Exercise-1

✍ ***Marked Questions can be used as Revision Questions.***

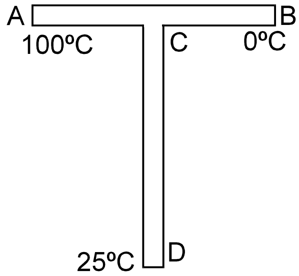
PART - I : SUBJECTIVE QUESTIONS

Section (A) : Thermal conduction in linear conductors at steady state

A-1. A uniform slab of dimension 10 cm × 10 cm × 1 cm is kept between two heat reservoirs at temperatures 10ºC and 90ºC. The larger surface areas touch the reservoirs. The thermal conductivity of the material is 0.80 W/m–ºC. Find the amount of heat flowing through the slab per second.

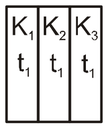
A-2. One end of a steel rod (K = 42 J/m–s–ºC) of length 1.0 m is kept in ice at 0ºC and the other end is kept in boiling water at 100ºC. The area of cross–section of the rod is $0.04 cm^2$. Assuming no heat loss to the atmosphere, find the mass of the ice melting per second. Latent heat of fusion of ice = 3.36×10^5 J/kg.

A-3.✍ A rod CD of thermal resistance 5.0 K/W is joined at the middle of an identical rod AB as shown in figure. The ends A, B and D are maintained at 100ºC, 0ºC and 25ºC respectively. Find the heat current in CD.



A-4. A semicircular rod is joined at its ends to a straight rod of the same material and same cross-sectional area. The straight rod forms a diameter of the other rod. The junctions are maintained at different temperatures. Find the ratio of the heat transferred through a cross-section of the semicircular rod to the heat transferred through a cross-section of the straight rod in a given time.

A-5. Three slabs of same surface area but different conductivities k_1, k_2, k_3 and different thickness t_1, t_2, t_3 are placed in close contact. After steady state this combination behaves as a single slab. Find its effective thermal conductivity.



Section (B) : Thermal conduction in nonlinear conductors at steady state

B-1.✍ A hollow metallic sphere of radius 20 cm surrounds a concentric metallic sphere of radius 5 cm. The space between the two spheres is filled with a nonmetallic material. The inner and outer spheres are maintained at 50°C and 10°C respectively and it is found that 160 π Joule of heat passes radially from the inner sphere to the outer sphere per second. Find the thermal conductivity of the material between the spheres.

B-2. A hollow tube has a length ℓ, inner radius R_1 and outer radius R_2. The material has thermal conductivity K. Find the heat flowing through the walls of the tube per second if the inside of the tube is maintained at temperature T_1 and the outside is maintained at T_2 [Assume $T_2 > T_1$]

Section (C) : Thermal conduction through conductors which have not achieved steady state

C-1.✍ A metal rod of cross-sectional area 1.0 cm^2 is being heated at one end. At one time, the temperature gradient is 5.0°C/cm at cross-section A and is 2.6 °C/cm at cross-section B. Calculate the rate at which the temperature is increasing in the part AB of the rod. The heat capacity of the part AB = 0.40 J/°C, thermal conductivity of the material of the rod = 200 W/m–°C. Neglect any loss of heat to the atmosphere.

Section (D) : Radiation, stefen's law and wein's law

D-1. When q_1 joules of radiation is incident on a body it reflects and transmits total of q_2 joules. Find the emissivity of the body.

D-2. A blackbody of surface area 1 cm^2 is placed inside an enclosure. The enclosure has a constant temperature 27ºC and the blackbody is maintained at 327ºC by heating it electrically. What electric power is needed to maintain the temperature? $\sigma = 6.0 \times 10^{-8}$ $W/m^2 - K^4$.

D-3. Estimate the temperature at which a body may appear blue or red. The values of λ_{mean} for these are 5000 Å and 7500Å respectively. [Given Wein's constant b = 0.3 cm K]

D-4 The temperature of a hot liquid in a container of negligible heat capacity falls at the rate of 3 K/min due to heat emission to the surroundings, just before it begins to solidify. The temperature then remains constant for 30 min, by the time the liquid has all solidified. Find the ratio of specific heat capacity of liquid to specific latent heat of fusion.

D-5. The earth receives at its surface radiation from the sun at the rate of 1400 Wm^{-2}. The distance of the centre of the sun from the surface of the earth is 1.5×10^{11} m and the radius of the sun is 7×10^8 m. Treating the sun as a black body calculate temperature of sun. **[1989; 2M]**

D-6 A solid copper sphere (density ρ and specific heat c) of radius r at an initial temperature 200 K is suspended inside a chamber whose walls are at almost 0 K. Calculte the time required for the temperature of the sphere to drop to 100 K. (Assume sphere as a black body) **[1991; 2M]**

Section (E) : Newton's Law of cooling

E-1. A liquid cools from 70ºC to 60ºC in 5 minutes. Find the time in which it will further cool down to 50 ºC, if its surrounding is held at a constant temperature of 30ºC.

