TRANSMISSION OF HEAT

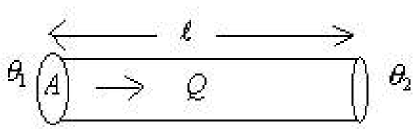
SYNOPSIS

Transmission of heat takes place in three modes.
1) Conduction
2) Convection
3) Radiation

- Due to temperature difference, heat flows from one place to another place.
- Due to potential difference, charge flows from one end to other end of a conductor.
- Due to pressure difference, fluid flows from one place to other.

CONDUCTION

- It is the transmission of heat without the actual movement of the particles of the medium.
- Conduction of heat requires a medium.
- It takes place mainly in solids.
- It takes place in metals due to free electrons.
- Heat transfer in **mercury** takes place by conduction not by convection.
- A substance which is good conductor of heat is also good conductor of electricity.
- In steady state, the temperature at any point or cross-section of the conductor remains constant with respect to time.
- In steady state, the heat received by any cross-section is partly conducted to the next section and partly radiated. i.e no heat is absorbed by the cross-section.
- **Coefficient of Thermal conductivity :**
In steady state the quantity of heat Q flowing through a metal rod of length l and cross-section A in a time t when its ends are at temperature θ_1 and θ_2 $(\theta_1 > \theta_2)$ is given by



$$Q = \frac{KA(\theta_1 - \theta_2)}{l} t$$

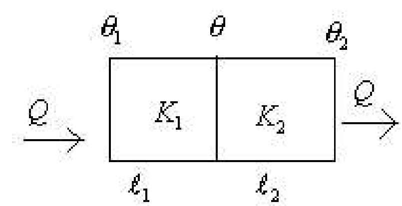
where K is coefficient of thermal conductivity

- K depends on the nature of the metal.
- It is defined as the rate of flow of heat per unit area and per unit temperature gradient in steady state.
- Units of K :
S.I - $Wm^{-1}K^{-1}$
$C.G.S - Cals^{-1}Cm^{-1}C^{-1}$
Dimensional formula - $MLT^{-3}K^{-1}$
- Values of K :
For a perfect conductor $K = \infty$.
For a perfect insulator K= 0
If K value is more, it is good conductor of heat. If K value is less, it is a bad conductor of heat.
- Silver is the best conductor of heat
- If one end of a metal rod is kept in a steam jacket and other end is kept in an ice block, then the amount of ice that melts is

$$m = \frac{KA(\theta_1 - \theta_2)t}{d.L_{ice}}$$

Junction temperature : In steady state when conduction takes place through two layers of composite wall with different thermal conductivities, then

$$\frac{Q}{t} = \frac{K_1 A(\theta_1 - \theta)}{l_1} = \frac{K_2 A(\theta - \theta_2)}{l_2}$$



Junction temperature or Interface temperature

$$\theta = \frac{\frac{K_1\theta_1}{l_1} + \frac{K_2\theta_2}{l_2}}{\frac{K_1}{l_1} + \frac{K_2}{l_2}}$$

$$= \frac{K_1\theta_1 l_2 + K_2\theta_2 l_1}{K_1 l_2 + K_2 l_1}$$

- If $l_1 = l_2 = l$ then

$$\theta = \frac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2}$$

- **Diffusivity :-D**
It is the ratio of thermal conductivity (K) to thermal capacity per unit volume (ms/V) of a material.

$$D = \frac{K}{\frac{ms}{V}} = \frac{K}{\rho s}$$ where 'ρ' is density of material and 's' is its specific heat.

- **Thermal Resistance : R**
  Thermal resistance R of a conductor of length l, cross-section A and conductivity K is given by

$$R = \frac{l}{KA}$$

S.I unit :- KW^{-1}

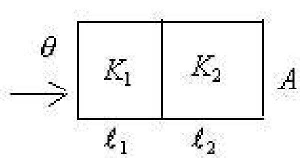
Dimensional formula : $M^{-1}L^{-2}T^{3}K$

Effective conductivity :

- **Series combination :**

(a) If two rods of same cross-sectional area having lengths l_1 and l_2 and conductivities K_1 and K_2 are connected in series, then in steady state conductivity of the combination K is given by

$$\frac{l_1 + l_2}{K} = \frac{l_1}{K_1} + \frac{l_2}{K_2} \rightarrow \left(R = R_1 + R_2\right)$$



$$K = \frac{K_1 K_2 \left(l_1 + l_2\right)}{K_1 l_2 + K_2 l_1}$$

- If $l_1 = l_2 = l$ then

$$K = \frac{2K_1K_2}{K_1 + K_2}$$

(b) If three rods of same cross-sectional area having lengths l_1, l_2, l_3 and conductivities K_1, K_2, K_3 are connected in series, then in steady state, the conductivity of the combination is

$$K = \frac{K_1K_2K_3\left(l_1 + l_2 + l_3\right)}{K_1K_2l_3 + K_2K_3l_1 + K_3K_1l_2}$$

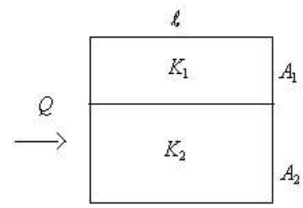
- If $l_1 = l_2 = l_3 = l$, then

$$K = \frac{3K_1K_2K_3}{K_1K_2 + K_2K_3 + K_3K_1}$$

- **Parallel combination :**

(a) If two rods of same length having cross-sectional area A_1, A_2 and conductivities K_1, K_2 are arranged in parallel, then is steady state, the conductivity of the combination is

$$\frac{K\left(A_1 + A_2\right)}{l} = \frac{K_1A_1}{l} + \frac{K_2A_2}{l}$$



$$K = \frac{K_1A_1 + K_2A_2}{A_1 + A_2}$$

- If $A_1 = A_2 = A_2$ then

$$K = \frac{K_1 + K_2}{2}$$

(b) If three rods of same length having cross-sectional areas A_1, A_2, A_3 and conductivities K_1, K_2, K_3 are connected in parallel, then in steady state

$$K = \frac{K_1A_1 + K_2A_2 + K_3A_3}{A_1 + A_2 + A_3}$$

- If $A_1 = A_2 = A_3 = A$, then

$$K = \frac{K_1 + K_2 + K_3}{3}$$

CONVECTION:-

- The process in which heat is transformed from one place to other by actual movement of particles of medium due to difference in density.
- Convection takes place in fluids. It is more predominant in liquids.
- Convection is two types. (1) Natural or Free convection (2) Forced convection.
- If the fluid particles move only due the temperature difference, it is called natural convection.
  Eg: Hot air rises by natural convection. sea breeze, land breeze etc.
- Natural convection can not take place in a gravity free space such as orbiting satellite or freely falling lift.

- If the fluid particles are forced to move by a fan or by a blower or by a pump etc., it is called forced convection.
  Eg: Ventilation in houses.
- The forced convection of blood in our body by the heart helps in keeping the temperature of the body constant.
- **RADIATION:**
  - It is the process of transmission of heat from one place to another without any material medium.
  - It is the fastest process of heat transmission.
  - In this process medium is not heated.
- **THERMAL RADIATION:** The heat energy transferred between the objects without the help of any medium is known as thermal radiation or radiant energy. (or)
  Heat energy transferred by means of electromagnetic waves is Thermal radiation.
- **NATURE AND PROPERTIES OF RADIANT ENERGY:**
  - It consists of long wavelength electromagnetic radiation.
  - The wave length of these waves is nearly 800nm to 4,00,000 nm.(i.e., greater than the wavelength of visible light.)
  - It occupies the infrared region of the electromagnetic spectrum.
  - It can be transmitted through vacuum.
  - These waves propagate in vacuum with a velocity $3 \times 10^8\ ms^{-1}$ like light waves.
  - It obeys laws of reflection, refraction, interference, polarisation and diffraction.
  - The intensity of radiant energy obeys inverse square law.
- **DETECTORS OF RADIANT ENERGY:**
  - To detect radiant energy Bolometer, thermopile, radiomicrometer, pyrometer are used.
  - By using surface Bolometer radiation coming from the surface of a body is measured.
  - By using linear Bolometer, the distribution of energy in a black body spectrum can be explained.
  - Bolometer works on the principle that the resistance changes with temperature.
- **PREVOST'S THEORY OF HEAT EXCHANGES:**
  - Every object emits and absorbs radiant energy at all temperatures except at absolute zero.
  - The energy emitted by a body does not depend on the temperature of the surroundings.
  - The rate of emission increases with the increase in the temperature of the body.
  - If the body emits more energy than absorbed its temperature decreases.
  - If the body absorbs more radiant energy than it emits, its temperature increases.
  - If the body absorbs and emits the equal amount of radiant energy, then its temperature remains constant.
  - If two bodies continuously emit and absorb same amount of energy, then they are in thermo dynamic equilibrium.
- The radiant energy emitted by a body depends on
  a) The nature of the surface. b) Surface area.
  c) Temperature of the body.
- **EMISSIVE POWER (e_λ) :**
  - The amount of energy emitted per second per unit surface area of a body at a given temperature for a given wavelength range $(\lambda \ and \ \lambda + d\lambda)$ is called emissive power.
  - At a given temperature if the radiations emitted have a wave length difference $d\lambda$, then the emissive power is equal to $e_\lambda d\lambda$.
  - S.I unit of emissive power is Wm^{-2} and its dimensional formula is MT^{-3}.
- **EMISSIVITY (e):** The ratio of radiant energy emitted by a surface to radiant energy emitted by a black body under same conditions is called emissivity.
  i) For a perfect black body emissivity $e = 1$.
- **ABSORPTIVE POWER (a_λ) :**
  - At a given temperature, for a given wavelength range, the ratio of energy absorbed to the energy incident on the body is absorptive power.

$$\therefore a_\lambda = \frac{Amount\ of\ radiant\ energy\ absorbed}{Amount\ of\ radiant\ energy\ incident}$$

  - For a perfect black body, the absorptive power, $a_\lambda = 1$.
  - A surface can have different absorptive powers for different wavelengths.
  - Whenever radiant energy is incident on a surface, a part of it is absorbed, a part of it is reflected and the remaining part is transmitted through it.

