# 1 Conduction

## Multiple Choice Questions

**Q.1** Heat transfer takes place according to
(a) Zeroth Law of thermodynamics
(b) First Law of the thermodynamics
(c) Second Law of thermodynamics
(d) Third Law of thermodynamics

**[ESE : 1996]**

**Q.2** A stainless steel tubig ($k_s$ = 19 W/mK) of 2 cm ID and 5 cm OD in insulated with 3 cm thick asbestos ($k_a$ = 0.2 W/mK). If the temperature difference between the inner most and outermost surfaces is 500°C, the heat transfer rate per unit length is
(a) 0.94 W/m (b) 9.44 W/m
(c) 944.72 W/m (d) 9447.21 W/m

**[GATE: 2004]**

**Q.3** Match List-I (Governing Equations of Heat Transfer) with List-II (Specific Cases of Heat Transfer) and select the correct answer using the code given below the lists:

List-I

A. $\frac{d^2T}{dr^2} + \frac{2}{r}\frac{dT}{dr} = 0$

B. $\frac{\partial^2 T}{\partial x^2} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$

C. $\frac{d^2T}{dr^2} + \frac{1}{r}\frac{dT}{dr} = 0$

D. $\frac{d^2\theta}{dx^2} - m^2\theta = 0$

List-II
1. Fin in 1-D case
2. 1-D conduction in cylinder
3. 1-D conduction in sphere
4. Plane slab (Symbols have their usual meaning)

Codes:

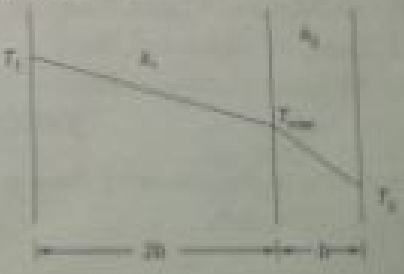
| | A | B | C | D |
|---|---|---|---|---|
| (a) | 2 | 4 | 3 | 1 |
| (b) | 3 | 1 | 2 | 4 |
| (c) | 2 | 1 | 3 | 4 |
| (d) | 3 | 4 | 2 | 1 |

**[ESE : 2005]**

**Q.4** Thermal diffusivity of a substance is
(a) inversely proportional to thermal conductivity
(b) directly proportional to thermal conductivity
(c) directly proportional to the square of thermal conductivity
(d) inversely proportional to the square of thermal conductivity

**[ESE : 2006]**

**Q.5** In a composite slab, the temperature at the interface ($T_{inter}$) between two materials is equal to the average of the temperature at the two ends. Assuming steady one dimensional heat conduction, which of the following statements is true about the respective thermal conductivities?

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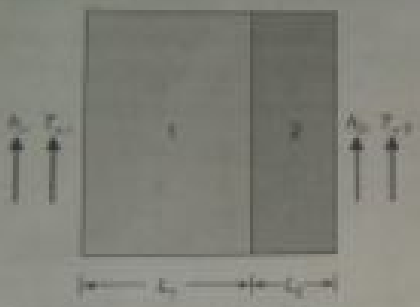
(c) $2k_1 = 3k_2$ (d) $k_1 = 2k_2$

[GATE : 2006]

**Q.6** Consider steady-state heat conduction across the thickness in a plane composite wall (as shown in the figure) exposed to convection conditions on both sides.

Given: $h_1$ = 20 W/m²K; $h_2$ = 50 W/m²K; $T_{\infty,1}$ = 20°C; $T_{\infty,2}$ = -2°C; $k_1$ = 20 W/mK; $k_2$ = 50 W/mK; $L_1$ = 0.30 m and $L_2$ = 0.15 m

Assuming negligible contact resistance between the wall surfaces, the interface temperature, T(in °C), of the two walls will be




(a) -0.50 (b) 2.75
(c) 3.75 (d) 4.50

[GATE : 2009]

**Q.7** Which one of the following is correct, in context of thermal diffusivity of liquid and gas

(a) $\alpha_{gas} > \alpha_{liquid}$
(b) $\alpha_{gas} < \alpha_{liquid}$
(c) $\alpha_{gas} = \alpha_{liquid}$
(d) Depend on other factors

**Q.8** Arrangement of silver, air, aluminium and lead in order of increasing thermal conductivity at room temperature yields

