14. (b) $\left(\frac{Q}{t}\right)_1 = \frac{K_1A_1(\theta_1-\theta_2)}{l}$ and $\left(\frac{Q}{t}\right)_2 = \frac{K_2A_2(\theta_1-\theta_2)}{l}$

given $\left(\frac{Q}{t}\right)_1 = \left(\frac{Q}{t}\right)_2 \Rightarrow K_1A_1 = K_2A_2$

15. (d) In variable state $\frac{Q}{t} \propto K$ and $\frac{Q}{t} \propto \frac{1}{\rho c} \Rightarrow$ $\frac{Q}{t} \propto \frac{K}{\rho c}$

(K = thermal conductivity, ρ = density, c = specific heat)

16. (b) $K_1 : K_2 = l_1^2 : l_2^2 \Rightarrow \frac{l_1}{l_2} = \sqrt{\frac{K_1}{K_2}} = \sqrt{\frac{10}{9}} = \frac{\sqrt{10}}{3}$

17. (c) $\frac{Q}{t} = \frac{KA(\Delta\theta)}{l} \Rightarrow 50 = \frac{5\times 20\ K}{0.4} \Rightarrow K = \frac{1}{5} = 0.2$

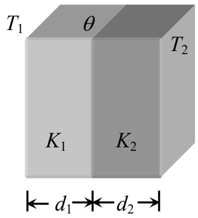
18. (c)

19. (a) Thermal resistance

$$= \frac{l}{KA} = \left[\frac{L}{MLT^{-3}K^{-1}\times L^2}\right] = [M^{-1}L^{-2}T^3K]$$

20. (a) When a piece of glass is heated, due to low thermal conductivity it does not conduct heat fast. Hence unequal expansion of it's layers crack the glass.

21. (a) In series both walls have same rate of heat flow. Therefore



$$\frac{dQ}{dt} = \frac{K_1A(T_1-\theta)}{d_1} = \frac{K_2A(\theta-T_2)}{d_2}$$

$$\Rightarrow K_1d_2(T_1-\theta) = K_2d_1(\theta-T_2)$$

$$\Rightarrow \theta = \frac{K_1d_2T_1 + K_2d_1T_2}{K_1d_2 + K_2d_1}$$

22. (a) Temperature of interface $\theta = \frac{K_1\theta_1 + K_2\theta_2}{K_1+K_2}$

($\because \frac{K_1}{K_2} = \frac{1}{4} \Rightarrow$ If $K_1 = K$ then $K_2 = 4K$)

$$\Rightarrow \theta = \frac{K\times 0 + 4K\times 100}{5K} = 80°C$$

23. (b) $\frac{\theta_1-\theta_2}{l} = 80 \Rightarrow \frac{30-\theta_2}{0.5} = 80 \Rightarrow \theta_2 = -10^oC$

24. (d) $\frac{dQ}{dt} = -KA\frac{d\theta}{dx}$; when $K=\infty$, $\frac{d\theta}{dx} = 0$

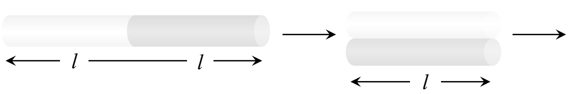
i.e. θ is independent of x *i.e.* constant or uniform.

25. (a) Air is poor conductor of heat.

26. (b)

27. (b)

28. (d) Let the heat transferred be Q.



When rods are joined end to end. Heat transferred by each rod $= Q = \frac{KA\Delta\theta}{l}\times 12$ .....(i)

When rods are joined lengthwise, $Q = \frac{KA\Delta\theta}{2l}t$ .....(ii)

From equation (i) and (ii) we get $t = 48\ s$

29. (d) $\frac{Q}{t} = \frac{KA\Delta\theta}{l} \Rightarrow \frac{K_A}{K_B} = \frac{A_B}{A_A} = \left(\frac{r_B}{r_B}\right)^2 = \frac{1}{4} \Rightarrow K_A = \frac{K_B}{4}$

30. (b) Thermal conductivity of composite plate

$$K_{eq} = \frac{2K_1K_2}{K_1+K_2} = \frac{2\times 2\times 3}{2+3} = \frac{12}{5} = 2.4$$

31. (b) $Q \propto \frac{A}{l} \propto \frac{r^2}{l} \Rightarrow \frac{Q_2}{Q_1} = \frac{r_2^2}{r_1^2}\times\frac{l_1}{l_2}$

$$\Rightarrow \frac{Q_2}{Q_1} = \frac{4}{1}\times\frac{1}{2} \Rightarrow Q_2 = 2Q_1$$

32. (c) $\frac{Q}{At} = K\frac{\Delta\theta}{l} \Rightarrow K\frac{\Delta\theta}{l} =$ constant $\Rightarrow \frac{\Delta\theta}{l} \propto \frac{1}{K}$

Hence If $K_c > K_m > K_g$, then

$$\left(\frac{\Delta\theta}{l}\right)_c < \left(\frac{\Delta\theta}{l}\right)_m < \left(\frac{\Delta\theta}{l}\right)_g \Rightarrow X_c < X_m < X_g$$

because higher K implies lower value of the temperature gradient.

33. (b) In series $R_{eq} = R_1 + R_2 \Rightarrow \frac{2l}{K_{eq}A} = \frac{l}{K_1A} + \frac{l}{K_2A}$

$$\Rightarrow \frac{2}{K_{eq}} = \frac{1}{K_1} + \frac{1}{K_2} \Rightarrow K_{eq} = \frac{2K_1K_2}{K_1+K_2}$$

34. (b) $\frac{dQ}{dt} = KA\frac{d\theta}{dl} \Rightarrow \frac{dQ}{dt} \propto \frac{d\theta}{dl}$ (Temperature gradient)

35. (a) $\frac{dQ}{dt} = \frac{K(\pi r^2)d\theta}{dl} \Rightarrow \frac{\left(\frac{dQ}{dt}\right)_s}{\left(\frac{dQ}{dt}\right)_l} = \frac{K_s\times r_s^2\times l_l}{K_l\times r_l^2\times l_s} = \frac{1}{2}\times\frac{1}{4}\times\frac{2}{1}$

$$\Rightarrow \left(\frac{dQ}{dt}\right)_s = \frac{\left(\frac{dQ}{dt}\right)_l}{4} = \frac{4}{4} = 1$$

36. (d) $Q = \frac{KA(\Delta\theta)t}{l}$

$\because$ Q and $\Delta\theta$ are same for both spheres hence

$K \propto \frac{l}{At} \propto \frac{l}{r^2t} \Rightarrow \frac{K_{larger}}{K_{smaller}} = \frac{l_l}{l_s}\times\left(\frac{r_s}{r_l}\right)^2\times\frac{t_s}{t_l}$. It is given that $r_l = 2r_s$, $l_l = \frac{1}{4}l_s$ and $t_1 = 25\ min$, $t_s = 16\ min$.

$\Rightarrow \frac{K_{larger}}{K_{smaller}} = \left(\frac{1}{4}\right)\left(\frac{1}{2}\right)^2 \times \frac{16}{25} = \frac{1}{25}$

37. (d) $\frac{Q}{t} = \frac{KA(\Delta\theta)}{l} \Rightarrow \frac{Q}{t} \propto \frac{A}{l} \propto \frac{r^2}{l}$

$\Rightarrow \frac{(Q/t)_1}{(Q/t)_2} = \left(\frac{r_1}{r_2}\right)^2 \times \frac{l_2}{l_1} = \left(\frac{2}{1}\right)^2 \times \left(\frac{4}{1}\right) = \frac{16}{1}$

38. (b) Temperature of interface $\theta = \frac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2}$

where $K_1 = 2K$ and $K_2 = 3K$ $\left(\because \frac{K_1}{K_2} = \frac{2}{3}\right)$

$\Rightarrow \theta = \frac{2K \times 100 + 3K \times 0}{2K + 3K} = \frac{200K}{5K} = 40°C$

39. (a) $\frac{K_1}{K_2} = \frac{l_1^2}{l_2^2}$ $\therefore K_2 = \frac{K_1 l_2^2}{l_1^2} = \frac{0.92 \times (4.2)^2}{(8.4)^2} = 0.23$

40. (c) Mud is bad conductor of heat. So it prevents the flow of heat between surroundings and inside.

41. (b) Temperature gradient $= \frac{100 - 20}{20} = 4°C/cm$

temperature at centre $= 100 - 4 \times 10 = 60°C$

42. (c) Temperature of interface

$\theta = \frac{K_1\theta_1 l_2 + K_2\theta_2 l_1}{K_1 l_2 + K_2 l_1} = \frac{K \times 0 \times 2 + 3K \times 100 \times 1}{K \times 2 + 3K \times 1}$

$= \frac{300K}{5K} = 60°C$

43. (c) $\Delta\theta = \frac{Q \times l}{KAt} = \frac{4000 \times 0.1}{400 \times 10^{-2}} = 100°C$

44. (b) Heat passes quickly from the body into the metal which leads to a cold feeling.

45. (c) Heat energy always flow from higher temperature to lower temperature. Hence, temperature difference *w.r.t.* length (temperature gradient) is required to flow heat from one part of a solid to other part.

46. (a) When the temperature of an object is equal to that of human body, no heat is transferred from the object to body and vice versa, Therefore block of wood and block of metal feel equally cold and hot if they have same temperature as human body.

47. (c)

48. (b) Temperature of water just below the lower surface of ice layer is 0°*C*.