- **REFLECTING POWER (r):**

$$r = \frac{\text{Amount of radiant energy reflected}}{\text{Amount of radiant energy incident}}$$

- **TRANSMITTING POWER (t):**

$$t = \frac{\text{Amount of radiant energy transmitted}}{\text{Amount of radiant energy incident}}$$

- $a_\lambda + r + t = 1$

  Here 'a_λ' is absorptive power, 'r' is reflecting power and 't' is the transmitting power.

- **PERFECT BLACK BODY:**
  - A body which completely absorbs all the heat radiation incident on it is called a perfect black body.(or) A body which emit the radiation of all wavelengths when at higher temperature is called perfect black body.
  - Ferry's black body and Wien's black body are examples of artificial black bodies.
  - A surface coated with lampblack or platinum black absorbs about 98% of the radiation incident on it.
  - A perfect black body is a good absorber and also a good emitter of heat.
  - The reflecting power of a black body is zero.

- **KIRCHOFF'S LAW:**
  - At a given temperature, for a given wave length range, the ratio of emissive power to absorptive power of a substance is constant.
  - This constant is equal to the emissive power of a perfect black body at the given temperature and wavelength.

    i.e., $\frac{e_\lambda}{a_\lambda} = const = E_\lambda$

    Where 'E_λ' is the emissive power of perfect black body. 'e_λ' and 'a_λ' are emissive and absorptive powers of a given substance respectively.
  - Good absorbers are good emitters.
  - Poor absorbers are poor emitters.

- **APPLICATIONS OF KIRCHOFF'S LAW:**
  - A piece of blue glass absorbs red wavelengths at ordinary temperature. When it is heated strongly and cooled it appears brighter than a piece of red glass.
  - A piece of yellow glass absorbs blue wavelengths at ordinary temperature. When heated in darkroom it appears blue because it emits blue colour.
  - Fraunhoffer lines in solar spectrum can be explained on the basis of Kirchhoff's law. They are absorption lines.
  - Black surfaces are good absorbers and so good emitters but bad reflectors.
  - Highly polished surfaces are bad absorbers and so bad emitters but good reflectors.
  - Cooking vessels are coated black outside because black surface is a good absorber and good emitter.

- **STEFAN'S LAW:**
  - The amount of heat radiated by a black body per second per unit area is directly proportional to the fourth power of its absolute temperature.

    $E \propto T^4 \Rightarrow E = \sigma T^4$.

    Where

    σ = Stefan's constant

    $= 5.67 \times 10^{-8} Wm^{-2}K^{-4}$
  - Dimensional formula of Stefan's constant is $MT^{-3}\theta^{-4}$.
  - Radiant energy emitted by a hot body per second = $eA\sigma T^4$ where e is the emissivity of the hot body, A its surface area, T its absolute temperature and σ the Stefan's constant. (for perfect black body, e = 1)
  - If the surface area of a body is more, it emits more heat energy. Hence it cools quickly.
  - A hot copper cube cools in a lesser time compared to a hot copper sphere of same mass because of least surface area for sphere.
  - Stefan's law holds good when the surrounding medium of the black body is vacuum.

- **STEFAN - BOLTZMANN'S LAW:**

  If a black body at absolute temperature T is surrounded by an enclosure at absolute temperature T_o, then the rate of loss of heat energy by radiation per unit area is given by.

  $E = \sigma(T^4 - T_0^4)$

- For any hot body, $E = \sigma Ae(T^4 - T_0^4)$

  Where 'e' is the emissive power and 'A' is the area of cross-section of the hot body.

- **NEWTON'S LAW OF COOLING:**
  - The rate of cooling of a hot body is directly proportional to the mean excess of temperature of the body above the surroundings, provided the difference in temperature of the body and the surroundings is small.

    $$\frac{d\theta}{dt} = K\left(\frac{\theta_1+\theta_2}{2}-\theta_s\right).$$

    here $\frac{d\theta}{dt}$ = Rate of cooling.

    θ_1, θ_2 are the initial and final temperatures of the body respectively. θ_s is temperature of surroundings and K is the cooling constant.
  - Rate of loss of heat of a hot body due to cooling $\frac{dQ}{dt} = ms\frac{d\theta}{dt}$.

    Here
    m = mass of the body
    s = specific heat of the body
  - specific heat of a liquid can be determined using Newton's law of cooling.
  - If m_1, m_2 and m_3 are masses of the calorimeter, water and liquid, s_1, s_2 and s_3 are the specific heats of the calorimeter, water and liquid and t_1 and t_2 are the times taken by water and liquid to cool from θ_2 to $\theta_1 °c$, then

    $$\frac{m_1s_1+m_2s_2}{m_1s_1+m_3s_3} = \frac{t_1}{t_2}.$$
  - Newton's law of cooling is a law connected with the process of convection.
  - It can be deduced from Stefan - Boltzmann's law of radiation.
  - A cube, a sphere, a circular plate of same material and same mass are heated to the same temperature. Among them the sphere cools at the lower rate because of its least surface area.
  - Out of a rough black surface and polished black surface, the rough black surface emits more radiant energy than the polished black surface.
- **DIATHERMANOUS SUBSTANCES:**
  The substances which allow the heat radiations to pass through them without getting themselves heated are called "diathermanous" substances.
  Ex: air, rock salt, fluorspar.
- **ATHERMANOUS SUBSTANCES:**
  The substances which do not allow the heat radiations to pass through them, but absorb heat and get themselves heated are called "athermanous" substances.
  Ex: glass, moist air, water, wood.
  - Cloudy day is cooler than clear day and cloudy night is warmer than clear night because moist air is athermanous.
  - Green houses are built with glass doors and roofs because glass is "athermanous".

CONCEPTUAL QUESTIONS

1. Metals are good conductors of heat because
   1) They contain large number of free electrons
   2) Their atoms are relatively apart
   3) Their atoms collide frequently
   4) They have reflecting surfaces
2. In steady state
   1) Heat received is partly conducted and partly radiated
   2) Heat is not absorbed
   3) both 1 and 2
   4) All the heat is conducted
3. The process in which rate of transfer of heat maximum is
   1) conduction
   2) convection
   3) radiation
   4) in all these heat is transferred with the same speed
4. Black body spectrum is
   1) continuous absorption
   2) line absorption
   3) continuous emission
   4) line emission
5. Two rods of different materials having different lengths and same cross sectional areas are joined end to end in a straight line. The free ends of this compound rod are maintained at different temperatures. The temperature gradient in each rod will be
   1) same 2) zero
   3) directly proportional to thermal conductivity of rod
   4) inversely proportional to thermal conductivity of the rod
6. A piece of paper wrapped tightly on a wooden rod is found to get charred quickly when held over a flame compared to similar piece when wrapped on a brass rod. This is because
   1) brass is good conductor and wood is a bad conductor of heat
   2) brass is a bad conductor of heat
   3) wood contains large number of free electrons
   4) wood is a good conductor of heat

7. When heat flow through a wire of uniform cross section under steady state
1) Temperature gradient is same every where
2) Temperature at a particular point remains same
3) Rate of heat flow is same at all cross sections
4) All the above

8. On heating one end of a rod the temperature of the whole rod will be uniform when
1) $k=1$ 2) $k=0$ 3) $k=100$ 4) $k=\infty$

9. For an ideal conductor thermal resistance is
1) unity 2) infinity 3) zero 4) 1000

10. A metal rod of area of cross section A has length l and coefficient of thermal conductivity K. The thermal resistance of the rod is
1) $\frac{l}{KA}$ 2) $\frac{Kl}{A}$ 3) $\frac{KA}{l}$ 4 $\frac{A}{Kl}$

11. Thermal conductivity of a metal rod depends on
1) area of cross section
2) temperature gradient
3) time of flow of heat
4) all the above

12. Coefficient of thermal conductivity
1) depends upon nature of the material of the body
2) is independent of dimensions of the body
3) both 1 and 2
4) only 1

