1. 10 gm of ice at 0°C is kept in a calorimeter of water equivalent 10 gm. How much heat should be supplied to the apparatus to evaporate the water thus formed? (Neglect loss of heat)
   (A) 6200 cal  (B) 7200 cal  
   (C) 13600 cal  (D) 8200 cal  
   Sol.

2. Heat is being supplied at a constant rate to a sphere of ice which is melting at the rate of 0.1 gm/sec. It melts completely in 100 sec. The rate of rise of temperature thereafter will be (Assume no loss of heat)
   (A) 0.8 °C/sec  (B) 5.4 °C/sec  
   (C) 3.6 °C/sec  (D) will change with time  
   Sol.

3. A 2100 W continuous flow geyser (instant geyser) has water inlet temperature = 10°C while the water flows out at the rate of 20 g/sec. The outlet temperature of water must be about
   (A) 20°C  (B) 30°C  (C) 35°C  (D) 40°C  
   Sol.

4. A continuous flow water heater (geyser) has an electrical power rating = 2 kW and efficiency of conversion of electrical power into heat = 80%. If water is flowing through the device at the rate of 100 cc/sec, and the inlet temperature is 10°C, the outlet temperature will be
   (A) 12.2 °C  (B) 13.8 °C  
   (C) 20 °C  (D) 16.5 °C  
   Sol.

5. Ice at 0°C is added to 200 g of water initially at 70°C in a vacuum flask. When 50 g of ice has been added and has all melted the temperature of the flask and contents is 40°C. When a further 80 g of ice has been added and has all melted, the temperature of the whole is 10°C. Calculate the specific latent heat of fusion of ice.
   [Take S_I = 1 cal/gm °C]  
   (A) 3.8 × 10^3 J/kg  (B) 1.2 × 10^4 J/kg  
   (C) 2.4 × 10^4 J/kg  (D) 3.0 × 10^4 J/kg  
   Sol.

6. A solid material is supplied with heat at a constant rate. The temperature of material is changing with heat input as shown in the figure. What does slope DE represent.
   (A) latent heat of liquid  (B) latent heat of vapour
7. A block of ice with mass m falls into a lake. After impact, a mass of ice m/5 melts. Both the block of ice and the lake have a temperature of 0°C. If L represents the heat of fusion, the minimum distance the ice fell before striking the surface is
\[
\begin{align*}
(A) & \frac{L}{5g} & (B) & \frac{5L}{g} & (C) & \frac{gL}{5m} & (D) & \frac{ml}{5g}
\end{align*}
\]
\text{Sol.}

8. The specific heat of a metal at low temperatures varies according to \( S = aT^2 \) where \( a \) is a constant and \( T \) is absolute temperature. The heat energy needed to raise unit mass of the metal from \( T = 1 \, K \) to \( T = 2 \, K \) is
\[
\begin{align*}
(A) & 3a & (B) & \frac{15a}{4} & (C) & \frac{2a}{3} & (D) & \frac{12a}{5}
\end{align*}
\]
\text{Sol.}

9. The graph shown in the figure represents change in the temperature of 5 kg of a substance as it absorbs heat at a constant rate of 42 kJ min\(^{-1}\). The latent heat of vaporization of the substance is:
\[
\begin{align*}
(A) & 630 \, kJ \, kg^{-1} & (B) & 126 \, kJ \, kg^{-1} & (C) & 84 \, kJ \, kg^{-1} & (D) & 12.6 \, kJ \, kg^{-1}
\end{align*}
\]
\text{Sol.}

10. The density of a material A is 1500 kg/m\(^3\) and that of another material B is 2000 kg/m\(^3\). It is found that the heat capacity of 8 volumes of A is equal to heat capacity of 12 volumes of B. The ratio of specific heats of A and B will be
\[
\begin{align*}
(A) & 1 : 2 & (B) & 3 : 1 & (C) & 3 : 2 & (D) & 2 : 1
\end{align*}
\]
\text{Sol.}

11. Find the amount of heat supplied to decrease the volume of an ice water mixture by 1 cm\(^3\) without any change in temperature. (\( \rho_w = 0.9 \)
\( \rho_{\text{water}}, L_{\text{lat}} = 80 \, \text{cal/gm} \))
\[
\begin{align*}
(A) & 360 \, \text{cal} & (B) & 500 \, \text{cal} & (C) & 720 \, \text{cal} & (D) & \text{none of these}
\end{align*}
\]
12. Some steam at 100°C is passed into 1.1 kg of water contained in a calorimeter of water equivalent 0.02 kg at 15°C so that the temperature of the calorimeter and its contents rises to 80°C. What is the mass of steam condensing. (in kg)
(A) 0.130  (B) 0.065  (C) 0.260  (D) 0.135

13. 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

14. Two metal cubes with 3 cm-edges of copper and aluminium are arranged as shown in figure. (KCu = 385 W/m-K, KA = 209 W/m-K) (KCu = 385 W/m-K, KA = 209 W/m-K)
(a) The total thermal current from one reservoir to the other is:
(A) 1.43 x 10^4 W  (B) 2.53 x 10^4 W  (C) 1.53 x 10^4 W  (D) 2.53 x 10^4 W

15. 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
16. 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) $\frac{k_1-k_2}{k_1+k_2}$
- (D) $\frac{2k_1k_2}{k_1+k_2}$

**Sol.**

18. A lake surface is exposed to an atmosphere where the temperature is $< 0^\circ$C. If 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

- (A) $-20^\circ$C
- (B) $0^\circ$C
- (C) $-30^\circ$C
- (D) $-15^\circ$C

**Sol.**

19. One end of a 2.35m long and 2.0cm radius aluminium rod ($K = 235 \text{ W.m}^{-1}\text{K}^{-1}$) is held at $20^\circ$C. The other end of the rod is in contact with a block of ice at its melting point. The rate in kg. s$^{-1}$ at which ice melts is

- (A) $48\pi \times 10^{-6}$
- (B) $24\pi \times 10^{-6}$
- (C) $2.4\pi \times 10^{-6}$
- (D) $4.8\pi \times 10^{-6}$

[Take latent heat of fusion for ice as $\frac{10}{3} \times 10^4 \text{ J.kg}^{-1}$]

**Sol.**

20. Four rods of same material with different radii $r$ and length $l$ are used to connect two reservoirs of heat at different temperatures. Which one will conduct most heat?

- (A) $r = 2 \text{ cm}, l = 0.5 \text{ m}$
- (B) $r = 2 \text{ cm}, l = 2 \text{ m}$
- (C) $r = 0.5 \text{ cm}, l = 0.5 \text{ m}$
- (D) $r = 1 \text{ cm}, l = 1 \text{ m}$
21. 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 a material of thermal conductivity \( k_2 \). The two ends of the combined system are maintained at different temperatures. There is no loss of heat from the cylindrical surface and the system is in steady state. The effective thermal conductivity of the system is

(A) \( k_1 + k_2 \)  
(B) \( \frac{k_1 k_2}{k_1 + k_2} \)  
(C) \( \frac{1}{4}(k_1 - 3k_2) \)  
(D) \( \frac{1}{4}(3k + k_2) \)

Sol.

22. A rod of length \( L \) and uniform cross-sectional area has varying thermal conductivity which changes linearly from \( 2k \) at end \( A \) to \( k \) at the other end \( B \). The ends \( A \) and \( B \) of the rod are maintained at constant temperature 100°C and 0°C, respectively. At steady state, the graph of temperature \( T = T(x) \) where \( x = \) distance from end \( A \) will be

(A)  
(B)  
(C)  
(D)

Sol.

23. Two sheets of thickness \( d \) and \( 2d \) and same area are touching each other on their face. Temperature \( T_a, T_b, T_c \) shown are in geometric progression with common ratio \( r = 2 \). Then ratio of thermal conductivity of thinner and thicker sheet are

(A) 1  
(B) 2  
(C) 3  
(D) 4

Sol.

24. The wall with a cavity consists of two layers of brick separated by a layer of air. All three layers have the same thickness and the thermal conductivity of the brick is much greater than that of air. The left layer is at a higher temperature than the right layer and steady state condition exists. Which of the following graphs predicts correctly the variation of temperature \( T \) with distance \( d \) inside the cavity?

(A)  
(B)  
(C)  
(D)
25. A ring consisting of two parts ADB and ACB of same conductivity $k$ carries an amount of heat $H$. The ADB part is now replaced with another metal keeping the temperatures $T_1$ and $T_2$ constant. The heat carried increases to $2H$. What should be the conductivity of the new ADB part? Given \[
\frac{ACB}{ADB} = 3 : \]
(A) $\frac{7}{3} k$  (B) $2k$  (C) $\frac{5}{2} k$  (D) $3k$

26. Three conducting rods of same material and cross-section are shown in figure. Temperatures of A, D and C are maintained at 20°C, 90°C and 0°C. The ratio of lengths of BD and BC if there is no heat flow in AB is:
\[
\text{A} \quad \text{B} \quad \text{C} \quad \text{D}
\]
(A) $2/7$  (B) $7/2$  (C) $9/2$  (D) $2/9$

27. Six identical conducting rods are joined as shown in figure. Points A and D are maintained at temperature of 200°C and 20°C respectively. The temperature of junction B will be:
\[
\begin{array}{ccc}
A & 200°C & B \\
200°C & B & C \\
C & D & 20°C
\end{array}
\]
(A) 120°C  (B) 100°C  (C) 140°C  (D) 80°C

28. A metallic rod of cross-sectional area 9.0 cm² and length 0.54 m, with the surface insulated to prevent heat loss, has one end immersed in boiling water and the other in ice-water mixture. The heat conducted through the rod melts the ice at the rate of 1 gm for every 33 sec. The thermal conductivity of the rod is:
(A) 330 Wm⁻¹K⁻¹  (B) 60 Wm⁻¹K⁻¹  (C) 600 Wm⁻¹K⁻¹  (D) 33 Wm⁻¹K⁻¹

Sol.
29. A hollow sphere of inner radius R and outer radius 2R is made of a material of thermal conductivity K. It is surrounded by another hollow sphere of inner radius 2R and outer radius 3R made of same material of thermal conductivity K. The inside of smaller sphere is maintained at 0°C and the outside of bigger sphere at 100°C. The system is in steady state. The temperature of the interface will be:

(A) 50°C  
(B) 70°C  
(C) 75°C  
(D) 45°C

Sol.

30. The ends of a metal bar of constant cross-sectional area are maintained at temperatures T₁ and T₂ which are both higher than the temperature of the surroundings. If the bar is unlagged, which one of the following sketches best represents the variation of temperature with distance along the bar?

(A)  
(B)  
(C)  
(D)

Sol.

31. Three identical rods AB, CD and PQ are joined as shown. P and Q are mid points of AB and CD respectively. Ends A, B, C and D are maintained at 0°C, 100°C, 30°C and 60°C respectively. The direction of heat flow in PQ is:

(A) from P to Q  
(B) from Q to P  
(C) heat does not flow in PQ  
(D) data not sufficient

Sol.

32. The temperature drop through each layer of two layer furnace wall is shown in figure. Assume that the external temperature T₁ and T₂ are maintained constant and T₁ > T₂. If the thickness of the layers x₁ and x₂ are the same, which of the following statements are correct.

(A) k₁ > k₂  
(B) k₁ < k₂  
(C) k₁ = k₂ but heat flow through material (1) is larger than that through (2)  
(D) k₁ = k₂ but heat flow through material (1) is less than that through (2)

Sol.
33. Two rods A and B of different materials but same cross section are joined as in figure. The free end of A is maintained at 100°C and the free end of B is maintained at 0°C. If I_A = 2I_B, K_A = 2K_B and rods are thermally insulated from sides to prevent heat losses then the temperature \( \theta \) of the junction of the two rods is

\[
\begin{array}{c}
\text{(A) } 80°C \\
\text{(B) } 60°C \\
\text{(C) } 40°C \\
\text{(D) } 20°C
\end{array}
\]

\[ \text{Sol.} \]

35. If \( T_A \) and \( T_B \) are the temperature drops across the rod A and B, then

\[
\begin{align*}
\text{(A) } & \quad \frac{T_A}{T_B} = \frac{3}{1} \\
\text{(B) } & \quad \frac{T_A}{T_B} = \frac{1}{3} \\
\text{(C) } & \quad \frac{T_A}{T_B} = \frac{3}{4} \\
\text{(D) } & \quad \frac{T_A}{T_B} = \frac{4}{3}
\end{align*}
\]

\[ \text{Sol.} \]

36. If \( G_A \) and \( G_B \) are the temperature gradients across the rod A and B, then

\[
\begin{align*}
\text{(A) } & \quad \frac{G_A}{G_B} = \frac{3}{1} \\
\text{(B) } & \quad \frac{G_A}{G_B} = \frac{1}{3} \\
\text{(C) } & \quad \frac{G_A}{G_B} = \frac{3}{4} \\
\text{(D) } & \quad \frac{G_A}{G_B} = \frac{4}{3}
\end{align*}
\]

\[ \text{Sol.} \]

37. Two sheets of thickness \( d \) and \( 3d \), are touching each other. The temperature just outside the thinner sheet side is \( A \), and on the side of the thicker sheet is \( C \). The interface temperature is \( B \). A, B and C are in arithmetic progressing, the ratio of thermal conductivity of thinner sheet and thicker sheet is

\[
\begin{align*}
\text{(A) } & \quad 1 : 3 \\
\text{(B) } & \quad 3 : 1 \\
\text{(C) } & \quad 2 : 3 \\
\text{(D) } & \quad 1 : 9
\end{align*}
\]

\[ \text{Sol.} \]
38. A cylindrical rod with one end in a steam chamber and the outer end in ice results in melting of 0.1 gm of ice per second. If the rod is replaced by another with half the length and double the radius of the first and if the thermal conductivity of material of second rod is 1/4 that of first, the rate at which ice melts is gm/sec will be
(A) 3.2 (B) 1.6 (C) 0.2 (D) 0.1
Sol.

39. A composite rod made of three rods of equal length and cross-section as shown in the fig. The thermal conductivities of the materials of the rods are K/2, 5K and K respectively. The end A and end B are at constant temperatures. All heat entering the face A goes out of the end B there being no loss of heat from the sides of the bar. The effective thermal conductivity of the bar is

(A) 15K/16 (B) 6K/13 (C) 5K/16 (D) 2K/13.
Sol.

40. A rod of length L with sides fully insulated is of a material whose thermal conductivity varies with temperature as \( K = \frac{\alpha}{T} \), where \( \alpha \) is a constant. The ends of the rod are kept at temperature \( T_1 \) and \( T_2 \). The temperature \( T \) at \( x \), where \( x \) is the distance from the end whose temperature is \( T_1 \), is

(A) \( \frac{T_1 - T_2}{L} \) (B) \( T_2 - T_1 \)

41. 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 \( \theta_1 \) and that of outer is \( \theta_2 \). The radial distance from centre of shell where the temperature is just half way between \( \theta_1 \) and \( \theta_2 \) is:

(A) \( \frac{R_1 + R_2}{2} \) (B) \( \frac{R_2}{R_1 + R_2} \)

42. The two ends of two similar non-uniform rods of length \( L \) each and thermal conductivity 'K' are maintained at different but constant temperature. The temperature gradient at any point on the rod is \( \frac{\Delta T}{L} \). The heat flow per unit time through the rod is \( I \). Given \( T_1 > T_2 \). Then which of the following is true:
43. A system S receives heat continuously from an electrical heater of power 10 W. The temperature of S becomes constant at 50°C when the surrounding temperature is 20°C. After the heater is switched off, S cools from 35.1 °C to 34.9 °C in 1 minute. The heat capacity of S is
(A) 100 J/°C
(B) 300 J/°C
(C) 750 J/°C
(D) 1500 J/°C
Sol.

44. A sphere of ice at 0°C having initial radius R is placed in an environment having ambient temperature > 0°C. The ice melts uniformly, such that shape remains spherical. After a time t the radius of the sphere has reduced to r. Assuming the rate of heat absorption is proportional to the surface area of the sphere at any moment, which graph best depicts r(t).