49. (b) $\frac{Q}{t} = \frac{KA(\theta_1 - \theta_2)}{l} = \frac{100 \times 100 \times 10^{-4}(100 - 0)}{1}$

$\Rightarrow \frac{Q}{t} = 100$ *Joule/sec* $= 6 \times 10^3$ *Joule/min*

50. (a) Temperature of interface $\theta = \frac{K_1\theta_1 l_2 + K_2\theta_2 l_1}{K_1 l_2 + K_2 l_1}$

It is given that $K_{Cu} = 9K_S$. So if $K_S = K_1 = K$ then $K_{Cu} = K_2 = 9K$

$\Rightarrow \theta = \frac{9K \times 100 \times 6 + K \times 0 \times 18}{9K \times 6 + K \times 18} = \frac{5400K}{72K} = 75°C$

51. (c) $\frac{Q}{t} = \frac{KA(\theta_1 - \theta_2)}{l} \Rightarrow \frac{Q}{t} \propto \frac{A}{l} \propto \frac{r^2}{l}$

[As $(\theta_1 - \theta_2)$ and K are constants]

$\Rightarrow \frac{\left(\frac{Q}{t}\right)_1}{\left(\frac{Q}{t}\right)_2} = \frac{r_1^2}{r_2^2} \times \frac{l_2}{l_1} = \frac{4}{9} \times \frac{2}{1} = \frac{8}{9}$

52. (b) In parallel combination equivalent conductivity

$K = \frac{K_1A_1 + K_2A_2}{A_1 + A_2} = \frac{K_1 + K_2}{2}$ (As $A_1 = A_2$)

53. (b) $Q = \frac{KA(\theta_1 - \theta_2)}{l} t \Rightarrow K_1 t_1 = K_2 t_2 \Rightarrow \frac{K_1}{K_2} = \frac{t_2}{t_1} = \frac{35}{20} = \frac{7}{4}$

(As Q, l, A and $(\theta_1 - \theta_2)$ are same)

54. (c) A lake cools from the surface down. Above $4°C$, the cooled water at the surface flows to the bottom because of it's greater density. But when the surface temperature drops below $4°C$ (here it is $2°C$), the water near the surface is less dense than the warmer water below. Hence the downward flow ceases, the water at the bottom remains at $4°C$ until nearly the entire lake, is frozen.

55. (a) Temperature gradient

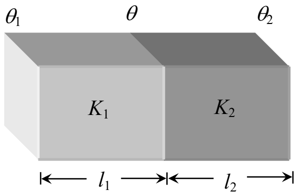
$\frac{d\theta}{dx} = \frac{(125 - 25)°C}{50\ cm} = 2°C/cm$

56. (a) $K \propto l^2 \Rightarrow \frac{K_1}{K_2} = \frac{l_1^2}{l_2^2} = \left(\frac{10}{25}\right)^2 = \frac{1}{6.25}$

57. (a) Thermal resistance of *Cu* is lesser than the thermal resistance of steel. Hence only in option (*a*) thermal resistance is minimum so heat current is maximum.

58. (c) At steady state, rate of heat flow for both blocks will be same *i.e.*, $\frac{K_1A(\theta_1 - \theta)}{l_1} = \frac{K_2A(\theta - \theta_2)}{l_2}$ (given $l_1 = l_2$)

$\Rightarrow K_1 A(\theta_1 - \theta) = K_2 A(\theta - \theta_2) \quad \Rightarrow \theta = \dfrac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2}$



59. (c) $K = \dfrac{2K_1K_2}{K_1 + K_2} = \dfrac{2.K.2K}{K + 2K} = \dfrac{4}{3}K$

60. (a) Temperature of interface $\theta = \dfrac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2}$

It is given that $\dfrac{K_1}{K_2} = \dfrac{5}{3} \Rightarrow K_1 = 5K$ and $K_2 = 3K$

$\theta = \dfrac{5K \times 100 + 3K \times 20}{5K + 3K} = \dfrac{560K}{8K} = 70°C$

61. (c) In winter, the temperature of surrounding is low compared to the body temperature $(37.4^o C)$. Since woolen clothes are bad conductors of heat, so they keep the body warm.

62. (d) Temperature of interface $T = \dfrac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2}$

$= \dfrac{300 \times 100 + 200 \times 0}{300 + 200} = 60°C$

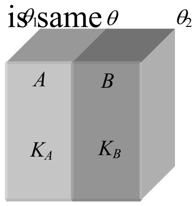
63. (b) Rate of heat flow $\left(\dfrac{Q}{t}\right) = \dfrac{k\pi r^2(\theta_1 - \theta_2)}{L} \propto \dfrac{r^2}{L}$

$\therefore \dfrac{Q_1}{Q_2} = \left(\dfrac{r_1}{r_2}\right)^2 \left(\dfrac{l_2}{l_1}\right) = \left(\dfrac{1}{2}\right)^2 \times \left(\dfrac{2}{1}\right) = \dfrac{1}{2} \Rightarrow Q_2 = 2Q_1$

64. (b) $\dfrac{Q}{t} = \dfrac{KA\Delta\theta}{l} \Rightarrow 6000 = \dfrac{200 \times 0.75 \times \Delta\theta}{1}$

$\therefore \Delta\theta = \dfrac{6000 \times 1}{200 \times 0.75} = 40°C$

65. (b) In series rate of flow of heat is same



$\Rightarrow \dfrac{K_A A(\theta_1 - \theta)}{l} = \dfrac{K_B A(\theta - \theta_2)}{l}$

$\Rightarrow 3K_B(\theta_1 - \theta) = K_B(\theta - \theta_2)$

$\Rightarrow 3(\theta_1 - \theta) = (\theta - \theta_2)$

$\Rightarrow 3\theta_1 - 3\theta = \theta - \theta_2 \Rightarrow 4\theta_1 - 4\theta = \theta_1 - \theta_2$

$\Rightarrow 4(\theta_1 - \theta) = (\theta_1 - \theta_2)$

$\Rightarrow 4(\theta_1 - \theta) = 20 \Rightarrow (\theta_1 - \theta) = 5°C$

66. (c) Let θ be temperature middle point C and in series rate of heat flow is same $\Rightarrow$ $K(2A)(100 - \theta) = KA(\theta - 70)$

$\Rightarrow 200 - 2\theta = \theta - 70 \Rightarrow 3\theta = 270 \Rightarrow \theta = 90°C$

67. (b) Thermal resistances are same

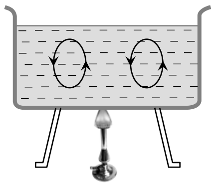
$\Rightarrow \dfrac{l_1}{K_1A_1} = \dfrac{l_2}{K_2A_2} \Rightarrow \dfrac{l_1}{K_1} = \dfrac{l_2}{K_2} \; (\because A_1 = A_2)$

$\Rightarrow \dfrac{l_1}{l_2} = \dfrac{K_1}{K_2} = \dfrac{5}{3}$

68. (b) $\dfrac{Q}{t} \propto \dfrac{r^2}{l}$; from the given options, option (b) has higher value of $\dfrac{r^2}{l}$.

Convection

1. (c) Convection significantly transferring heat upwards (Gravity effect).
2. (a) Heat flows from hot air to cold body so person feels comfort.
3. (c) No flow of heat by convection in vacuum.
4. (a)
5. (b) Density of hot air is lesser than the density of cold air so hot air rises up.
6. (a)
7. (c) In convection hot particles moves up ward (due to low density) and light particle moves downward (due to high density).



8. (b)
9. (a) Natural convection arises due to difference of density at two places and is a consequence of gravity.
10. (d)
11. (a) Convection is not possible in weightlessness. So the liquid will be heated through conduction.
12. (c) In forced convection rate of loss of heat $\dfrac{Q}{t} \propto A(T - T_0)$
13. (c)

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

1. (b) Because of uneven surfaces of mountains, most of it's parts remain under shadow. So, most of the mountains. Land is not heated up by sun rays. Besides this, sun rays fall slanting on the mountains and are spread over a larger area. So, the heat received by the mountains top per unit area is less and

they are less heated compared to planes (Foot).

2. (a) The velocity of heat radiation in vacuum is equal to that of light.

3. (c) Radiation is the fastest mode of heat transfer.

4. (d) A thermopile is a sensitive instrument, used for detection of heat radiation and measurement of their intensity.

5. (d) The polished surface reflects all the radiation.

6. (c) Heat radiations are electromagnetic waves of high wavelength.

7. (d) When element and surrounding have same temperature. There will be no temperature difference, hence heat will not flow from the filament and it's temperature remains constant.

8. (d) Every body at all time, at all temperatures emits radiation (except at $T=0$). The radiation emitted by the human body is in the infra-red region.

9. (c)

10. (b) Infrared radiations are detected by pyrometer.

11. (b)

12. (a) In vacuum heat flows by the radiation mode only.

13. (c) Good absorbers are always good emitters of heat.

14. (a) A perfectly black body is a good absorber of radiations falls on it. So it's absorptive power is 1.

15. (d) According to Kirchoff's law in spectroscopy. If a substance emit certain wavelengths at high temperature, it absorbs the same wavelength at comparatively lower temperature.

16. (b) A person with dark skin absorbs more heat radiation and feels more heat. It also radiates more heat and feels more cold.

17. (a) For a black body emissivity = absorptive power.

18. (b) Highly polished mirror like surfaces are good reflectors, but not good radiators.

19. (b) Black cloth is a good absorber of heat, therefore ice covered by black cloth melts more as compared to that covered by white cloth.

20. (c) According to Kirchoff's law, the ratio of emissive power to absorptive power is same for all bodies is equal to the emissive power of a perfectly black body *i.e.,*

$\left(\frac{e}{a}\right)_{body} = E_{\text{Black body}}$ for a particular wave length

$$\left(\frac{e_\lambda}{a_\lambda}\right)_{\text{body}} = (E_\lambda)_{\text{Black body}} \Rightarrow e_\lambda = a_\lambda E_\lambda$$

21. (b) Absorption power $= \frac{\text{Heat absorbed}}{\text{Total heat given}}$

22. (c) Because Planck's law explains the distribution of energy correctly at low temperature as well as at high temperature.

23. (c)

24. (a) The black spot on heating absorbs radiations and so emits them in the dark room while the polished shining part reflects radiation and absorbs nothing and so does not emit radiations and becomes invisible in the dark.

25. (b)

26. (b) When the light emitted from the sun's photosphere passes through it's outer part Chromosphere, certain wave lengths are absorbed. In the spectrum of sunlight, a large number of dark lines are seen called Fraunhoffer lines.

27. (a) As for a black body rate of absorption of heat is more. Hence thermometer *A* shows faster rise in temperature but finally both will acquire the atmospheric temperature.

28. (c) According to Kirchoff's law, a good emitter is also a good absorber.

29. (a) Red and green colours are complementary to each other. When red glass is heated it absorbs green light strongly, hence according to Kirchoff's law, the emissive power of red glass should be maximum for green light. That's why when this heated red glass is taken in dark room it strongly emits green light and looks greenish.