13. By which of the following methods could a cup of hot tea lose heat when placed on metallic table in a class room
a) conduction b) convection
c) radiation d) evaporation of liquid
1) a, b 2) b, c 3) a,b,c 4) a,b,c,d

14. If the end of metal rod is heated, then the rate of flow of heat does not depend on
1) area of the end of the rod
2) mass of the rod 3) time
4) temperature gradient

15. It is hotter at same distance over the flames than in front of it because
1) air conducts heat upwards only
2) heat is radiated upwards only
3) convection of heat occurs upwards only
4) heat is radiated downwards only

16. In the following solids thermal conductivity is maximum for
1) copper 2) aluminium
3) gold 4) silver

17. Which of the following combination of properties would be most desirable for a cooking vessel.
1) High specific heat and low thermal conductivity
2) Low specific heat and high thermal conductivity
3) High specific heat and high thermal conductivity
4) Low specific heat and low thermal conductivity

18. For a perfect insulator coefficient of thermal conductivity is
1) zero 2) infinite
3) one 4) two

19. Radiant energy depends upon
1) nature of the surface of the body
2) surface area of the body
3) temperature of the body
4) All the above

20. The correct statement of the following:
A) Water can be boiled inside the artificial satellite by convection
B) Heavy liquid can be boiled in artificial satellite by convection
1) Both statements are correct
2) Both statements are wrong
3) A is correct but B is wrong
4) B is correct but A is wrong

21. The correct statement of the following
A) Black body radiation is white
B) Emissive power of a body is proportional to its absorptive power
1) statement A is correct
2) statement B is correct
3) Both are correct
4) Both are wrong

22. A sphere, a cube and a thin circular plate of same material having same mass are initially heated to $200^0 C$. The body that cools faster is
1) circular plate 2) sphere
3) cube 4) all of these

23. The thermal radiations are similar to
1) X-rays 2) cathode rays
3) $\alpha-$rays 4) all

24. The bulb of a thermometer is spherical and that of another is cylindrical. Equal quantity of mercury is filled in them. Then
1) thermometer with spherical bulb will respond quickly
2) thermometer with cylindrical bulb will respond slowly
3) thermometer with spherical bulb will respond slowly
4) thermometer with cylindrical bulb will respond quickly

25. Temperature is analogous to
1) charge 2) potential difference
3) electric field strength) force

26. The temperature at which a black body ceases to radiate energy is
1. 0 K 2. 273 K
3. -273 K 4. at all temperatures

27. The intensity of energy radiated by a hot body at a distance (r) from it varies as
1. r^2 2. $\frac{1}{r^2}$ 3. $\frac{1}{r^4}$ 4. $\frac{1}{r^3}$

28 When a body has the same temperature as that of its surroundings :
1. It does not radiate heat
2. It radiates same quantity of heat as it receives from the surroundings
3. It radiates less quantity of heat as it receives from the surroundings
4. It radiates more quantity of heat as it receives from the surroundings.

29 One half of slab of ice is covered with black cloth and the other half with white cloth. This is then placed in sunlight. After some time the pieces of cloth are removed. Then
1. Ice has melted equally under both the pieces
2. More ice has melted under white cloth
3. More ice has melted under black cloth
4. It will depend on the medium in which ice is placed

30 Compared to a person with white skin another person with dark skin, will experience :
1. Less heat and more cold
2. More heat and more cold
3. More heat and less cold
4. Less heat and less cold

31 Which of the following statements is wrong
1. Rough surfaces are better radiators than smooth surfaces
2. Highly polished mirrorlike surfaces are very good radiators
3. Black surfaces are better absorbers than white ones
4. Black surfaces are better radiators than white ones

32 The absorptivity of Lamp black and platinum black is
1. 0.91 2. 0.98 3. 1.00 4. 0.99

33 The physical factor distinguishes thermal radiation from visible light is
1. Wave length 2. Pressure
3. Temperature 4. Amplitude

34 Absorptive power of a white body is
1. 1 2. 0 3.-1 4. ∞

35. A black body emits
1. Radiations of all wave lengths
2. No radiation
3. Radiation of single wave length
4. Radiation of selected wave length

36. The best laboratory approximation to an ideal black body is
1. A lump of charcoal heated to high temperature
2. A glass surface coated with coal tar
3. A metal coated with black dye
4. A hollow enclosure blackened inside with suth and have a small hole

37. If we place our hand below a lighted electric bulb. We feel warmer because of
1. convection 2. radiation
3. conduction 4. 1 and 2

38. The absorptive power of a perfectly black body is
1. zero 2. 5
3. 1 4. infinite

39. Heating effect of the incoming solar radiation is maximum at local noon because
1. Atmospheric absorption is zero
2. Sun's rays travel through minimum air thick-ness
3. Solar rays are vertical to the ground
4. Outgoing radiation is minimum

40. A black body does not
1. Emit radiation 2. Reflect radiation
3. Absorb radiation 4. All the above

41. If the amount of heat energy received per unit area from the sun is measured on Earth, Mars and Jupiter, it will be
1. The same for all
2. In decreasing order Jupiter, Mars, Earth
3. In increasing order Jupiter, Mars, Earth
4. In decreasing order Mars, Earth, Jupiter

KIRCHOFF'S LAW

42. The colour of a star is a measure of its
1. Age 2. Temperature
3. Size 4.Distance from the earth

43. A polished metal plate with a rough black spot on it is heated to about 1400K and quickly taken into a dark room. Then
1. The spot will appear brighter than the plate
2. The spot will appear darker than the plate
3. Heat conduction is easier downward
4. It is easier and more convenient to do so

44. If p calorie of heat energy is incident on a body and absorbs q calories, its coefficient of absorption is
1. p/q 2. p - q
3. q/p 4. q + p

45. A piece of red glass when heated in dark to red hot state will be
1. White 2. Red
3.Green 4. Invisible

46. A piece of blue glass when heated to a high temperature and a piece of red glass at room temperature are taken inside a dimly-lit room. Then:
1. The blue piece will look blue and the red piece will look red as usual
2. The red piece will look brighter red and the blue piece will look ordinary blue
3. The blue piece will look brighter red compared to the red piece
4. Both the piece will look equally red

47. Four pieces of iron are heated to different temperatures. The colours exhibited by them are respectively red, yellow, orange and white respectively. The one that is heated to the highest temperature will exhibit the colour
1. White 2. Yellow
3. Red 4. Orange

48. A star which appears blue will be
1. Much hotter than the sun
2. Colder than the Sun
3. As hot as the Sun
4. At-273^0 C

49. If a star is colder than the Sun it appears
1. Yellow 2. Red
3. Blue 4. Violet

50. A red-glass piece is heated until it glows in dark. The colour of the glow will be
1. Red 2. Orange
3. Green 4. Violet

51. At a given temperature, the ratio between emissive power and absorptive power is same for all bodies and is equal to the emissive power of black body. This statement is called
1. Newton's Law 2. Planck's law
3. Kirchoff's law 4. Wein's law

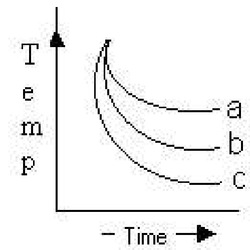
STEFAN'S LAW

52. If the sun become twice hotter, it will radiate
1. Energy sixteen times larger
2. Predominantly in the infrared
3. Predominantly in the ultra violet
4. Energy sixteen times smaller

53. Three identical spheres of different materials iron, gold and silver are at the same temperature. The one that radiates more energy is
1.Gold 2.Silver
3.Iron 4.All radiate equally

NEWTON'S LAW OF COOLING

54. Cooling graphs are drawn for three liquids a,b and c. The specific heat is maximum for liquid



1. a 2.b
3.c 4. for all the three a,b and c

55. A solid copper sphere of radius R and a hollow copper sphere of outer radius R are heated to the same temperature and allowed to cool in the same surroundings. Then
1. Solid sphere cools faster
2. Hollow sphere cools faster
3. Both cool equally
4. Cannot be decided

56. The rate of cooling of a body is
1. Independent of the nature of the surface of the body
2. Independent of the area of the body
3. Dependent on the excess of temperature of the body above that of the surroundings.
4. Independent of the temperature of the surroundings.

