \frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{P_2}{20} = \left(\frac{273+727}{273+227}\right)^4$

$\Rightarrow \frac{P_2}{20} = (2)^4 \Rightarrow P_2 = 320W$

37. (c) Energy radiated per sec $\frac{Q}{t} = P = A\varepsilon\sigma T^4$

$P \propto r^2 T^4 \Rightarrow \frac{P_2}{P_1} = \frac{r_2^2}{r_1^2} \cdot \frac{T_2^4}{T_1^4} = \frac{4^2}{1^2} \times \left(\frac{2000}{4000}\right)^4 = 1$

38. (c) $Q \propto AT^4 \propto r^2 T^4 \Rightarrow \frac{Q_{\text{star}}}{Q_{\text{sun}}} = \frac{r^2_{\text{star}} . T^4_{\text{star}}}{r^2_{\text{sun}} \times T^4_{sun}}$

$\Rightarrow \frac{10000}{1} = \frac{r_{\text{star}}^2}{r_{\text{sun}}^2} \times \left(\frac{6000}{2000}\right)^4 \Rightarrow \frac{r_{\text{star}}}{r_{\text{sun}}} = \frac{100 \times 9}{1} = \frac{900}{1}$

39. (a) $P = \left(\frac{Q}{t}\right) \propto T^4 \Rightarrow \frac{W}{P_2} = \left(\frac{T}{T/3}\right)^4 \Rightarrow P_2 = \frac{W}{81}$.

40. (c) Power $P \propto AT^4 \propto r^2 T^4$

$\Rightarrow \frac{P_2}{P_1} = \left(\frac{r_2}{r_1}\right)^2 \times \left(\frac{T_2}{T_1}\right)^4 = \left(\frac{4r}{r}\right)^2 \times \left(\frac{T/2}{T}\right)^4 = 1.$

41. (b) $\frac{Q_2}{Q_1} = \left(\frac{r_2^2}{r_1^2}\right)^2 \times \left(\frac{T_2}{T_1}\right)^4 = \left(\frac{100}{1}\right)^2 \times \left(\frac{1}{2}\right)^4 = 625$

42. (d) $Q \propto r^2 T^4 \Rightarrow \frac{Q_2}{Q_1} = \left(\frac{r_2}{r_1}\right)^2 \times \left(\frac{T_2}{T_1}\right)^4 = (2)^2 \times (2)^4 = 64$

43. (c) Energy radiated from a body $Q = A\varepsilon\sigma T^4 t$

$\Rightarrow \frac{Q_2}{Q_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{T_2}{T_1} = \left(\frac{Q_2}{Q_1}\right)^{1/4} = \left(\frac{4.32 \times 10^6}{2.7 \times 10^{-3}}\right)^{1/4}$

$= \left(\frac{16 \times 27}{27} \times 10^8\right)^{1/4} = 2 \times 10^2$

$\Rightarrow T_2 = 200 \times T_1 = 80000K$

44. (d) $E \propto AT^4 \Rightarrow \frac{E_{\text{sphere}}}{E_{\text{Disc}}} = \frac{4\pi r^2}{2\pi r^2} \times \left(\frac{T}{T}\right)^4 = \frac{2}{1}$

45. (a) $\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{T_2}{T_1} = \left(\frac{E_2}{E_1}\right)^{1/4} = \left(\frac{10^9}{10^5}\right)^{1/4} = 10$

$\Rightarrow T_2 = 10T_1 = 10 \times (273+227) = 5000K$

46. (b) Energy per second $P\left(=\frac{Q}{t}\right) \propto T^4$

$\frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^4 = \left(\frac{273-73}{273+327}\right)^4 = \left(\frac{200}{600}\right)^4 = \frac{1}{81}$

47. (a) $Q \propto T^4 \Rightarrow \frac{Q_1}{Q_2} = \left(\frac{T_1}{T_2}\right)^4$

If $T_1 = T$ then $T_2 = T + \frac{10}{100} T = 1.1T$

$\Rightarrow \frac{Q_1}{Q_2} = \left(\frac{T}{1.1T}\right)^4 \Rightarrow Q_2 = 1.46\, Q_1$

$\Rightarrow$ % increase in energy $= \frac{Q_2 - Q_1}{Q_1} \times 100 = 46\%$

48. (a) From Stefan's law $E = \sigma T^4$

$T^4 = \frac{E}{\sigma} = \frac{6.3 \times 10^7}{5.7 \times 10^8} = 1.105 \times 10^{15} = 0.1105 \times 10^{16}$

$T = 0.58 \times 10^4 K = 5.8 \times 10^3 K$

49. (a) Rate of cooling $\propto (T^4 - T_0^4)$

$\Rightarrow \frac{H}{H'} = \frac{(T_1^4 - T_0^4)}{(T_2^4 - T_0^4)} = \frac{400^4 - 200^4}{600^4 - 200^4}$

or $H' = \frac{(16+4)(16-4)H}{(36+4)(36-4)} = \frac{3}{16}H$

50. (a)

51. (a) Rate of cooling $\propto (T^4 - T_0^4) \Rightarrow \frac{R_1}{R_2} = \frac{(T_1^4 - T_0^4)}{(T_2^4 - T_0^4)}$

$\Rightarrow \frac{R}{R_2} = \frac{(600)^4 - (300)^4}{(900)^4 - (300)^4}$ or $R_2 = \frac{16}{3}R$

52. (d) Loss of heat $\Delta Q = A\varepsilon\sigma(T^4 - T_0^4)t$

$\Rightarrow$ Rate of loss of heat $\frac{\Delta Q}{t} = A\varepsilon\sigma(T^4 - T_0^4)$

$= 10 \times 10^{-4} \times 1 \times 5.67 \times 10^{-8}\{273+127)^4 - (273+27)^4\}$

= 0.99 W.

53. (b) According to Prevost theory every body radiate heat at all temperature (except $0K$) and also absorbs heat from surroundings.

$\because$ $T_A > T$ $\Rightarrow$ Object A emits radiations more than the radiations it absorbs.

and $T_B < T$ $\Rightarrow$ Object B absorbs more radiations than it emits.

After a certain time all bodies attains a common temperature.

54. (b) According to Prevost theory

55. (b) $Q \propto T^4 \Rightarrow \frac{Q_1}{Q_2} = \frac{T_1^4}{T_2^4} \Rightarrow T_2^4 = \left(\frac{E_2}{E_1}\right)T_1^4$

$\Rightarrow T_2^4 = \frac{1}{16} \times (1000)^4 = \left(\frac{1000}{2}\right)^4 \Rightarrow T_2 = 500K$

56. (c) $Q \propto T^4$

Radiation (Newton's Law of Cooling)

1. (b) According to Newton's law of cooling

$\frac{\theta_1 - \theta_2}{t} = K\left[\frac{\theta_1 + \theta_2}{2} - \theta_0\right]$

In the first case, $\frac{(60-50)}{10} = K\left[\frac{60+50}{2} - \theta_0\right]$

$1 = K(55 - \theta)$ ....(i)

In the second case, $\frac{(50-42)}{10} = K\left[\frac{50+42}{2} - \theta_0\right]$

$0.8 = K(46 - \theta_0)$ ....(ii)

Dividing (i) by (ii), we get $\frac{1}{0.8} = \frac{55 - \theta_0}{46 - \theta_0}$

or $46 - \theta_0 = 44 - 0.8\theta_0 \Rightarrow \theta_0 = 10^o C$

2. (c) According to Newton's law of cooling

Rate of cooling $\propto$ Mean temperature difference

$\Rightarrow \frac{\text{Fall in temperature}}{\text{Time}} \propto \left(\frac{\theta_1 + \theta_2}{2} - \theta_0\right)$

$\because \left(\frac{\theta_1 + \theta_2}{2}\right)_1 > \left(\frac{\theta_1 + \theta_2}{2}\right)_2 > \left(\frac{\theta_1 + \theta_2}{2}\right)_3$

$\Rightarrow T_1 < T_2 < T_3$

3. (a) Initially at $t = 0$

Rate of cooling (R) $\propto$ Fall in temperature of body $(\theta - \theta)$

$\Rightarrow \frac{R_1}{R_2} = \frac{\theta_1 - \theta_0}{\theta_2 - \theta_0} = \frac{100-40}{80-40} = \frac{3}{2}$

4. (a) For small difference of temperature, it is the special case of Stefan's law.

5. (b) Liquid having more specific heat has slow rate of cooling because for equal masses rate of cooling $\frac{d\theta}{dt} \propto \frac{1}{c}$.

6. (c) $S_l = \frac{1}{m_l}\left[\frac{t_l}{t_W}(m_W C_W + W) - W\right]$

$= \frac{1}{300}\left[\frac{95}{3 \times 60}(350 \times 1 + 10) - 10\right]$ =0.6 $Cal/gm \times ^\circ C$

7. (c) Newton's law of cooling is used for the determination of specific heat of liquids.

8. (c) By Newton's law of cooling.