30. (d) Black and rough surfaces are good absorber that's why they emit well. (Kirchoff's law).

31. (d)

32. (c) When light incident on pin hole, enters into the box and suffers successive reflection at the inner wall. At each reflection some energy is absorbed. Hence the ray once it enters the box can never come out and pin hole acts like a perfect black body.

33. (a) Initially black body absorbs all the radiant energy incident on it, So it is the darkest one. Black body radiates maximum energy if all other condition are same. So when the temperature of the black body becomes equal to the temperature of furnace it will be brightest of all.

34. (c) Open window behaves like a perfectly black body.

35. (a) Ordinary glass prism (crown, flint) absorbs the infrared radiation but rock salt prism transmit them. Hence it is used to obtain the spectrum of infrared radiation.

36. (d) A good absorber is a good emitter hence option (a) is wrong. Every body stops absorbing and emitting radiation at 0 K hence option (b) is wrong.

The energy of radiation emitted from a black body is not same for all wavelength hence option (c) is wrong.

Plank's law relates the wavelength (λ) and temperature (T) according to the relation $E_\lambda d_\lambda = \frac{8\pi hc}{\lambda^5}\frac{1}{[e^{hc/kT}-1]}d_\lambda$. Hence option (d) is correct.

37. (c) When blue glass is heated at high temperature, it absorbs all the radiation of, higher wavelength except blue. If it is taken inside a dark room, it emits all the radiation of higher wavelength, hence it looks brighter red as compared to the red piece.

38. (b)

Radiation (Wein's law)

1. (a)

2. (c) According to Wein's law, $\lambda_m T =$ constant

$\lambda_r > \lambda_y > \lambda_b \Rightarrow T_r < T_y < T_b$ or $T_A < T_C < T_B$

3. (d) $\lambda_m T$=constant $\Rightarrow \frac{T_1}{T_2} = \frac{\lambda_2}{\lambda_1} \Rightarrow \frac{10^{-4}}{0.5\times 10^{-5}}$ =200.

4. (c) $\lambda_m T =$ constant

5. (a) According to Wein's law $\lambda_m T =$ constant, on heating up to ordinary temperatures, only long wavelength (red) radiation is emitted. As the temperature rises, shorter wavelengths are also emitted in more and more quantity. Hence the colour of radiation emitted by the hot wire shifts from red to yellow, then to blue and finally to white.

6. (c) According to Wein's displacement law.

7. (d) $\lambda_{m_1}T_1 = \lambda_{m_2}T_2 \Rightarrow \lambda_{m_2} = \frac{\lambda_{m_1}T_1}{T_2} = 4.08\times\frac{700}{1400} = 2.04\ m$

8. (c) $\lambda_{m_1}T_1 = \lambda_{m_2}T_2 \Rightarrow \lambda_{m_2} = \frac{\lambda_{m_1}T_1}{T_2} = \frac{14\times 200}{1000} = 2.8\ \mu m$

9. (c) $\frac{T_1}{T_2} = \frac{\lambda_{m_2}}{\lambda_{m_1}} = \frac{4800}{3600} \Rightarrow \frac{48}{36} = \frac{4}{3}$

10. (b) $\lambda_{m_2} = \frac{T_1}{T_2}\times\lambda_{m_1} = \frac{1500}{2500}\times 5000 = 3000 Å$

11. (a) At low temperature short wavelength radiation is emitted. As the temperature rise colour of emitted radiation are in the following order

Red→Yellow→Blue→White (at highest temperature)

12. (b) Similar to Q. 11

13. (b) The wavelength corresponding to maximum emission of radiation from the sun is $\lambda_{max} = 4753 Å$ (close to the wavelength of violet colour of visible region). Hence if temperature is doubled λ_m is decreased $\left(\lambda_m \propto \frac{1}{T}\right)$ *i.e.* mostly ultraviolet radiations emits.

14. (c) $\frac{T_1}{T_2} = \frac{\lambda_{m_2}}{\lambda_{m_1}} = \frac{5.5\times 10^5}{11\times 10^5} = \frac{1}{2} \Rightarrow n = \frac{1}{2}$.

15. (b) $\therefore T = \frac{b}{\lambda_m} = \frac{2.93\times 10^{-3}}{2.93\times 10^{-10}} = 10^7\ K$

16. (a) $\therefore \frac{\lambda_{m_2}}{\lambda_{m_1}} = \frac{T_1}{T_2} \Rightarrow \lambda_{m_2} = \frac{2000}{2400}\times 4 = 3.33\ \mu m$

17. (b)

18. (a)

19. (b) $\lambda_{m_2} = \frac{T_1}{T_2} \times \lambda_{m_1} = \frac{2000}{3000} \times \lambda_{m_1} = \frac{2}{3}\lambda_{m_1} = \frac{2}{3}\lambda_m$

20. (a)

21. (c) $\frac{T_2}{T_1} = \frac{\lambda_{m_1}}{\lambda_{m_2}} = \frac{1.75}{14.35} \Rightarrow T_2 = \frac{1.75}{14.35} \times 1640 = 200\ K$

22. (a) $\frac{\lambda_2}{\lambda_1} = \frac{T_1}{T_2} \Rightarrow \lambda_2 = \frac{T_1}{T_2} \times \lambda_1 = \frac{900}{1200} \times 4 = 3\mu m$

23. (b) $\lambda_{m_2} = \frac{\lambda_{m_1} T_1}{T_2} = \frac{4800 \times 6000}{3000} = 9600 \mathring{A}$

24. (b) $\frac{T_1}{T_2} = \frac{\lambda_{m_2}}{\lambda_{m_1}} = \frac{4200}{140} = \frac{30}{1}$

25. (c) $\because \lambda_m T = \lambda'_m T' \Rightarrow \lambda_0 T = \lambda' \times 2T \Rightarrow \lambda' = \frac{\lambda_0}{2}$

26. (b) $\lambda_m T = \lambda'_m T' \Rightarrow \frac{\lambda_m}{\lambda'_m} = \frac{T'}{T} = \frac{3000}{2000} = \frac{3}{2}$

27. (b) $\lambda_{m_1} T = \lambda_{m_2} T_2 \Rightarrow 5.5 \times 10^{-7} \times 5500 = 11 \times 10^{-7}\ T$

$T = 550 \times 5K = 2750K$

28. (b) According to Wein's displacement law

$\lambda_m T = b$ or $\lambda_m = \frac{b}{T} = \frac{0.0029}{5 \times 10^4} = 58 \times 10^{-9} m = 58 nm$

29. (a) $\lambda_m = \frac{b}{T} \Rightarrow T = \frac{b}{\lambda_m} = \frac{2.93 \times 10^{-3}}{4000 \times 10^{-10}} = 7325\ K$

30. (b) $\frac{T_S}{T_N} = \frac{(\lambda_N)_{\max}}{(\lambda_S)_{\max}} = \frac{350}{510} = 0.69$

Radiation (Stefan's law)

1. (c) $E \propto T^4$ (Stefan's law)

2. (c) Rate of heat loss $E = \sigma e A (T^4 - T_0^4)$

$= 5.67 \times 10^{-8} \times 0.4 \times 200 \times 10^{-4} \times [(273+527)^4 - (273+27)^4]$

$= 5.67 \times 10^{-8} \times 0.4 \times 200 \times 10^{-4} \times (800)^4 - (300)^4 = 182 J/sec$

3. (a) $\frac{E_1}{E_2} = \left(\frac{T_1}{T_2}\right)^4 \Rightarrow \frac{E}{E_2} = \left(\frac{273+0}{273+273}\right)^4 \Rightarrow E_2 = 16\ E.$

4. (a) $E \propto T^4 \Rightarrow \frac{E_1}{E_2} = \frac{T^4}{T^4} \times 2^4 \Rightarrow E_2 = \frac{E}{16}$

5. (d) $\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{2}{1} = \left(\frac{420+273}{T}\right)^4 = \left(\frac{673}{T}\right)^4$

$\Rightarrow T = 2^{1/4} \times 673 = 800K.$

6. (a) $\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4 = \left(\frac{273+727}{237+227}\right) = \frac{(1000)^4}{(500)^4} = 16 \Rightarrow E_2 = 80$

7. (c) $\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow$

$T_2 = \left(\frac{E_2}{E_1}\right)^{1/4} \times T_1 = (16)^{1/4} \times (273+127)$

$\Rightarrow T_2 = 800\ K = 527^o C$

8. (b) In M.K.S. system unit of σ is $\frac{J}{m^2 \times sec \times K^4}$

$\Rightarrow 1 \frac{J}{m^2 \times sec \times K^4} = \frac{10^7\ erg}{10^4\ cm^2 \times sec \times K^4}$

$= 10^3 \frac{erg}{cm^2 \times sec \times K^4}$

9. (b) For a block body rate of energy $\frac{Q}{t} = P = A\sigma T^4$

$\Rightarrow P \propto T^4 \Rightarrow \frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^4 = \left\{\frac{(273+7)}{(273+287)}\right\}^4 = \frac{1}{16}$

10. (b) $E_2 = E_1 \frac{T_2^4}{T_1^4} = Q \times \frac{(273+151)^4}{(273+27)^4} = \left(\frac{424}{300}\right)^4 = 3.99Q \approx 4Q$

11. (b) $\frac{E_1}{E_2} = \left(\frac{T_1}{T_2}\right)^4 = \left(\frac{727+273}{127+273}\right)^4 = \frac{(1000)^4}{(400)^4} = \frac{10^4}{4^4} = \frac{625}{16}$

12. (c) $E = \sigma T^4 \Rightarrow 5.6 \times 10^{-8} \times T^4 = 1$

$\Rightarrow T = \left[\frac{1}{5.6 \times 10^{-8}}\right]^{1/4} = 65\ K$

13. (c) According to Stefen's law $E = \sigma \varepsilon A T^4$

$\Rightarrow \frac{1.58 \times 10^5 \times 4.2}{60 \times 60} = 5.6 \times 10^{-8} \times 10^{-4} \times 0.8 \times T^4$