(a) Air, Aluminium, Silver, Lead
(b) Air, Aluminium, Lead, Silver
(c) Lead, Air, Aluminium, Silver
(d) Air, Lead, Aluminium, Silver

[DRDO : 2006]

**Q.9** Which one of the following have a highest thermal conductivity

(a) Boiling water
(b) Steam
(c) Solid ice
(d) Rain water

[UP Irrigation : 2007, UPSC JWM : 2010]

**Q.10** At steady state, the temperature variation in a plane wall, made of two different solids I and II is shown below figure


Then the thermal conductivity of material I

(a) is smaller than that of II
(b) is greater than that of II
(c) is equal to that of II
(d) can be greater than or smaller than that of II

**Q.11** In descending order of magnitude, the thermal conductivity of

1. Pure iron
2. Water
3. Saturated water vapour
4. Pure aluminium

Can be arranged as

(a) 1, 2, 3, 4
(b) 2, 3, 1, 4
(c) 4, 1, 2, 3
(d) 4, 3, 1, 2

[GATE Chemical Engg. 2006]

**Q.12** The outer surface of a long cylinder is maintained at constant temperature. The cylinder does not have any heat source. The temperature in the cylinder will

(a) increase linearly with radius
(b) decrease linearly with radius
(c) be independent of radius
(d) vary logarithmically with radius

[ESE : 2000]

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**Q.13** A hollow sphere has inner and outer surface areas of 2 m² and 8 m² respectively. For a given temperature difference across the surfaces, the heat flow is to be calculated considering the material of the sphere as a plane wall of the same thickness. What is the equivalent mean area normal to the direction of heat flow?

(a) 6 m² (b) 5 m²
(c) 4 m² (d) None of these

[IAS Pre : 2007]

**Q.14** In a case of one dimensional heat conduction in a medium with constant properties, $T$ is the temperature at position $x$, at time $t$. Then $\frac{\partial T}{\partial t}$ is proportional to

(a) $\frac{T}{x}$ (b) $\frac{\partial T}{\partial x}$

(c) $\frac{\partial^2 T}{\partial x \partial t}$ (d) $\frac{\partial^2 T}{\partial x^2}$

[GATE : 2005]

**Q.15** A steel ball of diameter 60 mm is initially in thermal equilibrium at 1030°C in a furnace. It is suddenly removed from the furnace and cooled in ambient air at 30°C, with convective heat transfer coefficient $h = 20$ W/m²K. The thermo-physical properties of steel are : density $\rho = 7800$ kg/m³, conductivity $k = 40$ W/mK and specific heat $c = 600$ J/kg K. The time required in seconds to cool the steel ball in air from 1030°C to 430°C is

(a) 519 (b) 931
(c) 1195 (d) 2144

[GATE : 2013]

**Q.16** A small copper ball of 5 mm diameter at 500 K is dropped into an oil bath whose temperature is 300 K. The thermal conductivity of copper is 400 W/mK, its density 9000 kg/m³ and its specific heat 385 J/kgK. If the heat transfer coefficient is 250 W/m²K and lumped analysis is assumed to be valid, the rate of fall of the temperature of the ball at the beginning of cooling will be, in K/s,

(a) 8.7 (b) 13.9
(c) 17.3 (d) 27.7

[GATE : 2006]

**Linked Answer Questions (Q.17-Q18)**

Consider steady one-dimensional heat flow in a plate of 20 mm thickness with a uniform heat generation of 50 MW/m³. The left and right faces are kept at constant temperatures of 160°C and 120°C respectively. The plate has a constant thermal conductivity of 200 W/mK.