9. (d) Rate of loss of heat $\left(\frac{\Delta Q}{t}\right) \propto$ temperature difference $\Delta\theta$

$\frac{\left(\frac{\Delta Q}{t}\right)_1}{\left(\frac{\Delta Q}{t}\right)_2} = \frac{\Delta\theta_2}{\Delta\theta_1} \Rightarrow \frac{60}{\left(\frac{\Delta Q}{t}\right)_2} = \frac{80-60}{40-20} \Rightarrow \left(\frac{\Delta Q}{t}\right)_2 = \frac{20\,cal}{sec}$

10. (b) During clear nights object on surface of earth radiate out heat and temperature falls. Hence option (a) is wrong.

The total energy radiated by a body per unit time per unit area $E \propto T$. Hence option (c) is wrong.

Energy radiated per second is given by $\frac{Q}{t} = PA\varepsilon\sigma T^4$

$\Rightarrow \frac{P_1}{P_2} = \frac{A_1}{A_2} \cdot \left(\frac{T_1}{T_2}\right)^4 = \left(\frac{r_1}{r_2}\right)^2 \cdot \left(\frac{T_1}{T_2}\right)^4 = \left(\frac{1}{4}\right)^2 \left(\frac{4000}{200}\right) = \frac{1}{1}$

$\because$ $P = P$, hence option (d) is wrong.

Newton's law is an approximate form of Stefan's law of radiation and works well for natural convection. Hence option (b) is correct.

11. (b) $\frac{\theta_1 - \theta_2}{t} = K\left(\frac{\theta_1 + \theta_2}{2} - \theta_0\right)$

$\therefore \frac{100-70}{4} = K\left(\frac{100+70}{2} - 15\right)$ = $60K \Rightarrow K = \frac{1}{8}$

Again $\frac{70-40}{t} = \frac{1}{8}\left(\frac{70+40}{2} - 15\right)$ = $5 \Rightarrow t = 6$ min.

12. (d) $\frac{80-60}{1} = K\left(\frac{80+60}{2} - 30\right) \Rightarrow K = \frac{1}{2}$

Again $\frac{60-50}{t} = \frac{1}{2}\left(\frac{60+50}{2} - 30\right) \Rightarrow t = 0.8 \times 60 = 48$ sec.

13. (c) According to Newton's law of cooling

Rate of cooling $\propto$ mean temperature difference.

Initially, mean temperature difference

$$=\left(\frac{70+60}{2}-\theta_0\right)=(65-\theta_0)$$

Finally, mean temperature difference

$$=\left(\frac{60+50}{2}-\theta_0\right)=(55-\theta_0)$$

In second case mean temperature difference decreases, so rate of fall of temperature decreases, so it takes more time to cool through the same range.

14. (c) $\frac{\theta_1-\theta_2}{t}=K\left[\frac{\theta_1+\theta_2}{2}-\theta_0\right]$

In the first 10 minute

$$\frac{62-50}{10}=K\left[\frac{62+50}{2}-\theta_0\right]\Rightarrow 1.2=K[56-\theta_0] \quad .... \text{(i)}$$

$$\frac{50-42}{10}=K\left[\frac{50+42}{2}-\theta_0\right]\Rightarrow 0.8=K[46-\theta_0] \quad .... \text{(ii)}$$

from equations (i) and (ii) $\frac{1.2}{0.8}=\frac{(56-\theta_0)}{(46-\theta_0)} \Rightarrow \theta_0=26°C$

15. (d) $\frac{d\theta}{dt}=\frac{\sigma A}{mc}(T^4-T_0^4)$. If the liquids put in exactly similar calorimeters and identical surrounding then we can consider T and A constant then $\frac{d\theta}{dt}\propto\frac{(T^4-T_0^4)}{mc}$ ......(i)

If we consider that equal masses of liquid (m) are taken at the same temperature then $\frac{d\theta}{dt}\propto\frac{1}{c}$

So for same rate of cooling c should be equal which is not possible because liquids are of different nature. Again from equation (i)

$$\frac{d\theta}{dt}\propto\frac{(T^4-T_0^4)}{mc} \Rightarrow \frac{d\theta}{dt}\propto\frac{(T^4-T_0^4)}{V\rho c}$$

Now if we consider that equal volume of liquid (V) are taken at the same temperature then $\frac{d\theta}{dt}\propto\frac{1}{\rho c}$.

So for same rate of cooling multiplication of $\rho\times c$ for two liquid of different nature can be possible. So option (d) may be correct.

16. (c) $\frac{60-50}{10}=K\left(\frac{60+50}{2}-25\right)$ .....(i)

$$\frac{50-\theta}{10}=K\left[\frac{50+\theta}{2}-25\right] \quad .....\text{(ii)}$$

On dividing, we get $\frac{10}{50-\theta}=\frac{60}{\theta}\Rightarrow\theta=42.85^oC$

17. (a) $\frac{365-361}{2}=K\left[\frac{365+361}{2}-293\right]=70K \Rightarrow K=\frac{1}{35}$

Again $\frac{344-342}{t}=\frac{1}{35}\left[\frac{344-342}{2}-293\right]=\frac{10}{7}$

$$\Rightarrow t=\frac{14}{10}\text{min}=\frac{14}{10}\times 60=84 \text{ sec.}$$

18. (b) $\frac{50-49.9}{5}=K\left(\frac{50+49.9}{2}-30\right)$ .....(i)

$$\frac{40-39.9}{t}=K\left[\frac{40+39.9}{2}-30\right] \quad .....\text{(ii)}$$

from equations (i) and (ii) we get $t\approx 10$ *sec.*

19. (c) Rate of loss of heat is directly proportional to the temperature difference between water and the surroundings.

20. (b) Rate of cooling $=\frac{-d\theta}{dt}\propto\left(\frac{\theta_1+\theta_2}{2}-\theta_0\right)$

In second case average temperature will be less hence rate of cooling will be less. Therefore time taken will be more than 4 minutes.

21. (a)

22. (b) First case, $\frac{61-59}{4}=K\left[\frac{61+59}{2}-30\right]$ .....(i)

Second case, $\frac{51-49}{t}=K\left[\frac{51+49}{2}-30\right]$ .....(ii)

By solving equation (i) and (ii) we get $t=6$ *min.*

23. (d)

24. (c) In first case $\frac{60-40}{7}=K\left[\frac{60+40}{2}-10\right]$ ....(i)

In second case $\frac{40-28}{t}=K\left[\frac{40+28}{2}-10\right]$ ....(ii)

By solving $t=7$ *minutes*

25. (b) In first case $\frac{50-40}{5}=K\left[\frac{50+40}{2}-\theta_0\right]$ ....(i)

In second case $\frac{40-33.33}{5}=K\left[\frac{40+33.33}{2}-\theta_0\right]$ ....(ii)

By solving $\theta_0=20^oC$.

26. (b) In first case $\frac{50-40}{10}=K\left[\frac{50+40}{2}-20\right]$ ....(i)

In second case $\frac{40-\theta_2}{10}=K\left[\frac{40+\theta_2}{2}-20\right]$ ....(ii)

By solving $\theta_2=33.3^oC$.

27. (d) In first case $\frac{61-59}{10}=K\left[\frac{61+59}{2}-30\right]$ ....(i)

In second case $\frac{51-49}{10}=K\left[\frac{51+49}{2}-30\right]$ ....(ii)

By solving $t=15$ *min.*

28. (d) Rate of cooling (here it is rate of loss of heat)

$$\frac{dQ}{dt}=(mc+W)\frac{d\theta}{dt}=(m_lc_l+m_cc_c)\frac{d\theta}{dt}$$

$$\Rightarrow\frac{dQ}{dt}=(0.5\times 2400+0.2\times 900)\left(\frac{60-55}{60}\right)=115\frac{J}{\text{sec}}.$$

29. (a) According to Newton's law

Rate of cooling $\propto$ temperature difference $\Delta\theta$

30. (b) According to Newton's law $\frac{\theta_1-\theta_2}{t}=k\left[\frac{\theta_1+\theta_2}{2}-\theta_0\right]$

Initially,

$$\frac{(80-64)}{5}=K\left(\frac{80+64}{2}-\theta_0\right)\Rightarrow 3.2=K[72-\theta_0] \quad \text{... (i)}$$

Finally

$$\frac{(64-52)}{10}=K\left[\frac{64+52}{2}-\theta_0\right]\Rightarrow 1.2=K[58-\theta_0] \text{... (ii)}$$

On solving equation (i) and (ii) $\theta_0=49°C$.

31. (d) $\frac{50-45}{5}=K\left(\frac{50+45}{2}-\theta_0\right)$ .....(i)

$\frac{45-41.5}{5}=K\left(\frac{45+41.5}{2}-\theta_0\right)$ .....(ii)

Solving equation (i) and (ii) we set $\theta_0=33.3\ °C$.

32. (d) $\frac{65.5-62.5}{1}=K\left(\frac{65.5+62.5}{2}-22.5\right)\Rightarrow K=\frac{3}{41.5}$

And again $\frac{46.5-40.5}{t}=\frac{3}{41.5}\left(\frac{46.5+40.5}{2}-22.5\right)$

$\Rightarrow \frac{6}{t}=\frac{3}{41.5}\times 21 \Rightarrow t=\frac{82}{21}\simeq 4$ minute.

33. (a) $\frac{62-50}{10}=K\left(\frac{62+50}{2}-26\right)\Rightarrow \frac{6}{5}=K\times 30 \Rightarrow K=\frac{1}{25}$

And, $\frac{50-\theta}{10}=\frac{1}{25}\left(\frac{50+\theta}{2}-26\right)\Rightarrow \theta=42°\ C$.