$T \approx 2500\ K$

14. (c) Total energy radiated from a body $Q = A\varepsilon\sigma T^4 t$

$\Rightarrow Q \propto AT^4 \propto r^2 T^4 \quad (\because A = 4\pi r^2)$

$\Rightarrow \frac{Q_P}{Q_Q} = \left(\frac{r_P}{r_Q}\right)^2 \left(\frac{T_P}{T_Q}\right)^4 = \left(\frac{8}{2}\right)^2 \left\{\frac{(273+127)}{(273+527)}\right\}^4 = 1$

15. (c) Rate of energy $\frac{Q}{t} = P = A\varepsilon\sigma T^4 \Rightarrow P \propto T^4$

$\Rightarrow \frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^4 = \left(\frac{927+273}{127+273}\right)^4 \Rightarrow P_1 = 405\ W$

16. (b) The rate of radiated energy $\frac{Q}{t} = P = A\varepsilon\sigma T^4$

$\Rightarrow 1134 = 5.67 \times 10^{-8} \times (0.1)^2\ T^4 \Rightarrow T = 1189\ K$

17. (d) $Q \propto T^4 \Rightarrow$

$\frac{H_A}{H_B} = \left(\frac{273+727}{273+327}\right)^4 = \left(\frac{10}{6}\right)^4 = \left(\frac{5}{3}\right)^4 = \frac{625}{81}$

18. (d) $(Q)_{Blackbody} = A\sigma T^4 t \Rightarrow Q \propto T^4$

$\Rightarrow Q_2 = Q_1 \left(\frac{T_2}{T_1}\right)^4 = 10\left(\frac{273+327}{273+27}\right)^4$

$= 10\left(\frac{600}{300}\right)^4 = 160\ J$

19. (c) $\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{E_2}{20} = \left(\frac{2T}{T}\right)^4 = 16 \Rightarrow E_2 = 320\ kcal/m^2\ min.$

20. (d) Radiated power by blackbody $P = \frac{Q}{t} = A\sigma T^4$

$\Rightarrow P \propto AT^4 \propto r^2 T^4 \Rightarrow \frac{P_1}{P_2} = \left(\frac{r_1}{r_2}\right)^2 \left(\frac{T_1}{T_2}\right)^4$

$\Rightarrow \frac{440}{P_2} = \left(\frac{12}{6}\right)^2 \left(\frac{500}{1000}\right)^4 \Rightarrow P_2 = 1760\ W \approx 1800\ W$

21. (d) Amount of energy radiated $\propto$ (Temperature)^4.

22. (d) $\frac{Q_1}{Q_2} = \left(\frac{T_1}{T_2}\right)^4 = \left(\frac{273+27}{273+927}\right)^4 = \left(\frac{1}{4}\right)^4 = \frac{1}{256}$

23. (a) $\frac{E_2}{E_1} = \frac{T_2^4}{T_1^4} = \left(\frac{237+227}{273+27}\right)^4 = \left(\frac{600}{300}\right)^4 = 16$

24. (d) $(Q)_{Blackbody} = A\sigma T^4 t \Rightarrow \frac{Q}{t} \propto P = A\sigma T^4$

Breadth are halved so area becomes one fourth.

$\Rightarrow \frac{P_1}{P_2} = \frac{A_1}{A_2} \times \left(\frac{T_1}{T_2}\right)^4 \Rightarrow \frac{A_1}{(A_1/4)} \times \left(\frac{273+327}{273+127}\right)$

$\Rightarrow P_2 = \frac{81}{64} E$

25. (d) Power radiated $P \propto T^4 \Rightarrow \frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^4$

$\Rightarrow \frac{Q}{P_2} = \left(\frac{T}{3T}\right)^4 \Rightarrow P_2 = 81Q$

26. (a) For black body, $P = A\varepsilon\sigma T^4$. For same power $A \propto \frac{1}{T^4}$

$\Rightarrow \left(\frac{r_1}{r_2}\right)^2 = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{r_1}{r_2} = \left(\frac{T_2}{T_1}\right)^2$

27. (a) $\frac{Q_2}{Q_1} = \left(\frac{T_2}{T_1}\right)^4 = \left(\frac{273+927}{273+327}\right)^4 = \left(\frac{1200}{600}\right)^4 = 16$

$\Rightarrow Q_2 = 32\ KJ$

28. (b) $\frac{Q_2}{Q_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{2}{1} = \left(\frac{T_2}{T_1}\right)^4$

$\Rightarrow T_2^4 = 2 \times T_1^4 = 2 \times (273+727)^4 \Rightarrow T_2 = 1190K$.

29. (a) $\frac{Q_1}{Q_2} = \frac{r_1^2 T_1^4}{r_2^2 T_2^4} = \frac{4^2}{1^2} \times \left(\frac{2000}{4000}\right)^4 = 1$

30. (a) According to Wein's law $\lambda_m T =$ constant

$\Rightarrow \lambda_{m_1} T_1 = \lambda_{m_2} T_2 \Rightarrow T_2 = \frac{\lambda_{m_1}}{\lambda_{m_2}} T_1 = \frac{\lambda_0}{3\lambda_0/4} \times T_1 = \frac{4}{3} T_1$

Now $P \propto T^4 \Rightarrow \frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow$

$\frac{P_2}{P_1} = \left(\frac{4/3\ T_1}{T_1}\right)^4 = \frac{256}{81}$

31. (d) $E \propto T^4$

32. (d) $Q \propto T^4 \Rightarrow \frac{Q_1}{Q_2} = \left(\frac{T_1}{T_2}\right)^4$

$\Rightarrow \frac{Q_1}{Q_2} = \left(\frac{T}{T+T/2}\right)^4 = \frac{16}{81} \Rightarrow Q_2 = \frac{81}{16} Q_1$

% increase in energy $= \frac{Q_2 - Q_1}{Q_1} \times 100 = 400\%$

33. (d) If temperature of surrounding is considered then

net loss of energy of a body by radiation $Q = A\varepsilon\sigma(T^4 - T_0^4)t \Rightarrow Q \propto (T^4 - T_0^4) \Rightarrow$

$\frac{Q_1}{Q_2} = \frac{T_1^4 - T_0^4}{T_2^4 - T_0^4}$

$= \frac{(273+200)^4 - (273+27)^4}{(273+400)^4 - (273+27)^4} = \frac{(473)^4 - (300)^4}{(673)^4 - (300)^4}$

34. (c) $Q = A\varepsilon\sigma T^4 \Rightarrow Q \propto A \propto r^2$ $(\because T = \text{constant})$

$\Rightarrow \frac{Q_1}{Q_2} = \frac{r_1^2}{r_2^2} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$

35. (a) $\frac{Q_2}{Q_1} = \frac{T_2^4}{T_1^4} = \left(\frac{273+527}{273+127}\right)^4 = \left(\frac{800}{400}\right)^4 \Rightarrow Q_2 = 16 \frac{cal}{cm^2 \times s}$

36. (c) For a black body $\frac{Q}{t} = P = A\sigma T^4$

$\Rightarrow \frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{P_2}{20} = \left(\frac{273+727}{273+227}\right)^4$

$\Rightarrow \frac{P_2}{20} = (2)^4 \Rightarrow P_2 = 320W$

37. (c) Energy radiated per sec $\frac{Q}{t} = P = A\varepsilon\sigma T^4$

$P \propto r^2 T^4 \Rightarrow \frac{P_2}{P_1} = \frac{r_2^2}{r_1^2} \cdot \frac{T_2^4}{T_1^4} = \frac{4^2}{1^2} \times \left(\frac{2000}{4000}\right)^4 = 1$

38. (c) $Q \propto AT^4 \propto r^2 T^4 \Rightarrow \frac{Q_{star}}{Q_{sun}} = \frac{r^2_{star} . T^4_{star}}{r^2_{sun} \times T^4_{sun}}$

$\Rightarrow \frac{10000}{1} = \frac{r_{star}^2}{r_{sun}^2} \times \left(\frac{6000}{2000}\right)^4 \Rightarrow \frac{r_{star}}{r_{sun}} = \frac{100 \times 9}{1} = \frac{900}{1}$

39. (a) $P = \left(\frac{Q}{t}\right) \propto T^4 \Rightarrow \frac{W}{P_2} = \left(\frac{T}{T/3}\right)^4 \Rightarrow P_2 = \frac{W}{81}$.

40. (c) Power $P \propto AT^4 \propto r^2 T^4$

$\Rightarrow \frac{P_2}{P_1} = \left(\frac{r_2}{r_1}\right)^2 \times \left(\frac{T_2}{T_1}\right)^4 = \left(\frac{4r}{r}\right)^2 \times \left(\frac{T/2}{T}\right)^4 = 1.$

41. (b) $\frac{Q_2}{Q_1}=\left(\frac{r_2^2}{r_1^2}\right)^2\times\left(\frac{T_2}{T_1}\right)^4=\left(\frac{100}{1}\right)^2\times\left(\frac{1}{2}\right)^4=625$

42. (d) $Q\propto r^2T^4 \Rightarrow \frac{Q_2}{Q_1}=\left(\frac{r_2}{r_1}\right)^2\times\left(\frac{T_2}{T_1}\right)^4=(2)^2\times(2)^4=64$

43. (c) Energy radiated from a body $Q=A\varepsilon\sigma T^4 t$

$\Rightarrow \frac{Q_2}{Q_1}=\left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{T_2}{T_1}=\left(\frac{Q_2}{Q_1}\right)^{1/4}=\left(\frac{4.32\times10^6}{2.7\times10^{-3}}\right)^{1/4}$

$=\left(\frac{16\times27}{27}\times10^8\right)^{1/4}=2\times10^2$

$\Rightarrow T_2=200\times T_1=80000\,K$

44. (d) $E\propto AT^4 \Rightarrow \frac{E_{\text{sphere}}}{E_{\text{Disc}}}=\frac{4\pi r^2}{2\pi r^2}\times\left(\frac{T}{T}\right)^4=\frac{2}{1}$

45. (a) $\frac{E_2}{E_1}=\left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{T_2}{T_1}=\left(\frac{E_2}{E_1}\right)^{1/4}=\left(\frac{10^9}{10^5}\right)^{1/4}=10$

$\Rightarrow T_2=10T_1=10\times(273+227)=5000\,K$

46. (b) Energy per second $P\left(=\frac{Q}{t}\right)\propto T^4$

$\frac{P_1}{P_2}=\left(\frac{T_1}{T_2}\right)^4=\left(\frac{273-73}{273+327}\right)^4=\left(\frac{200}{600}\right)^4=\frac{1}{81}$