57. A cube, a sphere and a circular plate made of same material and having same mass are heated to same high temperature. The body that cools at the least rate when left in air at room temperature is
1. Sphere 2. Cube
3. Circular plate 4. All at the same rate

58. Newton's law of cooling is applied in laboratory for the determination of the
1. Specific heat of gases
2. Latent heat of gases
3. Specific heat of liquids
4. Latent heat of liquids

59. Newton's law of cooling is a special case of
1. Kirchoff's law 2. Wein's law
3. Stefan-Boltzmann's law 4. Planck's law

60. The amount of heat energy radiated per second by a surface depends upon:
1. Area of the surface
2. Difference of temperature between the surface and its surroundings
3. Nature of the surface
4. All the above

61. Four identical copper cylinders are painted. If they are all heated to the same temperature and left in vacuum which will cool most rapidly.
1. Painted shiny white 2. Painted rough black
3. Painted shiny black 4. Painted rough white

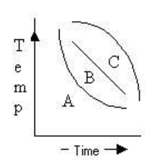
62. If T_B and T_s are the temperatures of the body and the surroundings and $T_B - T_S$ is of very high value, then the rate of cooling in natural convection is proportional to

1. ${T_B}^4$ 2. ${T_S}^4$ 3 $(T_B - T_S)^{\frac{5}{4}}$ 4. $\left(T_B^{\frac{5}{4}} - T_S^{\frac{5}{4}}\right)$

63. Newton's law of cooling is a law connected with
1. Conduction 2. Convection
3. Radiation 4. All of these

64. Newton's law of cooling holds good provided the temperature difference between the body and the surroundings is
1. Large 2. Small
3. Very large 4. Any value

65. A block of steel heated to 100^0C is left in a room to cool. Which of the curves shown in the figure, represents the correct behaviour



1. A 2. B 3. C 4. A and C

66. Let there be four articles having colours blue, red, black and white. When they are heated together and allowed to cool, the article that cool earlier is
1. Blue 2. Red
3. Black 4. White

NEW PATTERN QUESTIONS

1) TRUE OR FALSE TYPE

67. A) Heat transfer by conduction and convection require a material medium.
B) Heat transfer by radiation doesn't effect the medium the through which passes.
1) both A and B are true
2) A is true but B is false
3) B is true but A is false
4) both A and B are false

68. A) A body of low thermal capacity gets heated or cooled quickly.
B) Good emitters are bad reflectors.
1) both A and B are true
2) A is true but B is false
3) B is true but A is false
4) both A and B are false

69. In the following, which statement is correct
a) A hot body emits hot radiations only.
b) A cold body absorbs the radiations only.
c) A cold body emits cold radiations only.
d) All the bodies emits and absorbs radiations simultaneously
1) a 2) b
3) c 4) d

70. A) Greater the mass of radiating body slower will be cooling
B) Greater the temperature of the surrounding lower will be cooling
1) both A and B are true
2) A is true but B is false
3) B is true but A is false
4) both A and B are false

2) MATCHING TYPE

71. Match the following:

a) coefficient of thermal conductivity e) $Wm^{-2}K^{-4}$
b) temperature gradient f) $Wm^{-1}K^{-1}$
c) Stefan's constant g) mK
d) Wein's constant h) Km^{-1}

1) $a-h, b-e, c-g, d-f$
2) $a-f, b-h, c-e, d-g$
3) $a-e, b-h, c-f, d-g$
4) $a-g, b-h, c-e, d-f$

72. Match the following

a) Thermal resistance e) $MT^{-3}K^{-4}$
b) Stefan's constant f) $MLT^{-3}K^{-1}$
c) Wein's constant g) $M^{-1}L^{-2}T^{3}K$
d) coefficient of thermal conductivity h) M^0LK

1) $a-e, b-g, c-h, d-f$
2) $a-f, b-h, c-e, d-g$
3) $a-g, b-e, c-h, d-f$
4) $a-g, b-h, c-e, d-f$

73. Match the following

List - I	List - II
a) Fraunhofer lines	e) Newton's law of cooling
b) Black body	f) Kirchhoff's law
c) Specific heat of a liquid	g) Ferry
d) Thermal conductivity of a metal	h) Searle's apparatus

1) $a \to g; b \to f; c \to e; d \to h$
2) $a \to f; b \to g; c \to e; d \to h$
3) $a \to e; b \to h; c \to g; d \to f$
4) $a \to h; b \to e; c \to g; d \to f$

3) ORDER ARRANGING TYPE

74. I: A sphere II: A cube III: A thin circular plate all made of the same material having the same mass are initially heated to 200^0C. Identify the order in which the objects cool faster when left in air at room temperature
1) III,II and I 2) II, I and III
3) I, II and III 4) II, III and I

75. A beaker full of hot water is kept in a room and it cools from
I) 90^0C to 80^0C in t_1 sec.
II) 80^0C to 70^0C in t_2 sec.
III) 70^0C to 60^0C in t_3 sec.
IV) 60^0C to 50^0C in t_4 sec.
If the room temperature is 10^0C. Identify the order in which the times of cooling increases
1) IV,III,II & 1 2) I,III,IV & II
3. I, II,III & IV 4) III, I, II & IV

4) ASSERTION & REASON TYPE

76. **Assertion (A):** Woolen clothes keep the body warm in winter
Reason (R): Air is bad conductor of heat
1) Both A and R are true,
2) Both A and R are false
3) Both A and R are true, R is correct explanation of A
4) Both A and R are true, R is not correct explanation of A

77. **Assertion (A):** The radiation from the sun surface varies as the fourth power of its absolute temperature.
Reason (R): Sun is not a black body
1) Both A and R are true,
2) Both A and R are false
3) Both A and R are true, R is correct explanation of A
4) Both A and R are true, R is not correct explanation of A

78. **Assertion (A):** Thermal radiations are electromagnetic radiation with wave lengths greater than visible light.
Reason (R): Thermal radiations can propagate through vacuum
1) both A and R are true and the R is correct explanation of the A
2) both A and R are true, but R is not correct explanation of the A
3) A is true, but the R is false.
4) A is false, but the R is true.

79. **Assertion (A):** Two metallic spheres of same size , one of copper and other of aluminium heated to the same temperatures, will cool at the same rate when they are suspended in the same enclosure.
Reason (R): The rate of cooling of a body is directly proportional to the excess of temperature of the body over the surroundings.
1) both A and R are true and the R is correct explanation of the A
2) both A and R are true, but R is not correct explanation of the A
3) A is true, but the R is false.
4) A is false, but the R is true.

KEY

01) 1	02) 3	03) 3	04) 3	05) 4
06) 1	07) 4	08) 4	09) 3	10) 1
11) 4	12) 3	13) 4	14) 2	15) 3
16) 4	17) 2	18) 1	19) 4	20) 2
21) 3	22) 1	23) 1	24) 4	25) 2
26) 1	27) 2	28) 2	29) 3	30) 2
31) 2	32) 2	33) 1	34) 2	35) 1
36) 4	37) 2	38) 3	39) 2	40) 2
41) 3	42) 2	43) 1	44) 3	45) 4
46) 3	47) 1	48) 1	49) 2	50) 3
51) 3	52) 1	53) 4	54) 1	55) 2
56) 3	57) 1	58) 3	59) 3	60) 4
61) 2	62) 3	63) 2	64) 2	65) 1
66) 3	67) 1	68) 1	69) 4	70) 2
71) 2	72) 3	73) 2	74) 1	75) 3
76) 3	77) 4	78) 2	79) 1	

NUMERICAL PROBLEMS
LEVEL- I

1. In a steady state of heat conduction the temperature of the ends A and B of a rod 100cm long are 0^0 C and $100^0 C$. The temperature of the rod at a point 60cm distant from the end A is
1) $O^0 C$ 2) $40^0 C$
3) $60^0 C$ 4) $100^0 C$

2. In the steady state the two ends of a metre rod are at $30^0 C$ and $20^0 C$, the temperature at the 40th cm from the end at higher temperature is
1) $22^0 C$ 2) $26^0 C$
3) $25^0 C$ 4) $24^0 C$

3. An aluminium meter rod of area of cross section $4cm^2$ with $K = 0.5$ cal /gm-^{0}C is observed that at steady state 360 cal of heat flows per minute. The temperature gradient along the rod is
1) $3^0 C/cm$ 2) $6^0 C/cm$
3) $12^0 C/cm$ 4) $20^0 C/cm$

4. The amount of heat flowing in 10 seconds through a copper rod of length 50cm and area $15cm^2$ when the ends are at $100^0 C$ and $0^0 C$ is $\left(K = 380 Wm^{-1}K^{-1}\right)$
1) $1140 J$ 2) $1260 J$
3) 1520 J 4) 1380 J

5. The quantity of heat flowing for 10 seconds through a rod of length 40cm, area $50cm^2$ is 200J. If the temperature difference at the ends of the rod is $80^0 C$, the coefficient of thermal conductivity of the rod in $Wm^{-1}K^{-1}$ is
1) 20 2) 60
3) 80 4) 120

6. One end of metal bar of area of cross section $5cm^2$ and 25 cm in length is in steam other in contact with ice, the amount of ice melts in one minute is (K = 0.8 cal /gm-^{0}C)
1) 16 gm 2) 12 gm
3) 24 gm 4) 36 gm

7. Which of the following rods made of same material will conduct more heat in a given time when their ends are maintained at the same temperatures difference.
1) $l = 1m, r = 1cm$ 2) $l = 2m, r = 2cm$
3) $l = 3m, r = 1cm$ 4) $l = 100cm, r = 2cm$

8. The temperature of hot and cold ends of a 20cm long rod in thermal steady state are at $100^0 C$ and $20^0 C$ respectively. The temperature at the centre of the rod is
1) $30^0 C$ 2) $40^0 C$
3) $50^0 C$ 4) $60^0 C$

9. 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 same, then the ratio of amounts of heat conducted through them per unit time will be
1) 1 :1 2) 2 : 1
3) 1 : 4 4) 1 : 8