PART - II : ONLY ONE OPTION CORRECT TYPE

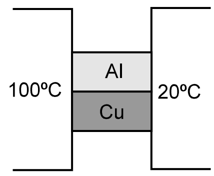
Section (A) : Thermal conduction in linear conductors at steady state

A-1. A wall has two layers A and B, each made of different material. Both the layers have the same thickness. The thermal conductivity for A is twice that of B. Under steady state, the temperature difference across the whole wall is 36°C. Then the temperature difference across the layer A is

(A) 6°C (B) 12°C (C) 18°C (D) 24°C

A-2. Two metal cubes with 3 cm-edges of copper and aluminium are arranged as shown in figure (assume no loss of heat from open surfaces) (K_{CU} = 385 W/m-K, K_{AL} = 209 W/m-K)

(a) The total thermal current from one reservoir to the other is :

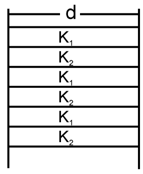


(A) 1.42×10^3 W (B) 2.53×10^3 W (C) 1.53×10^4 W (D) 2.53×10^4 W

(b) The ratio of the thermal current carried by the copper cube to that carried by the aluminium cube is

(A) 1.79 (B) 1.69 (C) 1.54 (D) 1.84

A-3. A wall consists of alternating blocks with length 'd' and coefficient of thermal conductivity k_1 and k_2. The cross sectional area of the blocks are the same. The equivalent coefficient of thermal conductivity of the wall between left and right is :



(A) $K_1 + K_2$ (B) $\frac{(K_1+K_2)}{2}$ (C) $\frac{K_1K_2}{K_1+K_2}$ (D) $\frac{2K_1K_2}{K_1+K_2}$

A-4. A boiler is made of a copper plate 2.4 mm thick with an inside coating of a 0.2 mm thick layer of tin. The surface area exposed to gases at 700°C is 400 cm^2. The amount of steam that could be generated per hour at atmospheric pressure is (K_{cu} = 0.9 and K_{tin} = 0.15 cal/cm/s/°C and L_{steam} = 540 cal/g)
(A) 5000 Kg (B) 1000 kg (C) 4000 kg (D) 200 kg

A-5. A lake surface is exposed to an atmosphere where the temperature is < 0°C. If the thickness of the ice layer formed on the surface grows from 2 cm to 4 cm in 1 hour, The atmospheric temperature, T_a will be (Thermal conductivity of ice K = 4 × 10^{-3} cal/cm/s/°C; density of ice = 0.9 gm/cc. Latent heat of fusion of ice = 80 cal/gm. Neglect the change of density during the state change. Assume that the water below the ice has 0^o temperature every where)
(A) – 20 °C (B) 0 °C (C) – 30 °C (D) – 15 °C

Section (B) : Thermal conduction in nonlinear conductors at steady state

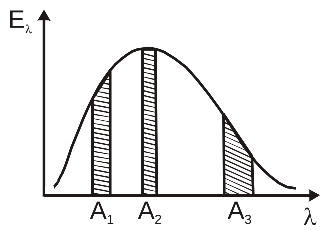
B-1. Heat flows radially outward through a spherical shell of outside radius R_2 and inner radius R_1. The temperature of inner surface of shell is θ_1 and that of outer is θ_2. The radial distance from centre of shell where the temperature is just half way between θ_1 and θ_2 is :
(A) $\frac{R_1+R_2}{2}$ (B) $\frac{R_1R_2}{R_1+R_2}$ (C) $\frac{2R_1R_2}{R_1+R_2}$ (D) $R_1 + \frac{R_2}{2}$

Section (C) : Radiation and stefen's law

C-1. A metallic sphere having radius 0.08 m and mass m = 10kg is heated to a temperature of 227°C and suspended inside a box whose walls are at a temperature of 27°C. The maximum rate at which its temperature will fall is : (Take e = 1, Stefan's constant σ = 5.8 × 10^{-8} Wm^{-2} K^{-4} and specific heat of the metal s = 90 cal/kg/deg J = 4.2 Joules/Calorie)
(A) .055 °C/sec (B) .066 °C/sec (C) .044 °C/sec (D) 0.03 °C/sec

C-2 A solid spherical black body of radius r and uniform mass distribution is in free space. It emits power 'P' and its rate of colling is R then
(A) R P α r^2 (B) R P α r (C) R P α $1/r^2$ (D) R P α

C-3 Three separate segments of equal area A_1, A_2 and A_3 are shown in the energy distribution curve of a blackbody radiation. If n_1, n_2 and n_3 are number of photons emitted per unit time corresponding to each area segment respectively then :

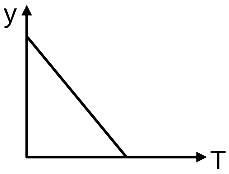


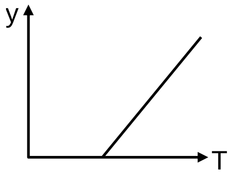
(A) $n_2 > n_1 > n_3$ (B) $n_3 > n_1 > n_2$ (C) $n_1 = n_2 = n_3$ (D) $n_3 > n_2 > n_1$

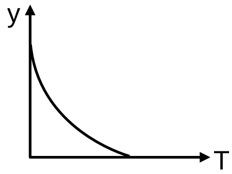
Section (D) : Newton's Law of cooling

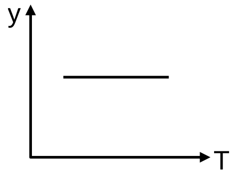
D-1. Which of the law can be understood in terms of Stefan's law
(A) Wien's displacement law (B) Kirchoff's law
(C) Newton's law of cooling (D) Planck's law

D-2. A hot liquid is kept in a big room. According to Newton's law of cooling rate of cooling of liquid (represented as y) is plotted against its temperature T. Which of the following curves may represent the plot ?

(A) 

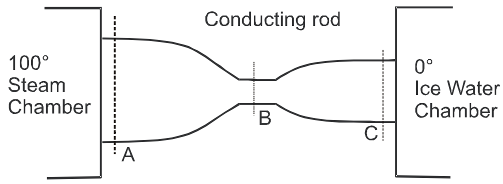
(B) 

(C) 

(D) 

PART - III : MATCH THE COLUMN

1. A copper rod (initially at room temperature 20°C) of non-uniform cross section is placed between a steam chamber at 100°C and ice-water chamber at 0°C.