47. (a) $Q\propto T^4 \Rightarrow \frac{Q_1}{Q_2}=\left(\frac{T_1}{T_2}\right)^4$

If $T_1=T$ then $T_2=T+\frac{10}{100}T=1.1T$

$\Rightarrow \frac{Q_1}{Q_2}=\left(\frac{T}{1.1T}\right)^4 \Rightarrow Q_2=1.46\,Q_1$

$\Rightarrow$ % increase in energy $=\frac{Q_2-Q_1}{Q_1}\times100=46\%$

48. (a) From Stefan's law $E=\sigma T^4$

$T^4=\frac{E}{\sigma}=\frac{6.3\times10^7}{5.7\times10^8}=1.105\times10^{15}=0.1105\times10^{16}$

$T=0.58\times10^4\,K=5.8\times10^3\,K$

49. (a) Rate of cooling $\propto(T^4-T_0^4)$

$\Rightarrow \frac{H}{H'}=\frac{(T_1^4-T_0^4)}{(T_2^4-T_0^4)}=\frac{400^4-200^4}{600^4-200^4}$

or $H'=\frac{(16+4)(16-4)H}{(36+4)(36-4)}=\frac{3}{16}H$

50. (a)

51. (a) Rate of cooling $\propto(T^4-T_0^4)\Rightarrow \frac{R_1}{R_2}=\frac{(T_1^4-T_0^4)}{(T_2^4-T_0^4)}$

$\Rightarrow \frac{R}{R_2}=\frac{(600)^4-(300)^4}{(900)^4-(300)^4}$ or $R_2=\frac{16}{3}R$

52. (d) Loss of heat $\Delta Q=A\varepsilon\sigma(T^4-T_0^4)t$

$\Rightarrow$ Rate of loss of heat $\frac{\Delta Q}{t}=A\varepsilon\sigma(T^4-T_0^4)$

$=10\times10^{-4}\times1\times5.67\times10^{-8}\{(273+127)^4-(273+27)^4\}$

$=0.99\,W$.

53. (b) According to Prevost theory every body radiate heat at all temperature (except 0*K*) and also absorbs heat from surroundings.

$\because\ T_A>T \Rightarrow$ Object *A* emits radiations more than the radiations it absorbs.

and $T_B<T \Rightarrow$ Object *B* absorbs more radiations than it emits.

After a certain time all bodies attains a common temperature.

54. (b) According to Prevost theory

55. (b) $Q\propto T^4 \Rightarrow \frac{Q_1}{Q_2}=\frac{T_1^4}{T_2^4}\Rightarrow T_2^4=\left(\frac{E_2}{E_1}\right)T_1^4$

$\Rightarrow T_2^4=\frac{1}{16}\times(1000)^4=\left(\frac{1000}{2}\right)^4 \Rightarrow T_2=500K$

56. (c) $Q\propto T^4$

Radiation (Newton's Law of Cooling)

1. (b) According to Newton's law of cooling

$\frac{\theta_1-\theta_2}{t}=K\left[\frac{\theta_1+\theta_2}{2}-\theta_0\right]$

In the first case, $\frac{(60-50)}{10}=K\left[\frac{60+50}{2}-\theta_0\right]$

$1=K(55-\theta)$ ....(i)

In the second case, $\frac{(50-42)}{10}=K\left[\frac{50+42}{2}-\theta_0\right]$

$0.8=K(46-\theta_0)$ ....(ii)

Dividing (i) by (ii), we get $\frac{1}{0.8}=\frac{55-\theta_0}{46-\theta_0}$

or $46-\theta_0=44-0.8\theta_0 \Rightarrow \theta_0=10^oC$

2. (c) According to Newton's law of cooling

Rate of cooling $\propto$ Mean temperature difference

$\Rightarrow \frac{\text{Fall in temperature}}{\text{Time}}\propto\left(\frac{\theta_1+\theta_2}{2}-\theta_0\right)$

$\because \left(\frac{\theta_1+\theta_2}{2}\right)_1>\left(\frac{\theta_1+\theta_2}{2}\right)_2>\left(\frac{\theta_1+\theta_2}{2}\right)_3$

$\Rightarrow T_1<T_2<T_3$

3. (a) Initially at $t=0$

Rate of cooling (R) $\propto$ Fall in temperature of body ($\theta - \theta_0$)

$\Rightarrow \frac{R_1}{R_2} = \frac{\theta_1 - \theta_0}{\theta_2 - \theta_0} = \frac{100-40}{80-40} = \frac{3}{2}$

4. (a) For small difference of temperature, it is the special case of Stefan's law.

5. (b) Liquid having more specific heat has slow rate of cooling because for equal masses rate of cooling $\frac{d\theta}{dt} \propto \frac{1}{c}$.

6. (c) $S_l = \frac{1}{m_l}\left[\frac{t_l}{t_W}(m_W C_W + W) - W\right]$

$= \frac{1}{300}\left[\frac{95}{3\times 60}(350\times 1 + 10) - 10\right]$ =0.6 *Cal/gm×°C*

7. (c) Newton's law of cooling is used for the determination of specific heat of liquids.

8. (c) By Newton's law of cooling.

9. (d) Rate of loss of heat $\left(\frac{\Delta Q}{t}\right) \propto$ temperature difference $\Delta\theta$

$\frac{\left(\frac{\Delta Q}{t}\right)_1}{\left(\frac{\Delta Q}{t}\right)_2} = \frac{\Delta\theta_2}{\Delta\theta_1} \Rightarrow \frac{60}{\left(\frac{\Delta Q}{t}\right)_2} = \frac{80-60}{40-20} \Rightarrow \left(\frac{\Delta Q}{t}\right)_2 = \frac{20\ cal}{sec}$

10. (b) During clear nights object on surface of earth radiate out heat and temperature falls. Hence option (a) is wrong.

The total energy radiated by a body per unit time per unit area $E \propto T^4$. Hence option (c) is wrong.

Energy radiated per second is given by $\frac{Q}{t} = PA\varepsilon\sigma T^4$

$\Rightarrow \frac{P_1}{P_2} = \frac{A_1}{A_2}\cdot\left(\frac{T_1}{T_2}\right)^4 = \left(\frac{r_1}{r_2}\right)^2\cdot\left(\frac{T_1}{T_2}\right)^4 = \left(\frac{1}{4}\right)^2\left(\frac{4000}{200}\right) = \frac{1}{1}$

$\because P_1 = P_2$, hence option (d) is wrong.

Newton's law is an approximate form of Stefan's law of radiation and works well for natural convection. Hence option (b) is correct.

11. (b) $\frac{\theta_1 - \theta_2}{t} = K\left(\frac{\theta_1 + \theta_2}{2} - \theta_0\right)$

$\therefore \frac{100-70}{4} = K\left(\frac{100+70}{2} - 15\right) = 60K \Rightarrow K = \frac{1}{8}$

Again $\frac{70-40}{t} = \frac{1}{8}\left(\frac{70+40}{2} - 15\right) = 5 \Rightarrow t = 6$ *min.*

12. (d) $\frac{80-60}{1} = K\left(\frac{80+60}{2} - 30\right) \Rightarrow K = \frac{1}{2}$

Again $\frac{60-50}{t} = \frac{1}{2}\left(\frac{60+50}{2} - 30\right) \Rightarrow$ $t = 0.8\times 60 = 48$ *sec*.

13. (c) According to Newton's law of cooling

Rate of cooling $\propto$ mean temperature difference.

Initially, mean temperature difference

$= \left(\frac{70+60}{2} - \theta_0\right) = (65 - \theta_0)$

Finally, mean temperature difference

$= \left(\frac{60+50}{2} - \theta_0\right) = (55 - \theta_0)$

In second case mean temperature difference decreases, so rate of fall of temperature decreases, so it takes more time to cool through the same range.

14. (c) $\frac{\theta_1 - \theta_2}{t} = K\left[\frac{\theta_1 + \theta_2}{2} - \theta_0\right]$

In the first 10 minute

$\frac{62-50}{10} = K\left[\frac{62+50}{2} - \theta_0\right] \Rightarrow 1.2 = K[56 - \theta_0]$ ....(i)

$\frac{50-42}{10} = K\left[\frac{50+42}{2} - \theta_0\right] \Rightarrow 0.8 = K[46 - \theta_0]$ ....(ii)

from equations (i) and (ii) $\frac{1.2}{0.8} = \frac{(56-\theta_0)}{(46-\theta_0)} \Rightarrow$ $\theta_0 = 26°C$

15. (d) $\frac{d\theta}{dt} = \frac{\sigma A}{mc}(T^4 - T_0^4)$. If the liquids put in exactly similar calorimeters and identical surrounding then we can consider T_0 and A constant then $\frac{d\theta}{dt} \propto \frac{(T^4 - T_0^4)}{mc}$

If we consider that equal masses of liquid (m) are taken at the same temperature then $\frac{d\theta}{dt} \propto \frac{1}{c}$

So for same rate of cooling c should be equal which is not possible because liquids are of different nature. Again from equation (i)

$\frac{d\theta}{dt} \propto \frac{(T^4 - T_0^4)}{mc} \Rightarrow \frac{d\theta}{dt} \propto \frac{(T^4 - T_0^4)}{V\rho\, c}$

Now if we consider that equal volume of liquid (V) are taken at the same temperature then $\frac{d\theta}{dt} \propto \frac{1}{\rho\, c}$.

So for same rate of cooling multiplication of $\rho\times c$ for two liquid of different nature can be possible. So option (d) may be correct.

16. (c) $\frac{60-50}{10} = K\left(\frac{60+50}{2} - 25\right)$ …..(i)

$\frac{50-\theta}{10}=K\left[\frac{50+\theta}{2}-25\right]$ …..(ii)

On dividing, we get $\frac{10}{50-\theta}=\frac{60}{\theta}\Rightarrow\theta=42.85^{o}C$

17. (a) $\frac{365-361}{2}=K\left[\frac{365+361}{2}-293\right]=70K\Rightarrow$ $K=\frac{1}{35}$

Again $\frac{344-342}{t}=\frac{1}{35}\left[\frac{344-342}{2}-293\right]=\frac{10}{7}$

$\Rightarrow t=\frac{14}{10}\min=\frac{14}{10}\times 60=84\,sec.$

18. (b) $\frac{50-49.9}{5}=K\left(\frac{50+49.9}{2}-30\right)$ …..(i)

$\frac{40-39.9}{t}=K\left[\frac{40+39.9}{2}-30\right]$ …..(ii)

from equations (i) and (ii) we get $t\approx 10\,sec.$

19. (c) Rate of loss of heat is directly proportional to the temperature difference between water and the surroundings.