10. A cylindrical rod with one end in a steam chamber and the other end is in ice. It is found that 1gm of ice melts per second. If the rod is replaced by another one of same material double the length and double area of cross section, The mass of ice that melts per second is
1) 2 gm 2) 4 gm
3) 1 gm 4) 0.5 gm

11. The area of glass of a window of a room is $10m^2$ and thickness is 2mm. The outer and inner temperatures are $40^0 C$ and $20^0 C$ respectively. Thermal conductivity of glass in S.I is 0.2. The heat flowing in the room per second will be
1) $3\times10^4 J$ 2) $2\times10^4 J$
3) $30 J$ 4) $45 J$

12. Three bodies A,B,C are at -27^{0}C, 0^{0}C, 100^{0}C respectively. The body which does not radiate heat is
1. A
2. B
3. C
4. All the bodies radiate heat

13. A black body at a temperature 400K placed in an enclosure at 300K has cooling rate r. If the temperature of the body were 800K and placed in the same enclosure, the cooling rate will be approximately
1. 2r 2. 16r
3. 23r 4. 8r

14. Two spherical black bodies of radii r_1 and r_2 are with surface temperatures T_1 and T_2 respectively radiate the same power. r_1 / r_2 must be equal to
1. $(T_1/T_2)^2$ 2. $(T_2/T_1)^2$
3. $(T_1/T_2)^4$ 4. $(T_2/T_1)^4$

15. Two spheres of the same material have radii 1m and 4m and temperature 4000K and 2000K respectively. The energy radiated per second by the first sphere is :
1. Greater than that of the second
2. Less than that of the second
3. Equal in both cases
4. The information is incomplete to draw any conclusion

16. Certain substance emits only the wavelengths λ_1, λ_2, λ_3 and λ_4 when it is at higher temperature. When this substance is at a lower temperature, it will absorb only the following wavelengths
1. λ_1 2. λ_2
3. λ_1 and λ_2 4. $\lambda_1, \lambda_2, \lambda_3$ and λ_4

17. Cadmium salt when put into a bunsen flame gives a red colour to the flame. If white light from a tungsten filament lamp is made to pass through a bulb containing cadmium vapour, the transmitted light will be
1. Red 2. White light
3. Blue
4. White light without the red part

18. Two objects A & B have exactly the same shape and are radiating the same power. If their emissivities are 0.1 and 0.9, the ratio of their temperatures is.
1. $\sqrt{3}:1$ 2. $1:\sqrt{3}$
3. 3 : 1 4. 1 : 3

19. A tungsten filament lamp of power 625 watt is at 2227^0C. The emissivity of the filament is 0.16. If σ = 6 x 10^{-8} $Wm^{-2}K^{-4}$, the surface area of the filament is nearly
1. $16m^2$ 2. 16.67 x 10^{-4} m^2
3. 625 x $10^{-4}m^2$ 4. 1667 m^2

20. Two black bodies at 327^0C and 627^0C are suspended in an environment at 27^0C. The ratio of their emissive powers is
1. 15 : 8 2. 16 : 3
3. 3 : 16 4. 5 : 8

21. The radiant power of a furnace of surface area of 0.6 m^2 is 34 KW. The temperature of the furnace is nearly [σ = 5.7 x 10^{-8} $Wm^{-2}K^{-4}$]
1. 3400 K 2. 1012 K
3. 1000 K 4. 5700 K

22. The radiant energy emitted by a perfect blackbody at 400K per unit area per second is
1. 5700 J 2. 1459 J
3. 256 J 4. 1000 J

23. A black body at 127^0C emits the energy at the rate of 10^6 J/m^2 s. The temperature of a black body at which the rate of energy emission is 16×10^6 J/m^2 s is
1. 508^0C 2. 273^0C
3. 400^0 C 4. 527^0C

24. The rate of radiation from a black body at 0^0C is E. The rate of radiation from this black body at 273^0C is
1. 2E 2. E/2
3. 16 E 4. E/16

25. An object is at a temperature of 400^0C. The temperature at which it can radiate energy twice as faster (Neglect the temperature of surroundings) is
($2^{\frac{1}{4}}$ = 1.189)
1. 800 K 2. 673 K
3. 500 K 4. 400 K

26. A body cools from 70^0C to 60^0C in 8 minute. The same body cools from 60^0C to 50^0C in
1. 8 minute
2. less than 8 minute
3. More than 8 minute
4. 1 or 2 or 3 depending on the specific heat of the body

KEY

01) 3	02) 2	03) 1	04) 1	05) 1
06) 2	07) 4	08) 4	09) 4	10) 3
11) 2	12) 4	13) 3	14) 2	15) 3
16) 4	17) 4	18) 1	19) 2	20) 3
21) 3	22) 2	23) 4	24) 3	25) 1
26) 3				

HINTS

2. $$\frac{\theta_1-\theta_2}{L}=\frac{\theta-\theta_2}{1}$$

4. $$Q=\frac{KA(\theta_1-\theta_2)t}{1}$$

6. $$Q=mL=\frac{KA(\theta_1-\theta_2)t}{1}$$

7. $$Q\propto\frac{r^2}{1}$$

13. $$\frac{E_1}{E_2}=\frac{T_{B_1}{}^4-T_s{}^4}{T_{B_2}{}^4-T_s{}^4}$$

15. $$\frac{E_1}{E_2}=\left(\frac{r_1}{r_2}\right)^2\left(\frac{T_1}{T_2}\right)^4$$

19. $A = \frac{E}{e\sigma T^4}$

20. $\frac{E_1}{E_2} = \frac{T_{B_1}^{\ 4} - T_s^{\ 4}}{T_{B_2}^{\ 4} - T_s^{\ 4}}$

LEVEL-II

1. The temperature gradient in a rod of 0.5m length is $80^0 C/m$. If the temperature of hotter end of the rod is $30^0 C$, then the temperature of colder end is
   1) 0^0 2) $-10^0 C$
   3) $10^0 C$ 4) $40^0 C$
2. Two metal plates of same area and thickness l_1 and l_2 are arranged in series. If the thermal conductivities of the materials of the two plates are k_1 and k_2. The thermal conductivity of the combination is
   1) $\frac{2k_1k_2}{k_1+k_2}$ 2) $\frac{k_1+k_2}{2}$
   3) $\frac{k_1k_2(l_1+l_2)}{k_1l_2+k_2l_1}$ 4) k_1+k_2
3. Two metal rods of same length and areas A_1 and A_2 are arranged in parallel. If the thermal conductivities of the materials are k_1 and k_2 the effective thermal conductivity of the combination is
   1) $\frac{2k_1k_2}{k_1+k_2}$ 2) $\frac{k_1+k_2}{2}$
   3) $\frac{k_1A_1+k_2A_2}{A_1+A_2}$ 4) $\frac{k_1k_2(A_1+A_2)}{k_1A_2+k_2A_1}$
4. Two walls of thickness l_1 and l_2 and thermal conductivities k_1 and k_2 are in contact. In the steady state, if the temperature at the outer faces are T_1 and T_2, the temperature at the common wall is
   1) $\frac{k_1T_1l_2+k_2T_2l_1}{k_1l_2+k_2l_1}$ 2) $\frac{k_1T_1+k_2T_2}{l_1+l_2}$
   3) $\left(\frac{k_1l_1+k_2l_2}{T_1+T_2}\right)T_1T_2$ 4) $\frac{k_1l_1T_1-k_2l_2T_2}{k_1l_1+k_1l_2}$
5. Two vessels of different materials are similar in size in every respect. The same quantity of ice filled in them gets melted in 20 minute and 40 minute respectively. The ratio of thermal conductivities of the materials is
   1) 5 : 6 2) 6 : 5
   3) 3 : 1 4) 2 : 1
6. If the radius and length of a copper rod are doubled, the rate of flowing heat along the rod increases to
   1) 4 times 2) 2 times
   3) 8 times 4)16 times
7. Two hollow spheres of same material one with double the radius of the other and double the thickness of the other filled with ice, The ratio of times in which ice gets melted in the two spheres is
   1) 2 :1 2) 1 : 2
   3) 4 : 1 4) 1 : 4
8. Two hollow spheres of same thickness are filled with ice. The ratio of their diameter is 1 : 2 and the ratio of thermal conductivities of the materials is 2 : 3. The ratio of times in which the ice gets melted in the two spheres is
   1) 3 : 4 2) 4 : 3
   3) 3 : 8 4) 8 : 3
9. Two hollow metal spheres with radii in the ratio 1 : 2 and ratio of thickness 2 : 3 are filled with ice. If the ratio of times taken for the ice to completely melt is 2 : 3, the ratio of their thermal conductivities is
   1) 1 : 4 2) 3 : 8
   3) 1 : 2 4) 2 : 1
10. A rod is of 40 cm in length and has a temperature difference of $80^0 C$ at its two ends. Another rod B is of length 60 cm and has a temperature difference $90^0 C$, but has 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
    1) 3 : 4 2) 4 : 3
    3) 1 : 2 4) 2 : 1
11. Arrange the following rods of same material in an increasing order of rate of flow of heat when they have equal difference of temperature between their ends
    a) $l = 2m,\ r = 2cm$ b) $l = 4m,\ r = 2cm$
    c) $l = 2m,\ r = 1cm$ d) $l = 2m,\ r = 4cm$
    1) a, b, c, d, 2) c, b, a, d
    2) d, a, b, c 4) b, c, d, a