45. The power radiated by a black body is P and it radiates maximum energy around the wavelength λ_m. If the temperature of the black body is now changed so that it radiates maximum energy around wavelength 3/4λ_m, the power radiated by it will increase by a factor of
(A) 4/3
(B) 16/9
(C) 64/27
(D) 256/81
Sol.

46. 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 distance are doubled, the power received by the foil will be:
(A) 16 P
(B) 4P
(C) 2 P
(D) P
47. Star $S_1$ emits maximum radiation of wavelength 420 nm and the star $S_2$ emits maximum radiation of wavelength 560 nm, what is the ratio of the temperature of $S_1$ and $S_2$:
(A) 4/3  (B) (4/3)$^{1/4}$  (C) 3/4  (D) (3/4)$^{1/2}$
Sol.

48. Spheres P and Q are uniformly constructed from the same material which is a good conductor of heat and the radius of Q is thrice the radius of P. The rate of fall of temperature of P is x times that of Q when both are at the same surface temperature. The value of x is:
(A) 1/4  (B) 1/3  (C) 3  (D) 4
Sol.

49. An ice cube at temperature -20°C is kept in a room at temperature 20°C. The variation of temperature of the body with time is given by

50. The spectral emissive power $E_\lambda$ for a body at temperature $T_1$ is plotted against the wavelength $\lambda$. The area under the curve is found to be $A$. At a different temperature $T_2$ the area is found to be $9A$. Then $\lambda_1/\lambda_2 =$
(A) 3  (B) 1/3  (C) 1/\sqrt{3}  (D) $\sqrt{3}$
Sol.

51. The intensity of radiation emitted by the Sun has its maximum value at a wavelength of 510 nm and that emitted by the North Star has the maximum value at 350 nm. If these stars behave like black bodies then the ratio of the surface temperature of the Sun and the North Star is
(A) 1.46  (B) 0.69  (C) 1.21  (D) 0.83
52. Two bodies P and Q have thermal emissivities of \( e_p \) and \( e_Q \) respectively. Surface areas of these bodies are same and the total radiant power is also emitted at the same rate. If temperature of P is \( T_p \) kelvin then temperature of Q i.e. \( T_Q \) is

\[
\begin{align*}
(A) & \quad \left( \frac{e_Q}{e_p} \right)^{\frac{1}{4}} T_p \\
(B) & \quad \left( \frac{e_Q}{e_p} \right)^{\frac{1}{4}} T_p \\
(C) & \quad \left( \frac{e_Q}{e_p} \right)^{\frac{1}{4}} T_p \\
(D) & \quad \left( \frac{e_Q}{e_p} \right)^{\frac{1}{4}} T_p
\end{align*}
\]

53. A black body calorimeter filled with hot water cools from 60°C to 50°C in 4 min and 40°C to 30°C in 8 min. The approximate temperature of surrounding is

\[
\begin{align*}
(A) & \quad 10^\circ C \\
(B) & \quad 15^\circ C \\
(C) & \quad 20^\circ C \\
(D) & \quad 25^\circ C
\end{align*}
\]

54. The rate of emission of radiation of a black body at 273°C is \( E \), then the rate of emission of radiation of this body at 0°C will be

\[
\begin{align*}
(A) & \quad \frac{E}{16} \\
(B) & \quad \frac{E}{4} \\
(C) & \quad \frac{E}{8} \\
(D) & \quad 0
\end{align*}
\]

55. A body cools from 75°C to 65°C in 5 minutes. If the room temperature is 25°C, then the temperature of the body at the end of next 5 minutes is:

\[
\begin{align*}
(A) & \quad 57^\circ C \\
(B) & \quad 55^\circ C \\
(C) & \quad 54^\circ C \\
(D) & \quad 53^\circ C
\end{align*}
\]

56. The temperature of a body falls from 40°C to 36°C in 5 minutes, when placed in a surrounding of constant temperature 16°C. Then the time taken for the temperature of the body to become 32°C is:

\[
\begin{align*}
(A) & \quad 5 \text{ min} \\
(B) & \quad 4.3 \text{ min} \\
(C) & \quad 6.1 \text{ min} \\
(D) & \quad 10.2 \text{ min}
\end{align*}
\]
1. From a black body, radiation is not:
   (A) emitted      (B) absorbed
   (C) reflected    (D) refracted
   Sol.

2. In accordance with Kirchhoff's law:
   (A) bad absorber is bad emitter
   (B) bad absorber is good reflector
   (C) bad reflector is good emitter
   (D) bad emitter is good absorber
   Sol.

3. The energy radiated by a body depends on:
   (A) area of body    (B) nature of surface
   (C) mass of body    (D) temperature of body
   Sol.

4. A hollow and a solid sphere of same material and identical outer surface are heated to the same temperature:
   (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.
   Sol.

5. The rate of cooling of a body by radiation depends on:
   (A) area of body    (B) mass of body
   (C) specific heat of body
   (D) temperature of body and surrounding.
   Sol.

6. A polished metallic piece and a black painted wooden piece are kept in open in bright sun for a long time:
   (A) the wooden piece will absorbs less heat than the metallic piece
   (B) the wooden piece will have a lower temperature than the metallic piece
   (C) if touched, the metallic piece will feel hotter than the wooden piece
   (D) when the two pieces are removed from the open to a cold room, the wooden piece will lose heat at a faster rate than the metallic piece
7. An experiment is performed to measure the specific heat of copper. A lump of copper is heated in an oven, then dropped into a beaker of water. To calculate the specific heat of copper, the experimenter must know or measure the value of all of the quantities below EXCEPT the
(A) heat capacity of water and beaker
(B) original temperature of the copper and the water
(C) final (equilibrium) temperature of the copper and the water
(D) time taken to achieve equilibrium after the copper is dropped into the water

Sol.

8. One end of a conducting rod is maintained at temperature 50°C and at the other end, ice is melting at 0°C. The rate of melting of ice is doubled if:
(A) the temperature is made 200°C and the area of cross-section of the rod is doubled
(B) the temperature is made 100°C and length of rod is made four times
(C) area of cross-section of rod is halved and length is doubled
(D) the temperature is made 100°C and the area of cross-section of rod and length both are doubled.

Sol.

9. Two metallic sphere A and B are made of same material and have got identical surface finish. The mass of sphere A is four times that of B. Both the spheres are heated to the same temperature and placed in a room having lower temperature but thermally insulated from each other.
(A) The ratio of heat loss of A to that of B is 2^{1/3}
(B) The ratio of heat loss of A to that of B is 2^{2/3}
(C) The ratio of the initial rate of cooling of A to that of B is 2^{-2/3}
(D) The ratio of the initial rate of cooling of A to that of B is 2^{-4/3}

Sol.

10. Two bodies A and B have thermal emissivities of 0.01 and 0.81 respectively. The outer surface areas of the two bodies are the same. The two bodies radiate energy at the same rate. The wavelength \( \lambda_m \) corresponding to the maximum spectral radiance in the radiation from B, is shifted from the wavelength corresponding to the maximum spectral radiance in the radiation from A by 1.00 \( \mu m \). If the temperature of A is 5802 K,
(A) the temperature of B is 1934 K
(B) \( \lambda_m = 1.5 \mu m \)
(C) the temperature of B is 11604 K
(D) the temperature of B is 2901 K

Sol.

11. Three bodies A, B and C have equal surface area and thermal emissivities in the ratio
\[ e_A : e_B : e_C = 1 : \frac{1}{2} : \frac{1}{4} \]
All the three bodies are
radiating at same rate. Their wavelengths corresponding to maximum intensity are \( \lambda_a, \lambda_b \) and \( \lambda_c \) respectively and their temperature are \( T_a, T_b \) and \( T_c \) on kelvin scale, then select the incorrect statement.

(A) \( \sqrt{T_a T_c} = T_b \) \( \sqrt{\lambda_a \lambda_c} = \lambda_b \)

(C) \( \sqrt{\theta_4 T_a \sqrt{\theta_4 T_c}} = \theta_0 T_b \)

(D) \( \sqrt{\theta_4 \lambda_a T_a \theta_0 \lambda_b T_b} = \theta_4 \lambda_c T_c \)

**Sol.**

13. If the temperature of the body is raised to a higher temperature \( T' \), then choose the correct statement(s)

(A) The intensity of radiation for every wavelength increases

(B) The maximum intensity occurs at a shorter wavelength

(C) The area under the graph increases

(D) The area under the graph is proportional to the fourth power of temperature

**Sol.**

**Question No. 12 to 14 (3 questions)**

The figure shows a radiant energy spectrum graph for a black body at a temperature \( T \).

12. Choose the correct statement(s)

(A) The radiant energy is not equally distributed among all the possible wavelengths

(B) For a particular wavelength the spectral intensity is maximum

(C) The area under the curve is equal to the total rate at which heat is radiated by the body at that temperature

(D) None of these

**Sol.**

14. Identify the graph which correctly represents the spectral intensity versus wavelength graph at two temperatures \( T' \) and \( T (T < T') \)

(A) ![Graph A]

(B) ![Graph B]

(C) ![Graph C]

(D) None of these

**Sol.**
1. In the following equation calculate the value of $H$.
1 kg steam at $200^\circ C = H + 1$ kg water at $100^\circ C$
\[ S_{steam} = \text{Constant} = 0.5 \text{ cal/gm}^\circ C \]
Sol.

2. From what height should a piece of ice ($0^\circ C$) fall so that it melts completely? Only one quarter of the heat produced is absorbed by the ice. The latent heat of ice is $3.4 \times 10^5$ J kg$^{-1}$ and g is 10 N/kg$^{-1}$.
Sol.

3. A copper cube of mass 200 g slides down on a rough inclined plane of inclination $37^\circ$ at a constant speed. Assume that any loss in mechanical energy goes into the copper block as thermal energy. Find the increase in the temperature of the block as it slides down through 60 cm. Specific heat capacity of copper = 420 J/kg$\cdot$K.
Sol.

4. 10 gm ice at $-10^\circ C$, 10 gm water at $20^\circ C$ and 2g steam at $100^\circ C$ are mixed with each other then final equilibrium temperature.
Sol.

5. Materials A, B and C are solids that are at their melting temperatures. Material A requires 200 J to melt 4 kg, material B requires 300 J to melt 5 kg, and material C requires 300 J to melt 6 kg. Rank the materials according to their heats of fusion, greatest first.
Sol.

6. In a thermally isolated container, material A of mass $m$ is placed against material B, also of mass $m$ but at higher temperature. When thermal equilibrium is reached, the temperature changes $\Delta T_A$ and $\Delta T_B$ of A and B are recorded. Then the experiment is repeated, using A with other materials. All of the same mass $m$. The results are given in the table. Rank the four materials according to their specific heats, greatest first.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Temperature Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>$\Delta T_A = +50^\circ C$, $\Delta T_B = -50^\circ C$</td>
</tr>
<tr>
<td>2.</td>
<td>$\Delta T_A = +10^\circ C$, $\Delta T_B = -20^\circ C$</td>
</tr>
<tr>
<td>3.</td>
<td>$\Delta T_A = +2^\circ C$, $\Delta T_B = -40^\circ C$</td>
</tr>
</tbody>
</table>
7. Indian style of cooling drinking water is to keep it in a pitcher having porous walls. Water comes to the outer surface very slowly and evaporates. Most of the energy needed for evaporation is taken from the water itself and the water is cooled down. Assume that a pitcher contains 10 kg of water and 0.2 g of water comes out per second. Assuming no backward heat transfer from the atmosphere to the water, calculate the time in which the temperature decreases by 5°C. Specific heat capacity of water = 4200 J/kg·°C and latent heat of vaporization of water = 2.27 × 10^6 J/kg.

Sol.

8. An aluminium container of mass 100 gm contains 200 gm of ice at −20°C. Heat is added to the system at the rate of 100 cal/s. Find the temperature of the system after 4 minutes (specific heat of ice = 0.5 and L = 80 cal/gm, specific heat of A = 0.2 cal/gm/°C)

Sol.

9. A volume of 120 ml of drink (half alcohol + half water by mass) originally at a temperature of 25°C is cooled by adding 20 gm ice at 0°C. If all the ice melts, find the final temperature of the drink. (density of drink = 0.833 gm/cc, specific heat of alcohol = 0.6 cal/gm/°C)

Sol.

10. Two identical calorimeters A and B contain equal quantity of water at 20°C. A 5 gm piece of metal X of specific heat 0.2 cal g⁻¹ (°C)⁻¹ is dropped into A and a 5 gm piece of metal Y into B. The equilibrium temperature in A is 22°C and in B 23°C. The initial temperature of both the metals is 40°C. Find the specific heat of metal Y in cal g⁻¹ (°C)⁻¹.

Sol.

11. Two 50 gm ice cubes are dropped into 250 gm of water into a glass. If the water was initially at a temperature of 25°C and the temperature of ice −15°C. Find the final temperature of water. (specific heat of ice = 0.5 cal/gm/°C and L = 80 cal/gm). Find final amount of water and ice.
12. A substance is in the solid form at 0°C. The amount of heat added to this substance and its temperature are plotted in the following graph. If the relative specific heat capacity of the solid substance is 0.5, find from the graph

(i) the mass of the substance; 
Sol.

(ii) the specific latent heat of the melting process, and 
Sol.

(iii) the specific heat of the substance in the liquid state. 
Sol.

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

14. One end of a steel rod (K = 42 J/m-s-°C) of length 1.0m is kept in ice at 0°C and the other end is kept in boiling water at 100°C. The area of cross-section of the rod is 0.04 cm². Assuming no heat loss to the atmosphere, find the mass of the ice melting per second. Latent heat of fusion of ice = 3.36 x 10⁸ J/kg. 
Sol.

15. 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 100°C, 0°C and 25°C respectively. Find the heat current in CD.

Sol.
16. A semicircular rod is joined at its end 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.

Sol.

18. 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 his combination behaves as a single slab. Find is effective thermal conductivity.

Sol.

19. A thin walled metal tank of surface area 5 m$^2$ is filled with water tank and contains an immersion heater dissipating 1 kW. The tank is covered with 4 cm thick layer of insulation whose thermal conductivity is 0.2 W/m$^o$K. The outer face of the Insulation is 25$^o$C. Find the temperature of the tank in the steady state.

Sol.

17. One end of copper rod of uniform cross-section and of length 1.45 m is in contact with ice at 0$^o$C and the other end with water at 100$^o$C. Find the position of point along its length where a temperature of 200$^o$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 [Assume that the whole system is insulated from surroundings]. [take $L_i = 540$ cal/g $L_v = 80$ cal/g]
20. The figure shows the face and interface temperature of a composite slab containing of four layers of two materials having identical thickness. Under steady state condition, find the value of temperature $\theta$.

\[
\begin{array}{|c|c|c|c|}
\hline
20^\circ C & 10^\circ C & \theta & -5^\circ C & -10^\circ C \\
\hline
k & 2k & k & 2k \\
\hline
\text{k=thermal conductivity} \\
\hline
\end{array}
\]

(A) 5\degree C  \quad (B) 6\degree C  \\
(C) 4\degree C  \quad (D) 7\degree C

21. In the square frame of side $l$ of metallic rods, the corners A and C are maintained at $T_1$ and $T_2$ respectively. The rate of heat flow from A to C is $Q$. If A and D are instead maintained $T_1$ & $T_2$ respectively find, find the total rate of heat flow.

Sol.

22. 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\degree C and 10\degree C respectively and it is found that 160 x Joule of heat passes from the inner sphere to the outer sphere per second. Find the thermal conductivity of the material between the spheres.

Sol.

23. Find the rate of heat flow through a cross-section of the rod shown in figure ($0_2 > 0_1$). Thermal conductivity of the material of the rod is $K$.

Sol.
24. A metal rod of cross-sectional area 1.0 cm² 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.

Sol.

25. A rod of negligible heat capacity has length 20 cm, area of cross-section 1.0 cm² and thermal conductivity 200 W/m·°C. The temperature of one end is maintained at 0°C and that of the other end is slowly and linearly varied from 0°C to 60°C in 10 minutes. Assuming no loss of heat through the sides, find the total heat transmitted through the rod in these 10 minutes.

Sol.

26. A pan filled with hot food cools from 50.1°C to 49.9°C in 5 sec. How long will it take to cool from 40.1°C to 39.9°C if room temperature is 30°C?