20. (b) Rate of cooling $=\frac{-d\theta}{dt}\propto\left(\frac{\theta_1+\theta_2}{2}-\theta_0\right)$

In second case average temperature will be less hence rate of cooling will be less. Therefore time taken will be more than 4 minutes.

21. (a)

22. (b) First case, $\frac{61-59}{4}=K\left[\frac{61+59}{2}-30\right]$ …..(i)

Second case, $\frac{51-49}{t}=K\left[\frac{51+49}{2}-30\right]$ …..(ii)

By solving equation (i) and (ii) we get $t = 6$ *min*.

23. (d)

24. (c) In first case $\frac{60-40}{7}=K\left[\frac{60+40}{2}-10\right]$ ….(i)

In second case $\frac{40-28}{t}=K\left[\frac{40+28}{2}-10\right]$ ….(ii)

By solving $t=7\,minutes$

25. (b) In first case $\frac{50-40}{5}=K\left[\frac{50+40}{2}-\theta_0\right]$ ….(i)

In second case $\frac{40-33.33}{5}=K\left[\frac{40+33.33}{2}-\theta_0\right]$ ….(ii)

By solving $\theta_0=20^{o}C$.

26. (b) In first case $\frac{50-40}{10}=K\left[\frac{50+40}{2}-20\right]$ ….(i)

In second case $\frac{40-\theta_2}{10}=K\left[\frac{40+\theta_2}{2}-20\right]$ ….(ii)

By solving $\theta_2=33.3^{o}C$.

27. (d) In first case $\frac{61-59}{10}=K\left[\frac{61+59}{2}-30\right]$ ….(i)

In second case $\frac{51-49}{10}=K\left[\frac{51+49}{2}-30\right]$ ….(ii)

By solving $t=15\,min.$

28. (d) Rate of cooling (here it is rate of loss of heat)

$\frac{dQ}{dt}=(mc+W)\frac{d\theta}{dt}=(m_l c_l+m_c c_c)\frac{d\theta}{dt}$

$\Rightarrow\frac{dQ}{dt}=(0.5\times 2400+0.2\times 900)\left(\frac{60-55}{60}\right)=115\frac{J}{sec}.$

29. (a) According to Newton's law

Rate of cooling $\propto$ temperature difference $\Delta\theta$

30. (b) According to Newton's law

$\frac{\theta_1-\theta_2}{t}=k\left[\frac{\theta_1+\theta_2}{2}-\theta_0\right]$

Initially,

$\frac{(80-64)}{5}=K\left(\frac{80+64}{2}-\theta_0\right)\Rightarrow 3.2=K[72-\theta_0]$ … (i)

Finally

$\frac{(64-52)}{10}=K\left[\frac{64+52}{2}-\theta_0\right]\Rightarrow 1.2=K[58-\theta_0]$ … (ii)

On solving equation (i) and (ii) $\theta_0=49^{\circ}C$.

31. (d) $\frac{50-45}{5}=K\left(\frac{50+45}{2}-\theta_0\right)$ …..(i)

$\frac{45-41.5}{5}=K\left(\frac{45+41.5}{2}-\theta_0\right)$ …..(ii)

Solving equation (i) and (ii) we set $\theta_0=33.3\,^{\circ}C$.

32. (d) $\frac{65.5-62.5}{1}=K\left(\frac{65.5+62.5}{2}-22.5\right)\Rightarrow K=\frac{3}{41.5}$

And again $\frac{46.5-40.5}{t}=\frac{3}{41.5}\left(\frac{46.5+40.5}{2}-22.5\right)$

$\Rightarrow\frac{6}{t}=\frac{3}{41.5}\times 21\Rightarrow t=\frac{82}{21}\simeq 4$ minute.

33. (a) $\frac{62-50}{10}=K\left(\frac{62+50}{2}-26\right)\Rightarrow\frac{6}{5}=K\times 30\Rightarrow$ $K=\frac{1}{25}$

And, $\frac{50-\theta}{10}=\frac{1}{25}\left(\frac{50+\theta}{2}-26\right)\Rightarrow\theta=42^{\circ}C.$

34. (c) $\frac{90-60}{5} = K\left(\frac{90+60}{2} - 20\right) \Rightarrow \quad 6 = K \times 55 \quad \Rightarrow$

$K = \frac{6}{55}$

And, $\frac{60-30}{t} = \frac{6}{55}\left(\frac{60+30}{2} - 20\right) \Rightarrow t = 11$ minute.

35. (a) According to Newton's law of cooling

in first case, $\frac{75-65}{t} = K\left[\frac{75+65}{2} - 30\right]$ .....(i)

in second case, $\frac{55-45}{t} = K\left[\frac{55+45}{2} - 30\right]$ .....(ii)

Dividing eq. (i) by (ii) we get $\frac{5t}{10} = \frac{40}{20} \Rightarrow$ $t = 4$ minutes

36. (b) According to Newton's law of cooling

in first case, $\frac{80-50}{5} = K\left[\frac{80+50}{2} - 20\right]$ .....(i)

in second case, $\frac{60-30}{t} = K\left[\frac{60+30}{2} - 20\right]$ (ii)

Dividing equation (i) by (ii) we get, $\frac{t}{2} = \frac{45}{25} \Rightarrow t = 9$ min.

37. (b) According to Newton's law of cooling.

Critical Thinking Questions

1. (a) $\frac{dQ}{dt} = \frac{KA\Delta\theta}{l}$, For both rods K, A and $\Delta\theta$ are same $\Rightarrow \frac{dQ}{dt} \propto \frac{1}{l}$ So

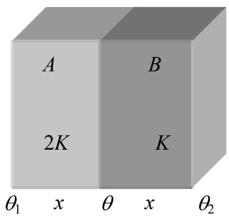
$\frac{(dQ/dt)_{semicircular}}{(dQ/dt)_{straight}} = \frac{l_{straight}}{l_{semicircular}} = \frac{2r}{\pi r} = \frac{2}{\pi}$.

2. (b) Suppose thickness of each wall is x then

$\left(\frac{Q}{t}\right)_{combination} = \left(\frac{Q}{t}\right)_A \Rightarrow \frac{K_S A(\theta_1 - \theta_2)}{2x} = \frac{2KA(\theta_1 - \theta)}{x}$

$\because K_S = \frac{2 \times 2K \times K}{(2K + K)} = \frac{4}{3}K$ and $(\theta_1 - \theta_2) = 36°$

$\Rightarrow \frac{\frac{4}{3}KA \times 36}{2x} = \frac{2KA(\theta_1 - \theta)}{x}$



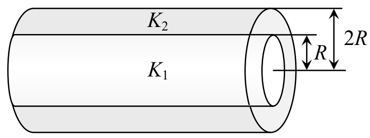
Hence temperature difference across wall A is

$(\theta_1 - \theta) = 12^o C$

3. (d) $t = \frac{\rho L}{2K\theta}(x_2^2 - x_1^2) \Rightarrow t \propto (x_2^2 - x_1^2)$

$\Rightarrow \frac{t}{t'} = \frac{(x_2^2 - x_1^2)}{(x_2'^2 - x_1'^2)} \Rightarrow \frac{9}{t'} = \frac{(1^2 - 0^2)}{(2^2 - 1^2)} \Rightarrow t = 21$ *hours*

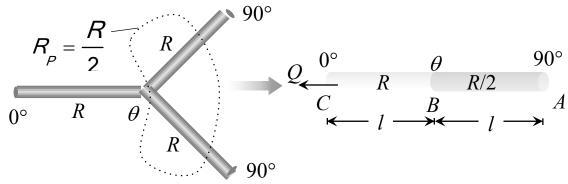
4. (c) Both the cylinders are in parallel, for the heat flow from one end as shown.



Hence $K_{eq} = \frac{K_1 A_1 + K_2 A_2}{A_1 + A_2}$; where A_1 = Area of cross-section of inner cylinder = πR^2 and A_2 = Area of cross-section of cylindrical shell $= \pi\{(2R)^2 - (R)^2\} = 3\pi R^2$

$\Rightarrow K_{eq} = \frac{K_1(\pi R^2) + K_2(3\pi R^2)}{\pi R^2 + 3\pi R^2} = \frac{K_1 + 3K_2}{4}$

5. (b) Let the temperature of junction be θ. Since roads B and C are parallel to each other (because both having the same temperature difference). Hence given figure can be redrawn as follows



$\because \frac{Q}{t} = \frac{(\theta_1 - \theta_2)}{R}$ and $\left(\frac{Q}{t}\right)_{AB} = \left(\frac{Q}{t}\right)_{BC}$

$\Rightarrow \frac{(90 - \theta)}{R/2} = \frac{(\theta - 0)}{R} \Rightarrow 180 - 2\theta = \theta \Rightarrow \theta = 60°C$

6. (a) Heat developed by the heater

$H = \frac{V^2}{R} \cdot \frac{t}{J} = \frac{(200)^2 \times t}{20 \times 4.2}$

Heat conducted by the glass $H = \frac{0.2 \times 1 \times (20 - \theta)t}{0.002}$

Hence $\frac{(200)^2 \times t}{20 \times 4.2} = \frac{0.2 \times (20 - \theta)t}{0.002} \Rightarrow \theta = 15.24^o C$

7. (a) Since $t = \frac{\rho L}{2k\theta}(x_2^2 - x_1^2)$

$\therefore t = \frac{\rho L}{2k\theta}(x^2 - y^2) = \frac{\rho L(x+y)(x-y)}{2K\theta}$

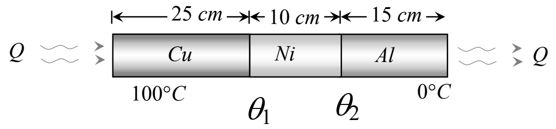
8. (b) If suppose $K_{Ni} = K \Rightarrow K_{Al} = 3K$ and $K_{Cu} = 6K$.