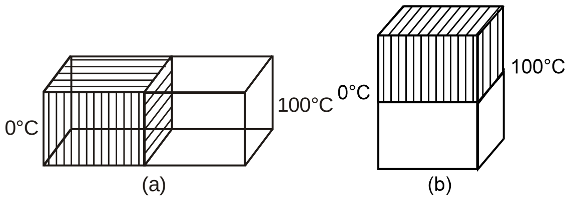
Column-I	**Column-II**
(A) Initially rate of heat flow $\left(\frac{dQ}{dt}\right)$ will be	(p) maximum at section A
(B) At steady state rate of heat flow $\left(\frac{dQ}{dt}\right)$ will be	(q) maximum at section B
(C) At steady state temperature gradient $\left\|\left(\frac{dT}{dx}\right)\right\|$ will be	(r) minimum at section A
(D) At steady state rate of change of temperature $\left(\frac{dT}{dt}\right)$ at a certain point will be	(s) minimum at section B
	(t) same for all section

Exercise-2

Marked Questions can be used as Revision Questions.

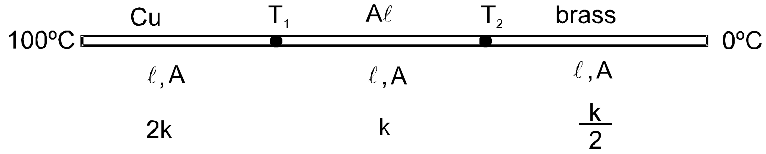
PART - I : ONLY ONE OPTION CORRECT TYPE

1. Two identical square rods of metal are welded end to end as shown in figure (a). Assume that 10 cal of heat flows through the rods in 2 min. Now the rods are welded as shown in figure, (b). The time it would take for 10 cal to flow through the rods now, is



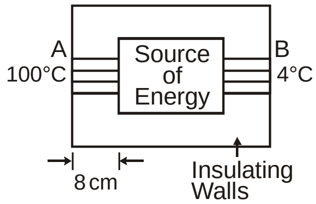
(A) 0.75 min (B) 0.5 min (C) 1.5 min (D) 1 min

2. Three metal rods made of copper, aluminium and brass, each 20 cm long and 4 cm in diameter, are placed end to end with aluminium between the other two. The free ends of copper and brass are maintained at 100 and 0°C respectively. Assume that the thermal conductivity of copper is twice that of aluminium and four times that of brass. The approximately equilibrium temperatures of the copper-aluminium and aluminium-brass junctions are respectively.



(A) 68 °C and 75 °C (B) 75 °C and 68 °C (C) 57 °C and 86 °C (D) 86 °C and 57 °C

3. A closed cubical box is made of a perfectly insulating material walls of thickness 8 cm and the only way for heat to enter or leave the box is through two solid metallic cylindrical plugs, each of cross-sectional area 12 cm^2 and length 8 cm, fixed in the opposite walls of the box. The outer surface A on one plug is maintained at 100°C while the outer surface B of the other plug is maintained at 4°C. The thermal conductivity of the material of each plug is 0.5 cal/°C/cm. A source of energy generating 36 cal/s is enclosed inside the box. Assuming the temperature to be the same at all points on the inner surface, the equilibrium temperature of the inner surface of the box is



(A) 62 °C (B) 46 °C (C) 76 °C (D) 52 °C

4. Two models of a windowpane are made. In one model, two identical glass panes of thickness 3 mm are separated with an air gap of 3 mm. This composite system is fixed in the window of a room. The other model consists of a single glass pane of thickness 6 mm, the temperature difference being the same as for the first model. The ratio of the heat flow for the double pane to that for the single pane is
($K_{glass} = 2.5 \times 10^{-4}$ cal/s.m. °C and $K_{air} = 6.2 \times 10^{-6}$ cal/s.m.°C)
(A) 1/20 (B) 1/70 (C) 31/1312 (D) 31/656

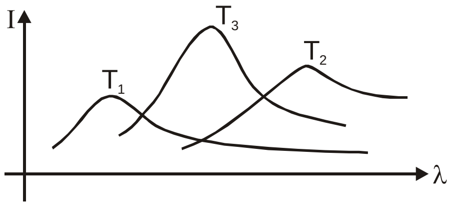
5. Heat is flowing through two cylindrical rods made of same materials whose ends are maintained at similar temperatures. If diameters of the rods are in ratio 1 : 2 and lengths in ratio 2 : 1, then the ratio of thermal current through them in steady state is :
(A) 1 : 8 (B) 1 : 4 (C) 1 : 6 (D) 4 : 1

6. The ends of a metre stick are maintained at 100ºC and 0ºC. One end of a rod is maintained at 25ºC. Where should its other end be touched on the metre stick so that there is no heat current in the rod in steady state?
(A) 25 cm from the hot end (B) 40 cm from the cold end
(C) 25 cm from the cold end (D) 60 cm from the cold end

7. A spherical solid black body of radius 'r' radiates power 'H' and its rate of cooling is 'C'. If density is constant then which of the following is/are true.
(A) $H \propto r$ and $c \propto r^2$ (B) $H \propto r^2$ and $c \propto \frac{1}{r}$ (C) $H \propto r$ and $c \propto \frac{1}{r^2}$ (D) $H \propto r^2$ and $c \propto r^2$