Sol.

27. A solid copper cube and sphere, both of same mass & emissivity are heated to same initial temperature and kept under identical conditions. What is the ratio of their initial rate of fall of temperature?

Sol.

28. Two spheres of same radius R have their densities in the ratio 8 : 1 and the ratio of their specific heats are 1 : 4. If by radiation their rates of fall of temperature are same, then find the ratio of their rates of losing heat.
29. The maximum wavelength in the energy distribution spectrum of the sun is at 4753 Å and its temperature is 6050K. What will be the temperature of the star whose energy distribution shows a maximum at 9506 Å.

Sol.

30. A black body radiates 5 watts per square cm of its surface area at 27°C. How much will it radiate per square cm at 327°C.

Sol.

31. A 100 W bulb has tungsten filament of total length 1. m and radius 4 × 10^{-4} m. The emissivity of the filament is 0.8 and σ = 6.0 × 10^{-8} W/m² - K⁴. Calculate the temperature of the filament when the bulb is operating at correct wattage.

Sol.

32. A copper sphere is suspended in an evacuated chamber maintained at 300K. The sphere is maintained at a constant temperature of 500K by heating it electrically. A total of 210 W of electric power is needed to do it. When the surface of the copper sphere is completely blackened, 700 W is needed to maintain the same temperature of the sphere. Calculate the emissivity of copper.

Sol.

33. During a certain duration in the day, the earth is in radiative equilibrium with the sun. Find the surface temperature of the earth during that duration.

[Given, radius of sun = 6.9 × 10⁸ m, surface temperature of sun = 6000 K and the distance of earth from the sun = 1.49 × 10¹¹ m. Assume that the sun and earth behave as black bodies.]

Sol.
34. Estimate the temperature at which a body may appear blue or red. The values of $\lambda_{\text{max}}$ for these are 5000 and 7500 Å respectively. [Given Wein's constant $b = 0.3$ cm K] Sol.

35. Find the quantity of energy radiated from 1 cm$^2$ of a surface in one second by a black body if the maximum energy density corresponds to a wavelength of 5000 Å ($b = 0.3$ cm K and $\sigma = 5.6 \times 10^{-8}$ w/m$^2$/k$^4$) Sol.

36. The following observations have been noted for a black body spectrum, taken for $T = 500$ K. Calculate the value of $\lambda_{\text{m}}$ at $T = 1000$ K.

<table>
<thead>
<tr>
<th>$\lambda$ (in µm)</th>
<th>10</th>
<th>8</th>
<th>6</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_\lambda$ (in SI units)</td>
<td>10</td>
<td>14</td>
<td>16</td>
<td>12</td>
</tr>
</tbody>
</table>

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

38. A body cools down from 50°C to 45°C in 5 minutes and to 40°C in another 8 minutes. Find the temperature of the surrounding. Sol.
LEVEL - II

1. A copper calorimeter of mass 100 gm contains 200 gm of a mixture of ice and water. Steam at 100°C under normal pressure is passed into the calorimeter and the temperature of the mixture is allowed to rise to 50°C. If the mass of the calorimeter and its contents is now 330 gm, what was the ratio of ice and water in beginning? Neglect heat losses.

Given: Specific heat capacity of copper
= 0.42 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1},
Specific heat capacity of water
= 4.2 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1},
Specific heat of fusion of ice
= 3.36 \times 10^3 \text{ J kg}^{-1},
Latent heat of condensation of steam
= 22.5 \times 10^3 \text{ J kg}^{-1}

2. A solid substance of mass 10 gm at −10°C was heated to −2°C (still in the solid state). The heat required was 64 calories. Another 88 calories was required to raise the temperature of the substance (now in the liquid state) to 1°C, while 900 calories was required to raise the temperature from −2°C to 3°C. Calculate the specific heat capacities of the substance in the solid and liquid state in calories per kilogram per kelvin. Show that the latent heat of fusion L is related to the melting point temperature \( T_m \) by \( L = 85400 + 200 T_m \).

3. A steel drill making 180 rpm is used to drill a hole in a block of steel. The mass of the steel block and the drill is 180 gm. If the entire mechanical work is used up in producing heat and the rate of rise in temperature of the block and the drill is 0.5 °C/s. Find (a) the rate of working of the drill in watts, and (b) the torque required to drive the drill.

Specific heat of steel = 0.1 and J = 4.2 J/cal.
Use: \( P = \omega \times T \).

4. A flow calorimeter is used to measure the specific heat of a liquid. Heat is added at a known rate to a stream of the liquid as it passes through the calorimeter at a known rate. Then a measurement of the resulting temperature difference between the inflow and the outflow points of the liquid stream enables us to compute the specific heat of the liquid. A liquid of density 0.2 g/cm³ flows through a calorimeter at the rate of 10 cm³/s. Heat is added by means of a 250-W electric heating coil, and a temperature difference of 25°C is established in steady-state conditions between the inflow and the outflow points. Find the specific heat of the liquid.

5. Ice at −20°C is filled up to height \( h = 10 \text{ cm} \) in a uniform cylindrical vessel. Water at temperature 0°C is filled in another identical vessel up to the same height \( h = 10 \text{ cm} \). Now, water from second vessel is poured into first vessel and it is found that level of upper surface falls through \( \Delta h = 0.5 \text{ cm} \) when thermal equilibrium is reached. Neglecting thermal capacity of vessels, change in density of water due to change in temperature and loss of heat due to radiation, calculate initial temperature \( \theta \) of water.

Given: Density of water, \( \rho_w = 1 \text{ gm cm}^{-3} \), Density of ice, \( \rho_i = 0.9 \text{ gm cm}^{-3} \), Specific heat of water, \( s_w = 1 \text{ cal/gm °C} \), Specific heat of ice \( s_i = 0.5 \text{ cal/gm °C} \), Specific latent heat of ice, \( L = 80 \text{ cal/gm} \)

6. A composite body consists of two rectangular plates of the same dimensions but different thermal conductivities \( K_a \) and \( K_b \). This body is used to transfer heat between two objects maintained at different temperatures. The composite body can be placed such that flow of heat takes place either parallel to the interface or perpendicular to it. Calculate the effective thermal conductivities \( K_a \) and \( K_b \), of the composite body for the parallel and perpendicular orientations. Which orientation will have more thermal conductivity?

7. A highly conducting solid cylinder of radius \( a \) and length \( l \) is surrounded by a coaxial layer of a material having thermal conductivity \( K \) and negligible heat capacity. Temperature of surrounding space (out side the layer) is \( T_s \), which is higher than temperature of the cylinder. If heat capacity per unit volume of cylinder material is \( s \) and outer radius of the layer is \( b \), calculate time required to increase temperature of the cylinder from \( T_i \) to \( T_f \). Assume end faces to be thermally insulated.

8. A vertical brick duct (tube) is filled with cast iron. The lower end of the duct is maintained at a temperature \( T_i \) which is greater than the melting point \( T_m \) of cast iron and the upper end at a temperature \( T_o \) which is less than the temperature of the melting point of cast iron. It is given that the conductivity of liquid cast iron is equal to \( k \) times the conductivity of solid cast iron. Determine the fraction of the duct filled with molten metal.
9. A lagged stick of cross section area 1 cm$^2$ and length 1 m is initially at a temperature of 0°C. It is then kept between 2 reservoirs of temperature 100°C and 0°C. Specific heat capacity is 10 J/kg°C and linear mass density is 2 kg/m. Find

(a) temperature gradient along the rod in steady state.
(b) total heat absorbed by the rod to reach steady state.

10. A cylindrical block of length 0.4 m an area of cross-section 0.04 m$^2$ is placed coaxially on a thin metal disc of mass 0.4 kg and of the same cross-section. The upper face of the cylinder is maintained at a constant temperature of 400K and the initial temperature of the disc is 300K. If the thermal conductivity of the material of the cylinder is 10 watt/m-K and the specific heat of the material of the disc in 600 J/kg-K, how long will it take for the temperature of the disc to increase to 350K? Assume, for purposes of calculation, the thermal conductivity of the disc to be very high and the system to be thermally insulated except for the upper face of the cylinder.

11. A solid copper sphere cools at the rate of 2.8°C per minute, when its temperature is 127°C. Find the rate at which another solid copper sphere of twice the radius lose its temperature at 327°C, if in both the cases, the room temperature is maintained at 27°C.

12. End A of a rod AB of length L = 0.5 m and of uniform cross-sectional area is maintained at some constant temperature. The heat conductivity of the rod is $k = 17$ J/s·m·K. The other end B of this rod is radiating energy into vacuum and the wavelength with maximum energy density emitted from this end is $\lambda = 75000$ Å. If the emissivity of the end B is $e = 1$, determine the temperature of the end A. Assuming that except the ends, the rod is thermally insulated.

13. The shell of a space station is a blackened sphere in which a temperature $T = 500K$ is maintained due to operation of appliances of the station. Find the temperature of the shell if the station is enveloped by a thin spherical black screen of nearly the same radius as the radius of the shell.

14. A liquid takes 5 minutes to cool from 80°C to 50°C. How much time will it take to cool from 60°C to 30°C? The temperature of surrounding is 20°C. Use exact method.

15. A barometer is faulty. When the true barometer reading are 73 and 75 cm of Hg, the faulty barometer reads 69 cm and 70 cm respectively.
(i) What is the total length of the barometer tube?
(ii) What is the true reading when the faulty barometer reads 69.5 cm?
(iii) What is the faulty barometer reading when the true barometer reads 74 cm?

16. A vessel of volume $V = 30 l$ is separated into three equal parts by stationary semipermeable thin membranes as shown in the Figure. The left, middle and right parts are filled with $m_N = 30g$ of hydrogen, $m_O = 160g$ of oxygen, and $m_N = 70g$ of nitrogen respectively. The left partition lets through only hydrogen, while the right partition lets through hydrogen and nitrogen. What will be the pressure in each part of the vessel after the equilibrium has been set in if the vessel is kept at a constant temperature $T = 300K$?

17. Twelve conducting rods form the riders of a uniform cube of side 'r'. If in steady state, B and H ends of the rod are at 100°C and 0°C. Find the temperature of the junction 'A'.
### Exercise - IV

#### PREVIOUS YEAR QUESTIONS

#### LEVEL - I

**JEE MAIN**

1. Which of the following is more close to a black body?
   - (A) Black board paint
   - (B) Green leaves
   - (C) Black holes
   - (D) Red roses

   **Sol.**

2. Infrared radiations are detected by
   - (A) spectrometer
   - (B) pyrometer
   - (C) nanometer
   - (D) photometer

   **Sol.**

3. Heat given to a body which raises its temperature by 1° C is
   - (A) water equivalent
   - (B) thermal capacity
   - (C) specific heat
   - (D) temperature gradient

   **Sol.**

4. Cooking gas containers are kept in a lorry moving with uniform speed. The temperature of the gas molecules inside will
   - (A) increase
   - (B) decrease
   - (C) remain same
   - (D) decrease for some, while increase for others

   **Sol.**

5. Two spheres of the same material have radii 1 m and 4 m and temperatures 4000 K and 2000 K respectively. The ratio of the energy radiated per second by the first sphere to that by the second is:
   - (A) 1 : 1
   - (B) 16 : 1
   - (C) 4 : 1
   - (D) 1 : 9

   **Sol.**
6. If mass-energy equivalence is taken into account, when water is cooled to form ice, the mass of water should [AIEEE 2002]
   (A) increase  (B) remain unchanged
   (C) decrease  (D) first increase then decrease
   Sol.

7. According to Newton's law of cooling, the rate of cooling of a body is proportional to \((\Delta T)^n\), where \(\Delta T\) is the difference of the temperature of the body and the surrounding, the \(n\) is equal to
   (A) 2    (B) 3    (C) 4    (D) 1
   Sol.

8. If the temperature of the sun were to increase from \(T\) to \(2T\) and its radius from \(R\) to \(2R\), then the ratio of the radiant energy received on earth to what it was previously, will be [AIEEE 2004]
   (A) 4    (B) 16    (C) 32    (D) 64
   Sol.

9. 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 \(T_1\) and \(T_2\) \((T_2 > T_1)\). The rate of heat transfer through the slab, in a steady state is \[\frac{A(T_2 - T_1)K}{x}\] with \(f\) equal to [AIEEE 2003]
   (A) 1    (B) 1/2    (C) 2/3    (D) 1/3
   Sol.
10. The figure shows a system of two concentric spheres of radii $r_1$ and $r_2$ and kept at temperature $T_1$ and $T_2$, respectively. The radial rate of flow of heat in a substance between the two concentric spheres, is proportional to

\[ \frac{r_1 - r_2}{r_1 r_2} \]  

(A) \( \frac{r_1 - r_2}{r_1 r_2} \)  

(B) \( \ln \left( \frac{r_2}{r_1} \right) \)  

(C) \( \frac{r_1 r_2}{r_2 - r_1} \)  

(D) \( r_2 - r_1 \)

**Sol.**

11. 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

\[ \frac{4\pi r^2 \sigma T^4}{r^2} \]  

(A) \( \frac{4\pi r^2 \sigma T^4}{r^2} \)  

(B) \( \pi r^2 \sigma T^4 \)  

(C) \( \frac{r_2 R^2 \sigma T^4}{4 \pi r^2} \)  

(D) \( \frac{R^2 \sigma T^4}{r^2} \)

where $r_2$ is the radius of the earth and $\sigma$ is Stefan’s constant.

12. 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 length $l_1$ and $l_2$ and thermal conductivities $K_1$ and $K_2$, respectively. The temperature at the interface of the two sections is

\[ \frac{K_1}{K_1 + K_2} T_1 + \frac{K_2}{K_1 + K_2} T_2 \]

(A) \( \frac{K_1}{K_1 + K_2} T_1 + \frac{K_2}{K_1 + K_2} T_2 \)

(B) \( \frac{K_1}{K_1 + K_2} (T_1 + K_1 l_1) \)

(C) \( \frac{K_2}{K_1 + K_2} (T_2 + K_2 l_2) \)

(D) \( \frac{K_1}{K_1 + K_2} (T_1 + K_1 l_1) \)

**Sol.**
13. A long metallic bar is carrying heat from one of its ends to the other end under steady-state. The variation of temperature $\theta$ along the length $x$ of the bar from its hot end is best described by which of the following figure. 

[AIEEE 2009]

(A) 

(B) 

(C) 

(D) 

Sol.

14. A liquid in a beaker has temperature $\theta(t)$ at time $t$ and $\theta_i$ is temperature of surrounding, then according to Newton’s law of cooling, the correct graph between $\log_e (\theta - \theta_i)$ and $t$ is 

[AIEEE 2012]

(A) 

(B) 

(C) 

(D) 

Sol.
1. The temperature of 100 gm of water is to be raised from 24°C to 90°C by adding steam to it. Calculate the mass of the steam required for this purpose. [JEE '96]

Sol.

2. Two metal cubes A & B of same size are arranged as shown in figure. The extreme ends of the combination are maintained at the indicated temperatures. The arrangement is thermally insulated. The coefficients of thermal conductivity of A & B are 300 W/m°C and 200 W/m°C respectively. After steady state is reached the temperature T of the interface will be [JEE '96]

Sol.

3. A double pane window used for insulating a room thermally from outside consists of two glass sheets each of area 1 m² and thickness 0.01 m separated by a 0.05 m thick stagnant air space. In the steady state, the room glass interface and the glass outdoor interface are at constant temperatures of 27°C and 0°C respectively.

4. A spherical black body with a radius of 12 cm radiates 450 W power at 500 K. If the radius were halved and the temperature doubled, the power radiated in watt would be (A) 225 (B) 450 (C) 900 (D) 1800 [JEE '97]

Sol.