Since all metal bars are connected in series

So $\left(\frac{Q}{t}\right)_{Combination} = \left(\frac{Q}{t}\right)_{Cu} = \left(\frac{Q}{t}\right)_{Al} = \left(\frac{Q}{t}\right)_{Ni}$

and $\frac{3}{K_{eq}} = \frac{1}{K_{Cu}} + \frac{1}{K_{Al}} + \frac{1}{K_{Ni}} = \frac{1}{6K} + \frac{1}{3K} + \frac{1}{K} = \frac{9}{6K}$

$\Rightarrow K_{eq} = 2K$



Hence, if $\left(\frac{Q}{t}\right)_{Combination} = \left(\frac{Q}{t}\right)_{Cu}$

$\Rightarrow \frac{K_{eq}A(100-0)}{l_{Combination}} = \frac{K_{Cu}A(100-\theta_1)}{l_{Cu}}$

$\Rightarrow \frac{2KA(100-0)}{(25+10+15)} = \frac{6KA(100-\theta_1)}{25} \Rightarrow$

$\theta_1 = 83.33°C$

Similar if $\left(\frac{Q}{t}\right)_{Combination} = \left(\frac{Q}{t}\right)_{Al}$

$\Rightarrow \frac{2KA(100-0)}{50} = \frac{3KA(\theta_2 - 0)}{15} \Rightarrow \theta_2 = 20°C$

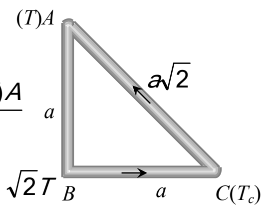
9. (b) $\because T_B > T_A \Rightarrow$ Heat will flow B to A via two paths (i) B to A (ii) and along BCA as shown.

Rate of flow of heat in path BCA will be same

i.e. $\left(\frac{Q}{t}\right)_{BC} = \left(\frac{Q}{t}\right)_{CA}$

$\Rightarrow \frac{k(\sqrt{2}T - T_C)A}{a} = \frac{k(T_C - T)A}{\sqrt{2}a}$

$\Rightarrow \frac{T_C}{T} = \frac{3}{1+\sqrt{2}}$



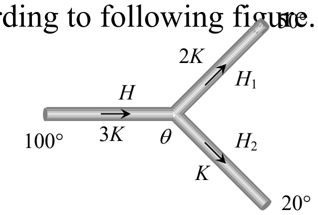
10. (a) $mL = \frac{KA\Delta\theta\ t}{\Delta x} \Rightarrow 500 \times 80 = \frac{0.0075 \times 75 \times (40-0)t}{5}$

$\Rightarrow t = 8.9 \times 10^3\ sec = 2.47\ hr.$

11. (a) Rate of cooling $\frac{\Delta\theta}{t} = \frac{A\varepsilon\sigma(T^4 - T_0^4)}{mc} \Rightarrow \frac{\Delta\theta}{t} \propto A$.

Since area of plate is largest so it will cool fastest.

12. (b) Let the temperature of junction be θ then according to following figure.

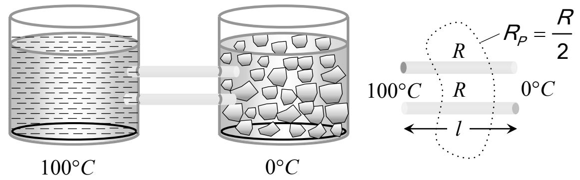


$H = H_1 + H_2$

$\Rightarrow \frac{3K \times A \times (100-\theta)}{l} = \frac{2KA(\theta - 50)}{l} + \frac{KA(\theta - 20)}{l}$

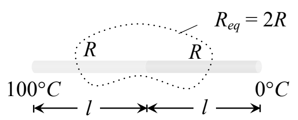
$\Rightarrow 300 - 3\theta = 3\theta - 120 \Rightarrow \theta = 70°C$

13. (c) Initially the rods are placed in vessels as shown below



$\frac{Q}{t} = \frac{(\theta_1 - \theta_2)}{R} \Rightarrow \left(\frac{Q}{t}\right)_1 = \frac{mL}{t} = q_1 L = \frac{(100-0)}{\frac{R}{2}}$ ... (i)

Finally when rods are joined end to end as shown



$\Rightarrow \left(\frac{Q}{t}\right)_2 = \frac{mL}{t} = q_2 L = \frac{(100-0)}{2R}$ ... (ii)

From equation (i) and (ii), $\frac{q_1}{q_2} = \frac{4}{1}$

14. (b) Rate of cooling of a body $R = \frac{\Delta\theta}{t} = \frac{A\varepsilon\sigma(T^4 - T_0^4)}{mc}$

$\Rightarrow R \propto \frac{A}{m} \propto \frac{\text{Area}}{\text{Volume}}$

$\Rightarrow$ For the same surface area. $R \propto \frac{1}{\text{Volume}}$

$\because$ Volume of cube < Volume of sphere

$\Rightarrow R_{Cube} > R_{Sphere}$ *i.e.* cube, cools down with faster rate.

15. (a,b) According to Stefan's law

$E = eA\sigma T^4 \Rightarrow E_1 = e_1 A\sigma T_1^4$ and $E_2 = e_2 A\sigma T_2^4$

$\because E_1 = E_2 \ \therefore e_1 T_1^4 = e_2 T_2^4$

$\Rightarrow T_2 = \left(\frac{e_1}{e_2} T_1^4\right)^{\frac{1}{4}} = \left(\frac{1}{81} \times (5802)^4\right)^{\frac{1}{4}} \Rightarrow T_B = 1934\ K$

And, from Wein's law $\lambda_A \times T_A = \lambda_B \times T_B$

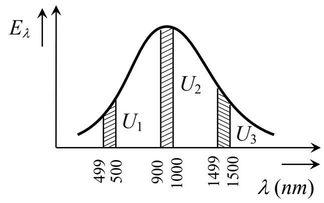
$\Rightarrow \frac{\lambda_A}{\lambda_B} = \frac{T_B}{T_A} \Rightarrow \frac{\lambda_B - \lambda_A}{\lambda_B} = \frac{T_A - T_B}{T_A}$

$\Rightarrow \frac{1}{\lambda_B} = \frac{5802 - 1934}{5802} = \frac{3968}{5802} \Rightarrow \lambda_B = 1.5\ \mu m$

16. (d) Wein's displacement law is $\lambda_m T = b$

$\Rightarrow \lambda_m = \frac{b}{T} = \frac{2.88\times10^6}{2880} = 1000\, nm.$

Energy distribution with wavelength will be as follows



From the graph it is clear that $U_2 > U_1$.

17. (b) Energy received per second *i.e.,* power $P \propto (T^4 - T_0^4)$

$\Rightarrow P \propto T^4$ $(\because T_0 << T)$

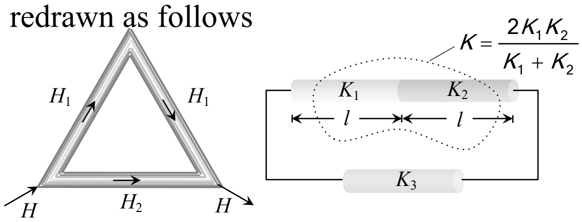
Also energy received per sec $(p) \propto \frac{1}{d^2}$

(inverse square law)

$\Rightarrow P \propto \frac{T^4}{d^2} \Rightarrow \frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^4 \times \left(\frac{d_2}{d_1}\right)^2$

$\Rightarrow \frac{P}{P_2} = \left(\frac{T}{2T}\right)^2 \times \left(\frac{2d}{d}\right)^2 = \frac{1}{4} \Rightarrow P_2 = 4P.$

18. (c) The given arrangement of rods can be redrawn as follows



It is given that $H_1 = H_2$

$\Rightarrow \frac{KA(\theta_1 - \theta_2)}{2l} = \frac{K_3 A(\theta_1 - \theta_2)}{l} \Rightarrow K_3 = \frac{K}{2} = \frac{K_1K_2}{K_1 + K_2}$

19. (b) Rate of cooling $(R) = \frac{\Delta\theta}{t} = \frac{A \in \sigma(T^4 - T_0^4)}{mc}$

$\Rightarrow R \propto \frac{A}{m} \propto \frac{\text{Area}}{\text{volume}} \propto \frac{r^2}{r^3} \propto \frac{1}{r}$

$\Rightarrow$ Rate $(R) \propto \frac{1}{r} \propto \frac{1}{m^{1/3}}$

$\left[\because m = \rho \times \frac{4}{3}\pi r^3 \Rightarrow r \propto m^{1/3}\right]$

$\Rightarrow \frac{R_1}{R_2} = \left(\frac{m_2}{m_1}\right)^{1/3} = \left(\frac{1}{3}\right)^{1/3}$

20. (b) Radiated power $P = A\varepsilon\sigma T^4 \Rightarrow P \propto AT^4$

From Wein's law, $\lambda_m T =$ constant $\Rightarrow T \propto \frac{1}{\lambda_m}$

$\therefore P \propto \frac{A}{(\lambda_m)^4} \propto \frac{r^2}{(\lambda_m)^4}$

$\Rightarrow Q_A : Q_B : Q_C = \frac{2^2}{(300)^4} : \frac{4^2}{(400)^4} : \frac{6^2}{(500)^4}$

$\therefore Q_B$ will be maximum.

21. (d) The total energy radiated from a black body per minute.

$Q \propto T^4 \Rightarrow \frac{Q_2}{Q_1} = \left(\frac{2T}{T}\right)^4 = 16 \Rightarrow Q_2 = 16Q_1$

If m be mass of water taken and S be its specific heat capacity, then $Q_1 = ms(20.5 - 20)$ and $Q_2 = ms(\theta - 20)$

$\theta° C =$ Final temperature of water

$\Rightarrow \frac{Q_2}{Q_1} = \frac{\theta - 20}{0.5} \Rightarrow \frac{16}{1} = \frac{\theta - 20}{0.5} \Rightarrow \theta = 28°C$

22. (a) Rate of cooling $\frac{\Delta\theta}{t} = \frac{A\varepsilon\sigma(T^4 - T_0^4)}{mc}$

As surface area, material and temperature difference are same, so rate of loss of heat is same in both the spheres. Now in this case rate of cooling depends on mass.