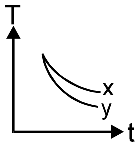
8. The earth is getting energy from the sun whose surface temperature is T_s and radius is R. Let the radius of the earth the r and the distance from the sun be d. Assume the earth and the sun both to behave as perfect black bodies and the earth is in thermal equilibrium at a constant temperature T_e. Therefore, the temperature T_s of the sun is xT_e where x is **[Olympiad 2015 stage-1]**
(A) $\sqrt{\frac{2d}{R}}$ (B) $\sqrt{\frac{2R}{r}}$ (C) $\sqrt{\frac{4d}{r}}$ (D) $\frac{d}{r}$

9. The plots of intensity vs. wavelength for three black bodies at temperatures T_1, T_2 and T_3 respectively are as shown. Their temperatures are such that- **[JEE (Scr) 2000, 3/35]**



(A) $T_1 > T_2 > T_3$ (B) $T_1 > T_3 > T_2$ (C) $T_2 > T_3 > T_1$ (D) $T_3 > T_2 > T_1$

10. The temperature of bodies X and Y vary with time as shown in the figure. If emissivity of bodies X and Y are e_X & e_Y and absorptive powers are A_X and A_Y, (assume other conditions are identical for both) : then: **[JEE (Scr.) 2003, 3/84, –1]**

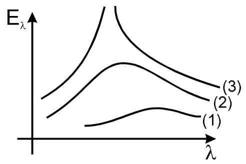


(A) $e_Y > e_X$, $A_Y > A_X$ (B) $e_Y < e_X$, $A_Y < A_X$ (C) $e_Y > e_X$, $A_Y < A_X$ (D) $e_Y < e_X$, $A_Y > A_X$

11. Three discs of same material A, B, C of radii 2 cm, 4 cm and 6 cm respectively are coated with carbon black. Their wavelengths corresponding to maximum spectral radiancy are 300, 400 and 500 nm respectively then maximum power will be emitted by **[JEE (Scr.) 2004, 3/84, –1]**

(A) A (B) B (C) C (D) same for all

12. Three graphs marked as 1, 2, 3 representing the variation of maximum emissive power and wavelength of radiation of the sun, a welding arc and a tungsten filament. Which of the following combination is correct **[JEE (Scr.) 2005, 3/84, –1]**

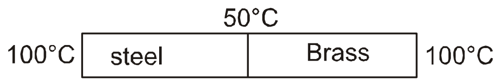


(A) 1- bulb, 2 → welding arc, 3 → sun (B) 2- bulb, 3 → welding arc, 1 → sun
(C) 3- bulb, 1 → welding arc, 2 → sun (D) 2- bulb, 1 → welding arc, 3 → sun

PART - II : SINGLE AND DOUBLE VALUE INTEGER TYPE

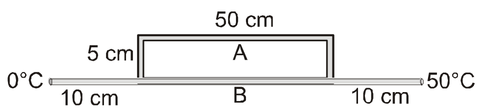
1. Two rods of same dimensions, but made of different materials are joined end to end with their free ends being maintained at 100ºC and 0ºC respectively. The temperature of the junction is 70ºC. Then the temperature of the junction if the rods are interchanged will be equal to T °C Find T :

2. Figure shows a steel rod joined to a brass rod. Each of the rods has length of 31 cm and area of cross-section 0.20 cm^2. The junction is maintained at a constant temperature 50°C and the two ends are maintained at 100°C.



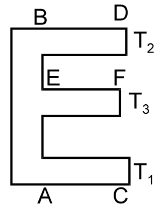
The amount of heat taken out from the cold junction in 10 minutes after the steady state is reached in $n \times 10^2$ J. Find 'n'. The thermal conductivities are K_{steel} = 46 W/m–°C and K_{brass} = 109 W/m–°C.

3. Consider the situation shown in figure. The frame is made of the same material and has a uniform cross-sectional area everywhere. If amount of heat flowing per second through a cross-section of part A is 60 J.



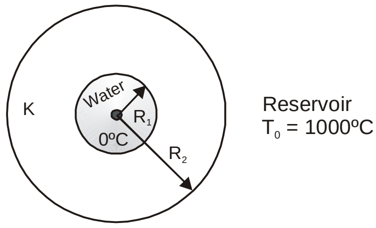
The amount of total heat taken out per second from the end at 50°C is 0.132×10^n J/s. Find 'n'.

4. Four thin identical rods AB, AC, BD and EF made of the same material are joined as shown. The free-ends C, D and F are maintained at temperatures T_1, T_2 and T_3 respectively. Assuming that there is no loss of heat to the surroundings, the temperature at joint E when the steady state is attained is $\frac{1}{K}(2T_1 + 2T_2 + 3T_3)$. Find K (E is mid point of AB)



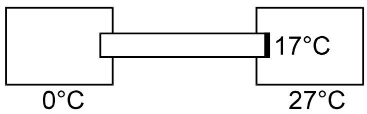
5. One end of copper rod of uniform cross-section and of length 1.45 m is in contact with ice at 0ºC and the other end with water at 100°C. The position of point along its length where a temperature of 200°C should be maintained so that in steady state the mass of ice melting is equal to that of steam produced in the same interval of time is x cm from hotter end of rod. Find x [Assume that the whole system is insulated from surroundings]. (Take L_v = 540 cal/g L_f = 80 cal/g)

6. A hollow spherical conducting shell of inner radius $R_1 = 0.25$ m and outer radius $R_2 = 0.50$ m is placed inside a heat reservoir of temperature T_0 = 1000 ºC. The shell is initially filled with water at 0ºC. The thermal conductivity of the material is $k = \frac{10^2}{4\pi}$ W/m-K and its heat capacity is negligible.