12. Two cylindrical rods of the same substance have diameters d_1 and d_2. The amounts of heat conducted by these two rods, for same temperature difference between two ends will be equal if their lengths are related by

1) $\frac{l_1}{l_2} = \frac{d_1}{d_2}$ 2) $\frac{l_1}{l_2} = \left(\frac{d_1}{d_2}\right)^2$

3) $\frac{l_1}{l_2} = \frac{d_2}{d_1}$ 4) $\frac{l_1}{l_2} = \left(\frac{d_2}{d_1}\right)^2$

13. Two rods of length l and $2l$ thermal conductivities $2K$ and K are connected end to end. If cross sectional areas of two rods are equal, then equivalent thermal conductivity of the system is

1) $\left(5/6\right)K$ 2) 1.5K

3) 1.2 K 4) $\left(8/9\right)K$

14. A wall has two layers A and B, each made of different material. Both the layers have the same thickness. The thermal conductivity of material of A is twice that of B. Under thermal equilibrium, the temperature difference across the wall is 42^0C. The temperature difference across the layer A is

1) 8^0C 2) 14^0C

3) 18^0C 4) 24^0C

15. Two rods of same length and cross sections are joined end to end. Their thermal conductivities are in the ratio 2 : 3. If the free end of the first rod is at 0^0C and free end of the second rod is at 100^0C, the temperature at the junction of the two rods after attaining steady state is

1) 33.33^0C 2) 40^0C

3) 50^0C 4) 60^0C

16. Two metal plates of same area and ratio of thickness 1 : 2 are having ratio of thermal conductivities 1 : 2 are in contact. If the free sides of the first plate is maintained at -20^0C and the free side of the other plate is maintained at $+40^0C$, the temperature of the common surface after attaining steady state is

1) 0^0C 2) -10^0C

3) 10^0C 4) 20^0C

17. A wall has two layers A and B, each of same thickness and same area of cross-section but made of different materials. The thermal conductivity of A is three times that of B. The temperature difference across the wall is 20^0C. In thermal equilibrium

a) the temperature difference across the layer A is 15^0C

b) the temperature difference across the B is 15^0C

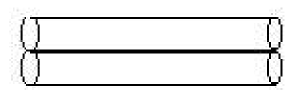
c) the rate of flow of heat across A is more than across B.

d) the rate of flow of heat across A and B are same

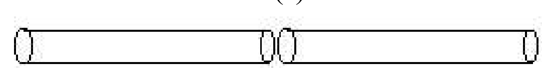
1) a,b correct 2) b, c correct

3) c, d correct 4) b, d correct

18. Two rods of same lengths, radii and material transfer a given amount of heat in 12 second when they are joined as shown in the figure (a). But when they are joined as shown in figure (b), then they will transfer same heat in same conditions in



(a)



(b)

1) 24 sec 2) 13 sec

3) 15 sec 4) 48 sec

19. Thermal conductances of two slabs of equal length are 2 and 3 units respectively. If they are joined in series. The conductance of the combination is

1) 1 unit 2) 5 units

3) 2.4 units 4) 1.2 units

20. A vessel full of hot water is kept in a room and it cools from 80^0C to 75^0C in T_1 minutes, from 75^0C to 70^0C in T_2 minutes and from 70^0C to 65^0C in T_3 minutes. Then

1. $T_1=T_2=T_3$ 2. $T_1>T_2>T_3$

3. $T_1<T_2=T_3$ 4. $T_1<T_2<T_3$

21. Two hot copper spheres of radii in the ratio 2 : 3 are kept in an evacuated enclosure. If each sphere is initially at a temperature 10^0C above that of the enclosure, the rates of loss of heat of the spheres will be in the ratio of

1. 4 : 9 2. 9 : 4

3. 2 : 3 4. 3 : 2

22. A hot body is placed in cold surroundings. Its rate of cooling is 3^0C per minute when its temperature is 70^0C and 1.5^0C per minute when its temperature is 50^0C it rate of cooling when its temperature is 40^0C.

1. 0.25^0C / min   2. 0.5^0C / min
3. 0.75^0C / min   4. 1^0C / min

23. Two electric bulbs have filaments of lengths L and 2 L, diameters 2d and d and emissivities 3e and 4e. If their temperatures are in the ratio 2 : 3, their powers will be in the ratio of

1. 8 : 27   2. 4 : 27
3. 8 : 3   4. 4 : 9

24. If the absolute temperature of a black body is doubled the percentage increase in the rate of loss of heat by radiation is

1. 15%   2. 16%
3.1600%   4. 1500%

25. If the absolute temperature of a black body is doubled the maximum energy density

1. Increases to 16 times
2. Increases to 32 times
3. Increases to 31 times
4. Decreases to 32 times

26. Two bodies have thermal capacities in the ratio 3 : 4 and the rates of loss of heat in the ratio 3 : 5. Their rates of cooling will be in the ratio of

1. 9 : 20   2. 4 : 5
3. 5 : 4   4. 1 : 1

27. 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 double, the power received by the foil will be :

1. 16P   2. 4P
3. 2P   4. P

28. The temperature of a black body is increased by 50%. The amount of radiation emitted by the body increases by :

1.50%   2.100%
3. 225%   4.406.25%

29. Two perfectly conducting spheres of the same metal have radii 3cm and 6cm respectively and are 10^0C and 15^0C hotter than the surroundings. The ratio of loss of heat of the spheres is

1. 1 : 6   2. 4 : 3
3. 4 : 9   4. 1 : 16

30. A body takes 4 minute to cool from 100^0C to 70^0C. The time taken by it to cool from 70^0C to 40^0C in a room with temperature 15^0C is nearly

1. 4 minute   2. 5 minute
3. 6 minute   4. 7 minute

31. Two spheres of the same metal have radii 1m and 4m and temperature 4000K and 2000K respectively. The ratio of the energy radiated per second by the first to the second is _______.

1. 1:1   2. 1:2
3. 2:1   4. 1:4

32. A small hole in a furnace acts like a black body. Its area is $1cm^2$, and its temperature is the same as that of the interior of the furnace, 1727^0c. The energy radiated out of the hole per second is nearly

1. 79 J   2. 60 J
3. 91J   4. 104 J

33. If the temperature of a hot body is raised by 0. 5% then the heat energy radiated would increase by

1. 0.5%   2. 1.0%
3. 1.5%   4. 2.0%

34. The emissive power of a sphere of radius 5cm coated with lamp black is $1500Wm^{-2}$. The amount of energy radiated per second is.

1. 15.7 J   2. 3.14 J
3. 47.10 J   4. 4.71 J

35. At a particular temperature and wavelength, the spectral emissive power and monochromatic absorptive power of a body are 10 and 8 units respectively. The emissive power of a black body at the same temperature will be

1. 1 unit   2. 1.25 unit
3. zero   4. Infinity

KEY

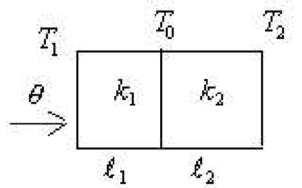
01) 2	02) 3	03) 3	04) 1	05) 4
06) 2	07) 3	08) 1	09) 3	10) 1
11) 2	12) 2	13) 3	14) 2	15) 4
16) 3	17) 4	18) 4	19) 3	20) 4
21) 1	22) 3	23) 2	24) 4	25) 2
26) 2	27) 2	28) 4	29) 1	30) 4
31) 1	32) 3	33) 3	34) 1	35) 2

HINTS

2. $\frac{l_1 + l_2}{K} = \frac{l_1}{k_1} + \frac{l_2}{k_2}$

3. $K\left(A_1 + A_2\right) = k_1 A_1 + k_2 A_2$

4. $\frac{k_1\left(T_1 - T_0\right)}{l_1} = \frac{k_2\left(T_0 - T_2\right)}{l_2}$



5. $k \propto \frac{1}{t}$

7. $mL = \frac{KA(\theta_1-\theta_2)t}{l}, m = \frac{4}{3}\pi r^3 \rho$

$A = \pi r^2$

10. $\frac{\theta}{t} = \frac{KA(\theta_1-\theta_2)}{l}$

13. $\frac{l_1+l_2}{K} = \frac{l_1}{k_1} + \frac{l_2}{k_2}$

14. $k\Delta\theta =$ constant

15. $k\Delta\theta =$ constant or when $l_1 = l_2$

$\theta = \frac{k_1\theta_1 + k_2\theta_2}{k_1+k_2}$

16. $\frac{k\Delta\theta}{l} =$ constant

18. $Q = \frac{K2A(\theta_1-\theta_2)t_1}{l} = \frac{kA(\theta_1-\theta_2)t_2}{2l}$