34. (c) $\frac{90-60}{5}=K\left(\frac{90+60}{2}-20\right)\Rightarrow 6=K\times 55 \Rightarrow K=\frac{6}{55}$

And, $\frac{60-30}{t}=\frac{6}{55}\left(\frac{60+30}{2}-20\right)\Rightarrow t=11$ minute.

35. (a) According to Newton's law of cooling

in first case, $\frac{75-65}{t}=K\left[\frac{75+65}{2}-30\right]$ .....(i)

in second case, $\frac{55-45}{t}=K\left[\frac{55+45}{2}-30\right]$ .....(ii)

Dividing eq. (i) by (ii) we get $\frac{5t}{10}=\frac{40}{20}\Rightarrow t=4$ minutes

36. (b) According to Newton's law of cooling

in first case, $\frac{80-50}{5}=K\left[\frac{80+50}{2}-20\right]$ .....(i)

in second case, $\frac{60-30}{t}=K\left[\frac{60+30}{2}-20\right]$ (ii)

Dividing equation (i) by (ii) we get, $\frac{t}{2}=\frac{45}{25}\Rightarrow t=9$ min.

37. (b) According to Newton's law of cooling.

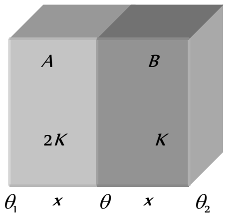
Critical Thinking Questions

1. (a) $\frac{dQ}{dt}=\frac{KA\Delta\theta}{l}$, For both rods K, A and $\Delta\theta$ are same $\Rightarrow$ $\frac{dQ}{dt}\propto\frac{1}{l}$ So $\frac{(dQ/dt)_{semi\ circular}}{(dQ/dt)_{straight}}=\frac{l_{straight}}{l_{semicircular}}=\frac{2r}{\pi r}=\frac{2}{\pi}$.

2. (b) Suppose thickness of each wall is x then $\left(\frac{Q}{t}\right)_{combination}=\left(\frac{Q}{t}\right)_A \Rightarrow \frac{K_S A(\theta_1-\theta_2)}{2x}=\frac{2KA(\theta_1-\theta)}{x}$

$\because K_S=\frac{2\times 2K\times K}{(2K+K)}=\frac{4}{3}K$ and $(\theta_1-\theta_2)=36°$

$\Rightarrow \frac{\frac{4}{3}KA\times 36}{2x}=\frac{2KA(\theta_1-\theta)}{x}$



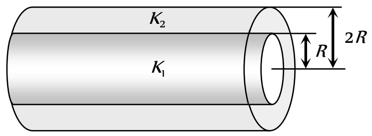
Hence temperature difference across wall A is

$(\theta_1-\theta)=12^oC$

3. (d) $t=\frac{\rho L}{2K\theta}(x_2^2-x_1^2)\Rightarrow t\propto(x_2^2-x_1^2)$

$\Rightarrow \frac{t}{t'}=\frac{(x_2^2-x_1^2)}{(x'^2_2-x'^2_1)}\Rightarrow \frac{9}{t'}=\frac{(1^2-0^2)}{(2^2-1^2)}\Rightarrow t'=21\,hours$

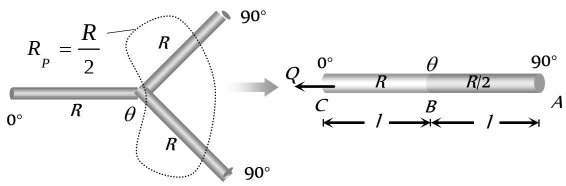
4. (c) Both the cylinders are in parallel, for the heat flow from one end as shown.



Hence $K_{eq}=\frac{K_1A_1+K_2A_2}{A_1+A_2}$; where A_1 = Area of cross-section of inner cylinder = πR and A_2 = Area of cross-section of cylindrical shell $=\pi\{(2R)^2-(R)^2\}=3\pi R^2$

$\Rightarrow K_{eq}=\frac{K_1(\pi R^2)+K_2(3\pi R^2)}{\pi R^2+3\pi R^2}=\frac{K_1+3K_2}{4}$

5. (b) Let the temperature of junction be θ. Since roads B and C are parallel to each other (because both having the same temperature difference). Hence given figure can be redrawn as follows



$\because \frac{Q}{t}=\frac{(\theta_1-\theta_2)}{R}$ and $\left(\frac{Q}{t}\right)_{AB}=\left(\frac{Q}{t}\right)_{BC}$

$\Rightarrow \frac{(90-\theta)}{R/2}=\frac{(\theta-0)}{R}\Rightarrow 180-2\theta=\theta \Rightarrow\theta=60°C$

6. (a) Heat developed by the heater $H=\frac{V^2}{R}.\frac{t}{J}=\frac{(200)^2\times t}{20\times 4.2}$

Heat conducted by the glass $H=\frac{0.2\times 1\times(20-\theta)t}{0.002}$

Hence $\frac{(200)^2\times t}{20\times 4.2}=\frac{0.2\times(20-\theta)t}{0.002}\Rightarrow\theta=15.24^oC$

7. (a) Since $t = \frac{\rho L}{2k\theta}(x_2^2 - x_1^2)$

$\therefore t = \frac{\rho L}{2k\theta}(x^2 - y^2) = \frac{\rho L(x+y)(x-y)}{2K\theta}$

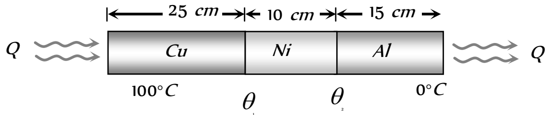
8. (b) If suppose $K_{Ni} = K \Rightarrow K_{Al} = 3K$ and $K_{Cu} = 6K$.

Since all metal bars are connected in series

So $\left(\frac{Q}{t}\right)_{Combination} = \left(\frac{Q}{t}\right)_{Cu} = \left(\frac{Q}{t}\right)_{Al} = \left(\frac{Q}{t}\right)_{Ni}$

and $\frac{3}{K_{eq}} = \frac{1}{K_{Cu}} + \frac{1}{K_{Al}} + \frac{1}{K_{Ni}} = \frac{1}{6K} + \frac{1}{3K} + \frac{1}{K} = \frac{9}{6K}$

$\Rightarrow K_{eq} = 2K$



Hence, if $\left(\frac{Q}{t}\right)_{Combination} = \left(\frac{Q}{t}\right)_{Cu}$

$\Rightarrow \frac{K_{eq}\,A(100-0)}{l_{Combination}} = \frac{K_{Cu}A(100-\theta_1)}{l_{Cu}}$

$\Rightarrow \frac{2K\,A(100-0)}{(25+10+15)} = \frac{6K\,A(100-\theta_1)}{25} \Rightarrow \theta_1 = 83.33°C$

Similar if $\left(\frac{Q}{t}\right)_{Combination} = \left(\frac{Q}{t}\right)_{Al}$

$\Rightarrow \frac{2K\,A(100-0)}{50} = \frac{3K\,A(\theta_2 - 0)}{15} \Rightarrow \theta_2 = 20^o C$

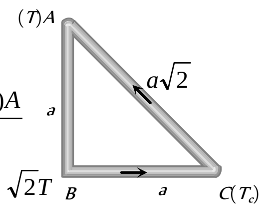
9. (b) $\because T_B > T_A \Rightarrow$ Heat will flow B to A via two paths (i) B to A (ii) and along BCA as shown.

Rate of flow of heat in path BCA will be same

i.e. $\left(\frac{Q}{t}\right)_{BC} = \left(\frac{Q}{t}\right)_{CA}$

$\Rightarrow \frac{k(\sqrt{2}T - T_C)A}{a} = \frac{k(T_C - T)A}{\sqrt{2}a}$

$\Rightarrow \frac{T_C}{T} = \frac{3}{1+\sqrt{2}}$

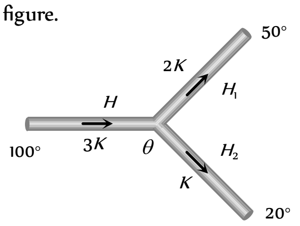


10. (a) $mL = \frac{KA\Delta\theta\ t}{\Delta x} \Rightarrow 500 \times 80 = \frac{0.0075 \times 75 \times (40-0)t}{5}$

$\Rightarrow t = 8.9 \times 10^3$ *sec* = 2.47 *hr.*

11. (a) Rate of cooling $\frac{\Delta\theta}{t} = \frac{A\varepsilon\sigma(T^4 - T_0^4)}{mc} \Rightarrow \frac{\Delta\theta}{t} \propto A$. Since area of plate is largest so it will cool fastest.

12. (b) Let the temperature of junction be θ then according to following figure.