The time required to raise the temperature of water to 100ºC is 1100 K □n $\frac{10}{9}$ sec. Find K. Take specific heat of water s = 4.2 kJ/kg.°C, density of water d_w = 1000 kg/m^3, $\pi = \frac{22}{7}$

7. A cylindrical rod of length 1 m is fitted between a large ice chamber at 0°C and an evacuated chamber maintained at 27°C as shown in figure. Only small portions of the rod are inside the chambers and the rest is thermally insulated from the surrounding.



The cross-section going into the evacuated chamber is blackened so that it completely absorbs any radiation falling on it. The temperature of the blackened end is 17°C when steady state is reached. Stefan constant $\sigma = 6 \times 10^{-8}$ W/m^2–K^4. The thermal conductivity of the material of the rod is 1.2 P (W/m – °C). Find P ($29^4 = 707281$)

8. A spherical tungsten piece of radius 1.0 cm is suspended in an evacuated chamber maintained at 300 K. The piece is maintained at 1000 K by heating it electrically.The rate at which the electrical energy must be supplied P Watt. Find P. The emissivity of tungsten is 0.30 and the stefan constant σ is 6.0×10^{-8} W/m^2–K^4.

PART - III : ONE OR MORE THAN ONE OPTIONS CORRECT TYPE

1. Assume transmitivity $t \to 0$ for all the cases :

(A) bad absorber is bad emitter
(B) bad absorber is good reflector
(C) bad reflector is good emitter
(D) bad emitter is good absorber

2. A hollow and a solid sphere of same material and having identical outer surface are heated under identical condition to the same temperature at the same time (both have same e, a) :

(A) in the beginning both will emit equal amount of radiation per unit time
(B) in the beginning both will absorb equal amount of radiation per unit time
(C) both spheres will have same rate of fall of temperature (dT/dt)
(D) both spheres will have equal temperatures at any moment

3. Two bodies A and B have thermal emissivities of 0.01 and 0.81 respectively. The 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 μm. If the temperature of A is 5802 K, **[JEE 1994, 2]**

(A) the temperature of B is 1934 K
(B) λ_B = 1.5 μm
(C) the temperature of B is 11604 K
(D) the temperature of B is 2901 K

4. The solar constant is the amount of heat energy received per second per unit area of a perfectly black surface placed at a mean distance of the Earth from the Sun, in the absence of Earth's atmosphere, the surface being held perpendicular to the direction of Sun's rays. Its value is 1388 W/m^2. If the solar constant for the earth is 's'. The surface temperature of the sun is TK, D is the diameter of the Sun, R is the mean distance of the Earth from the Sun. The sun subtends a small angle 'θ' at the earth. Then correct options is/are :

(A) $s = \sigma T^4\left(\frac{D}{R}\right)^2$ (B) $s = \frac{\sigma T^4}{4}\left(\frac{D}{R}\right)^2$ (C) $s = \frac{\sigma T^4}{4}\theta^2$ (D) $s = \frac{\sigma T^4}{4}\left(\frac{R}{D}\right)^2$

5. A heated body emits radiation which has maximum intensity at frequency ν_m. If the temperature of the body is doubled:

(A) the maximum intensity radiation will be at frequency $2\nu_m$

(B) the maximum intensity radiation will be at frequency ν_m.

(C) the total emitted power will increase by a factor 16

(D) the total emitted power will increase by a factor 2.

6. Two identical rods made of two different metals A and B with thermal conductivities K_A and K_B respectively are joined end to end. The free end of A is kept at a temperature T_1 while the free end of B is kept at a temperature T_2 ($< T_1$). Therefore, in the steady state **[Olympiad (Stage-1) 2017]**

(A) the temperature of the junction will be determined only by K_A and K_B

(B) if the lengths of the rods are doubled the rate of heat flow will be halved.

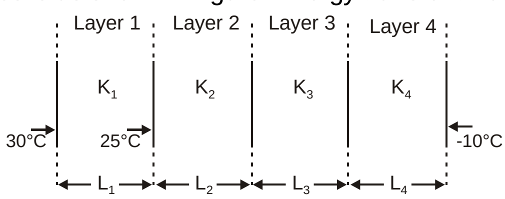
(C) if the temperature at the two free ends are interchanged the junction temperature will change

(D) the composite rod has an equivalent thermal conductivity of $\frac{2K_AK_B}{K_A + K_B}$

PART - IV : COMPREHENSION

Comprehension - 1

Figure shows in cross section a wall consisting of four layers with thermal conductivities $K_1 = 0.06$ W/mK; $K_3 = 0.04$ W/mK and $K_4 = 0.10$ W/mK. The layer thicknesses are $L_1 = 1.5$ cm ; $L_3 = 2.8$ cm and $L_4 = 3.5$ cm. The temperature of interfaces is as shown in figure. Energy transfer through the wall is steady.