**Q.17** The location of maximum temperature within the plate from its left face is

(a) 15 mm (b) 10 mm
(c) 5 mm (d) 0 mm

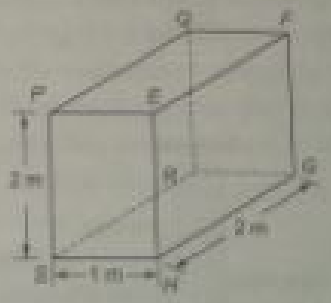
[GATE : 2007]

**Q.18** The maximum temperature within the plate in °C is

(a) 160 (b) 165
(c) 200 (d) 250

[GATE : 2007]

**Q.19** For the three-dimensional object shown in the figure below, five faces are insulated. The sixth face (PQRS), which is not insulated, interacts thermally with the ambient, with a convective heat transfer coefficient of 10 W/m²K. The ambient temperature is 30°C. Heat is uniformly generated inside the object at the rate of 100 W/m³. Assuming the face PQRS to be at uniform temperature, its steady state temperature is




(a) 10°C (b) 20°C
(c) 30°C (d) 40°C

[GATE : 2007]

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**Q.20** An aluminium sheet of 10 mm thickness is brought into contact with an iron sheet of 20 mm thickness. The outer surface of aluminium is kept at 100°C. Where as the outer surface of iron is maintained at 0°C. If the ratio of thermal conductivity of aluminium and iron is 3 : 1, then the interface temperature in °C is

(a) 40 (b) 60
(c) 75.7 (d) 85.7

[DRDO : 2009]

**Q.21** A metallic rod of uniform diameter and length $L$ connects two heat sources each at 500°C. The atmospheric temperature is 30°C. The temperature gradient $dT/dL$ at the centre of the bar will be

(a) $\frac{500}{L/2}$

(b) $-\frac{500}{L/2}$

(c) $\frac{470}{L/2}$

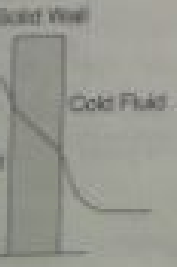
(d) Zero

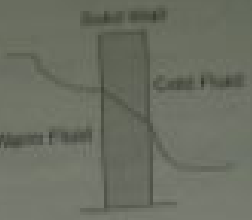
[IAS Pre : 2001]

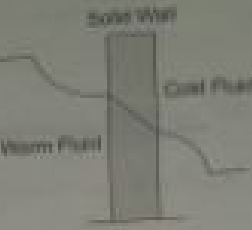
**Q.22** The temperature profile for heat transfer from one fluid to another separated by a solid wall is

(a)



(b)



(c)



(d)



**Q.23** A composite hollow sphere with steady internal heating is made of 2 layers of materials of equal thickness with thermal conductivities in the ratio of 1 : 2 for inner to outer layers. Ratio of inside to outside diameter is 0.8. What is ratio of temperature drop across the inner and outer layers?

(a) 0.4 (b) 1.6
(c) 2 ln 0.8 (d) 2.5

[ESE : 2005]

**Q.24** A 0.5 m thick plane wall has its two surfaces kept a 300°C and 200°C. Thermal conductivity of the wall varies linearly with temperature and its values at 300°C and 200°C are 25 W/mK and 15 W/mK, respectively. Then the steady heat flux through the wall is

(a) 8 kW/m$^2$ (b) 5 kW/m$^2$
(c) 4 kW/m$^2$ (d) 3 kW/m$^2$

[ESE : 2002]

**Q.25** A metal wall has an area of 5 m$^2$, thickness 10 cm and a thermal conductivity 200 W/mK what is the value of thermal resistance of the wall in k/W

(a) $10^{-4}$ (b) $10^{-3}$
(c) $2 \times 10^3$ (d) $10^4$

[UPSC JWM : 2008]

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**Q.26** A flat plate has thickness 5 cm, thermal conductivity 1 W/m-K, convective heat transfer coefficients on its two flat faces of 10 W/m²K and 20 W/m²K. The overall heat transfer coefficient for such a flat plate is

(a) 5 W/m²K (b) 6.30 W/m²K
(c) 20 W/m²K (d) 30 W/m²K

[ESE : 2001]

**Q.27** A large concrete slab 1 m thick has one dimensional temperature distribution

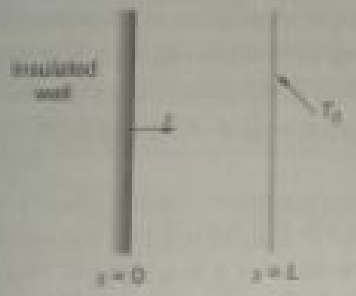
$$T = 4 - 10x + 20x^2 + 10x^3$$

where $T$ is temperature and $x$ is distance from one face towards other face of wall. If the slab material has thermal diffusivity of $2 \times 10^{-3}$ m²/hr, what is the rate of change of temperature at the other face of the wall?