5. Earth receives 1400 W/m² of solar power. If all the solar energy falling on a lens of area 0.2 m² is focussed on to a block of ice of mass 280 grams, the time taken to melt the ice will be _______ minutes. (Latent heat of fusion of ice = 3.3 x 10⁴ J/kg) [JEE '97]

Sol.
6. A solid body X of heat capacity $C$ is kept in an atmosphere whose temperature is $T_a = 300K$. At time $t = 0$, the temperature of $X$ is $T_x = 400K$. It cools according to Newton’s law of cooling. At time $t$, its temperature is found to be $350K$. At this time $t$, the body $X$ is connected to a larger body $Y$ at atmospheric temperature $T_a$, through a conducting rod of length $L$, cross-sectional area $A$ and thermal conductivity $K$. The heat capacity of $Y$ is so large that any variation in its temperature may be neglected. The cross-sectional area $A$ of the connecting rod is small compared to the surface area of $X$. Find the temperature of $X$ at time $t = 3t_1$.  

Sol.  

7. A black body is at a temperature of 2880 K. The energy of radiation emitted by this object with wavelength between 499 nm and 500 nm is $U_1$, between 999 nm and 1000 nm is $U_2$, and between 1499 nm and 1500 nm is $U_3$. The Wien constant $b = 2.88 \times 10^4$ nm K. Then  

(A) $U_1 = 0$  
(B) $U_2 = 0$  
(C) $U_1 > U_2$  
(D) $U_2 > U_1$  

Sol.  

8. A block of ice at $-10^\circ C$ is slowly heated and converted to steam at $100^\circ C$. Which of the following curves represents the phenomenon qualitatively?  

Sol.  

9. The plots of intensity versus wavelength for three black bodies at temperature $T_1$, $T_2$, and $T_3$ respectively are as shown. Their temperatures are such that  

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

Sol.
10. Three rods made of the same material and having the same cross-section have been joined as shown in the figure. Each rod is of the same length. The left and right ends are kept at 0°C and 90°C respectively. The temperature of the junction of the three rods will be

\[ \text{[JEE (Scr) 2001]} \]

\[ 90°C \]

\[ 0°C \]

(A) 45°C  (B) 60°C  (C) 30°C  (D) 20°C

Sol.

13. 2 kg ice at -20°C is mixed with 5 kg water at 20°C. Then final amount of water in the mixture would be: Given specific heat of ice = 0.5 cal/g°C, specific heat of water = 1 cal/g°C.

\[ \text{[JEE' (Scr) 2003]} \]

Latent heat of fusion of ice = 80 cal/g.

(A) 6 kg  (B) 5 kg  (C) 4 kg  (D) 2 kg

Sol.

11. An ideal black body at room temperature is thrown into a furnace. It is observed that
(A) initially it is the darkest body and at later times the brightest.
(B) it is the darkest body at all times
(C) it cannot be distinguished at all times.
(D) initially it is the darkest body and at later times it cannot be distinguished.[JEE(Scr)2002]

Sol.

14. If emissivity of bodies X and Y are \( e_x \) and \( e_y \), and absorptive power are \( A_x \) and \( A_y \), then

\[ T \]

\[ x \]

\[ y \]

(A) \( e_x > e_y \); \( A_x > A_y \)  (B) \( e_x < e_y \); \( A_x < A_y \)

(C) \( e_x > e_y \); \( A_x < A_y \)  (D) \( e_x = e_y \); \( A_x = A_y \)

Sol.

12. An ice cube of mass 0.1 kg at 0°C is placed in an isolated container which is at 227°C. The specific heat \( S \) of the container varies with temperature \( T \) according the empirical relations = \( A + BT \), where \( A = 100 \text{ cal/kg-K} \) and \( B = 2 \times 10^{-2} \text{ cal/kg-K}^2 \). If the final temperature of the container is 27°C, determine the mass of the container. (Latent heat of fusion for water = \( 8 \times 10^4 \text{ cal/kg} \). Specific heat of water = \( 10^3 \text{ cal/kg-K} \))

\[ \text{[JEE'2001]} \]
15. Hot oil is circulated through an insulated container with a wooden lid at the top whose \( t = 5 \text{ mm}, \) emissivity = 0.6. Temperature of the top of the lid in steady state is at \( T_l = 127^\circ \text{C}. \) If the ambient temperature \( T_a = 27^\circ \text{C}. \) Calculate

(a) rate of heat loss per unit area due to radiation from the lid.

(b) temperature of the oil. (Given \( \alpha = \frac{17}{3} \times 10^{-4} \))

**Sol.**

17. Two identical conducting rods are first connected independently to two vessels, one containing water at 100°C and the other containing ice at 0°C. In the second case, the rods are joined end to end and connected to the same vessels. Let \( q_1, q_2 \) g/s be the rate of heat in the two cases respectively. The ratio \( q_1/q_2 \) is

(A) 1/2 \hspace{1cm} (B) 2/1 \hspace{1cm} (C) 4/1 \hspace{1cm} (D) 1/4

**Sol.**

18. Liquid oxygen at 50 K is heated to 300 K at constant pressure of 1 atm. The rate of heating is constant. Which of the following graphs represents the variation of temperature with time?

**[JEE'2004(Scr.)]**

(A) \hspace{1cm} (B) \hspace{1cm} (C) \hspace{1cm} (D)

**Sol.**

16. Three discs A, B, and C having radii 2 m, 4m and 6m respectively are coated with carbon black on their outer surfaces. The wavelengths corresponding to maximum intensity are 300 nm, 400 nm and 500 nm respectively. The power radiated by them are \( Q_A, Q_B \) and \( Q_C \) respectively.

(A) \( Q_A \) is maximum \hspace{1cm} (B) \( Q_B \) is maximum \hspace{1cm} (C) \( Q_C \) is maximum \hspace{1cm} (D) \( Q_A = Q_B = Q_C \)

**Sol.**
19. A cube of coefficient of linear expansion $\alpha$, is floating in a bath containing a liquid of coefficient of volume expansion $\gamma$. When the temperature is raised by $\Delta T$, the depth up to which the cube is submerged in the liquid remains the same. Find the relation between $\alpha$ and $\gamma$, showing all the steps. [JEE 2004]

Sol.

20. One end of a rod of length $L$ and cross-sectional area $A$ is kept in a furnace of temperature $T_1$. The other end of the rod is kept at a temperature $T_2$. The thermal conductivity of the material of the rod is $K$ and emissivity of the rod is $e$. It is given that $T_1 = T_2 + \Delta T$ where $\Delta T \ll T_2$, $T_2$ being the temperature of the surroundings. If $\Delta T \approx (T_1 - T_2)$, find the proportionality constant. Consider that heat is lost only by radiation at the end where the temperature of the rod is $T_2$. [JEE 2004]

Sol.

21. 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

(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

[JEE'2005(Scr)]

Sol.

22. In which of the following phenomenon heat convection does not take place [JEE' 2005 (Scr)]
(A) land and sea breeze
(B) boiling of water
(C) heating of glass surface due to filament of the bulb
(D) air around the furance

Sol.
23. 2 litre water at 27°C is heated by a 1 kW heater in an open container. On an average heat is lost to surroundings at the rate 160 J/s. The time required for the temperature to reach 77°C is
(A) 8 min 20 sec  (B) 10 min
(C) 7 min  (D) 14 min

Sol.

24. A spherical body of area A, and emissivity e = 0.6 is kept inside a black body. What is the rate at which energy is radiated per second at temperature T
(A) 0.6πAT²  (B) 0.4πAT²
(C) 0.8πAT²  (D) 1.0πAT²

Sol.

25. 1 calorie is the heat required to increased the temperature of 1 gm of water by 1°C from
(A) 13.5°C to 14.5°C at 76 mm of Hg
(B) 14.5°C to 15.5°C at 760mm of Hg
(C) 0°C to 1°C at 760mm of Hg
(D) 3°C to 4°C to 760mm of Hg

Sol.

26. In a dark room with ambient temperature T, a black body is kept at a temperature T. Keeping the temperature of the black body constant (at T), sunrays are allowed to fall on the black body through a hole in the roof of the dark room. Assuming that there is no change in the ambient temperature of the room, which of the following statement(s) is/are correct?
(A) The quantity of radiation absorbed by the black body in unit time will increase.
(B) Since emissivity = absorptivity, hence the quantity of radiation emitted by black body in unit time will increase.
(C) Black body radiates more energy in unit time in the visible spectrum.
(D) The reflected energy in unit time by the black body remains same.

Sol.

27. In an insulated vessel, 0.05 kg steam at 373K and 0.45 kg of ice at 253K are mixed. Then, find the final temperature of the mixture.
Given, \( L_{\text{sub}} = 80 \text{ cal/g} = 336 \text{ J/g}, \) \( L_{\text{vap}} = 540 \text{ cal/g} = 2268 \text{ J/g}, \)
\( S_{\text{vap}} = 2100 \text{ J/kg K} = 0.5 \text{ cal/gK} \) and \( S_{\text{sub}} = 4200 \text{ J/kg K} = 1 \text{ cal/gK} \)
28. **Column I** gives some devices and **Column II** gives some processes on which the functioning of these devices depend. Match the devices in **Column I** with the processes in **Column II** and indicate your answer by darkening appropriate bubbles in the $4 \times 4$ matrix given in the ORS.

**[JEE 2007]**

<table>
<thead>
<tr>
<th>Column I</th>
<th>Column II</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Bimetallic strip</td>
<td>(P) Radiation from a hot body</td>
</tr>
<tr>
<td>(B) Steam engine</td>
<td>(Q) Energy conversion</td>
</tr>
<tr>
<td>(C) Incandescent lamp</td>
<td>(R) Melting</td>
</tr>
<tr>
<td>(D) Electric fuse</td>
<td>(S) Thermal expansion of solids</td>
</tr>
</tbody>
</table>

**Sol.**

29. A metal rod $AB$ of length $10x$ has its one end $A$ in ice at $0^\circ$C, and the other end $B$ in water at $100^\circ$C. If a point $P$ on the rod is maintained at $400^\circ$C, 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 $540 \text{ cal g}^{-1}$ and latent heat of melting of ice is $80 \text{ cal g}^{-1}$. If the point $P$ is at a distance of $lx$ from the ice end $A$, find the value of $l$. [Neglect any heat loss to the surrounding.]

**[JEE 2009]**

30. A piece of ice (heat capacity $= 2100 \text{ J kg}^{-1} \text{ °C}^{-1}$ and latent heat $= 3.36 \times 10^3 \text{ J kg}^{-1}$) of mass $m$ grams is at $-5^\circ$C at atmospheric pressure. It is given $420 \text{ J}$ of heat so that the ice starts melting. Finally when the ice-water mixture is in equilibrium, it is found that $1 \text{ gm}$ of ice has melted. Assuming there is no other heat exchange in the process, the value of $m$ is:

**[JEE 2010]**

**Sol.**

31. 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

**[JEE 2012]**

(A) $\left(\frac{65}{2}\right)^4 T$

(B) $\left(\frac{97}{4}\right)^4 T$

(C) $\left(\frac{97}{2}\right)^4 T$

(D) $\left(\frac{97}{3}\right)^4 T$
32. Two rectangular blocks, having identical dimensions, can be arranged either in configuration I or in configuration II as shown in the figure. One 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 9 s to transport a certain amount of heat from the hot end to the cold end in configuration I. The time to transport the same amount of heat in the configuration II is

<table>
<thead>
<tr>
<th>Configuration I</th>
<th>Configuration II</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K$</td>
<td>$2K$</td>
</tr>
<tr>
<td>$2K$</td>
<td>$K$</td>
</tr>
</tbody>
</table>

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

[Sol.]

33. The figure below shows the variation of specific heat capacity ($C$) of a solid as a function of temperature ($T$). The temperature is increased continuously from 0 to 500 K at a constant rate. Ignoring any volume change, the following statement(s) is (are) correct to a reasonable approximation. [JEE 2013]

(A) the rate at which heat is absorbed in the range 0-100 K varies linearly with temperature $T$.
(B) heat absorbed in increasing the temperature from 0-100 K is less than the heat required for increasing the temperature from 400-500 K.
(C) there is no change in the rate of heat absorption in the range 400-500 K.
(D) the rate of heat absorption increases in the range 200-300 K.

[Sol.]
## ANSWER KEY

### Exercise - I

| 55. | A | 56. | C |

### Exercise - II

| 1. | CD | 2. | ABC | 3. | ABD | 4. | AB | 5. | ABCD | 6. | CD |

### Exercise - III

#### JEE ADVANCED - OBJECTIVE

| 1. | H = 590 Kcal. | 2. | 136 km |
| 3. | 8.8 \times 10^{-3} °C |
| 4. | \frac{315}{1050} \text{ sec.} = 7.7 \text{ min} |
| 5. | L_a > L_b = L_c |
| 6. | S_a = S_b > S_c > S_o |
| 8. | 25.5°C |
| 9. | 9.4°C |
| 10. | 18.27/85 |
| 11. | 0°C, 125/4 g ice, 1275/4 g water |
| 12. | (i) 0.02 kg, (ii) 40,000 cal kg⁻¹, (iii) 750 cal kg⁻¹ K⁻¹ |
| 13. | 64 J |
| 14. | 5 \times 10^{-4} g/s |
| 15. | 4.0 W |
| 16. | 2 : \pi |
| 17. | 10 cm from end in contact with water at |
| 18. | \frac{t_1 + t_2 + t_3}{t_1 \times t_2 \times t_3} |
| 19. | 65°C |
| 20. | 20.5°C |
| 21. | 4/3 \text{ m} |
| 22. | 22.15 W/m⁻¹°C |
| 23. | \frac{K\alpha t}{\sqrt{2}(0.2 - 0.1)} |
| 24. | 12°C/s |
| 25. | 1800 J |
| 26. | 10 \text{ sec} |
| 27. | \left(\frac{6}{n}\right)^{1/3} |
| 28. | 2 : 1 |
| 29. | 3025 K |
| 30. | 80 Watt |
| 31. | 1700 K |
| 32. | 0.3 |
| 33. | 15°C |
| 34. | 6 \times 10^4 K ; 4 \times 10^4 K |
| 35. | 7.31 \times 10^m \text{ erg/cm}^2 \text{ sec} |
| 36. | \lambda_\omega = 3 \mu m |
| 37. | 7 \text{ minutes} |
| 38. | 34°C |
LEVEL - II

1. 1 : 1.26  
2. 800 cal kg⁻¹ K⁻¹, 1000 cal kg⁻¹ K⁻¹  
3. (a) 37.8 J/s (Watts), (b) 2.005 N-m  
4. 5000 J/°C kg  
5. 45°C  
6. \(K_n > K_i, \quad K_n = \frac{K_A - K_n}{2}, \quad K_i = \frac{2K_A K_B}{K_A + K_B}\)  
7. \(\frac{a^2}{2} \log_a \left( \frac{T_0 - T_1}{T_0 - T_2} \right)\)  
8. \(I = \frac{k(T_i - T_m)}{k(T_i - T_m) + (T_m - T_2)}\)  
9. (a) -100°C/m, (b) 1000 J  
10. 166.3 sec  
11. 9.72°C/min  
12. \(T_s = 423K\)  
13. \(T' = \sqrt{2} \times 500 = 600 K\)  
14. 10 minutes  
15. (i) 74 cm, (ii) 73.94 cm, (iii) 69.52 cm  
16. (i) \(p_1 = p_{H_2} = 1.25 \times 10^6 Pa\) ; \(p_2 = p_{H_2} + p_{O_2} + p_{N_2} = 2.8125 \times 10^6 Pa\) ; \(p_3 = p_{H_2} + p_{O_2} = 1.5625 \times 10^6 Pa\)  
17. 60°C  

Exercise - IV  
PREVIOUS YEAR QUESTIONS  

LEVEL - I  
JEE MAIN  

1. A  
2. B  
3. B  
4. C  
5. A  
6. A  
7. D  
8. D  
9. D  
10. C  
11. B  
12. C  
13. B  
14. D  

LEVEL - II  
JEE ADVANCED  

1. 12 gm  
2. 60°C  
3. 41.53 Watt; 26.48 °C; 0.55 °C  
4. D  
5. 5.5 min  
6. \(k = \frac{\log_2 \frac{2}{T_i}}{T_i}; \quad T = 300 + 50 \exp \left[ \frac{[K_A \log_2 \frac{2}{T_i}]}{LC} \right] \)  
7. D  
8. A  
9. B  
10. B  
11. D  
12. 0.5 kg  
13. A  
14. A  
15. (a) 595 watt/m², (b) \(T_s = 420K\)  
16. B  
17. D  
18. C  
19. \(\gamma = 2\alpha_s\)  
20. \(\frac{K}{4\pi cL T_0^2 + K}\)  
21. A  
22. C  
23. A  
24. A  
25. B  
26. A, D  
27. 273K  
28. (A) S, Q; (B) Q; (C) P, Q; (D) Q, R or (A) S, (B) Q, (C) P, (D) R  
29. 9  
30. 8 g  
31. C  
32. A  
33. A, B, C, D
HEAT - 1

Exercise - I

OBJECTIVE PROBLEMS (JEE MAIN)

1. D
   Heat is required to raise temperature of
   (Calorimeter + Ice to vapour)\n   \[ Q = 10 \times 100 + (10 \times 80 + 5 \times 1 \times 100 + 10 \times 540) \]
   = 8200 Cal.