1. The temperature of the interface between layers 3 and 4 is :

(A) – 1°C (B) – 3°C (C) 2°C (D) 0°C

2. The temperature of the interface between layers 2 and 3 is :

(A) 11°C (B) 8°C (C) 7.2°C (D) 5.4°C

3. If layer thickness L_2 is 1.4 cm, then its thermal conductivity K_2 will have value (in W/mK) :

(A) 2×10^{-2} (B) 2×10^{-3} (C) 4×10^{-2} (D) 4×10^{-3}

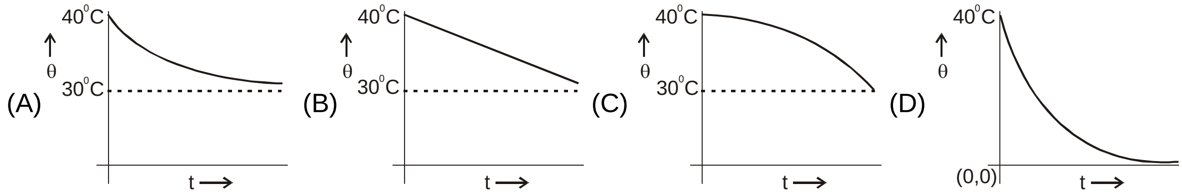
Comprehension-2

A body cools in a surrounding of constant temperature 30ºC. Its heat capacity is 2J/ºC. Initial temperature of the body is 40ºC. Assume Newton's law of cooling is valid. The body cools to 38ºC in 10 minutes.

4.✍ In further 10 minutes it will cool from 38ºC to :

(A) 36ºC (B) 36.4ºC (C) 37ºC (D) 37.5ºC

5.✍ The temperature of the body in ºC denoted by θ the variation of θ versus time t is best denoted as



6.✍ When the body temperature has reached 38ºC, it is heated again so that it reaches to 40ºC in 10 minutes.The total heat required from a heater by the body is:

(A) 3.6J (B) 7J (C) 8 J (D) 4 J

Comprehension-3

A metal ball of mass 2 kg is heated by means of a 40 W heater in a room at 25°C. The temperature of the ball becomes steady at 60°C.

7. Find the rate of loss of heat to the surrounding when the ball is at 60°C.

(A) 40 W (B) 16W (C) 96W (D) 100 W

8. Assuming Newton's law of cooling, calculate the rate of loss of heat to the surrounding when the ball is at 39°C.

(A) 40 W (B) 16W (C) 96W (D) 100 W

9. Assume that the temperature of the ball rises uniformly from 25°C to 39°C in 2 minutes. Find the total loss of heat to the surrounding during this period.

(A) 900 J (B) 940 J (C) 960 J (D) 1000 J

Exercise-3

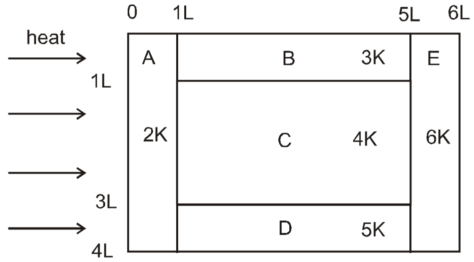
✍ Marked Questions can be used as Revision Questions.
*** Marked Questions may have more than one correct option.**

PART - I : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

1. A metal rod AB of length 10*x* has its one end A in ice at 0ºC and the other end B in water at 100ºC. If a point P on the rod is maintained at 400ºC, then it is found that equal amounts of water and ice evaporate and melt per unit time. The latent heat of evaporation of water is 540 cal/g and latent heat of melting of ice is 80 cal/g. If the point P is at a distance of λx from the ice end A, find the value of λ. [Neglect any heat loss to the surrounding] **[JEE, 2009, 4/160, –1]**

2.✍ Two spherical bodies A (radius 6 cm) and B (radius 18 cm) are at temperature T_1 and T_2 respectively. The maximum intensity in the emission spectrum of A is at 500 nm and in that of B is at 1500 nm. Considering them to be black bodies, what will be the ratio of the rate of total energy radiated by A to that of B ? **[JEE, 2010, 3/163]**

3.* A composite block is made of slabs A, B, C, D and E of different thermal conductivities (given in terms of a constant K) and sizes (given in terms of length, L) as shown in the figure. All slabs are of same width. Heat 'Q' flows only from left to right through the blocks. Then in steady state **[JEE, 2011, 4/160]**



(A) heat flow through A and E slabs are same

(B) heat flow through slab E is maximum

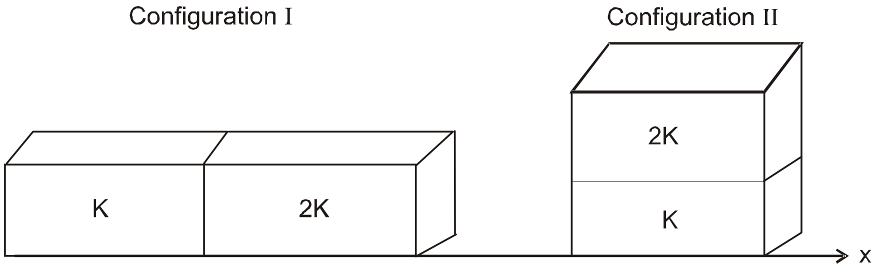
(C) temperature difference across slab E is smallest

(D) heat flow through C = heat flow through B + heat flow through D.

4. Three very large plates of same area are kept parallel and close to each other. They are considered as ideal black surfaces and have very high thermal conductivity. The first and third plates are maintained at temperatures 2T and 3T respectively. The temperature of the middle (i.e. second) plate under steady state condition is **[IIT-JEE-2012, Paper-1; 3/70, –1]**

(A) $\left(\frac{65}{2}\right)^{\frac{1}{4}}T$ (B) $\left(\frac{97}{4}\right)^{\frac{1}{4}}T$ (C) $\left(\frac{97}{2}\right)^{\frac{1}{4}}T$ (D) $(97)^{\frac{1}{4}}T$

5. Two rectangular blocks, having indentical dimensions, can be arranged either in configuration I or in configuration II as shown in the figure, On of the blocks has thermal conductivity k and the other 2k. The temperature difference between the ends along the x-axis is the same in both the configurations. It takes 9s to transport a certain amount of heat from the hot end to the cold end in the configuration I. The time to transport the same amount of heat in the configuration II is : **[JEE (Advanced) 2013,3/60,–1]**