19. $\frac{l_1+l_2}{k} = \frac{l_1}{k_1} + \frac{l_2}{k_2}$

21. Sphere has less surface area

22. $\frac{dQ}{dt} = K(T_B - T_s)$

23. $E \propto AeT^4$

$\frac{E_1}{E_2} = \left(\frac{T_1}{T_2}\right)^4 \frac{e_1}{e_2} \times \frac{r_1}{r_2} \times \frac{l_1}{l_2}$

24. $E \propto T^4$

25. $E_m \propto T^5$

27. $E \propto T^4$ and $E \propto \frac{1}{r^2}$

28. $\frac{E_2 - E_1}{E_1} \times 100 = \frac{T_2^4 - T_1^4}{T_1^4} \times 100$

29. $\frac{\left(\frac{dQ}{dt}\right)_1}{\left(\frac{dQ}{dt}\right)_2} = \left(\frac{r_1}{r_2}\right)^2 \left(\frac{\Delta T_1}{\Delta T_2}\right)$

32. $\frac{E}{t} = \sigma A T^4$ where $A = 4\pi r^2$

33. $\frac{\Delta E}{E} \times 100 = 4\left[\frac{\Delta T}{T} \times 100\right]$

34. $W = EA$

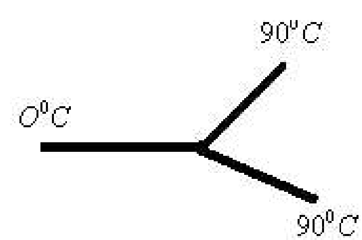
35. $E_\lambda = \frac{e_\lambda}{a_\lambda}$

LEVEL-III

1. A cube of side 10cm is filled with ice of density 0.9gm/c.c. Thickness of the walls of the cube is 1mm and thermal conductivity of the material of the cube is 0.01 C.G.S. units. If the cube is placed in steam bath maintained at a temperature of $100^0 C$, the time in which ice completely melts, is
1) 6 sec 2) 12 sec
3) 24 sec 4)48 sec

2. A cylindrical rod with one end in a steam chamber and the other end in ice results in melting of 0.1gm of ice per second. If the rod is replaced by another rod with half the length and double the radius of the first and if the thermal conductivity of the material of the second rod is 0.25 times that of first, the rate at which ice melts in gms^{-1} will be
1) 0.1 2) 0.2
3) 1.6 4) 3. 2

3. Three rods made of same material and having the same cross section and lengths have been joined as shown in the figure. The temperature of the junction of the rods will be



1) $45^0 C$ 2) $60^0 C$
3) $30^0 C$ 4) $20^0 C$

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 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 is

1) $k_1 + k_2$ 2) $\frac{k_1 k_2}{k_1 + k_2}$

3) $\frac{k_1 + 3k_2}{4}$ 4) $\frac{3k_1 + k_2}{4}$

5. A calorimeter of water equivalent 5 g has water of mass 55 g upto a certain level. Another identical calorimeter has a liquid of mass 38 g upto same level. As both of them cool in the same surroundings from 50^0C to 46^0C, water takes 80 s where as the liquid takes 32 s to cool. If the specific heat of water is 1 cal/g-^{0}C, the specific heat of the liquid in cal/g-^{0}C is

1. 0.8 2. 0.4
3. 0.5 4. 0.2

6. A calorimeter of water equivalent 6 g has water of mass 64 g up to a certain volume. Another identical calorimeter has liquid of mass 50 g and specific heat 0.6 cal/g-^{0}C upto same level. If both of them cool in the same surroundings through same range of temperture and the time taken for the water to cool is 140 s, the time taken for the liquid to cool is

1. 72 s 2. 140 s
3. 36 s 4. 120 s

7. A sphere of density d, specific heat capacity c and radius r is hung by a thermally insulating thread in an enclosure which is kept at lower temperature than the sphere. The temperature of the sphere starts to drop at a rate which is proportional to

1. $c / r^3 d$ 2. $1 / r^3 dc$
3. $3r^3 dc$ 4. $1 /r\ dc$

8. 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 to 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 S_2 is :

1. 1/3 2. $(1/3)^{\frac{1}{3}}$
3. $1/\sqrt{3}$ 4. $\sqrt{3}/1$

9. An aluminum foil of emissivity 0.1 is placed in between two concentric spheres at temperatures 300K and 200K respectively. Assume that the spheres are perfect black body radiators. The rate of energy transfer between one of the spheres and the foil is (σ = 5.672 x 10^{-8} M.K.S.units)

1. 20.2 watt 2. 15.6 watt
3. 12.3 watt 4. 18.5 watt

10. A star behaves like a perfectly black body emitting radiant energy. The ratio of radiant energy per second by this star to that emitted by another star having 8 times the radius of former, but having temperature, one-fourth that of the former in kelvin is

1. 1 : 4 2. 1 : 16
3. 4 : 1 4. 16 : 1

11. The rates of heat radiation from two patches of skin each of area S, on a patient's chest differ by 2%. If the patch of the lower temperature is at 300K and the emissivity of both the patches is assumed to be unity, The temperature of the other patch

1. 301.5K 2. 601.5K
3. 103.5K 4. 106.5K

KEY

01) 2	02) 2	03) 2	04) 3	05) 3
06) 1	07) 4	08) 2	09) 4	10) 3
11)1				

HINTS

1. $$mL = 6 \times \frac{kA(\theta_1 - \theta_2)t}{l}$$

$$m = V\rho$$

2. $$\left(\frac{m}{t}\right)L = \frac{k\pi r^2(\theta_1 - \theta_2)}{l}$$

$$\left(\frac{m}{t}\right) \propto \frac{kr^2}{l}$$

3. $$\frac{KA(\theta - 0)}{l} = \frac{KA(90 - \theta)}{l} + \frac{KA(90 - \theta)}{l}$$

4. $$Q = \frac{K\pi R^2(\theta_1 - \theta_2)t}{l}$$

For the given problem KR^2 =constant

$$k(2R)^2 = k_1R^2 + k_2(4R^2 - R^2)$$

$$4K = k_1 + 3k_2$$

$$K = \frac{k_1 + 3k_2}{4}$$

5. $\dfrac{W + m_1 s_1}{W + m_2 s_2} = \dfrac{t_1}{t_2}$

6. $\dfrac{m_1 s_1 + m_2 s_2}{t_1} = \dfrac{m_1 s_1 + m_3 s_3}{t_2}$

7. $mc\dfrac{d\theta}{dt} \propto r^2$

9. $\dfrac{1}{2}\dfrac{E}{At} = \sigma e\left(T_1^4 - T_2^4\right)$

11. $\dfrac{\Delta E}{E}\times 100 = 4\left(\dfrac{\Delta T}{T}\times 100\right)$

LEVEL - IV

COMPREHENSION TYPE QUESTIONS

Read the passage given below.

I) **(i) Insulators:** The conduction takes place by lattice vibrations. At absolute zero, the atoms in a solid are staying at their lattice points. As the temperature rises all the atoms are in a state of random vibration about their mean lattice positions. When a body is brought near a hot source the particles nearest the hot source will receive heat and thus begin to vibrate with higher energies. So, the vibration of an atom will automatically change the attraction pattern of the neighbouring atom and thus influence the motion of these neighbouring atoms. Thus the atoms vibrating with high amplitudes near the hot end will tend to increase the amplitude of vibration of the next nearest neighbours. Thus thermal energy is imparted to them. So, a chain process starts and heat in the form of vibration motion of atoms in their lattice points slowly moves outwards from the hot end towards the cold end. Obviously, this process has to be slow, and thus, the K value will be small in this case.

(ii) Metals: Metals have the core ions fixed in their spaces and these are embedded in an ocean of free electrons which move as a gas within the body of the metal. The conduction in metals is due to free electrons. The free electrons moving at random come near and strike the hot end, receive energy, absorb it and increasing their own kinetic energy thereby, impart their energy to other electrons towards the cold end. Thus heat is conducted from end to end. As the electrons are more mobile, the heat is transferred much more quickly. The core ions in their lattice positions also take part in conduction by means of their vibrations.The main carriers of heat energy in metals are the mobile electrons. So the conductivity of metals is rather high as compared to the conductivity in insulators.

Answer the following questions.

1. Metals are good conductors because
   1) molecules are closely packed in them
   2) they contain free electrons
   3) of collisions occurring between their molecules
   4) they have reflecting surface

2. **Statement A:** The conduction in insulators takes place by lattice vibrations.
   Statement B: The conduction in metals is due to mobile electrons.
   1) A is true, B is true
   2) A is true, B is false
   3) A is false, B is true
   4) both A and B are false

3. **Assertion:** Conduction of heat in conductors is quicker than that in insulators.
   Reason: Electrons are more mobile and conduction of heat in metals is due to mobile electrons.
   1) both A and R are true and the R is correct explanation of the A
   2) both A and R are true, but R is not correct explanation of the A
   3) A is true, but the R is false.
   4) A is false, but the R is true.