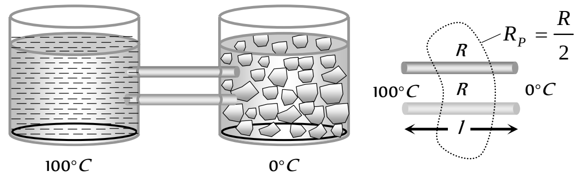


$H = H_1 + H_2$

$\Rightarrow \frac{3K \times A \times (100-\theta)}{l} = \frac{2KA(\theta - 50)}{l} + \frac{KA(\theta - 20)}{l}$

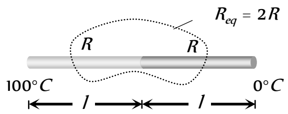
$\Rightarrow 300 - 3\theta = 3\theta - 120 \Rightarrow \theta = 70°C$

13. (c) Initially the rods are placed in vessels as shown below



$\frac{Q}{t} = \frac{(\theta_1 - \theta_2)}{R} \Rightarrow \left(\frac{Q}{t}\right)_1 = \frac{mL}{t} = q_1 L = \frac{(100-0)}{\frac{R}{2}}$ ... (i)

Finally when rods are joined end to end as shown



$\Rightarrow \left(\frac{Q}{t}\right)_2 = \frac{mL}{t} = q_2 L = \frac{(100-0)}{2R}$ ... (ii)

From equation (i) and (ii), $\frac{q_1}{q_2} = \frac{4}{1}$

14. (b) Rate of cooling of a body $R = \frac{\Delta\theta}{t} = \frac{A\varepsilon\sigma(T^4 - T_0^4)}{mc}$

$\Rightarrow R \propto \frac{A}{m} \propto \frac{\text{Area}}{\text{Volume}}$

$\Rightarrow$ For the same surface area. $R \propto \frac{1}{\text{Volume}}$

$\because$ Volume of cube < Volume of sphere

$\Rightarrow R_{Cube} > R_{Sphere}$ *i.e.* cube, cools down with faster rate.

15. (a,b) According to Stefan's law

$E = eA\sigma T^4 \Rightarrow E_1 = e_1 A\sigma T_1^4$ and $E_2 = e_2 A\sigma T_2^4$

$\because E_1 = E_2 \;\therefore e_1 T_1^4 = e_2 T_2^4$

$\Rightarrow T_2 = \left(\frac{e_1}{e_2}T_1^4\right)^{\frac{1}{4}} = \left(\frac{1}{81} \times (5802)^4\right)^{\frac{1}{4}} \Rightarrow T_B = 1934\ K$

And, from Wein's law $\lambda_A \times T_A = \lambda_B \times T_B$

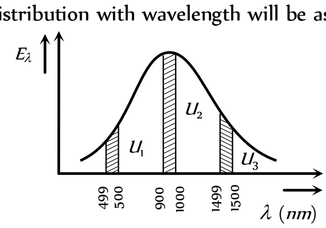
$\Rightarrow \frac{\lambda_A}{\lambda_B} = \frac{T_B}{T_A} \Rightarrow \frac{\lambda_B - \lambda_A}{\lambda_B} = \frac{T_A - T_B}{T_A}$

$\Rightarrow \frac{1}{\lambda_B} = \frac{5802 - 1934}{5802} = \frac{3968}{5802} \Rightarrow \lambda_B = 1.5\ \mu m$

16. (d) Wein's displacement law is $\lambda_m T = b$

$\Rightarrow \lambda_m = \frac{b}{T} = \frac{2.88 \times 10^6}{2880} = 1000\,nm.$

Energy distribution with wavelength will be as follows



From the graph it is clear that $U_2 > U_1$.

17. (b) Energy received per second *i.e.*, power $P \propto (T^4 - T_0^4)$

$\Rightarrow P \propto T^4 \qquad (\because T_0 << T)$

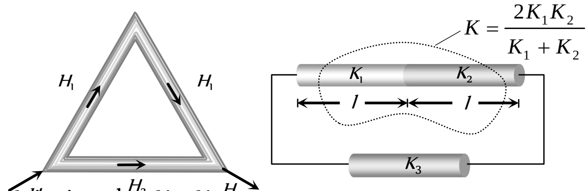
Also energy received per sec $(p) \propto \dfrac{1}{d^2}$

(inverse square law)

$$\Rightarrow P \propto \frac{T^4}{d^2} \Rightarrow \frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^4 \times \left(\frac{d_2}{d_1}\right)^2$$

$$\Rightarrow \frac{P}{P_2} = \left(\frac{T}{2T}\right)^2 \times \left(\frac{2d}{d}\right)^2 = \frac{1}{4} \Rightarrow P_2 = 4P.$$

18. (c) The given arrangement of rods can be redrawn as follows



It is given that $H_1 = H_2$

$$\Rightarrow \frac{KA(\theta_1 - \theta_2)}{2l} = \frac{K_3A(\theta_1 - \theta_2)}{l} \Rightarrow K_3 = \frac{K}{2} = \frac{K_1K_2}{K_1 + K_2}$$

19. (b) Rate of cooling $(R) = \dfrac{\Delta\theta}{t} = \dfrac{A \in \sigma(T^4 - T_0^4)}{mc}$

$$\Rightarrow R \propto \frac{A}{m} \propto \frac{\text{Area}}{\text{volume}} \propto \frac{r^2}{r^3} \propto \frac{1}{r}$$

$$\Rightarrow \text{Rate } (R) \propto \frac{1}{r} \propto \frac{1}{m^{1/3}} \left[\because m = \rho \times \frac{4}{3}\pi r^3 \Rightarrow r \propto m^{1/3}\right]$$

$$\Rightarrow \frac{R_1}{R_2} = \left(\frac{m_2}{m_1}\right)^{1/3} = \left(\frac{1}{3}\right)^{1/3}$$

20. (b) Radiated power $P = A\varepsilon\sigma T^4 \Rightarrow P \propto AT^4$

From Wein's law, $\lambda_m T = \text{constant} \Rightarrow T \propto \dfrac{1}{\lambda_m}$

$$\therefore P \propto \frac{A}{(\lambda_m)^4} \propto \frac{r^2}{(\lambda_m)^4}$$

$$\Rightarrow Q_A : Q_B : Q_C = \frac{2^2}{(300)^4} : \frac{4^2}{(400)^4} : \frac{6^2}{(500)^4}$$

$\therefore Q_B$ will be maximum.

21. (d) The total energy radiated from a black body per minute.

$$Q \propto T^4 \Rightarrow \frac{Q_2}{Q_1} = \left(\frac{2T}{T}\right)^4 = 16 \Rightarrow Q_2 = 16Q_1$$

If m be mass of water taken and S be its specific heat capacity, then $Q_1 = ms(20.5 - 20)$ and $Q_2 = ms(\theta - 20)$

$\theta°C$ = Final temperature of water

$$\Rightarrow \frac{Q_2}{Q_1} = \frac{\theta - 20}{0.5} \Rightarrow \frac{16}{1} = \frac{\theta - 20}{0.5} \Rightarrow \theta = 28°C$$

22. (a) Rate of cooling $\dfrac{\Delta\theta}{t} = \dfrac{A\varepsilon\sigma(T^4 - T_0^4)}{mc}$

As surface area, material and temperature difference are same, so rate of loss of heat is same in both the spheres. Now in this case rate of cooling depends on mass.

$\Rightarrow$ Rate of cooling $\dfrac{\Delta\theta}{t} \propto \dfrac{1}{m}$

$\because m_{solid} > m_{hollow}$. Hence hollow sphere will cool fast.

23. (c) Rate of cooling $\dfrac{\Delta\theta}{t} = \dfrac{A\varepsilon\sigma(T^4 - T_0^4)}{mc}$

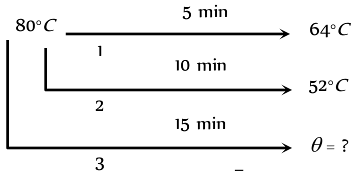
$\Rightarrow t \propto \dfrac{m}{A} \qquad [\because \Delta\theta, t, \sigma, (T^4 - T_0^4) \text{ are constant}]$

$$\Rightarrow t \propto \frac{m}{A} \propto \frac{\text{Volume}}{\text{Area}} \propto \frac{a^3}{a^2} \Rightarrow t \propto a \Rightarrow \frac{t_1}{t_2} = \frac{a_1}{a_2}$$

$$\Rightarrow \frac{100}{t_2} = \frac{1}{2} \Rightarrow t_2 = 200 sec.$$

24. (a) According to Newton law of cooling

$$\frac{\theta_1 - \theta_2}{t} = K\left[\frac{\theta_1 + \theta_2}{2} - \theta_0\right]$$



For first process : $\dfrac{(80 - 64)}{5} = K\left[\dfrac{80 + 64}{2} - \theta_0\right]$ ...(i)

For second process : $\dfrac{(80 - 52)}{10} = K\left[\dfrac{80 + 52}{2} - \theta_0\right]$ ...(ii)

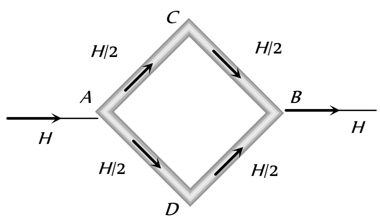
For third process : $\dfrac{(80 - \theta)}{15} = K\left[\dfrac{80 + \theta}{2} - \theta_0\right]$ ...(iii)

On solving equation (i) and (ii) we get $K = \dfrac{1}{15}$ and $\theta_0 = 24°C$. Putting these values in equation (iii) we get $\theta = 42.7°C$

25. (c) $t = \dfrac{Ql}{KA(\theta_1 - \theta_2)} = \dfrac{mLl}{KA(\theta_1 - \theta_2)} = \dfrac{V\rho Ll}{KA(\theta_1 - \theta_2)}$

$$= \frac{5 \times A \times 0.92 \times 80 \times \dfrac{5 + 10}{2}}{0.004 \times A \times 10 \times 3600} = 19.1\, hours.$$

26. (a) Suppose temperature difference between A and B is 100°C and $\theta_A > \theta_B$



Heat current will flow from A to B via path ACB and ADB. Since all the rod are identical so $(\Delta\theta)_{AC} = (\Delta\theta)_{AD}$

(Because heat current $H = \dfrac{\Delta\theta}{R}$; here R = same for all.)