(A) 2.0 s (B) 3.0 s (C) 4.5 s (D) 6.0 s

6. Parallel rays of light of intensity I = 912 Wm^{-2} are incident on a spherical balck body kept in surroundings of temperature 300 K. Take Stefan-Biltzmann constant $\sigma = 5.7 \times 10^{-8}\ Wm^{-2}\ K^{-4}$ and assume that the energy exchange with the surroundings is only through radiation. Th final steady state temperature of the black body is close to: **[JEE (Advanced) 2014, 3/60, –1]**

(A) 330 K (B) 660 K (C) 990 K (D) 1550 K

7. Two spherical stars A and B emit blackbody radiation. The radius of A is 400 times that of B and A emits 10^4 times the power emitted from B. The ratio $\left(\frac{\lambda_A}{\lambda_B}\right)$ fo their wavelengths λ_A and λ_B at which the peaks occur in their respective radiation curves is : **[JEE (Advanced) 2015 ; P-1, 4/88]**

8.* An incandescent bulb has a thin filament of tungsten that is heated to high temperature by passing an electric current. The hot filament emits black-body radiation. The filament is observed to break up at random locations after a sufficiently long time of operation due to non-uniform evaporation of tungsten from the filament. If the bulb is powered at constant voltage, which of the following statement(s) is (are) true ? **[JEE (Advanced) 2016 ; P-1, 4/62, –2]**

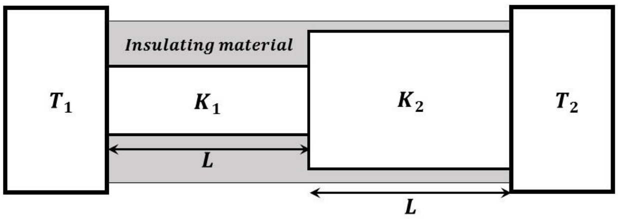
(A) The temperature distribution over the filament is uniform

(B) The resistance over small sections of the filament decreases with time
(C) The filament emits more light at higher band of frequencies before it breaks up
(D) The filament consumes less electrical power towards the end of the life of the bulb

9. A metal is heated in a furnace where a sensor is kept above the metal surface to read the power radiated (P) by the metal. The sensor has scale that displays $\log_2 (P / P_0)$, where P_0 is a constant. When the metal surface is at a temperature of 487 ºC, the sensor shows a value 1. Assume that the emissivity of the metallic surface remains constant. What is the value displayed by the sensor when the temperature of the metal surface is raised to 2767 ºC. **[JEE (Advanced) 2016 ; P-1, 3/62]**

10. A human body has surface area of approximately $1m^2$. The normal body temperature is 10 K above the surrounding room temperature T_0. Take the room temperature to be T_0 = 300 K. For T_0 = 300K, the value of σT_0^4 = 460 Wm^{-2} (where σ is the Stefan-Boltzmann constant). Which of the following options is/are correct ? **[JEE (Advanced) 2017 ; P-1, 4/61, –2]**
(A) If the surrounding temperature reduces by a small amount $\Delta T_0 << T_0$, then to maintain the same body temperature the same (living) human being needs to radiate $\Delta W = 4\sigma T_0^3 \Delta T_0$ more energy per unit time.
(B) Reducing the exposed surface area of the body (e.g. by curling up) allows humans to maintain the same body temperature while reducing the energy lost by radiation
(C) If the body temperature rises significantly then the peak in the spectrum of electromagnetic radiation emitted by the body would shift to longer wavelengths
(D) The amount of energy radiated by the body in 1 second is close to 60 joules

11. Two conducting cylinders of equal length but different radii are connected in series between two heat baths kept at temperatures T_1 = 300K and T_2 = 100K, as shown in the figure. The radius of the bigger cylinder is twice that of the smaller one and the thermal conductivities of the materials of the smaller and the larger cylinders are K_1 and K_2 respectively. If the temperature at the junction of the two cylinders in the steady state is 200K, then K_1/K_2 =__________. **[JEE (Advanced) 2018 ; P-1, 3/60]**

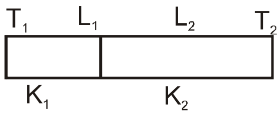


PART - II : JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

1. Assuming the sun to be a spherical body of radius R at a temperature of T K, evaluate the total radiant power, incident on Earth, at a distance r from the Sun. (earth radius = r_0) **[AIEEE-2006; 3/180]**

(1) $\frac{R^2\sigma T^4}{r^2}$ (2) $\frac{4\pi r_0^2 R^2\sigma T^4}{r^2}$ (3) $\frac{\pi r_0^2 R^2\sigma T^4}{r^2}$ (4) $\frac{r_0^2 R^2\sigma T^4}{4\pi r^2}$

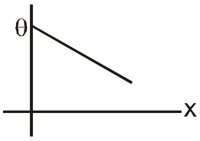
2. One end of a thermally insulated rod is kept at a temperature T_1 and the other at T_2. The rod is composed of two sections of lengths L_1 and L_2 and thermal conductivities k_1 and k_2 respectively. The temperature at the interface of the sections is

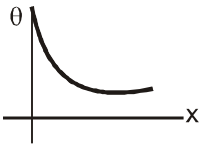


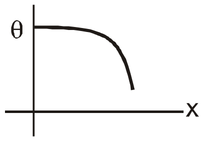
[AIEEE-2007; 3/120]