II. When we sit before a fire, we feel warm. This is because our body is receiving more thermal energy per unit area from the fire than it is losing by its own radiation. On the other hand, when we sit near a block of ice, we feel cold. This is because our body loses more heat energy by radiation than what it receives from ice. Thus, when a body absorbs more radiant energy than what it emits, there is rise in the temperature of the body. when a body absorbs less energy absorbed is equal to the quantity of thermal energy emitted, then there is no change in the temperature of the body.

When a body has the same temperature as that of its surrounding, it is a case of dynamic equilibrium and not that of a static equilibrium.

Prevost's theory of heat exchanges leads to the fact that good absorbers are good radiators and vice versa as proved below.

Consider two bodies, one of black coloured 'B' and the other of white coloured 'W', suspended by insulating threads inside a constant temperature enclosure. The bodies will be in thermal equilibrium with the enclosure.

Since B is a black body therefore it should absorb most of the radiation incident on it. But its temperature remains constant. So, it must also be emitting at the same rate at which it absorbs. Thus, good absorbers are good radiators. Applying the same type of argument in the case of white body, we can conclude that poor absorbers are poor emitters.

Answer the following questions.

1. A small hole in the wall of an enclosure behaves as
   1) Good absorber & Poor emitter
   2) Good absorber & Good emitter
   3) Poor absorber & Poor emitter
   4) Poor absorber & Good emitter
2. **Statement A*:*** A body of low Thermal capacity gets heated or cooled quickly
   Statement B*:* Good emitters are bad reflectors
   1) A is true, B is true
   2) A is true, B is false
   3) A is false, B is true
   4) both A and B are false
3. A Blackbody, a white body, A Blue body and a Red coloured body are heated to same temperature and are allowed to cool in the same surroundings. Then the body that cools early is
   1) Red 2) Blue 3) White 4) Black
4. A person with dark skin when compared to a person with white skin will experience
   1) Less heat, less cold
   2) Less heat, more cold
   3) More heat, more cold
   4) More heat, less cold

KEY

I) 1) 2 2) 1 3) 1
II) 1) 2 2) 1 3) 4 4) 3

PREVIOUS EAMCET QUESTIONS

1. Two identical bodies have temperature 277^0C and 67^0C. If the surrounding temperature is 27^0C, the ratio loss of heat of the two bodies during the same interval of time is (approximately) (EAMCET- 2005/E)
   1) 4 : 1 2) 8 : 1
   3) 12 : 1 4) 16 : 1
2. Two bodies of same shape, same size and same radiating power have emissivities 0.2 and 0.8. The ratio of their temperature is (EAMCET- 2005/M)
   1) $\sqrt{3}:1$ 2) $\sqrt{2}:1$
   3) $1:\sqrt{5}$ 4) $1:\sqrt{3}$
3. A black body of mass 34.38gm and surface area $19.2cm^2$ is at an initial temperature of 400k. It is allowed to cool inside an evacuated enclosure kept at constant temperature 300k. The rate of cooling is 0.04^0C per second. The specific heat of the body in $Jkg^{-1}k^{-1}$ is (Stefan's constant $\sigma = 5.73\times10^{-8}Wm^{-2}k^{-4}$) (EAMCET - 2004/E)
   1) 2800 2) 2100
   3) 1400 4) 1200
4. The absolute temperature of a body A is four times that of another body B. For two bodies, the difference in wave lengths at which energy radiated is maximum is 3.0 μm. Then the wavelength at which the body B radiates maximum energy in micrometer is (EAMCET - 2004/M)
   1) 2 2) 2.5
   3) 4.0 4) 45
5. The radiation emitted by a star A is 10,000 times that of the sun. If the surface temperature of the sun and the star A are 6000K and 2000k respectively, the ratio of the radii of the star A and the sun is (EAMCET-2003/E)
   1) 300 : 1 2) 600: 1
   3) 900 : 1 4) 1200:1
6. A particular star (assuming it as a black body) has a surface temperature of about $5\times10^4 k$. The wave length in nano-meters at which its radiation becomes maximum is (b = 0.0029mk) (EAMCET-2003/M)
   1) 48 2) 58
   3) 60 4) 70

7. The rate of emission of a black body at temperature 27^0C is E_1 .If its temperature is increased to 327^0C, the rate of emission of radiation is E_2 . The relation between E_1 and E_2 is (EAMCET 2002 / M)
1. $E_2 = 24E_1$ 2. $E_2 = 16E_1$
3. $E_2 = 8E_1$ 4. $E_2 = 4E_1$

8. When the temperature of a black body increases, it is observed that the wavelength corresponding to maximum energy changes from 0.26 mm to 0.13mm. The ratio of the emissive powers of the body at the respective temperatures is: (EAMCET 2002 E)
1.16/1 2.4/1 3.1/4 4.1/16

9. The wave length corresponding to maximum intensity of radiation emitted by a star is 289.8nm. The intensity of radiation for the star is (Stefan's constant = $5.6 \times 10^{-8} Wm^{-2} K^{-4}$) (EAMCET 2001/ E)
1. $5.67 \times 10^8 \, Wm^{-2}$ 2. $5.67 \times 10^4 \, Wm^{-2}$
3. $10.67 \times 10^7 \, Wm^{-2}$ 4. $10.67 \times 10^4 \, Wm^{-2}$

10. The temperature of a black body is increased by 50% . Then the percentage of increase of radiation is approximately (EAMCET,2001/ M)
1. 100% 2. 25%
3. 400% 4. 500%

QUESTIONS FROM OTHER COMPETITIVE EXAMS

11. The radiant energy from the sun, incident normally at the surface of earth, is 20kcal/m^2 - min. 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)
1. 40 kcal/(m^2 - min) 2. 80kcal/(m^2-min)
3. 160 kCal/(m^2-min) 4. 320 Kcal/(m^2-min)

12. A black body is at a temperature of 500K. It emits energy at a rate which is proportional to (CBSE, PMT 1997)
1.500 2. $(500)^2$
3. $(500)^3$ 4. $(500)^4$

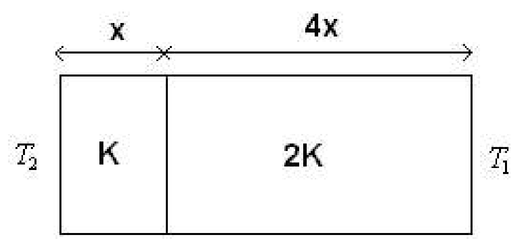
13. The temperature of the sun is doubled, the rate of energy received on earth will be increased by a factor of (CBSE, PMT 1993)
1. 2 2. 4
3. 8 4. 16

14. A body cools from 50^0C to 49.9^0C in 5 seconds. Assuming Newton's law fo cooling and temperature of the surroundings fixed at 30^0C, how long will the same body take for cooling from 40^0C to 39.9^0C? (CBSE, PMT 1994)
1. 2.5 Second 2. 5 Second
3. 7.5 Second 4. 10 Second

15. For an enclosure maintained at 1000K the maximum radiation occurs at wavelength λ_m . If the temperature is raised to 2000K, the peak will shift to (CBSE, PMT 1993)
1. 0.5 λ_m 2. λ_m
3. 4 λ_m 4. 8 λ_m

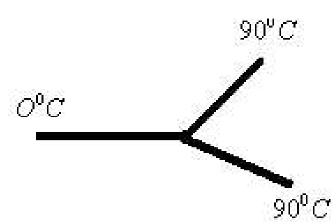
16. Which of the following qualities are best suited for cooking a utensil (MP PMT 2001)
1. high specific heat and low thermal conductivity
2. high specific heat and high thermal conductivity
3. low specific heat and low thermal conductivity
4. low specific heat and high thermal conductivity

17. 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 equal to
(AIEEE 2004)



1. 1 2. 1/2
3. 2/3 4. 1/3

18. Three rods made of same material and having the same cross section and lengths have been joined as shown in the figure. The temperature of the junction of the rods will be



1) $45^0 C$ 2) $60^0 C$
3) $30^0 C$ 4) $20^0 C$

19. Two identical conducting rods are first connected independently to two vessels, one containing water at 100^0C and the other containing ice at 0^0C. In the second case the rods are joining 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 the two cases respectively. Then the ratio $\frac{Q_1}{Q_2}$ is

(IIT screening 2004)

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

20. According to Newton's law of cooling, the rate of cooling of a body is proportional to $(\Delta\theta)^n$ when $\Delta\theta$ is the difference of the temperature of the body and the surrondings, and 'n' is equal to

(AIEEE 2003)

1) two 2) three
3) four 4) one

21. Two solid spheres A and B made of the same material have radii r_A and r_B respectively. Both the spheres are cooled from the same temperature under the conditions valid for Newton's law of cooling. The ratio of rate of change of temperatures of A and B is

(EAMCET,2006/ E)

1. $\frac{r_A}{r_B}$ 2) $\frac{r_B}{r_A}$ 3) $\frac{r_A^2}{r_B^2}$ 4) $\frac{r_B^2}{r_A^2}$

KEY

01) 4	02) 2	03) 3	04) 3	05) 3
06) 2	07) 2	08) 4	09) 1	10) 3
11) 4	12) 4	13) 3	14) 4	15) 1
16) 4	17) 4	18) 2	19) 3	20) 4

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