$\Rightarrow \theta_A - \theta_C = \theta_A - \theta_D \Rightarrow \theta_C = \theta_D$

i.e. temperature difference between C and D will be zero.

27. (c) $\frac{Q}{t}=\frac{KA\Delta\theta}{l}\Rightarrow\frac{mL}{t}=\frac{K(\pi r^2)\Delta\theta}{l}$

$\Rightarrow$ Rate of melting of ice $\left(\frac{m}{t}\right)\propto\frac{Kr^2}{l}$

Since for second rod K becomes $\frac{1}{4}th$ r becomes double and length becomes half, so rate of melting will be twice *i.e.* $\left(\frac{m}{t}\right)_2=2\left(\frac{m}{t}\right)_1=2\times 0.1=0.2\ gm/sec.$

28. (c) Heat transferred in one minute is utilised in melting the ice so,

$$\frac{KA(\theta_1-\theta_2)t}{l}=m\times L$$

$$\Rightarrow m=\frac{10^{-3}\times 92\times(100-0)\times 60}{1\times 8\times 10^4}=6.9\times 10^{-3}\,kg$$

29. (d) $\frac{dQ}{dt}=\frac{KA}{l}d\theta=\frac{0.01\times 1}{0.05}\times 30=6J/sec$

Heat transferred in on day (86400 *sec*)

$\theta=6\times 86400=518400\ J$

Now $Q=mL\Rightarrow m=\frac{Q}{L}=\frac{518400}{334\times 10^3}$

$= 1.552\ kg = 1552g.$

30. (b) For no current flow between C and D

$$\left(\frac{Q}{t}\right)_{AC}=\left(\frac{Q}{t}\right)_{CB}\Rightarrow\frac{K_1A(\theta_A-\theta_C)}{l}=\frac{K_2A(\theta_C-\theta_B)}{l}$$

$$\Rightarrow\frac{\theta_A-\theta_C}{\theta_C-\theta_B}=\frac{K_2}{K_1}\quad\text{...(i)}$$

Also $\left(\frac{Q}{t}\right)_{AD}=\left(\frac{Q}{t}\right)_{DB}\Rightarrow\frac{K_3A(\theta_A-\theta_D)}{l}=\frac{K_4A(\theta_D-\theta_B)}{l}$

$$\Rightarrow\frac{\theta_A-\theta_D}{\theta_D-\theta_B}=\frac{K_4}{K_3}\quad\text{...(ii)}$$

It is given that $\theta_C=\theta_D$, hence from equation (i) and (ii) we get $\frac{K_2}{K_1}=\frac{K_4}{K_3}\Rightarrow K_1K_4=K_2K_3$

31. (d) Rate of cooling $R_C=\frac{d\theta}{dt}=\frac{A\varepsilon\sigma(T^4-T_0^4)}{mc}$

$$\Rightarrow\frac{d\theta}{dt}\propto\frac{A}{V}\propto\frac{r^2}{r^3}\Rightarrow\frac{d\theta}{dt}\propto\frac{1}{r}$$

32. (b) $\frac{dT}{dt}=\frac{\sigma A}{mcJ}(T^4-T_0^4)$ [In the given problem fall in temperature of body $dT=(200-100)=100K$, temp. of surrounding $T_0=0K$, Initial temperature of body $T=200K$].

$$\frac{100}{dt}=\frac{\sigma 4\pi r^2}{\frac{4}{3}\pi r^3\rho c\,J}(200^4-0^4)$$

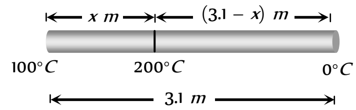
$$\Rightarrow dt=\frac{r\rho c\,J}{48\sigma}\times 10^{-6}s=\frac{r\rho c}{\sigma}.\frac{4.2}{48}\times 10^{-6}$$

$$=\frac{7}{80}\frac{r\rho c}{\sigma}\mu s\simeq\frac{7}{72}\frac{r\rho c}{\sigma}\mu s$$ [As J = 4.2]

33. (a) Rate of flow of heat is given by $\frac{dQ}{dt}=\frac{\Delta\theta}{l/KA}$ also

$\frac{dQ}{dt}=L\frac{dm}{dt}$ (where L = Latent heat)

$\Rightarrow\frac{dm}{dt}=\frac{KA}{l}\left(\frac{\Delta\theta}{L}\right)$. Let the desire point is at a distance x from water at 100°C.



$\because$ Rate of ice melting = Rate at which steam is being produced

$$\Rightarrow\left(\frac{dm}{dt}\right)_{Steam}=\left(\frac{dm}{dt}\right)_{Ice}\Rightarrow\left(\frac{\Delta\theta}{Ll}\right)_{Steam}=\left(\frac{\Delta\theta}{Ll}\right)_{Ice}$$

$$\Rightarrow\frac{(200-100)}{540\times x}=\frac{(200-0)}{80\,(3.1-x)}\Rightarrow x=0.4\ m=40\ cm$$

34. (c) $Q=\sigma A\,t\,(T-T_0)$

If T, T_0, σ and t are same for both bodies then

$$\frac{Q_{sphere}}{Q_{cube}}=\frac{A_{sphere}}{A_{cube}}=\frac{4\pi r^2}{6a^2}\quad\text{.....(i)}$$

But according to problem, volume of sphere = Volume of cube

$$\Rightarrow\frac{4}{3}\pi r^3=a^3\Rightarrow a=\left(\frac{4}{3}\pi\right)^{1/3}r$$

Substituting the value of a in equation (i) we get

$$\frac{Q_{sphere}}{Q_{cube}}=\frac{4\pi r^2}{6a^2}=\frac{4\pi r^2}{6\left\{\left(\frac{4}{3}\pi\right)^{1/3}r\right\}^2}$$

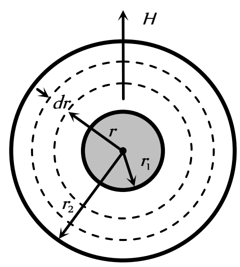
$$=\frac{4\pi r^2}{6\left(\frac{4}{3}\pi\right)^{2/3}r^2}=\left(\frac{\pi}{6}\right)^{1/3}:1$$

35. (d) Equation of thermal conductivity of the given combination $K_{eq}=\frac{l_1+l_2}{\frac{l_1}{K_1}+\frac{l_2}{K_2}}=\frac{x+4x}{\frac{x}{K}+\frac{4x}{2K}}=\frac{5}{3}K$. Hence rate of flow of heat through the given combination is

$$\frac{Q}{t}=\frac{K_{eq}.A(T_2-T_1)}{(x+4x)}=\frac{\frac{5}{3}K\,A\,(T_2-T_1)}{5x}=\frac{\frac{1}{3}K\,A\,(T_2-T_1)}{x}$$

On comparing it with given equation we get $f=\frac{1}{3}$

36. (a) Consider a concentric spherical shell of radius r and thickness dr as shown in fig.



The radial rate of flow of heat through this shell in steady state will be $H = \frac{dQ}{dt} = -KA\frac{dT}{dr} = -K(4\pi r^2)\frac{dT}{dr}$

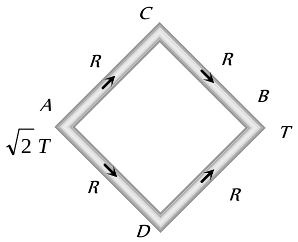
$$\Rightarrow \int_{r_1}^{r_2} \frac{dr}{r^2} = -\frac{4\pi K}{H}\int_{T_1}^{T_1} dT$$

Which on integration and simplification gives

$$H = \frac{dQ}{dt} = \frac{4\pi K r_1 r_2 (T_1 - T_2)}{r_2 - r_1} \Rightarrow \frac{dQ}{dt} \propto \frac{r_1 r_2}{(r_2 - r_1)}$$

37. (c) Similar to Q.No.26

Temperature difference between C and D is zero.



Graphical Questions

1. (c) Rate of cooling $\left(-\frac{dT}{dt}\right) \propto$ emissivity (e)

From graph, $\left(-\frac{dT}{dt}\right)_x > \left(-\frac{dT}{dt}\right)_y \Rightarrow e_x > e_y$

Further emissivity (e) $\propto$ Absorptive power (a) $\Rightarrow a_x > a_y$

($\because$ good absorbers are good emitters).

2. (b) According to Wien's law $\lambda_m \propto \frac{1}{T}$ and from the figure $(\lambda_m)_1 < (\lambda_m)_3 < (\lambda_m)_2$ therefore $T_1 > T_3 > T_2$.