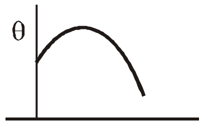
(1) $\frac{(K_2L_2T_1 + K_1L_1T_2)}{(K_1L_1 + K_2L_2)}$ (2) $\frac{(K_2L_1T_1 + K_1L_2T_2)}{(K_2L_1 + K_1L_2)}$ (3) $\frac{(K_1L_2T_1 + K_2L_1T_2)}{(K_1L_2 + K_2L_1)}$ (4) $\frac{(K_1L_1T_1 + K_2L_2T_2)}{(K_1L_1 + K_2L_2)}$

3. A long metallic bar is carrying heat from one of its ends to the other end under steady-state. The variation of temperature θ along the length x of the bar from its hot end is best described by which of the following figures **[AIEEE-2009, 4/144]**

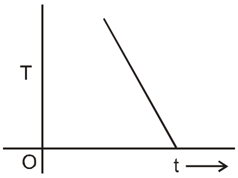
(1) 

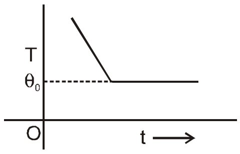
(2) 

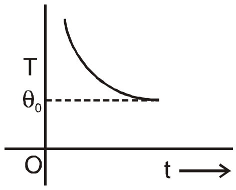
(3) 

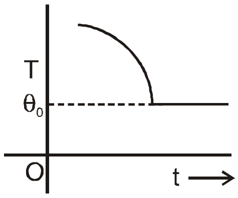
(4) 

4. If a piece of metal is heated to temperature θ and then allowed to cool ina room which is at temperature θ_0, the graph between the temperature T of the metal and time t will be closest to : **[JEE (Main) 2013, 4/120, –1]**

(1) 

(2) 

(3) 

(4) 

5. Three rods of Copper, brass and steel are welded together to form a Y-shaped structure. Area of cross-section of each rod = 4 cm^2. End of copper rod is maintained at 100°C where as ends of brass and steel are kept at 0°C. Lengths of the copper, brass and steel rods are 46, 13 and 12 cms respectively. The rods are thermally insulated from surroundings except at ends. Thermal conductivities of copper, brass and steel are 0.92, 0.26 and 0.12 CGS units respectively. Rate of heat flow through copper rod is: **[JEE (Main) 2014, 4/120, –1]**

(1) 1.2 cal/s (2) 2.4 cal/s (3) 4.8 cal/s (4) 6.0 cal/s

6. An ideal gas undergoes a quasi static, reversible process in which its molar heat capacity C remains constant. If during this process the relation of pressure P and volume V is given by PV^n = constant, then n is given by (Here C_p and C_V are molar specific heat at constant pressure and constant volume, respectively) : **[JEE (Main) 2016, 4/120, –1]**

(1) $n = \frac{C - C_p}{C - C_V}$ (2) $n = \frac{C_p - C}{C - C_V}$ (3) $n = \frac{C - C_V}{C - Cp}$ (4) $n = \frac{C_p}{C_V}$

Answers

EXERCISE-1

PART - I

Section (A) :

A-1.	64 J	**A-2.**	5×10^{-5} g/s
A-3.	4.0 W	**A-4.**	$2 : \pi$

A-5. $\dfrac{t_1 + t_2 + t_3}{\dfrac{t_1}{k_1} + \dfrac{t_2}{k_2} + \dfrac{t_3}{k_3}}$

Section (B) :

B-1. 15 W/m–°C **B-2.** $\dfrac{2\pi K\ell(T_2 - T_1)}{\ln(R_2 / R_1)}$

Section (C) :

C-1. 12 °C/s

Section (D) :

D-1. $\dfrac{q_1 - q_2}{q_1}$ **D-2.** 0.73 W.

D-3. 6×10^3 K; 4×10^3 K

D-4 $\dfrac{1}{90}$ **D-5.** 5803

D-6 1.71 ρrc

Section (E) :

E-1. 7 minutes

PART - II

Section (A) :

A-1. (B) **A-2.** (a) (A), (b) (D)

A-3. (B) **A-4.** (C) **A-5.** (C)

Section (B) :

B-1. (C)

Section (C) :

C-1. (B) **C-2.** (B) **C-3.** (D)

Section (D) :

D-1. (C) **D-2.** (B)

PART - III

1. (A) $\rightarrow$ p, s ; (B) $\rightarrow$ t ; (C) $\rightarrow$ q, r ; (D) $\rightarrow$ t

EXERCISE-2

PART - I

1.	(B)	**2.**	(D)	**3.**	(C)
4.	(D)	**5.**	(A)	**6.**	(C)
7.	(B)	**8.**	(A)	**9.**	(B)
10.	(A)	**11.**	(B)	**12.**	(A)

PART - II

1.	30	**2.**	3	**3.**	3
4.	7	**5.**	10	**6.**	5
7.	3	**8.**	22		

PART - III

1.	(ABC)	**2.**	(AB)	**3.**	(AB)
4.	(BC)	**5.**	(AC)	**6.**	(BCD)

PART - IV

1.	(B)	**2.**	(A)	**3.**	(A)
4.	(B)	**5.**	(A)	**6.**	(C)
7.	(A)	**8.**	(B)	**9.**	(C)

EXERCISE-3

PART - I

1.	9	**2.**	9	**3.**	(ACD)
4.	(C)	**5.**	(A)	**6.**	(A)
7.	2	**8.**	(CD)	**9.**	9
10.	(B)	**11.**	4.00		

PART - II

1.	(3)	**2.**	(3)	**3.**	(1)
4.	(3)	**5.**	(3)	**6.**	(1)