(a) 0.1°C/h (b) 0.2°C/h
(c) 0.3°C/h (d) 0.4°C/h

[ESE : 2009]

**Q.28** A slab of thickness $L$ with one side ($x = 0$) insulated and other side ($x = L$) maintained at a constant temperature $T_0$ is shown below




A uniformly distributed internal heat source produces heat in the slab at the rate of $S$ W/m³. Assume the heat conduction to be steady state and 1-D along the $x$-direction, the maximum temperature in the slab occurs at $x$ equal to

(a) 0 (b) $\frac{L}{4}$

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

**Q.29** As the thickness of insulation around a heated cable gradually increases from zero, heat transfer from the conductor

(a) goes on decreasing monotonically
(b) goes on increasing monotonically
(c) first increases and then decreases
(d) first decreases and then increases

[DRDO : 2008]

**Q.30** It is desired to increase the heat dissipation rate over the surface of an electronic device of spherical shape of 5 mm radius exposed to convection with $h = 10$ W/m²K by encasing it in a spherical sheath of conductivity 0.04 W/mK. For maximum heat flow, the diameter of the sheath should be

(a) 18 mm (b) 16 mm
(c) 12 mm (d) 8 mm

[ESE : 1996]

**Q.31** A steam pipe is covered with two layers of insulating materials, with the better insulating material forming the outer part. If the two layers are interchanged, the heat conducted

(a) will decrease
(b) will increase
(c) will remain unaffected
(d) may increase or decrease depending upon the thickness of each layer

[ESE : 1997]

**Q.32** A copper wire of radius 0.5 mm is insulated with a sheathing of thickness 1 mm having a thermal conductivity of 0.5 W/mK. The outside surface convective heat transfer coefficient is 10 W/m²K. If the thickness of insulation sheathing is raised by 10 mm, then the electrical current-carrying capacity of the wire will

(a) increase
(b) decrease
(c) remain the same
(d) vary depending upon the electrical conductivity of the wire

[ESE : 2000]

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**Q.33** Consider the following statements pertaining to heat transfer through fins
1. Fins are equally effective irrespective of whether they are on the hot-side or cold-side of the fluid
2. The temperature along the fin is variable hence the rate of heat transfer varies along the elements of the fin
3. The fins should be made of materials that have a higher thermal conductivity than the material of the wall
4. Fins must be arranged at right angles to the direction of flow of the working fluid

Which of these statements are correct?
(a) 1 and 2 (b) 1 and 3
(c) 2 and 4 (d) 2 and 3

**Q.34** A fin has 5 mm diameter and 100 mm length. The thermal conductivity of fin material is 400 W/mK. One end of the fin is maintained at 130°C and its remaining surface is exposed to ambient air at 30°C. If the convective heat transfer coefficient is 40 W/m²K, the heat loss (in W) from the fin is
(a) 0.08 (b) 5.0
(c) 7.0 (d) 7.8

[GATE : 2010]

**Q.35** Consider one-dimensional steady state heat conducting along x-axis ($0 \le x \le L$), through a plane wall with the boundary surfaces ($x = 0$ and $x = L$) maintained at temperature of 0°C and 100°C. Heat is generated uniformly through out the wall. Choose the CORRECT statement
(a) The direction of heat transfer will be from the surface at 100°C to the surface of 0°C.
(b) The maximum temperature inside the wall must be greater than 100°C
(c) The temperature distribution is linear within the wall
(d) The temperature distribution is symmetric about the mid-plane of the wall

[GATE : 2013]

**Q.36** A spherical steel ball of 12 mm diameter is initially at 1000 K. It is slowly cooled in a surrounding of 300 K. The heat transfer coefficient between the steel ball and the surroundings is 5 W/m²K. The thermal conductivity of steel is 20 W/mK. The temperature difference between the centre and the surface of the steel ball is
(a) large because conduction resistance is far higher than the convective resistance.
(b) large because conduction resistance is far less than the convective resistance.
(c) small because conduction resistance is far higher than the convective resistance.
(d) small because conduction resistance is far less than the convective resistance.