3. (d) $\frac{A_T}{A_{2000}} = \frac{16}{1}$ (given)

Area under $e_\lambda - \lambda$ curve represents the emissive power of body and emissive power $\propto T^4$

(Hence area under $e_\lambda - \lambda$ curve) $\propto T^4$

$$\Rightarrow \frac{AT}{A_{2000}} = \left(\frac{T}{2000}\right)^4 \Rightarrow \frac{16}{1} = \left(\frac{T}{2000}\right)^4 \Rightarrow T = 4000K.$$

4. (c) According to Wein's law $\lambda_m \propto \frac{1}{T} \Rightarrow \nu_m \propto T$. As the temperature of body increases, frequency corresponding to maximum energy in radiation (ν) increases this is shown in graph (c).

5. (c) According to Wein's displacement law.

6. (b) For θ-t plot, rate of cooling $= \frac{d\theta}{dt}$ = slope of the curve.

At P, $\frac{d\theta}{dt} = \tan\phi_2 = k(\theta_2 - \theta_0)$, where k = constant.

At Q $\frac{d\theta}{dt} = \tan\phi_1 = k(\theta_1 - \theta_0) \Rightarrow \frac{\tan\phi_2}{\tan\phi_1} = \frac{\theta_2 - \theta_0}{\theta_1 - \theta_0}$

7. (a) According to Wein's displacement law

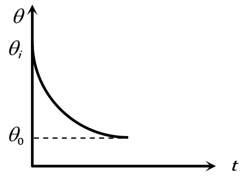
$$\lambda_m \propto \frac{1}{T} \Rightarrow \lambda_{m_2} < \lambda_{m_1} \quad (\because\ T_1 < T_2)$$

There fore I–λ graph for T_2 have lesser wavelength (λ_m) and so curve for T_2 will shift towards left side.

8. (d) Area under given curve represents emissive power and emissive power $\propto T \Rightarrow A \propto T^4$

$$\Rightarrow \frac{A_2}{A_1} = \frac{T_2^4}{T_1^4} = \frac{(273+327)^4}{(273+27)^4} = \left(\frac{600}{300}\right)^4 = \frac{16}{1}$$

9. (b) According to Newton's law of cooling



Rate of cooling $\propto$ Temperature difference

$$\Rightarrow -\frac{d\theta}{dt} \propto (\theta - \theta_0) \Rightarrow -\frac{d\theta}{dt} = \alpha(\theta - \theta_0) \quad (\alpha = \text{constant})$$

$$\Rightarrow \int_{\theta_i}^{\theta} \frac{d\theta}{(\theta - \theta_0)} = -\alpha \int_0^t dt \Rightarrow \theta = \theta_0 + (\theta_i - \theta_0)e^{-\alpha t}$$

This relation tells us that, temperature of the body varies exponentially with time from θ_i to θ_0

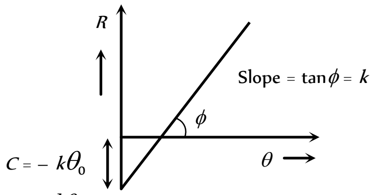
Hence graph (b) is correct.

10. (a) According to Wein's displacement law $\lambda_m \propto \frac{1}{T}$. Hence, if temperature increases λ_m decreases *i.e.,* peak of the $E - \lambda$ curve shift towards left.

11. (c) Rate of loss of heat (R) $\propto$ temperature difference

$\Rightarrow R \propto (\theta - \theta_0) \Rightarrow R = k(\theta - \theta_0) = k\theta - k\theta_0$ (k= constant)

on comparing it with $y = mx + c$ it is observed that, the graph between R and θ will be straight line with slope $= k$ and intercept $= -k\theta_0$



12. (c) $\frac{dQ}{dt} = -KA\frac{d\theta}{dx}$

$\because \frac{dQ}{dt}$, K and A are constants for all points

$\Rightarrow d\theta \propto -dx$; *i.e.* temperature will decrease linearly with x.

13. (b) Since the curved surface of the conductor is thermally insulated, therefore, in steady state, the rate of flow of heat at every section will be the same. Hence the curve between H and x will be straight line parallel to x-axis.

14. (d) According to Stefan's law $E = \sigma T^4$

$\Rightarrow \log E = \log\sigma + 4\log T \Rightarrow \log E = 4\log T + \log\sigma$

on comparing this equations with $y = mx + C$

we find that graph between log E and log T will be a straight line, having positive slope (m = 4) and intercept on log E axis equal to $\log\sigma$

15. (c) $\frac{d\theta}{dt} = \frac{\varepsilon A\sigma}{mc} 4\theta_0^3 \Delta\theta$

For given sphere and cube $\frac{\varepsilon A\sigma}{mc} 4\theta_0^3\Delta\theta$ is constant so for both rate of fall of temperature $\frac{d\theta}{dt}$ = constant

16. (b) $\lambda_m T = b$ where $b = 2.89 \times 10^{-3} mK$

$$\Rightarrow T = \frac{b}{\lambda_m} = \frac{2.89 \times 10^{-3}}{1.5 \times 10^{-6}} \approx 2000K$$

17. (b) Wein's law $\lambda_m \propto \frac{1}{T}$ or $\nu_m \propto T$

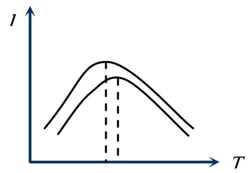
ν increases with temperature. So the graph will be straight line.

Assertion and Reason

1. (a) According to Kirchoff's law $\frac{e_\lambda}{a_\lambda} = E_\lambda$

If for a particular wave length $E_\lambda = 1 \Rightarrow e_\lambda = a_\lambda$ *i.e.,* aborptivity of a body is equal to it's emissivity. This statement also reveals that a good radiator is also a good absorber and vice versa.

2. (c) According to Weins law $\lambda_m T$ = constant *i.e.,* peak emission wavelength $\lambda_m \propto \frac{1}{T}$. Also as T increases λ_m decreases.



Hence assertion is true but reason is false.

3. (b) During the day when water is cooler than the land, the wind blows off the water onto the land (as warm air rises and cooler air fills the place). Also at night, the effect is reversed (since the water is usually warmer than the surrounding air on land). Due to this wind flow the temperature near the sea coast remains moderate.

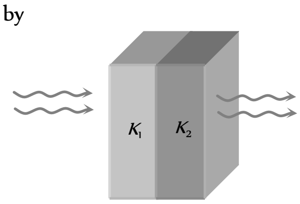
4. (c) Heat is carried away from a fire sideways mainly by radiations. Above the fire, heat is carried by both radiation and by convection of air. The latter process carries much more heat.

5. (e) Assertion is false because at absolute zero (0 K), heat is neither radiates nor absorbed. Reason is the statement of Stefan's law, as $E \propto T^4$.

6. (a) Woolen fibres encloses a large amount of air in them. Both wool and air are the bad conductors of heat and the coefficient of thermal conductivity is small. So, they prevent any loss of heat from our body.

7. (d) Equivalent thermal conductivity of two equally thick plates in series combination is given by

$$\frac{2}{K} = \frac{1}{K_1} + \frac{1}{K_2}$$



If $K_1 < K_2$

then $K_1 < K < K_2$

Hence assertion and reason both are false.

8. (c) Hollow metallic closed container maintained at a uniform temperature can act as source of black body. It is also well-known that all metals cannot act as black body because if we take a highly metallic polished surface. It will not behave as a perfect black body.

9. (b) This is in accordance with the Stefan's law $E \propto T^4$.

10. (c) At a high temperature (6000 K), the sun acts like a perfect blackbody emitting complete radiation. That's why the radiation coming from the sun's surface follows Stefan's law $E = \sigma T^4$.

11. (a) From Wein's displacement law, temperature $(T) \propto 1/\lambda_m$ (where λ_m is the maximum wavelength). Thus temperature of a body is inversely proportional to the wavelength. Since blue star has smaller wavelength and red star has maximum wavelength, therefore blue star is at higher temperature then red star.

12. (b) From the definition heat flow, $Q = \frac{KA.\Delta\theta\, t}{l}$

Thermal conductivity $K = \frac{\theta \times l}{A \times \Delta\theta \times t}$

$\Rightarrow K = \frac{J \times m}{m^2 \times K \times \sec} = \frac{watt}{m \times K}$

If thermal conductivity of a substance is high, it will pass more heat.

13. (c) The thermal conductivity of brass is high *i.e.,* brass is a good conductor of heat. So, when a brass tumbler is touched, heat quickly flows from human body to tumbler. Consequently, the tumbler appears colder, on the other hand wood is a bad conductor. So, heat does not flow from the human body to the wooden tray in this case. Thus it appears comparatively hotter.

14. (b) Light radiations and thermal radiations both belongs to electromagnetic spectrum. Light radiations belongs to visible region while thermal radiation belongs to infrared region of *EM* spectrum. Also *EM* radiations requires no medium for propagation.

15. (a) When the temperature of the atmosphere reaches below 0°C, then the water vapours present in air, instead of condensing, freeze directly in the form of minute particles of ice. Many particles coalesce and take cotton-like shape which is called snow. Thus snow contains air packets in which convection currents cannot be formed. Hence snow is a good heat insulator. In ice there is no air, so it is a bad insulator.

16. (e) In the process of convection, the liquid at the bottom, becoming lighter, rises up. Thus the basis of convection is the difference in weight and upthrust. In weightlessness, this difference does not exist. So convection is not possible.