2. A
   Required heat/sec = 0.1 \times 80 \text{ cal/gm} = 8 \text{ cal/sec}
   Produced mass = 0.1 \times 100 = 10 \text{ gm ice or water}
   [now Q = ms\Delta T]
   In unit time rise of temperature will be
   \[ \Delta T = \frac{Q}{ms} = \frac{8}{(10 \times 1) \times 0.8} = 10 \text{ C/s} \]
   R = 0.1 \times 80 = 8 \text{ cal/sec}.

3. C
   Water flow rate = 20 \text{ gm/sec for 1 sec}
   Q = \rho \times t = 2100 \times 1 = 2100 \text{ J}
   Q = 2100 = 20 \times 4.2 (t - 10)
   t = 35°C

4. B
   For 1 sec we can say that
   \[ 2 \times 10^3 \times \frac{80}{100} \times \text{1000} = (1000).100 \times (10^3)^2 \times 4.2 \text{(t - 10)} \]
   On solving
   t = 13.8°C

5. A
   (m + w)(1) \{ (70 - 40) = mL + m - (1) (40 - 0)
   (200 + w)(70 - 40) = 500 L + 50 \times 4 \text{(1)}
   \[ (m + w + m) (40 - 10) = mL + m - (1) (10 - 0) \]
   (200 + w + 50) \{ 30 = 80 L + 80 \times 10 \text{(2)} \}
   from eq. (1 & 2)
   50 \times 30 = 30 \text{ L - 30} \times 40
   L = 90 \text{ cal/gm} = 3.78 \times 10^3 \text{ J/kg}

6. D
   \[ \therefore \frac{dQ}{dt} = ms\Delta T \Rightarrow \frac{dT}{dQ} = \frac{1}{ms} \]
   \[ \text{Solid} \quad \text{Liquid} \quad \text{Vapour} \]

7. A
   Using Energy conservation
   The energy loss due to potential energy goes into increasing the temperature of ice.
   \[ \frac{m}{5} (L) \cdot mgh \]
   \[ \Rightarrow h = \frac{L}{5g} \]

8. B
   At a temperature \( T \)
   \[ dQ = \rho V(dT) = \alpha T^2 \left( \frac{dT}{t} \right) \]
   \[ \text{so} \quad \frac{Q_1}{1} = \frac{15a}{4} \]

9. C
   For vapourization the total time required is
   \( (30 - 20) \times 10 = 10 \text{ min} \)
   \[ \text{Total Heat Given} = 42 \text{ KJ} \times 10 = 420 \text{ KJ} \]
   \[ \text{so} \quad mL = 420 \]
   \[ SL = 420 \Rightarrow L = 84 \text{ KJ/kg} \]

10. D
    From the data given
    \[ S \rho \left( \frac{8V}{(12V)} \right) = \frac{8}{2} \]
    \[ \text{So} \quad \frac{8k}{2000} = 2 \]

11. C
    Ice Changes to water hence volume decreases but mass remains same hence
    \[ V = \frac{8 \rho m}{(V - P)} \]
    \[ V = \frac{V_0}{P} \]
    Let volume \( V \) change to water
    \[ (0.9 \rho \text{, } V + \rho \text{)} \text{L} = H \]
    \[ \text{...(1)} \]
    \[ \Delta V = V - V_0 = \left( \frac{V - V_0}{P} \right) \]
    \[ V_0 \text{ cm}^3 = 1 \text{ cm}^3 \]
    \[ V_0 = 10 \text{ cm}^3 \]
    \[ 50 \text{ from eq. (1)} \]
    \[ (0.9 \times 1 \times 10) \times 80 = H \]
    \[ H = 720 \text{ cal} \]

12. A
    Let \( m \text{ is the mass} \)
    \[ mLc + ms (100 - 80) = (1.1 + 0.02) s (80 - 15) \]
    \[ m (s + 20) = (1.12) 65 \Rightarrow m = 0.130 \text{ kg} \]

13. B
    \[ 0^\circ \text{C} \quad 36^\circ \text{C} \]
    \[ A \quad B \]
    \[ x = 12^\circ \text{C} \]
    \[ \begin{align*}
    \frac{dU_A}{dt} & = \frac{dU_B}{dt} \\
    2K & = KA \left( \frac{36 - x}{t} \right) \\
    x & = 12^\circ \text{C}
    \end{align*} \]
14. (a) \[ I_{\text{act}} = I_A + I_v \]
\[ -K_A A \left( \frac{100 - 20}{3 \times 10^{-2}} \right) + K_{CA} A \left( \frac{100 - 20}{3 \times 10^{-2}} \right) = (209 + 385) \left( \frac{3 \times 10^{-2}}{3 \times 10^{-2}} \right) = \frac{80}{3 \times 10^{-2}} \]
\[ = 1.43 \times 10^4 \text{ W} \]
\[ K_{CA} = \frac{385}{209} \]
(b) \[ K_A = 1.84 \]

15. B
\[ \text{in (a)} \quad \frac{dQ}{dt} = \frac{10}{2} \text{ cal/min} = AK \left( \frac{100 - 0}{29} \right) \quad \ldots(1) \]
\[ \text{in (b)} \quad \frac{di}{dt} = (2A) K \left( \frac{100 - 0}{a} \right) \quad \ldots(2) \]
\[ \text{so} \quad \frac{di}{dt} = 2 \times 10 \times t \]
\[ t = 0.5 \text{ min} \]

16. B
Here the thermal resistances are in parallel as temperature difference across all the rods is same.
\[ \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} \]
\[ K_{eq} = \frac{K_1 A + K_2 A}{2} \]

17. A
The heat current in the bottom of pot is due to temperature difference at the lower & upper surface.
\[ I_2 = K_{\text{steel}} \frac{dT}{dx} = \frac{m}{t} \cdot L_v \]
\[ 50.2 \times 0.15 \times 1.2 \times 10^{-2} = 0.44 \times 2.25 \times 10^4 \]
[Let \( x \) be temperature of surface in contact with stove]
\[ x = 105.25 \text{°C} \]

18. C
The heat current is equal to heat released to formation of ice at the surface in dt time.
In the first case, where \( w \), is water equivalent of flask.
\[ T\text{o°C} \]
\[ x \]
\[ \text{dx} \]
\[ t + dt \]
\[ \frac{dT}{dx} = \frac{dx}{dt} \cdot L_v \]
\[ \Rightarrow K_{\text{AT}} \frac{dx}{t} = A_{\text{AT}} L_v \int \frac{dx}{t} \]
\[ T = 30 \text{°C} \]

19. C
The heat current is equal to the heat required for fusion of ice per dt time.
\[ i = \frac{dm}{dt} \cdot L_v = K A \left( \frac{20 - 0}{2.35} \right) \]
\[ \frac{dm}{dt} = 2.4 \times 10^{-6} \]

20. A
We know that
\[ i = K(sR^2) \cdot \frac{dT}{dx}, \quad i = \frac{R^2}{t} \]

21. C
The resistance formed by two cylinders \( R_1 \) & \( R_2 \) are in parallel as they are kept between same temperature difference.
\[ A_1 = sR^2 \quad A_2 = s4R^2 - sR^2 = 3sR^2 \]
Now \[ R_{eq} = \frac{R_{R_1 R_2}}{R_1 - R_2} \]
\[ \Rightarrow \]
\[ \frac{1}{4K_{feq}} = \frac{1}{3K_2} + k_2 \]
\[ k_e = \frac{1}{4} (k_1 + 3k_2) \]

22. B
We know that
\[ i = - kA \frac{dT}{dx} \]
And slope of the curve but \( \frac{dT}{dx} = - i/kA \)
i is constant (steady state), A is constant but since \( k \) is decreasing from 2k to k, hence slope is -ve but less - ve to more -ve.

23. A
From the given condition as the plates are in series so heat current is same.
\[ l_1 = I \]
\[ \Rightarrow \]
\[ K_1 \frac{T_c - T_b}{d} = \frac{k_2 (T_c - T_b)}{2d} \]
\[ k_1 \frac{T_c - T_b}{d} = \frac{4k_2 (2T_c - 2T_b)}{2} \]
\[ K_2 \frac{T_c - T_b}{d} = 1 \]

24. D
\[ i = kA \frac{dT}{dx} \]
\[ \Rightarrow \]
\[ \frac{dT}{dx} = \frac{1}{k} \]
\[ \Rightarrow i \text{ and } A \text{ are same for both the layers.} \]
\[ i = - kA \frac{dT}{dx} \]
i and A are constant hence slope
\[ \frac{dT}{dx} = \frac{i}{(kA)} \] is - ve but
\[ \text{Slope} = \frac{1}{k} \]
Hence in air slope will be more - ve due to very less conductivity.

25. A
Now $R_1$ (when $r_1 = R$, $r_2 = 2R$) = \( \frac{1}{8\pi kr} \)
and $R_2$ (when $r_1 = 2R$, $r_2 = 3R$)
\( = \frac{1}{4\pi kr} \left[ \frac{1}{2} - \frac{1}{3} \right] \)
\( = \frac{1}{24\pi kr} \)

\[ T = \frac{R_1}{R_1 + R_2} \times 100 = 75^\circ C \]

30. C

Slope $dT/dx = -i/kA$ is $-ve$ but due to radiation loss because of not lagged, as we move ahead current $i$ will be less. Hence slope will be more $-ve$ to less $-ve$.

31. A

$T_p = \frac{100 + 0}{2} = 50^\circ C$
As $T_p > T_q$ so flow is from P to Q.
$T_q = \frac{30 + 60}{2} = 45^\circ C$

32. A

Slope $dT/dx = -i/kA$ is less $-ve$ for 1st layer.
Hence 1st layer should have larger $k$.

So $k_1 > k_2$

33. A

Consider the two sections like two resistance $R_1$ and $R_2$.

$R_1 = k_1A$
$R_2 = \frac{2r_1}{2}$

So

$\theta = \left( \frac{R_2}{R_2 + R_1} \right)(100 - 0)$
$\theta = 80^\circ C$

34. A

Thermal resistance is given as

$R_n = \frac{r}{3kA}$
$R_A = \frac{1}{3}$
$R_B = \frac{1}{3}$

35. B

As the rods are in series so that current is same.

$i = \frac{3k_A T_A}{\ell} = kA \left( \frac{dT}{dx} \right)_A$
$\frac{T_A}{T_B} = \frac{1}{3}$

36. B

For temperature gradient comparing $\frac{dT}{dx}$ for A & B.

$i_A = kA \left( \frac{dT}{dx} \right)_A - kA \left( \frac{dT}{dx} \right)_B$

$3kA_G = kA_G$
$G_A = \frac{1}{3}$
$G_B = \frac{1}{3}$
37. A

\[ A \quad K_A \quad K_B \quad C \]
\[ \begin{array}{c|cc|c}
 & \quad & \\
 d & 3d & \\
\end{array} \]

38. C

Initially \( i = \frac{dm}{dt} \). \( L_t = kr^2 \cdot \frac{100}{i} \)

Hence \( \frac{dm}{dt} \cdot \frac{k}{r^2} = \frac{\partial}{\partial t} \)

From given condition

\[ \frac{dm_2}{dt} = \frac{k}{r^2} \cdot \frac{(2R)^2}{4} \]

\[ \frac{dm_1}{dt} = \frac{k}{r^2} \]

\[ \frac{dm_2}{dt} - 2 \Rightarrow \frac{dm_2}{dt} = 0.2 \]

39. A

As the heat current through all the rods is same.
So all the resistance are in series.

\[ R_e = R_1 + R_2 + R_3 \]

\[ \frac{3}{k_e A} = \frac{k}{A} + \frac{1}{5k} = \frac{k}{A} + \frac{1}{5k} \]

\[ k_e = \frac{15}{16} k \]

40. A

\[ T_1 \quad x \quad T + dT \quad T_2 \]

Taking an element at a distance \( x \) of length \( dx \) and having at temperature difference \( dT \).

\[ i = \frac{\alpha}{T} A \frac{dT}{dx} = C \text{ (const.)} \]

\[ \Rightarrow \alpha A \left( \frac{T}{T_1} \right) = C x \]

\[ \alpha A \left( \frac{T}{T_1} \right) - \left( \frac{C}{A} \right) x \]

at \( x = L, T = T_2 \Rightarrow \frac{C}{A} = \frac{\alpha}{L} \ln \frac{T_2}{T_1} \)

SoT = \( T_1 \left( \frac{T_2}{T_1} \right) \)

41. B

\[ \text{Req.} = \frac{1}{4\pi k} \left[ \frac{1}{R_1} - \frac{1}{R_2} \right] \]

Let at \( R \) then

\[ \frac{1}{R_1} - \frac{1}{R} - \frac{1}{R_2} \]

\[ R = \frac{2R_1 R_2}{R_1 + R_2} \]

42. A

Req. is same for both the rods and same temperature same difference so \( i_1 = i_2 \)

43. D

\[ i = ms \frac{d\theta}{dt} = msk (50^\circ - 20^\circ) = 10 W \]

\[ \begin{align*}
35.1 - 34.9 & = k (35 - 20) \\
& = \frac{60}{k} \\
0.2 & = \frac{10}{60} = \frac{ms(30)}{C} \times 15 \\
m & = 1500 J/\text{C} \\
\end{align*} \]

44. B

Let at time \( t \) radius be \( r \)

\[ \text{Then} \quad \frac{dQ}{dt} = CA = 4C \pi r^2 = - \frac{dm}{dt} \cdot L_1 \]

\[ m = \rho \pi \frac{4}{3} \pi r^3 \Rightarrow dm = C \pi r^2 \frac{dr}{dt} \]

\[ \Rightarrow \frac{dr}{dt} = \text{const} \]

45. D

Power

\[ P = \frac{d\theta}{dt} = A \theta T^4 = A \theta \left( \frac{b}{\lambda} \right)^4 \]

\[ \frac{P}{P_1} = \left( \frac{\lambda_1}{\lambda_2} \right)^4 = \left( \frac{3}{\lambda_0} \right)^4 = \frac{256}{81} \]

46. B

Let \( I = \frac{P'}{4\pi d^2} \) or \( I = \frac{enA(2T)^4}{4\pi d^2} \)

and \( I \ A_1 = P \) (Given)

Now \( P_{rev} = I_{rev} A_1 = \frac{enA(2T)^4}{4\pi d^2} \cdot A_1 \)

\[ = \frac{16}{4} \left( \frac{enA(2T)^4}{4\pi d^2} \cdot A_1 \right) = \frac{16}{4} P \]
47. A

We know that
\[ \lambda_{\text{max}} < \frac{1}{T} \]
\[ \frac{\lambda_{1 \text{ max}}}{\lambda_{2 \text{ max}}} = \frac{T_2}{T_1} \]
\[ \frac{T_2}{T_1} = \frac{3}{4} \]

48. C

\[ -\frac{dT_F}{dt} = x \left( -\frac{dT_Q}{dt} \right) \]
\[ \frac{eA_p\sigma(T^4 - T_0^4)}{m_pS} = xe\sigma A_Q(T^4 - T_0^4) \]
\[ \Rightarrow x = \frac{A_p\sigma}{A_Q\sigma} = \left( \frac{r}{3r} \right)^2 \times \left( \frac{3r}{r} \right)^3 \]
\[ \Rightarrow x = 3 \]

49. B

Initially the temperature of the substance increases and then phase change from ice to water occurs and this process continues.