[GATE : 2011]

**Q.38** Heisler charts are used to determine transient heat flow rate and temperature distribution when:
(a) Solids possess infinitely large thermal conductivity
(b) Internal conduction resistance is small and convective resistance is large
(c) Internal conduction resistance is large and the convective resistance is small
(d) Both conduction and convention resistance are almost of equal significance

[ESE : 1997]

**Q.39** A spherical thermocouple junction of diameter 0.706 mm is to be used for the measurement of temperature of a gas stream. The convective heat transfer coefficient on bend surface is 400 W/m²K. Thermophysical properties of thermocouple material are $k = 20$ W/m² K, $c = 400$ J/kg K and $\rho = 8500$ kg/m³. If the thermocouple initially at 30°C is placed in a hot stream of 300°C, the time taken by the bead to reach 296°C, is
(a) 2.35 s (b) 4.9 s
(c) 14.7 s (d) 29.4 s

**Q.40** A 10 mm diameter electrical conductor is covered by an insulation of 2 mm thickness


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The conductivity of the insulation is 0.06 W/m-K and the convection coefficient at the insulation surface is 10 W/m²-K. Addition of further insulation of the same material will

(a) increase heat loss continuously
(b) decrease heat loss continuously
(c) increase heat loss to a maximum and then decrease heat loss
(d) decrease heat loss to a minimum and then increase heat loss

[GATE : 2015]

**Q.41** A brick wall $k = 0.9$ W/mK of thickness 0.18 m separates the warm air in a room from the cold ambient air. On a particular winter day, the outside air temperature is – 5°C and the room needs to be maintained at 27°C. The heat transfer coefficient associated with outside air is 20 W/m²K. Neglecting the convective resistance of the air inside the room, the heat loss, in (W/m²), is

(a) 80 (b) 110
(c) 126 (d) 160

[GATE : 2015]

**Q.42** **Assertion (A):** Addition of insulation to the inside surface of a pipe always reduces heat transfer rate and critical radius concept has no significance.

**Reason (R):** If insulation is added to the inside surface, both surface resistance and internal resistance increase.

(a) both *A* and *R* are true and *R* is the correct explanation of *A*
(b) both *A* and *R* are true but *R* is not a correct explanation of *A*
(c) *A* is true but *R* is false
(d) *A* is false but *R* is true

**Q.43** A plastic sleeve of outer radius $r_0 = 1$ mm covers a wire (radius $r = 0.5$ mm) carrying electric current. Thermal conductivity of the plastic is 0.12 W/mK. The heat transfer coefficient on the outer surface of the sleeve exposed to air is 25 W/m²K. Due to the addition of the plastic cover, the heat transfer from the wire to the ambient will

(a) increase (b) remain the same
(c) decrease (d) be zero

[GATE : 2016]

**Q.44** A hollow cylinder has length $L$, inner radius $r_i$, outer radius $r_o$ and thermal conductivity $k$. The thermal resistance of the cylinder for radial conduction is

(a) $\frac{\ln(r_o/r_i)}{2\pi kL}$ (b) $\ln\left(\frac{r_o/r_i}{2\pi kL}\right)$

(c) $\frac{2\pi kL}{\ln(r_o/r_i)}$ OR $\frac{2\pi kL}{\ln(r_i/r_o)}$

[GATE : 2016]

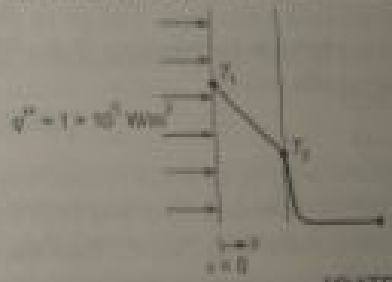
**Q.45** Grashof number signifies the ratio of

(a) inertia force to viscous force
(b) buoyancy force to viscous force
(c) buoyancy force to inertia force
(d) inertia force to surface tension force

[GATE : 2016]

## Numerical Data Type Questions

**Q.46** Consider one dimensional steady state heat conduction across a wall (as shown in figure below) of thickness 30 mm and thermal conductivity 15 W/mK. At $x = 0$, a constant heat flux, $q'' = 1 \times 10^5$ W/m² is applied. On the other side of the wall, heat is removed from the wall by convection with a fluid at 25°C and heat transfer coefficient of 250 W/m²K. The temperature (in °C), at $x = 0$ is _____




[GATE : 2014]