17. (b) Both assertion and reason are true but reason is not correctly explaining the assertion.

18. (c) The 98.4°F is the standard body temperature of a man. If a man touch a iron or wooden ball at 98.4° F, no heat transfer takes place between ball and man, so both the balls would feel equally hot for the man.

19. (c) According to Wien's displacement law the $\lambda_m \propto \frac{1}{T}$.

Hence assertion is true but reason is false.

20. (e) It is not necessary that all black coloured object are black bodies. For example, if we take a black surface which is highly polished, it will not behave as a perfect black body.

A perfectly black body absorbs all the radiations incident on it.

21. (b) By definition, $R = \frac{(\theta_1 - \theta_2)}{Q/t} = \frac{l}{KA} \Rightarrow R \propto \frac{1}{K}$.

22. (c) Actually, the process of radiation does not require any material for transmission of heat.

Thermal radiation travels with the velocity of light and hence the fastest mode of the transfer. Thermal radiation is always transmitted in a straight line.

23. (c) Two thin blankets put together are more warm because an insulating layer of air (as air is good insulator of heat) is enclosed between two blankets due to which it gives more warmness.

24. (a) When the animals feel cold, they curl their bodies into a ball so as to decrease the surface area of their bodies. As total energy radiated by body varies directly as the surface area of the body, the loss of heat due to radiation would be reduced.

Transmission of Heat

SET Self Evaluation Test - 15

1. A rod of 40 cm in length and temperature difference of 80^oC at its two ends. Another rod B of length 60 cm and of temperature difference 90^oC, having the same area of cross-section. If the rate of flow of heat is the same, then the ratio of their thermal conductivities will be
(a) 3 : 4 (b) 4 : 3
(c) 1 : 2 (d) 2 : 1

2. Two vessels of different materials are similar in size in every respect. The same quantity of ice filled in them gets melted in 20 *minutes* and 40 *minutes* respectively. The ratio of thermal conductivities of the materials is [AFMC 1998]
(a) 5 : 6 (b) 6 : 5
(c) 3 : 1 (d) 2 : 1

3. In a steady state of thermal conduction, temperature of the ends A and B of a 20 *cm* long rod are 100^oC and 0^oC respectively. What will be the temperature of the rod at a point at a distance of 6 *cm* from the end A of the rod
(a) -30^oC (b) 70^oC
(c) 5^oC (d) None of the above

4. Four rods of silver, copper, brass and wood are of same shape. They are heated together after wrapping a paper on it, the paper will burn first on
(a) Silver (b) Copper
(c) Brass (d) Wood

5. The two opposite faces of a cubical piece of iron (thermal conductivity = 0.2 CGS units) are at 100^oC and 0^oC in ice. If the area of a surface is $4cm^2$, then the mass of ice melted in 10 minutes will be
(a) 30 *gm* (b) 300 *gm*
(c) 5 *gm* (d) 50 *gm*

6. Wein's constant is 2892×10^{-6} MKS unit and the value of λ_m from moon is 14.46 microns. What is the surface temperature of moon
(a) 100 *K* (b) 300 *K*
(c) 400 *K* (d) 200 *K*

7. If at temperature $T_1 = 1000K$, the wavelength is $1.4\times10^{-6}m$, then at what temperature the wavelength will be $2.8\times10^{-6}m$
(a) 2000*K* (b) 500*K*
(c) 250*K* (d) None of these

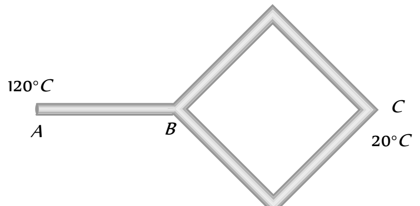
8. The wavelength of maximum intensity of radiation emitted by a star is 289.8 *nm*. The radiation intensity for the star is : (Stefan's constant $5.67\times10^{-8}Wm^{-2}K^{-4}$, constant $b = 2898\mu mK$) -
(a) $5.67\times10^8\ W/m^2$ (b) $5.67\times10^{12}W/m^2$
(c) $10.67\times10^7W/m^2$ (d) $10.67\times10^{14}W/m^2$

9. Two friends A and B are waiting for another friend for tea. A took the tea in a cup and mixed the cold milk and then waits. B took the tea in the cup and then mixed the cold milk when the friend comes. Then the tea will be hotter in the cup of

(a) A
(b) B
(c) Tea will be equally hot in both cups
(d) Friend's cup

10. There are two spherical balls A and B of the same material with same surface, but the diameter of A is half that of B. If A and B are heated to the same temperature and then allowed to cool, then
(a) Rate of cooling is same in both
(b) Rate of cooling of A is four times that of B
(c) Rate of cooling of A is twice that of B
(d) Rate of cooling of A is $\frac{1}{4}$ times that of B

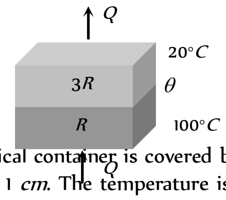
11. Five identical rods are joined as shown in figure. Point A and C are maintained at temperature 120°C and 20°C respectively. The temperature of junction B will be



(a) 100°C
(b) 80°C
(c) 70°C
(d) 0°C

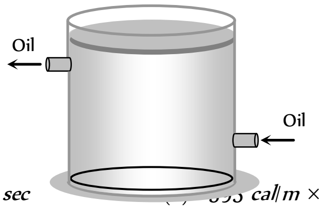
12. Can we boil water inside the earth satellite by convection
(a) Yes
(b) No
(c) Nothing can be said
(d) In complete information is given

13. In the following figure, two insulating sheets with thermal resistances R and $3R$ as shown in figure. The temperature θ is



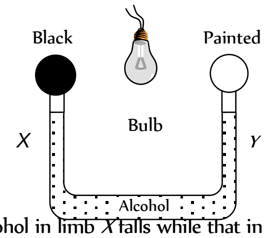
(a) 20°C
(b) 60°C
(c) 75°C
(d) 80°C [RPMT 2004]

14. The top of insulated cylindrical container is covered by a disc having emissivity 0.6 and thickness 1 *cm*. The temperature is maintained by circulating oil as shown in figure. If temperature of upper surface of disc is 127°C and temperature of surrounding is 27°C, then the radiation loss to the surroundings will be (Take $\sigma = \frac{17}{3}\times10^{-8}W/m^2K^4$) [EAMCET 2001]



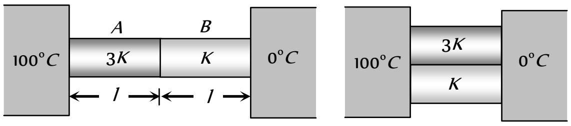
(a) 595 *J/m × sec* (b) [illegible] *cal/m × sec*
(c) 991.0 *J/m × sec* (d) 440 *J/m × sec*

15. The following figure shows two air-filled bulbs connected by a U-tube partly filled with alcohol. What happens to the levels of alcohol in the limbs X and Y when an electric bulb placed midway between the bulbs is lighted



(a) The level of alcohol in limb X falls while that in limb Y rises
(b) The level of alcohol in limb X rises while that in limb Y falls
(c) The level of alcohol falls in both limbs
(d) There is no change in the levels of alcohol in the two limbs

16. Two conducting rods A and B of same length and cross-sectional area are connected (i) In series (ii) In parallel as shown. In both combination a temperature difference of $100°C$ is maintained. If thermal conductivity of A is $3K$ and that of B is K then the ratio of heat current flowing in parallel combination to that flowing in series combination is



(i) (ii)

(a) $\frac{16}{3}$ (b) $\frac{3}{16}$
(c) $\frac{1}{1}$ (d) $\frac{1}{3}$

17. The area of the glass of a window of a room is $10\ m^2$ and thickness $2mm$. The outer and inner temperature are 40^oC and 20^oC respectively. Thermal conductivity of glass in MKS system is 0.2. The heat flowing in the room per second will be

(a) 3×10^4 *joules* (b) 2×10^4 *joules*
(c) 30 *joules* (d) 45 *joules*

18. The spectrum from a black body radiation is a

[MP PMT 1989; RPET 2000]

(a) Line spectrum
(b) Band spectrum
(c) Continuous spectrum
(d) Line and band spectrum both

19. The Wien's displacement law express relation between

[CBSE PMT 2002]

(a) Frequency and temperature
(b) Temperature and amplitude
(c) Wavelength and radiating power of black body
(d) Wavelength corresponding to maximum energy and temperature

20. A black body is heated from 27^oC to 127^oC. The ratio of their energies of radiations emitted will be

[AIIMS 2001]

(a) 3: 4 (b) 9 : 16
(c) 27 : 64 (d) 81: 256

21. A body takes T *minutes* to cool from 62^oC to 61^oC when the surrounding temperature is 30^oC. The time taken by the body to cool from 46^oC to 45.5^oC is

[MP PET 1999]

(a) Greater than T *minutes*
(b) Equal to T *minutes*
(c) Less than T *minutes*
(d) Equal to $T/2$ *minutes*

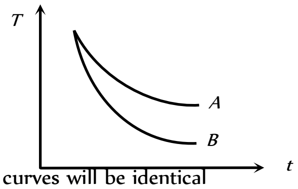
22. A partition wall has two layers A and B in contact, each made of a different material. They have the same thickness but the thermal conductivity of layer A is twice that of layer B. If the steady state temperature difference across the wall is $60K$, then the corresponding difference across the layer A is