50. D

Area = \( \int y dx = \int \frac{dE}{dx} \times dx = \int dE \)

Area (A) = E = \( \sigma A T^4 = \sigma \left( \frac{T}{T_0} \right)^4 \)

\[ \frac{\text{Area}_1}{\text{Area}_2} = \frac{\lambda_2}{\lambda_1} \Rightarrow \frac{1}{9} = \left( \frac{\lambda_2}{\lambda_1} \right)^3 \]
\[ \Rightarrow \lambda_2 = \sqrt[3]{3} \lambda_1 \]

51. B

Using relation \( \lambda_{\text{max}} < \frac{1}{T} \)
\[ \frac{T_1}{T_{\text{ns}}} = \frac{\lambda_{\text{ns}}}{\lambda_{\text{max}}} = \frac{350}{510} = 0.69 \]

52. B

Using formula
\[ P = \sigma eA T^4 \]
\[ P_1 = \sigma_1 A_1 \theta_1^4 \text{ and } P_2 = \sigma_2 A_2 \theta_2^4 \]

Now \( P_1 = P_2 \)
\[ \left( \frac{\sigma_2}{\sigma_1} \right)^{1/4} \theta_1 - \theta_2 \]

53. B

If the body cools from \( \theta_1 \) to \( \theta_2 \) then using formula
\[ \frac{\theta_1 - \theta_2}{t} = \alpha \left( \frac{\theta_1 - \theta_2 - \theta_0}{2} \right) \]
\[ \frac{60 - 50}{4} = k \left( \frac{60 + 50 - \theta_0}{2} \right) \]
\[ \frac{5}{2} = k \left( 55 - \theta_0 \right) \]
\[ 5 = \frac{k(35 - \theta_0)}{4} \]
from (1) & (2)
\[ 2 = \frac{55 - \theta_0}{35 - \theta_0} \]
\[ \theta_0 = 70 - 55 = 15^\circ C \]

54. A

\[ E_{\text{eff}} = eA(273 + 273)^4 = E(\text{Given}) \]
\[ E_E = eA(273 + 0)^4 \]
\[ E_E = \frac{E}{16} \]

55. A

If the body cools from \( \theta_1 \) to \( \theta_2 \), then using formula
\[ \frac{\theta_1 - \theta_2}{t} = \alpha \left( \frac{\theta_1 - \theta_2 - \theta_0}{2} \right) \]
\[ \frac{75 - 65}{5} = k \left( \frac{75 - 65 - 25}{2} \right) \]
\[ 2 = k(70 - 25) \Rightarrow k = \frac{2}{45} \]
Now \( \frac{65 - x}{5} = k \left( \frac{65 + x - 25}{2} \right) \]
\[ 2 \left( 65 - x \right) = 5k (65 + x - 50) \]
\[ 130 - 2x = 5 \times \frac{2}{45} (15 + x) \]
\[ x = 57^\circ C \]

56. C

\[ \frac{40 - 36}{5} = k \left( \frac{40 + 36 - 16}{2} \right) \]
\[ \frac{4}{5} = \frac{k}{55} \]
\[ \Rightarrow k = \frac{2}{55} \]
\[ \frac{36 - 32}{t} = \frac{2}{55} \left( \frac{36 + 32 - 16}{2} \right) \]
\[ 2 \times 55 = \frac{(34 - 16)}{t} \]
\[ t = 6.1 \text{ min} \]
Exercise - II

1. C,D
   Not Reflected and Not Refracted.
2. A,B,C
   Good Absorbers are good emitters.
3. A,B,D
   \[ \frac{dQ}{dt} = e \alpha a T^4 \]
   So, \[ \frac{dQ}{dt} \propto A \]
   \[ \times e \text{ (nature of surface)} \]
   \[ \times T \text{ (temperature)} \]
   But independent of mass.
4. A,B
   (A) \[ \frac{dQ}{dt} = e \alpha a T^4 \]
   (Rate of emission is same initially)
   (B) \[ \frac{dQ}{dt} = e \alpha a T_a^4 \]
   (Rate of absorption is same always)
   (C) \[ \frac{-dT}{dt} = eAe(T_a - T_b) \]
   (Due to lesser mass of hollow sphere it cools fast.) (wrong)
   (D) Since hollow sphere cools fast; hollow will have smaller temperature at any moment. (wrong)
5. A,B,C,D
   \[ \left( \frac{-dT}{dt} \right) = \frac{eAe}{mc} (T_a - T_b) \]
6. C,D
   (A) Heat absorption is surface phenomenon hence wooden (Black surface) absorbs more. (wrong)
   (B) After long time both will have temperature of surroundings. (wrong)
   (C) Because metal is better conductor it feels hotter.
   (D) Because emission depend on surface (i.e. more for black surface)
7. D
   Loss(copper) = gain (water + beaker)
   \[ m_e s_e (T_e - T) = m_b s_b (T - T_b) \]
   Hence final temperature can be calculated.
8. D
   Rate of melting is doubled if Rate of heat flow is doubled and Rate of melting
   \[ \frac{dQ}{dt} = \frac{K A (T - 0)}{dt} \]
   in (D) T is doubled (50 to 100°C)
   and area and length are also doubled hence
   \[ dQ \]
   doubles.
9. AC
   \[ m_e = 4 m_b, \]
   \[ \rho \times \frac{4}{3} \pi r_4^2 = \rho \times \frac{4}{3} \pi r_b^2 \times 4 \]
   \[ \Rightarrow \frac{r_a}{r_b} = 4^{1/3} = 2^{1/3} \]
   Rate of heat loss = \[ \frac{dQ}{dt} = eAe(T_a - T_b) \]

10. A,B
    \[ \frac{dQ}{dt} = eAeT^4 \text{ is same} \]
    \[ \Rightarrow eT_a^4 = eT_b^4 \]
    \[ 0.01 \times (5802)^4 = 0.81 \times (T_b)^4 \]
    \[ \Rightarrow T_b = 1934 \text{ K} \]
    \[ \frac{\lambda_A}{\lambda_b} = T_A \]
    \[ \frac{T_A}{T_b} = 5802 \]
    \[ \frac{\lambda_A}{\lambda_b} = 1934 = 3 \]
    \[ \lambda_b - \lambda_a = 1 \mu \text{m} \]
    \[ \Rightarrow \lambda_b - \frac{\lambda_a}{3} = 1 \mu \text{m} \]
    \[ \Rightarrow \lambda_a = 1.5 \mu \text{m} \]
11. D
    \[ e_a : e_b : e_c = 1 : \frac{1}{2} : \frac{1}{4} \]
    Rate of emission: \[ \frac{dQ}{dt} = eAeT^4 \text{ is same} \]
    So, \( eT^4 \) is same
    \[ \Rightarrow T_a : T_b : T_c = \frac{1}{e_a} : \frac{1}{e_b} : \frac{1}{e_c} \]
    \[ = 1 : 2 : 4 \]
    as \( \lambda T = b \) is constant
    \[ \Rightarrow \frac{\lambda_a}{\lambda_b} = \frac{1}{\frac{1}{4} \frac{1}{2} \frac{1}{4}} \]
    On solving
    \[ \sqrt{\frac{e_a \lambda_a T_a + e_b \lambda_b T_b}{e_c \lambda_c T_c}} \]
12. A,B
    (A) Emitted energy is very less for longer and shorter wavelength.
    (B) From fig. at \( \lambda_m \) intensity is maximum
    (C) Area under the curve shows amount of energy emitted.
13. A,B,C,D
    When \( T^2 \) curve shifts towards shorter wavelength hence curve spreads i.e. Area increases.
14. B
    \[ \lambda_m = \frac{1}{T}, \quad T > T \text{ So, option B is correct.} \]
1. \( H = \text{Energy/heat required to change } 100^\circ C \) 
Water in 200°C Vapour 
= 1000 \( L_v + 1000 \times 0.5 \times (200-100) \) 
= 590 Kcal.

2. Let mass = \( m \)

So, \( \frac{1}{4} \text{[mgH]} = mL_v \)

\[ h = \frac{4L_v}{10} = 4 \times 3.4 \times 10^5 \text{m} \]

3. From energy conservation

\[ mgh + \Delta K = m\Delta T \]

\( (200 \times 10^{-3}) \times 10 \times (60 \times 10^{-2} \sin 37^\circ) + 0 \)

\[ = 200 \times 10^{-1} \times 420 \times \Delta T \]

\( \Delta T = 86 \times 10^{-1}^\circ C \)

4. Let all are at 0°C water then heat given is

\( \Delta Q_{\text{water}} = -(10 \times 0.5 \times 10 + (10 \times 80)) = -850 \text{ cal} \)

\( \Delta Q_{\text{water}} = 10 \times 1 \times 20 = 200 \text{ cal} \)

\( \Delta Q_{\text{vapor}} = [2 \times 540 + 2 \times 1 \times 100] + 1280 \text{ cal.} \)

So, at 0°C water now have (1280+200-850) cal.

As the heat is extra so it will increase temperature to t

(10 + 10 + 2) \( (1 \times t - 0) \)

= (1280 + 200 - 850)

\( t = 28.63^\circ C \)

5. \( A = 200 \text{ J} = 4 \times L_v \Rightarrow L_v = 50 \)

\( B = 300 \text{ J} = 5 \times L_v \Rightarrow L_v = 60 \)

\( C = 300 \text{ J} = 6 \times L_v \Rightarrow L_v = 50 \)

6. \( m_s \Delta T = -m_s \Delta T_{\text{vapor}} \Rightarrow m_s \Delta T = -m_s \Delta T_{\text{vapor}} \)

\[ \Rightarrow S_v \Delta T_{\text{vapor}} = S_s \Delta T_1 \]

\( S_v = \frac{27}{85} \)

7. Total energy released

\[ = 10 \times 5 \times 4200 \]

\[ = 21 \times 10^4 \text{ J} \]

Energy released/min

\[ = 0.2 \times 60 \]

\[ = \frac{1000}{100} \times 2.27 \times 10^4 \]

\[ = 27.24 \times 10^3 \text{ J} \]

Time required

\[ = \frac{21 \times 10^4}{27.24 \times 10^3} = 7.7 \text{ min} \]

8. \( \Delta Q = 100 \times 4 \times 600 \)

\[ = 24000 \text{ Cal.} \]

For 0°C water

\( \Delta Q = (100 \times 0.2 \times 20) + (200 \times 0.5 \times 20) + (200 \times 80) \)

\[ = 18400 \text{ cal}. \]

So, let temperature is t then

= 20000 - 18400

\[ = 20000 - 18400 \]

\[ = 25^\circ C \]

9. Density of drink = \( \frac{2m}{120} \)

\[ = 0.833 \text{ g/cm} \]

\( m = 50 \text{ gm.} \)

\( m_s \Delta T + m_s \Delta T = m_s L_v + m_s S_v (t - 0) \)

\[ = 50 \times 0.6 \times (25-t) + 50 \times 1 \times (25-t) = 20 \times 80 + 20 \times t \]

\[ = \frac{50 \times 25(t-0.6)-20 \times 80}{50 \times (1-0.6)+20} = t = 4^\circ C \]

10. A

20°C 

W

5 gm \( X = 40^\circ C \)

eq = 22°C

B

20°C 

W

5 gm \( Y = 40^\circ C \)

eq = 23°C

For A \( W(22-20) = 5 \times S_x \times (40-22) \)

\( W = 9 \text{ gm.} \)

For B \( W(23-20) = 5 \times S_y \times (40-23) \)

\( S_x = \frac{27}{85} \)

11. If ice completely melts then heat released

\( \Delta Q_{\text{ice}} = (2 \times 50) (0.5) (15) + (2 \times 50) \times 80 \)

\[ = 8750 \text{ cal.} \]

for water at 25°C

\( \Delta Q_{\text{water}} = 250 \times 1 \times 25 \text{ cal} = 6250 \text{ cal.} \)

Let m gram ice then \( mL_v = (8750 - 6250) \)

\[ = 125 \]

\( m = \frac{4}{5} \text{ g} \)

12. (I) Let m

\[ \left( \frac{4}{5} \times 1000 \right) = m \times \Delta T \]

\[ = m \times 0.5 \times 80 \]

\[ = 20 \text{ gm.} \]

(II) \( mL = \left[ \frac{1000}{5} \right] \times 4 \)

\[ = \frac{1000 \times 4}{5 \times 20} \]

\[ = 40 \text{ cal/gm} \]

(III) \( m_s (120-80) = \frac{1000}{5} \times 3 \)

\[ = \frac{1000 \times 3}{5 \times 40 \times 20} \]

\[ = 0.75 \text{ cal/gm} \]

13. \( \frac{dQ}{dt} = kA \frac{dT}{dx} \)

\[ = 0.8 \times (10 \times 10^{-2}) \times \left( \frac{90-10}{1 \times 10^{-2}} \right) \]

\[ = 64 \text{ J} \]
14. \[ i = mL_x = KA \frac{dT}{dx} \]

\[ m = 42 \times (0.04 \times 10^{-4})100 \]
\[ = 3.36 \times 10^3 \times 1 \]
\[ = 5 \times 10^4 \text{Kg} \]
\[ = 5 \times 10^{-3} \text{g/s} \]

15. \[ (T-100)/2.5 + (T-0)/2.5 + (T-25)/5 = 0 \]

So, \[ T = 45^\circ \text{C} \]

Hence,
\[ I/CD = \frac{V}{R} = (45-25)/5 = 4 \text{ W} \]

\[ l_c = \frac{aR}{KA} \frac{dT}{dx} \]

\[ i_i = \frac{2}{r} \]

17. \[ \text{200}\^\circ \text{C} \]

\[ \frac{dm_v}{dt} L_v = \frac{KA(200-100)}{r} \]

\[ \frac{dm_{SSC}}{dt} L_s = \frac{KA(200-0)}{r} \]

\[ (1) + (2) \]

\[ \frac{L_v}{L_s} = \frac{100}{2} \left( \frac{t_2-t_1}{200} \right) \]

\[ \frac{540}{80} \times 40 = 10 \left( \frac{1.45-t}{2} \right) \]

\[ 2\pi r = 2 \times 1.45 - 2t \]

\[ t = 0.1 \text{m} \]

18. \[ \text{Req} = R_1 + R_2 + R_3 \]

\[ \frac{e_{12} + t_2 + t_3}{\text{Req} A} \]

\[ = \frac{t_1}{k_1 A} + \frac{t_2}{k_2 A} + \frac{t_3}{k_3 A} \]

19. \[ KA \frac{dT}{dx} = 1 \times 10^4 \text{W} \]

\[ 0.2 \times 5 \times (T-25)\]

\[ 4 \times 10^{-2} = 10^4 \]

\[ T = 4 \times 10^4 \times 10^4 + 25 \]

\[ T = 65\^\circ \text{C} \]

20. \[ \frac{dQ}{dt} = KA \frac{10}{d} \]

\[ \Rightarrow \theta - 5^\circ \text{C} \]

\[ \frac{dQ}{dt} = 2KA \frac{10 - \theta}{d} \]

\[ \Rightarrow \theta - 5^\circ \text{C} \]

\[ \frac{dQ}{dt} = KA \frac{(t_1 + t_2)}{d} \]

\[ \Rightarrow \theta - 5^\circ \text{C} \]

\[ \frac{dQ}{dt} = 2k \frac{(5)}{d} \]

\[ \Rightarrow \theta - 5^\circ \text{C} \]

21. Initially

\[ \text{W} = i_i + i_i^t \]

\[ \Rightarrow \text{W} = \frac{KA(T_2 - T_1)}{2r} \times 2 \]

\[ \text{W} = \frac{KA(T_2 - T_1)}{r} \]

Now,

\[ \text{W} = \frac{W}{3} = \frac{4W}{3} \]

From eq-1

22. \[ 160\pi = \frac{50 - 10}{\text{Req}} \]

\[ 160\pi = \frac{50 \times 10}{ \frac{1}{4\pi} \frac{1}{r_1} \frac{1}{r_2} } \]

\[ 160\pi = \frac{40K}{(5 - \frac{1}{20}) \times 10^{-2}} \]

\[ \Rightarrow K = 15 \]