**Q.47** A material *P* of thickness 1 mm is sandwiched between two steel slabs, as shown in the figure below. A heat flux 10 kW/m² is supplied to one of the steel slabs as shown. The boundary temperatures of the slabs are indicated in the figure. Assume thermal conductivity of the steel

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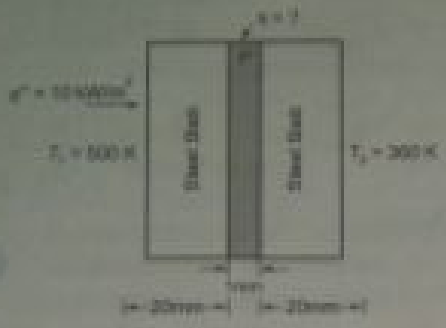
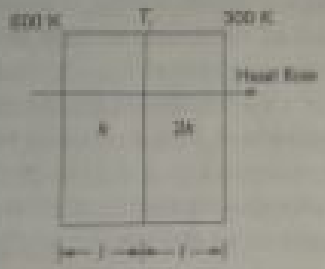
is 10 W/mK. Considering one-dimensional steady state heat conduction for the configuration, the thermal conductivity ($k$, in W/mK) of material $P$ is _____




[GATE : 2014]

**Q.48** Heat transfer through a composite wall is shown in figure. Both the sections of the wall have equal thickness ($\delta$). The conductivity of one section is $k$ and that of the other is $2k$. The left face of the wall is at 600 K and the right face is at 300 K.



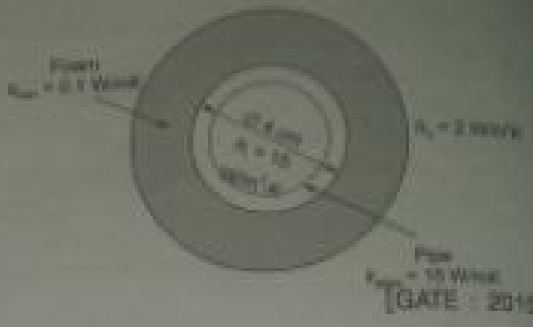

The interface temperature $T$ (in K) of the composite wall is _____

[GATE : 2014]

**Q.49** A plane wall has a thermal conductivity of 1.15 W/mK. If the inner surface is at 1100°C and the outer surface is at 350°C, then the design thickness (in meter) of the wall to maintain a steady heat flux of 2500 W/m² should be _____

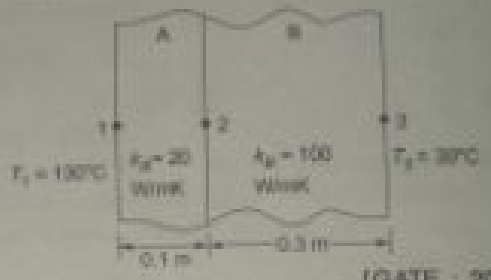
[GATE : 2014]

**Q.50** If a foam insulation is added to a 4 cm outer diameter pipe as shown in the figure, the critical radius of insulation (in cm) is _____




[GATE : 2015]

**Q.51** Steady one-dimensional heat conduction takes place across the faces 1 and 3 of a composite slab consisting of slabs A and B in perfect contact as shown in the figure, where $k_A$, $k_B$ denote the respective thermal conductivities. Using the data as given in the figure, the interface temperature $T_2$ (in °C) is _____




[GATE : 2016]

**Q.52** A cylindrical steel rod, 0.01 m in diameter and 0.2 m in length is first heated to 750°C and then immersed in a water bath at 100 °C. The heat transfer coefficient is 250 W/m²K. The density, specific heat and thermal conductivity of steel are $\rho$ = 7801 kg/m³, c = 473 J/kgK, and k = 43 W/mK, respectively. The time required for the rod to reach 300°C is _____ seconds.

[GATE : 2016]

**Q.53** A steel ball of 10 mm diameter at 1000 K is required to be cooled to 350 K by immersing it in a water environment at 300 K. The convective heat transfer coefficient is 1000 W/m²K. Thermal conductivity of steel is 40 W/mK. The time constant for the cooling process $\tau$ is 16 s. The time required (in s) to reach the final temperature is _____

[GATE : 2016]

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