[SCRA 1994; JIPMER 2001]

(a) $10\ K$ (b) $20\ K$
(c) $30K$ (d) $40\ K$

23. Water and turpentine oil (specific heat less than that of water) are both heated to same temperature. Equal amounts of these placed in identical calorimeters are then left in air

[MP PMT 1989]



(a) Their cooling curves will be identical
(b) A and B will represent cooling curves of water and oil respectively
(c) B and A will represent cooling curves of water and oil respectively
(d) None of the above

Answers and Solutions

(SET -15)

1. (a) $\frac{dQ}{dt} = \frac{KA(\theta_1-\theta_2)}{d}$

$\Rightarrow \frac{K_1\Delta\theta_1}{l_1} = \frac{K_2\Delta\theta_2}{l_2}$ $\left(\because \frac{dQ}{dt} \text{ and } A \text{ are same}\right)$

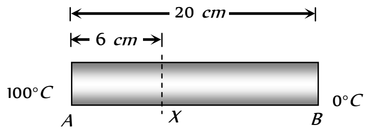
$\Rightarrow \frac{K_1\times80}{40} = \frac{K_2\times90}{60} \Rightarrow \frac{K_1}{K_2} = \frac{3}{4}$

2. (d) $\frac{Q}{t} = \frac{KA(\theta_1-\theta_2)}{l} \Rightarrow \frac{mL}{t} = \frac{KA(\theta_1-\theta_2)}{l}$

$\Rightarrow K \propto \frac{1}{t}$ ($\because$ remaining quantities are same)

$\Rightarrow \frac{K_1}{K_2} = \frac{t_2}{t_1} = \frac{40}{20} = \frac{2}{1}$.

3. (b) In steady state, temperature gradient = constant



$$\Rightarrow \frac{(\theta_A-\theta_x)}{6}=\frac{(\theta_A-\theta_B)}{20}\Rightarrow (100-\theta)=\frac{6}{20}\times(100-0)$$

$$\Rightarrow \theta_x = 70°C$$

4. (d) In conducting rod given heat transmits so burning temperature does not reach soon. In wooden rod heat doesn't conducts.

5. (b) $Q = mL = KA\dfrac{(\theta_1-\theta_2)}{l}t \Rightarrow m=\dfrac{1}{L}\times KA\dfrac{(\theta_1-\theta_2)}{l}\times t$

$$=\frac{1}{80}\times 0.2\times 4\times\frac{(100-0)}{\sqrt{4}}\times 10\times 60 \quad (\because l^2=4\Rightarrow l=\sqrt{4})$$

$$=\frac{0.2\times 4\times 100\times 600}{80\times 2}=300\ gm$$

6. (d) $\lambda_m T = 2892\times 10^{-6} \Rightarrow T=\dfrac{2892\times 10^{-6}}{14.46\times 10^{-6}}=200\ K$

7. (a) $\lambda_m \propto \dfrac{1}{T}\Rightarrow \lambda m_1 T_1=\lambda m_2 T_2$

$$\Rightarrow T_2=\frac{\lambda m_1 T_1}{\lambda m_2}=\frac{1.4\times 10^{-6}\times 1000}{2.8\times 10^{-6}}=2000K$$

8. (a) We know $\lambda_{max}T=b$

$$\Rightarrow T=\frac{b}{\lambda_{max}}=\frac{2898\times 10^{-6}}{289.8\times 10^{-9}}=10^4 K$$

According to Stefan's Law

$$E=\sigma T^4=(5.67\times 10^{-8})(10^4)^4=5.67\times 10^8 W/m^2$$

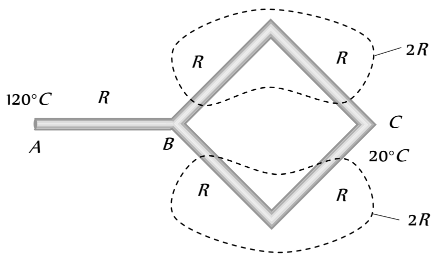
9. (a) The rate of heat loss is proportional to the difference in temperature. The difference of temperature between the tea in cup A and the surrounding is reduced, so it loses less heat. the tea in cup B loses more heat because of large temperature difference. Hence the tea in cup A will be hotter.

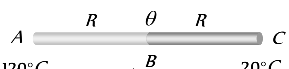
10. (c) Rate of cooling $R_C=\dfrac{A\varepsilon\sigma(T^4-T_0^4)}{mc}=\dfrac{A\varepsilon\sigma(T^4-T_0^4)}{V\rho C}$

$$\Rightarrow R_C\propto\frac{A}{V}\propto\frac{1}{r}\propto\frac{1}{(\text{Diameter})} \qquad (\because m=\rho V)$$

Since diameter of A is half that of B so it's rate of cooling will be doubled that of B

11. (c) If thermal resistance of each rod is considered R then, the given combination can be redrawn as follows





(Heat current) = (Heat current)

$$\frac{(120-20)}{R}=\frac{(120-\theta)}{R}\Rightarrow \theta=70°C$$

12. (b) No, In convection the hot liquid at the bottom becomes lighter and hence it rises up. In this way the base of the convection is the difference in weight and upthrust. In the state of weightlessness this difference does not occur, so convection is not possible.

13. (b)

14. (d) For the two sheets $H_1 = H_2$ (H = Rate of heat flow)

$$\Rightarrow \frac{(100-\theta)}{R}=\frac{(\theta-20)}{3R}\Rightarrow \theta = 80°C$$

15. (a) Rate of heat loss per unit area due to radiation *i.e.* emissive power $e=\varepsilon\sigma(T^4-T_0^4)$

$$=0.6\times\frac{17}{3}\times 10^{-8}\times[(400)^4-(300)^4]$$

$$=3.4\times 10^{-8}\times(175\times 10^8)=3.4\times 175=595\ J/m^2\times\sec$$

16. (a) Black bulb absorbs more heat in comparison with painted bulb. So air in black bulb expands more. Hence the level of alcohol in limb X falls while that in limb Y rises.

17. (a) Heat current $H=\dfrac{\Delta\theta}{R}\Rightarrow\dfrac{H_P}{H_S}=\dfrac{R_S}{R_P}$

In first case : $R_S=R_1+R_2=\dfrac{l}{(3K)A}+\dfrac{l}{KA}=\dfrac{4}{3}\dfrac{l}{KA}$

In second case : $R_P=\dfrac{R_1R_2}{R_1+R_2}=\dfrac{\dfrac{l}{(3K)A}\times\dfrac{l}{KA}}{\left(\dfrac{l}{(3K)A}+\dfrac{l}{KA}\right)}=\dfrac{l}{4KA}$

$$\therefore \frac{H_P}{H_S}=\frac{\dfrac{4l}{3KA}}{\dfrac{l}{4KA}}=\frac{16}{3}$$

17. (b) $\dfrac{Q}{t}=\dfrac{KA(\theta_1-\theta_2)}{l}=\dfrac{0.2\times 10\times 20}{2\times 10^{-3}}=2\times 10^4\ J/\sec$

18. (c) All wavelengths are emitted.

19. (d)

20. (d) $\dfrac{Q_1}{Q_2}=\dfrac{T_1^4}{T_2^4}=\left(\dfrac{273+27}{273+127}\right)^4=\left(\dfrac{300}{400}\right)^4=\dfrac{81}{256}$

21. (b) In first step

$$\frac{62-61}{T}=K\left[\frac{62-61}{2}-30°\right]\Rightarrow\frac{1}{T}=K[81.5] \qquad ...(i)$$

In second step, suppose process takes T' min then

$$\frac{46-45.5}{T'}=K\left[\frac{46-45.5}{2}-30\right]\frac{0.5}{T'}=K[15.75] \qquad ...(ii)$$

On diving equation (i) and (ii) $\dfrac{2T'}{T}=2\Rightarrow T'=T$

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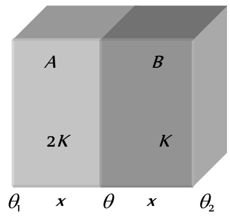
22. (b) Suppose conductivity of layer B is K, then it is $2K$ for layer A. Also conductivity of

combination layers A and B is K

$$= \frac{2\times 2K\times K}{(2K+K)} = \frac{4}{3}K$$



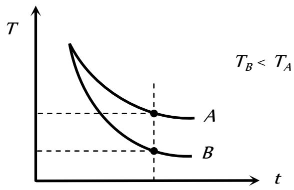
Hence $\left(\frac{Q}{t}\right)_{Combination} = \left(\frac{Q}{t}\right)_A$

$$\Rightarrow \frac{4}{3}\frac{KA\times 60}{2x} = \frac{2K.A\times(\Delta\theta)_A}{x} \Rightarrow (\Delta\theta)_A = 20K$$

23. (b) As we know, Rate of cooling $\propto \frac{1}{\text{specific heat(c)}}$

$\because c_{\text{oil}} < c_{\text{Water}}$

$\Rightarrow$ (Rate of cooling)$_{\text{oil}}$ > (Rate of cooling)$_{\text{Water}}$



It is clear that, at a particular time after start cooling, temperature of oil will be less than that of water.

So graph B represents the cooling curve of oil and A represents the cooling curve of water