23.
r_2 - r_1 = \frac{r - r_1}{x} \\
\Rightarrow r = r_1 + \frac{x}{L} (r_2 - r_1) \\
\int \text{d}R = \int \frac{\text{d}x}{Kn^2} \\
R = \frac{1}{Kn} \int \frac{\text{d}x}{\left[r_1 + \frac{x}{L} (r_2 - r_1)\right]^2} \\
R = \frac{L}{K \pi (r_2 r_1)} \\
\Rightarrow i = \frac{Q_s - Q_i}{R} \\
24. \\
\frac{\Delta Q_{AB}}{\Delta t} = \frac{dQ_A}{dt} - \frac{dQ_B}{dt} \\
\Rightarrow \frac{\Delta Q}{\Delta t} = I_A - I_B \\
= (ms) \frac{dQ_{AB}}{dt} = KA \frac{dT}{dx}_A - KA \frac{dT}{dx}_B \\
= 0.40 \frac{dQ_{AB}}{dt} = 200 \times (1 \times 10^{-4}) [5 - (2.6) \times 10^2] \\
25. 0^\circ C \quad \boxed{(T - 0)} \quad \text{(at time t)} \\
\Rightarrow i = \frac{dQ}{dt} = K A (T - 0) \\
Q_s = \int dQ = \int_0^{(10-60)sec} \frac{K A T}{t} \text{d}t \\
\text{Now, } T = \frac{t}{10} \\
\Rightarrow Q_s = \int dQ = \frac{600 \times K A t}{10} = \frac{600}{20} = 1800 J \\
26. \text{Here} \\
\frac{50.1 - 49.9}{5} = K (50 - 30^\circ) \\
\frac{0.2}{5} = K \times 20 \quad \Rightarrow \quad K = \frac{1}{500} \\
\text{Now,} \\
\frac{40.1 - 39.9}{t} = K (40 - 30) \\
\frac{0.2}{t} = \frac{0.2}{5 \times 20} (10) \quad \Rightarrow \quad t = 10 \text{sec.} \\
27. M_{cube} = m_{sphere} \\
\Rightarrow \rho \times a^3 = \rho \times \frac{4}{3} \pi r^3 \\
\Rightarrow a = \left(\frac{4}{3} \pi \right)^{\frac{1}{3}} \\
\text{Rate of cooling } \frac{-dT}{dt} = e A_0 (T^4 - T_e^4) \\
\text{Ratio:} \\
\frac{\text{Cube}}{\text{Sphere}} = \frac{A_{\text{sa}}}{A_{\text{sp}}} = \frac{6a^2}{4 \pi r^2} \\
= \frac{3}{2} \times \left(\frac{4}{3} \pi \right)^{\frac{1}{3}} = \frac{6}{\pi}^{\frac{1}{3}} \\
28. \frac{dQ}{dt} \text{ (loss)} \\
= \text{ms} \left(\frac{-dT}{dt}\right) = \frac{4}{3} \pi R^3 \rho S \text{ (loss)} \\
\frac{d Q_i}{dt} = \frac{d Q_{s}}{dt} = \frac{Q_s}{R} \left(\frac{0.2 \times 0.2}{0.2 \times 0.2} \right) \\
\Rightarrow \frac{0.2}{1} \times \frac{1}{4} = 2 \\
29. \lambda_{\text{net}} = \frac{b}{T} \\
\Rightarrow \frac{\lambda_{\text{net}}}{\lambda_{\text{inf}}} = \frac{T_{\text{star}}}{T_{\text{sum}}} = \frac{4753}{9506} \times 6050 \text{ K} \\
= 3025 \text{ K} \\
30. a(300)^4 = 5 ............ (1) \\
a(600)^4 = x ............ (2) \\
\text{Now, eq (2)/(1)} \\
\Rightarrow x = \frac{600}{5} \left(\frac{300}{200}\right) \\
31. 100 = \epsilon \alpha A T^4 \\
\Rightarrow T^4 = \frac{100}{\epsilon \alpha A} \\
\Rightarrow T = \sqrt[4]{\frac{100}{\epsilon \alpha A}} \\
\Rightarrow A = 2 \pi R^2 \\
T = 1696.7 \text{ K} \\
= 1700 \text{ K} \\
32. i = \epsilon \alpha A (T^4 - T_e^4) = 210 \\
= \epsilon \alpha A ((500)^4 - (300)^4) \\
\Rightarrow 210 = \frac{700}{200} \text{ ....... (1)} \\
\text{Now,} \\
\Rightarrow i = 700 = \alpha A ((500)^4 - (300)^4) \text{ .......... (2)} \\
\Rightarrow \frac{1}{(1)/(2)} \text{ (10)} \\
\Rightarrow i = \frac{210}{0.3} = 700 \\
33. \frac{P}{4 \pi d^2} \left(\frac{\pi d^2}{4}\right) = \epsilon \alpha A T_e^4 \\
\text{and } P = \epsilon \alpha A T_e^4 \\
\Rightarrow T_e^4 = \frac{R_e^4}{4 \pi d^2} \cdot T_e^4 \\
\Rightarrow \frac{T_e^4}{4} = \frac{R_e^4}{d^2} \cdot T_e^4
34. \( T = \frac{b}{\lambda_{\text{max}}} \)
\( T_a = \frac{0.3}{5000 \times 10^{-8}} = 6 \times 10^4 \text{ K} \)
\( T_x = \frac{0.3}{7500 \times 10^{-8}} = 4 \times 10^4 \text{ K} \)

35. \( T = \frac{\lambda_{\text{max}}}{5000 \times 10^{-8}} = 6000 \text{ K} \)
\( E = \omega \text{AT}^4 \)
\( = (5.6 \times 10^{-4}) (1 \times 10^{-4}) (6000)^4 \)
\( = 7.2576 \times 10^{-10} \text{ erg cm}^{-2} \text{ sec}^{-1} \)

36. \( E_{\text{max}} = 16 \)
\( \lambda = 6 \text{ at } 500 \text{ K} \)
\( \lambda = \text{Constant} \)
\( 6 \times 500 = \lambda = 1000 \)
\( \lambda = 3 \mu \text{m} \)

LEVEL - II

1. Steam = 330 - 200 - 100 = 30 g
Let ice = x g & water = (200 - x) g
loss (steam) = gain (ice + water + calorimeter)
\[ 30 \times 2.25 \times 10^6 = x \times 3.36 \times 10^6 \]
\[ + 200 \times 4.2 \times 10^3 \times 50 \]
\[ + 100 \times 0.42 \times 10^1 \times 50 \]
\[ \Rightarrow x = 70 \text{ g} & \text{ water } = 200 - x = 130 \text{ g} \]
Ratios = 7

2. \(-10^\circ C \rightarrow 2^\circ C \)
\( Q = m_s \times T \)
\( 64 = 10 \times S_1 \times 8 \Rightarrow S_1 = 0.8 \)
\( 1^\circ C \text{ to } 3^\circ C \Rightarrow Q = 900 - 880 = 20 \text{ cal} \)
\( Q = m_s \times T \Rightarrow 20 = 10 \times S_2 \times 2 \Rightarrow S_2 = 1 \)
Now, \(-2^\circ C \text{ to } +1^\circ C \)
\( 880 = 10 \times 0.8 \times (t_m + 2) + 10 \times 1 \times (1 - t_m) \)
\[ \Rightarrow L = 85.4 + 0.2 t_m (\text{ in cal/gm}) \]
for cal/kg
\( \Rightarrow L = 85400 + 200 t_m \)

3. \( Q = m_s \times T \)
In one second
\( a) \quad 180 \times 0.1 \times 0.5 = 9 \text{ cal/s} \)
\( = 37.8 \text{ water} \)
\( b) \quad P = \text{tw} \Rightarrow t = P = 37.8 \]
\( \Rightarrow \quad T_s = \text{water} \)

4. \( Q = m_s \times T \)
in one second
\( 250 = \frac{0.2 \times 10}{1000} \times 5 \times 25 \Rightarrow S = 5000 \)

37. \( \frac{70 - 60}{5} = K \left( \frac{70 + 60}{2} - 30 \right) \)
\( 2 = K \left( \frac{65 - 30}{2} \right) \)
Now,
\( \frac{60 - 50}{t} = K \left( \frac{60 - 50}{2} - 30 \right) \)
\( 2t = 35 \)
\( \Rightarrow t = 35 \times \frac{5}{25} = 7 \text{ min} \)

38. \( \frac{50 - 45}{5} = K \left( \frac{50 + 45}{2} - \theta_0 \right) \)
Or \( 2 = K \left( 95 - 2 \theta_0 \right) \)
\( \Rightarrow 45 - 40 = K \left( \frac{45 + 40}{2} - \theta_0 \right) \)
\[ \Rightarrow \cos \frac{5}{2} = K \left( 85 - 2 \theta_0 \right) \]
\( \Rightarrow \theta_0 = 34.16^\circ C \)

5. If y length of ice melts then
\( y - 0.5 \text{ length of water forms} \)
\( \Rightarrow Ay \times 0.9 = A(y - 0.5) \times 1 \)
\( \Rightarrow y = 5 \text{ cm ice melts.} \)
loss (water) = gain (ice)
\( A \times 10 \times 1 \times 1 \times T \)
\( = A \times 10 \times 0.9 \times 0.5 \times 20 \)
\( + A \times 5 \times 0.9 \times 80 \Rightarrow T = 45^\circ C \)

6. \( K_{\text{II}} \)
\( \Rightarrow \quad K_{\text{I}} \left( 2ab \right) = K_{\alpha} \left( ab \right) + K_{\beta} \left( cb \right) \)
\( \Rightarrow \quad \frac{K_{\text{I}}}{C} \left( 2 ight) = \frac{K_{\alpha \left( ac \right)}}{C} + \frac{K_{\beta \left( ac \right)}}{C} \)
\( \Rightarrow \quad T = \frac{R^2}{K_{\alpha \left( ac \right)} + K_{\beta \left( ac \right)}} \)
\( \Rightarrow \quad \frac{2b}{Q_{\text{e}}} = \frac{b}{K_{\alpha \left( ac \right)}} + \frac{b}{K_{\beta \left( ac \right)}} \Rightarrow Q_{\text{e}} = \frac{2b}{K_{\alpha \left( ac \right)} + K_{\beta \left( ac \right)}} \)
7. For cylinder (a to b)

\[
\frac{dQ}{dt} = \frac{\pi a^2 l}{2} \left( T_2 - T_1 \right) \ln \left( \frac{b}{a} \right)
\]

8. \( \frac{dQ}{dt} = \frac{\pi a^2 l}{2} \left( T_2 - T_1 \right) \ln \left( \frac{b}{a} \right) \frac{T_2 - T}{\ln(b/a)} \times 2\pi kl \)

\[
\Rightarrow \frac{a^2 l}{2} \int_0^t \frac{dt}{T_2 - T} = \ln \left( \frac{b}{a} \right) \frac{t}{T_2 - T} = \frac{a^2 l}{2} \int_0^t \frac{dt}{T_2 - T}
\]

\[
\Rightarrow t = \frac{a^2 l}{2k} \ln \left( \frac{b}{a} \right) \ln \left( \frac{T_2 - T_1}{T_2 - T} \right)
\]

9. (a) \( \frac{dT}{dx} = \frac{-100}{l} \) \( \text{C/m} \)

(b) \( 100^\circ C \)

\[
dQ = dm (T - 0) \times s = 2dx \times 10 \times 100(1-x)
\]

\[
Q = 2000 \int_0^1 (1-x) dx = 1000 J
\]

10. \( dQ = ms \frac{dT}{dt} \)

\[
10(0.04)(400 - T) = 0.4 \times 600 \times \frac{dT}{dt} \)

\[
t = 240 \ln 2 = 166.3 s
\]

11. \( -\frac{dT}{dt} = \frac{dQ}{dt} = \frac{eA(T^4 - T_s^4)}{ms} \)

\[
-\frac{dT}{dt} = \frac{K(T^4 - T_s^4)}{R}
\]

\[
\Rightarrow \frac{dT}{dt} = \frac{KR}{R} (400^4 - 300^4)
\]

\[
\Rightarrow -\frac{dT}{dt} = -\frac{k}{2R} (600^4 - 300^4)
\]

\[
d\frac{T}{dt} = -9.72^4 C/s
\]

12. \( \lambda T = b \Rightarrow T = b \times \frac{3 \times 10^{-3}}{7.5 \times 10^{-4}} \Rightarrow T = 400 K
\]

\[
KA(T_2 - T_s) = A \sigma T_s^4 \Rightarrow \frac{17 \times (T_A - 400)}{0.5}
\]

\[
= 5.67 \times 10^4 \times 40^4 \Rightarrow T_s = 423^4 \text{Kelvin}
\]

13. The shell of a space station is a blackened Rate of loss initially

\[
P = A \sigma T^4 = A \sigma (500)^4
\]

Later half of radiation emitted are emitted back by shell but not loss must be the same. So, it radiated double P = 2p

\[
A \sigma T^4 = 2 A \sigma (500)^4
\]

\[
T = 200 \times 2^4
\]

14. \( -\frac{dT}{dt} = -k(T - T_s) \Rightarrow \ln \left( \frac{T_2 - T_s}{T_2 - T_s} \right) = kt
\]

\[
\ln \left( \frac{60 - 20}{50 - 20} \right) = k \times 5 \Rightarrow k = \frac{1}{5} \ln 2
\]

\[\text{and in} \left( \frac{60 - 20}{30 - 20} \right) = kt
\]

\[
\Rightarrow \ln 4 = \frac{1}{5} \ln 2 \times t
\]

\[t = 10 \text{ min}
\]

15. \( \text{Pressure of trapped air is } P = \gamma \text{ and for } T = \text{ cons} \) PV = cons for \( P = \text{ cons} \)

\( P = (P_0 - \gamma) (l - y) = 1 \text{ cm}

(a) \( P = (P_0 - \gamma) (l - y) = 1 \text{ cm}

\( P = (P_0 - \gamma) (l - y) = 20 \Rightarrow P = 73.94 \text{ cm}

(b) \( P = (P_0 - \gamma) (l - y) = 20 \Rightarrow P = 73.94 \text{ cm}

(c) \( P = (P_0 - \gamma) (l - y) = 20 \Rightarrow (74 - y)(74 - y) = 20

\Rightarrow 74 - y = \sqrt{20} \Rightarrow y = 69.52 \text{ cm}

16. (i) \( p_1 = p_2 = 1.25 \times 10^8 \text{ Pa}

p_2 = 2.125 \times 10^8 \text{ Pa}

p_2 = 1.5625 \times 10^8 \text{ Pa}

17. 100°C \( R \) 10°C 0°C

\[T_A = 60^4 \text{ C}
\]
1. **B**
Spectrometer is an instrument which is used to obtain a pure spectrum of white light. It is used to determine the wavelength of different colours of white light (or wavelength of monochromatic light source), the refractive index of the material of the prism and the dispersive power of the material of the prism. Pyrometer is infrared sensitive device, so it is used to detect infrared radiations.
Nanometer is the small unit of distance and is not a device.
Photometer is used to measure luminous intensity, illuminance and other photometric quantities.

2. **B**
The thermal capacity of a substance is defined as the amount of heat required to raise its temperature by 1°C.

3. **C**
Temperature of a gas is determined by the total translational kinetic energy measured with respect to the centre of mass of the gas. Therefore, the motion of centre of mass of the gas does not affect the temperature. Hence, the temperature of gas will remain same.

4. **A**
Energy radiated per second by a body which has surface area A at temperature T is given by Stefan's law,
\[ E = \sigma A T^4 \]
Therefore,
\[ \frac{E_1}{E_2} = \left( \frac{T_1}{T_2} \right)^4 = \left( \frac{1}{4} \right)^4 \]
\[ 4000 \]
[Since bodies are of same material, so \( e_1 = e_2 \)]
\[ \Rightarrow \frac{E_1}{E_2} = 16 \cdot 1 = 1:1 \]

5. **A**
According to the mass-energy equivalence, mass and energy remain conserved. So, when water is cooled to form ice, water loses its energy, so change in energy increases the mass of water.

6. **D**
According to Newton's law of cooling,
\[ \frac{dQ}{dt} = \Delta \theta \]
But \( \frac{dQ}{dt} = (\Delta \theta)^n \) (given)
\[ \therefore \ n = 1 \]

7. **D**
From Stefan’s law, the energy radiated by sun in given by \( P = \sigma A T^4 \).
In 1st case,
\[ P_1 = \sigma A \times 4 \pi R_1^2 \times T_1^4 \]
In 2nd case,
\[ P_2 = \sigma A \times 4 \pi R_2^2 \times (2T)^4 \]
\[ = \sigma A \times 4 \pi R_1^2 \times T_1^4 \times 64 = 64P_1 \]
The rate at which energy received at earth is
\[ E = \frac{P}{4 \pi R_1^2} \times A_e \]
where \( A_e = \text{Area of earth} \)
\( R_1 \) = Distance between sun and earth
So, In 1st case,
\[ E_1 = \frac{P_1}{4 \pi R_1^2} \times A_e \]
\( E_2 = \frac{P_2}{4 \pi R_1^2} \times A_e \]
\[ = 64E_1 \]

8. **D**
Let the temperature of common interface be \( T^\circ C \). Rate of heat flow
\[ H = \frac{Q}{t} = \frac{K A T}{t} \]
\[ \therefore \ H_1 = \left( \frac{Q}{t_1} \right) = \frac{2KA(T - T_1)}{4x} \]
and \( H_2 = \left( \frac{Q}{t_2} \right) = \frac{2KA(T_2 - T)}{x} \)
In steady state, the rate of heat flow should be same in whole system ie,
\[ H_1 = H_2 \]
\[ \Rightarrow \frac{2KA(T - T_1)}{4x} = \frac{2KA(T_2 - T)}{x} \]
or \( \frac{T - T_1}{2} = (T_2 - T) \)
or \( T - T_1 = 2T_2 - 2T \)
or \( T = \frac{2T_1 + 2T_2}{3} \) \( \ldots (i) \)
Hence, heat flow from composite slab is
\[ H = \frac{KA(T_2 - T)}{x} \]
\[ = \frac{KA}{x} \left( \frac{T_2 - 2T_2 + T_1}{3} \right) \]
\[ = \frac{KA}{3x} (T_2 - T_1) \] \( \ldots (ii) \)
Accordingly, \( H = \left[ \frac{A(T_1 \cdot T_k)}{x} \right] \) ...(iii)

By comparing Eqs. (ii) and (iii), we get

\[ f = \frac{1}{3} \]

10. C

To measure the radial rate of heat flow, we have to go for integration technique as here the area of the surface through which heat will flow is not constant.

Let us consider an element (spherical shell) of thickness \( dx \) and radius \( x \) as shown in figure. Let us first find the equivalent thermal resistance between inner and outer sphere.

\[
R = \frac{1}{K A} \left[ \frac{1}{r_1} - \frac{1}{r_2} \right]
\]

Rate of heat flow = \( H \)

\[
H = \frac{T_1 - T_2}{R} = \frac{T_1 - T_2}{4 \pi K (r_2 - r_1)}
\]

11. B

From Stefan's law, the rate at which energy is radiated by sun at its surface is

\[
P = \sigma \times 4 \pi R^2 \times T^4
\]

[Sun is a perfectly black body as it emits radiation of all wavelengths and so for \( \epsilon = 1 \).]

The intensity of this power at earth's surface [under the assumption \( r >> r_s \)] is

\[
I = \frac{P}{4 \pi r^2} = \frac{\sigma \times 4 \pi R^2 T^4}{4 \pi r^2} = \frac{\sigma R^2 T^4}{r^2}
\]

The area of earth which receives this energy is only one half of total surface area of earth, whose projection would be \( \pi \cdot r_s^2 \)

\[ \therefore \text{Total radiant power as received by earth} \]

\[ = \pi r_s^2 \times \sigma R^2 T^4 \]

\[ = \frac{\pi r_s^2 \times \sigma R^2 T^4}{r^2} \]

12. C

Let temperature at the interface is \( T \)

For part AB,

\[ Q_{ab} = \frac{(T_1 - T_k)}{\frac{1}{I_1}} \]

For part BC,

\[ Q_{bc} = \frac{(T - T_k)}{\frac{1}{I_2}} \]

At equilibrium, \( Q_{ab} = Q_{bc} \)

\[ \frac{(T_1 - T_k)}{I_1} = \frac{(T - T_k)}{I_2} \]

or \[ T = \frac{T_1 I_2 - T_k I_1}{I_2 - I_1} \]

13. A

The forces acting on the ball are gravity force, buoyancy force and viscous force. When ball acquires terminal speed, it is in dynamic equilibrium, let terminal speed of ball is \( v_t \). So,

\[ V_P \cdot g + kv_t^2 = V_t \cdot g \]

or \[ V_t = \sqrt{\frac{(v_1 - v_2) g}{k}} \]

14. D

According to Newton's law of cooling, rate of fall in temperature is proportional to the difference in temperature of the body with surrounding i.e.

\[ \frac{d \theta}{dt} = k(\theta - \theta_s) \]

\[ \Rightarrow \int \frac{d \theta}{\theta - \theta_s} = \int -k dt \]

\[ \ln(\theta - \theta_s) = kt + C \]

Which is a straight line with negative slope.
LEVEL - II

1. \( m_v[L_v + S_v \Delta v] = 100S_v \Delta v \)
\( m_1[540 + 1(100 - 90)] = 100(1)(90 - 24) \)
\( m_v = 12 \text{ gm} \)
\( R_A - K_A = \frac{200}{3} = 2 \)
\( R_B - K_B = \frac{300}{3} = 3 \)
\( \frac{\Delta T_A}{\Delta T_B} = \frac{R_A}{R_B} \frac{2}{3} \Rightarrow \frac{100 - T}{T - 0} \frac{2}{3} \Rightarrow T = 60^\circ C \)

2. \( R_1 = R_2 = \frac{0.01}{(0.8)(1)} \)
\( i = i_1 = i_2 = i_3 \)
\( 27 - Q_1 = Q_1 - Q_2 \)
\( 0.0125 = 0.625 \)
\( Q_1 = 0.0125 \)
\( Q_2 = 26.48^\circ C \)
\( Q_2 = 0.52^\circ C \) hence i = 41.6 watt.

4. \( P = \frac{AT^4}{(A/4)(2T)^4} \)
\( P = \frac{450}{(16)} = 1800 \text{ W} \)

5. \( \Delta Q_{ice} = 0.28 \times 10^8 \text{ J/kg} = 9.24 \times 10^4 \text{ J/kg} \)
Heated received/second = (1400)(0.2) = 280 J
Time taken = \( \frac{9.24 \times 10^4}{280} = 5.5 \text{ min} \)

6. For \( t < t_1 \)
Newton's law of cooling
\[ \frac{dT}{dt} = k(T - T_x) \]
\[ T = \int_{T_0}^{T_0} \frac{dT}{k(T - T_x)} = \int_{T_0}^{T_0} \frac{kA}{CL} \]
\[ kt_1 = -\ln \left( \frac{350 - 300}{400 - 300} \right) = \ln(2) \]
For \( t > t_1 \) (Radiation + conduction)
\[ T_x = x \]
\[ T_{TA} = T \]
Rate of cooling \( -\frac{dT}{dt} - k(T - T_x) + \frac{kA}{CL} (T - T_x) \)
Let at \( t = 3t_1 \), temp. of \( x \) becomes \( T_2 \)
\[ T - T_x = \left( \frac{kA}{CL} \right) \int_{t_1}^{3t_1} \]
\[ T_2 = 300 + 50 \exp \left( \frac{-kA}{L + \frac{ln2}{t_1} T_1} \right) \]

7. Wien's Displacement law
\[ \frac{\lambda_m}{T} = b \Rightarrow \frac{\lambda_m}{b} = \frac{b}{T} \]
\[ \Rightarrow \lambda_m = 1000 \text{ nm} \]
from graph \( U_2 > U_1 \)

8. A
Initially the heat absorbed goes into increasing the temperature of ice. At \( 0^\circ C \) the phase changes. So temperature is constant. Till \( 100^\circ C \) again this process and at \( 100^\circ C \) again phase change occurs.

9. B
\[ \lambda_m = \frac{1}{T} \]
from fig. \( (\lambda_m)_1 < (\lambda_m)_2 < (\lambda_m)_3 \)
\[ T_1 > T_2 > T_3 \]

10. B
Using junction law and assuming the temperature of the junction to be 0.
\[ 90 - 0 + 90 - 0 = 0 - 0 \]
\[ R = R = R \]
\[ \Rightarrow 0 = 60^\circ C \]

11. D
Initially it will absorb all the radiant energy so it will be the darkest one.
Then radiate maximum energy and it will be the brightest of all.

12. Heat gained by ice = heat lost by container
\( (0.1)(8 \times 10^4) + (0.1)(10^2) \)
\[ = m [A + BT] \int_{0}^{10^3} \int_{0}^{10^3} \]
\[ 10700 - m \left[ \frac{A + BT^2}{2} \right]_{10^3} \Rightarrow m = 0.495 \text{ kg} \]

13. A
\[ Q_{m, \Delta T} = 5(10^4)(20 - 0) = 10^6 \text{ cal} \]
\[ Q_{m, \Delta T} = 2(500)(20) = 0.2 \times 10^3 \text{ cal} \]
\[ \Delta Q = 0.8 \times 10^3 \text{ cal will melt a mass m of ice} \]
\[ m = \frac{Q}{L} = \frac{0.8 \times 10^3}{80 \times 10^3} = 1 \text{ kg} \]
\[ m_{water} = 5 + 1 = 6 \text{ kg} \]

---

Physicswallah
14. A
\[
\frac{dT}{dt} = e \Rightarrow \left( \frac{dT}{dt} \right)_{T_1} \left( - \frac{dT}{dt} \right)_{T_2} \text{ from graph}
\]
\[
T_2 > T_1 \Rightarrow e_2 > e_1
\]
15. (a) Rate of heat loss per unit area
\[
I = e \sigma (T^4 - T_a^4)
\]
\[
= 0.5 \times \left( 1 - 3 \times 10^{-4}((400)^4 - (300)^4) \right) = 595 \text{ W/m}^2
\]
(b) \[r/\kappa_A = 595 \text{ A} \]
\[r = 0.005 \quad k = 0.149 \]
\[\theta = 146.98 \text{ °C} = 419.96 \text{ k} \]
16. B
\[Q = AT^4 \text{ and } \lambda_T = \text{ const.} \]
\[
\text{hence } Q = \frac{A}{\lambda_T} \Rightarrow Q_A : Q_B : Q_C = \frac{2^2}{3^2} : \frac{4^2}{4^3} : \frac{6^2}{5^3}
\]
17. D
\[
\frac{dQ}{dt} = L \left( \frac{dm}{dt} \right) \quad \Rightarrow \frac{dT}{R} = L \left( \frac{dm}{dt} \right)
\]
\[
\Rightarrow \frac{dT}{R} \quad \Rightarrow q = \frac{1}{R} \quad \Rightarrow \text{ II } \quad \text{Parallel } \quad \text{Series } \quad R_{eq} = 2R
\]
\[
Q_L = \frac{2R}{(R/2)} - 1/4
\]
18. C

19. T \uparrow \quad V_{cub} \uparrow \quad \rho \uparrow \quad \gamma \uparrow \quad \phi \uparrow \quad g \uparrow
\[\text{Depth of container submerged in liquid remains same} \]
\[\nu, \rho, g = \nu', \rho', g' \]
\[\Delta h_1 \rho, g = \Delta h(1+2\alpha, \Delta T) \quad \frac{\rho}{1+\gamma} \rightarrow \gamma = 2\alpha
\]
20. Rate of heat conduction = Rate of heat lost from right end
\[k(T_a - T_e) = \epsilon \sigma(T^4 - T_a^4) \quad \frac{L}{k(T_a - T_e)} = \epsilon \sigma(T^4 - T_a^4)
\]
\[\text{As } T_e = (T_a - \Delta T)^4 = T_a^4 \left( 1 + \frac{4\Delta T}{T_a} \right)
\]
\[\text{hence } \frac{k(T_a - T_e)}{L} = 4\epsilon \sigma T_a^4 \Delta T
\]
\[\Rightarrow \Delta T = \frac{k(T_a - T_e)}{4\epsilon \sigma T_a^4 + K}
\]
on comparing proportional const. = \[\frac{k}{4\epsilon \sigma T_a^4 + K}
\]
21. A
\[\lambda_T = \text{ const.} \quad \text{from graph } T_3 > T_2 > T_1
\]
22. C
Glass of bulb heats due to filament by radiation

23. A
Energy gained by water (in 1 s)
\[= 1000 - 160 + 8405 \quad \text{Time required } t = \frac{m \cdot \lambda}{s} = 2(4.2 \times 10^{-5}) \times 500 \text{ Sec.}
\]
24. A
\[\frac{dQ}{dt} = e \sigma AT^4 = 0.6 \times A \quad T^4
\]
25. B
We know that 14.5°C to 15.5°C at 760 mm of Hg.
26. A,D
Using theory.
27. 0.05 kg steam at (373 k) \[\rightarrow \text{O.58 m 1 atm water} \]
\[\rightarrow \text{0.05 kg water at 373 k} \]
\[\rightarrow \text{0.05 kg water at 273 k} \]
\[\rightarrow \text{0.45 kg ice at 0°C} \]
\[\rightarrow \text{0.45 kg water at 273 k} \]
\[\text{Q_1 > Q_3} \quad \text{but } Q_1 > Q_2 > Q_3 + Q_4 \quad \text{whole ice will not melt}
\]
\[T = 273 \kappa \]
28. (A) \rightarrow S, Q, (B) \rightarrow Q, (C) \rightarrow P, Q, (D) \rightarrow D, R \quad \text{or}
\[\text{(A) \rightarrow S, (B) \rightarrow Q, (C) \rightarrow P, (D) \rightarrow R \text{ using theory.)}
\]
\[0^\circ \text{C ice} \rightarrow \text{water} \rightarrow 100^\circ \text{C}
\]
29. \[\text{Let the mass of water that melts or evaporates is } m
\]
\[\Rightarrow \Delta Q_1 = \frac{kA}{r_1} = m \times 80 \times 42
\]
\[\Delta Q_2 = \frac{kA}{r_2} = \frac{m \times 540 \times 42}{300}
\]
\[\Rightarrow \frac{\Delta Q_1}{\Delta Q_2} = \frac{80}{540} \quad \Rightarrow \frac{r_1}{r_2} = \frac{1}{9}
\]
\[\Rightarrow \frac{r_1}{r_2} = \frac{10}{9} \quad \Rightarrow r_1 = \frac{9}{10} \times 10 = 9
\]
30. Total Heat given \[\Delta Q = 420 \text{ J}
\]
\[\text{ice} \rightarrow \text{5°C m} \rightarrow \text{0°C m} \rightarrow \text{ice} \rightarrow \text{ice water} + 1 \text{ gm} \rightarrow \text{0°C}
\]
\[\text{ice} \rightarrow \text{5°C m} \rightarrow \text{0°C m} \rightarrow \text{ice} \rightarrow \text{ice water} + 1 \text{ gm} \rightarrow \text{0°C}
\]
\[\Delta Q_3 = m \times 2100 \times (0 - (-5)) \times m \times 2100 \times 5 \text{J}
\]
\[\Delta Q_4 = 10^{-3} \times 3.36 \times 10^8 \times 336 \text{ J}
\]
\[\Delta Q = \Delta Q_1 + \Delta Q_2 + \Delta Q_3 + \Delta Q_4
\]
\[2100 \times 5 \times 9 = 336 \text{ J}
\]
\[m = \frac{84}{2100 \times 5 \times 9} \times 8 \text{ gm}
\]
31. C
For middle plate (in unit time)
Heat absorbed/Area
\[= \text{Heat emitted/Area}
\]
\[\sigma (2T)^4 + \sigma (3T)^4 = \sigma (T_0)^4 \times 2
\]
\[T_0 = \left( \frac{97}{2} \right)^{1/4} \quad T
\]