$\Rightarrow$ Rate of cooling $\frac{\Delta\theta}{t} \propto \frac{1}{m}$

$\because m_{solid} > m_{hollow}$. Hence hollow sphere will cool fast.

23. (c) Rate of cooling $\frac{\Delta\theta}{t} = \frac{A\varepsilon\sigma(T^4 - T_0^4)}{mc}$

$\Rightarrow t \propto \frac{m}{A}$

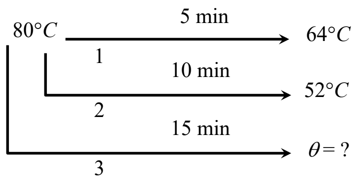
$[\because \Delta\theta, t, \sigma, (T^4 - T_0^4)$ are constant$]$

$\Rightarrow t \propto \frac{m}{A} \propto \frac{\text{Volume}}{\text{Area}} \propto \frac{a^3}{a^2} \Rightarrow t \propto a \Rightarrow \frac{t_1}{t_2} = \frac{a_1}{a_2}$

$\Rightarrow \frac{100}{t_2} = \frac{1}{2} \Rightarrow t_2 = 200\, sec$

24. (a) According to Newton law of cooling

$\frac{\theta_1 - \theta_2}{t} = K\left[\frac{\theta_1 + \theta_2}{2} - \theta_0\right]$



For first process : $\frac{(80 - 64)}{5} = K\left[\frac{80 + 64}{2} - \theta_0\right]$ ...(i)

For second process : $\frac{(80 - 52)}{10} = K\left[\frac{80 + 52}{2} - \theta_0\right]$ ...(ii)

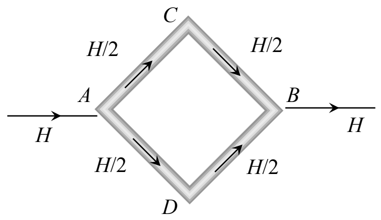
For third process : $\frac{(80-\theta)}{15} = K\left[\frac{80+\theta}{2} - \theta_0\right]$ …(iii)

On solving equation (i) and (ii) we get $K = \frac{1}{15}$ and $\theta_0 = 24°C$. Putting these values in equation (iii) we get $\theta = 42.7°C$

25. (c) $t = \frac{Ql}{KA(\theta_1-\theta_2)} = \frac{mLl}{KA(\theta_1-\theta_2)} = \frac{V\rho Ll}{KA(\theta_1-\theta_2)}$

$= \frac{5 \times A \times 0.92 \times 80 \times \frac{5+10}{2}}{0.004 \times A \times 10 \times 3600} = 19.1\ hours.$

26. (a) Suppose temperature difference between *A* and *B* is 100°*C* and $\theta_A > \theta_B$



Heat current will flow from *A* to *B* via path *ACB* and *ADB*. Since all the rod are identical so $(\Delta\theta)_{AC} = (\Delta\theta)_{AD}$

(Because heat current $H = \frac{\Delta\theta}{R}$; here *R* = same for all.)

$\Rightarrow \theta_A - \theta_C = \theta_A - \theta_D \Rightarrow \theta_C = \theta_D$

i.e. temperature difference between *C* and *D* will be zero.

27. (c) $\frac{Q}{t} = \frac{KA\Delta\theta}{l} \Rightarrow \frac{mL}{t} = \frac{K(\pi r^2)\Delta\theta}{l}$

$\Rightarrow$ Rate of melting of ice $\left(\frac{m}{t}\right) \propto \frac{Kr^2}{l}$

Since for second rod *K* becomes $\frac{1}{4}th$ *r* becomes double and length becomes half, so rate of melting will be twice *i.e.* $\left(\frac{m}{t}\right)_2 = 2\left(\frac{m}{t}\right)_1 = 2 \times 0.1 = 0.2\ gm/sec$

28. (c) Heat transferred in one minute is utilised in melting the ice so, $\frac{KA(\theta_1-\theta_2)t}{l} = m \times L$

$\Rightarrow m = \frac{10^{-3} \times 92 \times (100-0) \times 60}{1 \times 8 \times 10^4} = 6.9 \times 10^{-3}\ kg$

29. (d) $\frac{dQ}{dt} = \frac{KA}{l}d\theta = \frac{0.01 \times 1}{0.05} \times 30 = 6 J/sec$

Heat transferred in on day (86400 *sec*)

$\theta = 6 \times 86400 = 518400\ J$

Now $Q = mL \Rightarrow m = \frac{Q}{L} = \frac{518400}{334 \times 10^3}$

$= 1.552\ kg = 1552 g.$

30. (b) For no current flow between *C* and *D*

$\left(\frac{Q}{t}\right)_{AC} = \left(\frac{Q}{t}\right)_{CB} \Rightarrow \frac{K_1A(\theta_A-\theta_C)}{l} = \frac{K_2A(\theta_C-\theta_B)}{l}$

$\Rightarrow \frac{\theta_A-\theta_C}{\theta_C-\theta_B} = \frac{K_2}{K_1}$ ...(i)

Also $\left(\frac{Q}{t}\right)_{AD} = \left(\frac{Q}{t}\right)_{DB} \Rightarrow$

$\frac{K_3A(\theta_A-\theta_D)}{l} = \frac{K_4A(\theta_D-\theta_B)}{l}$

$\Rightarrow \frac{\theta_A-\theta_D}{\theta_D-\theta_B} = \frac{K_4}{K_3}$ ...(ii)

It is given that $\theta_C = \theta_D$, hence from equation (i) and (ii) we get $\frac{K_2}{K_1} = \frac{K_4}{K_3} \Rightarrow K_1K_4 = K_2K_3$

31. (d) Rate of cooling $R_C = \frac{d\theta}{dt} = \frac{A\varepsilon\sigma(T^4 - T_0^4)}{mc}$

$\Rightarrow \frac{d\theta}{dt} \propto \frac{A}{V} \propto \frac{r^2}{r^3} \Rightarrow \frac{d\theta}{dt} \propto \frac{1}{r}$

32. (b) $\frac{dT}{dt} = \frac{\sigma A}{mcJ}(T^4 - T_0^4)$ [In the given problem fall in temperature of body $dT = (200-100) = 100K$, temp. of surrounding T_0 = 0*K*, Initial temperature of body $T = 200K$].

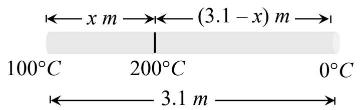
$\frac{100}{dt} = \frac{\sigma 4\pi r^2}{\frac{4}{3}\pi r^3 \rho c J}(200^4 - 0^4)$

$\Rightarrow dt = \frac{r\rho cJ}{48\sigma} \times 10^{-6} s = \frac{r\rho c}{\sigma} \cdot \frac{4.2}{48} \times 10^{-6}$

$= \frac{7}{80}\frac{r\rho c}{\sigma}\mu s \simeq \frac{7}{72}\frac{r\rho c}{\sigma}\mu s$ [As *J* = 4.2]

33. (a) Rate of flow of heat is given by $\frac{dQ}{dt} = \frac{\Delta\theta}{l/KA}$ also $\frac{dQ}{dt} = L\frac{dm}{dt}$ (where *L* = Latent heat)

$\Rightarrow \frac{dm}{dt} = \frac{KA}{l}\left(\frac{\Delta\theta}{L}\right)$. Let the desire point is at a distance *x* from water at 100°*C*.



$\because$ Rate of ice melting = Rate at which steam is being produced

$\Rightarrow \left(\frac{dm}{dt}\right)_{Steam} = \left(\frac{dm}{dt}\right)_{Ice} \Rightarrow \left(\frac{\Delta\theta}{Ll}\right)_{Steam} = \left(\frac{\Delta\theta}{Ll}\right)_{Ice}$

$\Rightarrow \frac{(200-100)}{540\times x} = \frac{(200-0)}{80(3.1-x)} \Rightarrow x = 0.4\ m = 40\ cm$

34. (c) $Q = \sigma A\, t\,(T^4 - T_0^4)$

If T, T_0, σ and t are same for both bodies then $\frac{Q_{sphere}}{Q_{cube}} = \frac{A_{sphere}}{A_{cube}} = \frac{4\pi r^2}{6a^2}$ .....(i)

But according to problem, volume of sphere = Volume of cube $\Rightarrow \frac{4}{3}\pi r^3 = a^3 \Rightarrow a = \left(\frac{4}{3}\pi\right)^{1/3} r$

Substituting the value of a in equation (i) we get

$$\frac{Q_{sphere}}{Q_{cube}} = \frac{4\pi r^2}{6a^2} = \frac{4\pi r^2}{6\left\{\left(\frac{4}{3}\pi\right)^{1/3} r\right\}^2}$$

$$= \frac{4\pi r^2}{6\left(\frac{4}{3}\pi\right)^{2/3} r^2} = \left(\frac{\pi}{6}\right)^{1/3} : 1$$

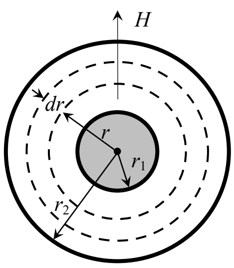
35. (d) Equation of thermal conductivity of the given combination $K_{eq} = \frac{l_1 + l_2}{\frac{l_1}{K_1} + \frac{l_2}{K_2}} = \frac{x + 4x}{\frac{x}{K} + \frac{4x}{2K}} = \frac{5}{3}K$.

Hence rate of flow of heat through the given combination is

$$\frac{Q}{t} = \frac{K_{eq}\cdot A(T_2 - T_1)}{(x + 4x)} = \frac{\frac{5}{3}K\,A(T_2 - T_1)}{5x} = \frac{\frac{1}{3}K\,A(T_2 - T_1)}{x}$$

On comparing it with given equation we get $f = \frac{1}{3}$

36. (a) Consider a concentric spherical shell of radius r and thickness dr as shown in fig.



The radial rate of flow of heat through this shell in steady state will be

$$H = \frac{dQ}{dt} = -KA\frac{dT}{dr} = -K(4\pi r^2)\frac{dT}{dr}$$

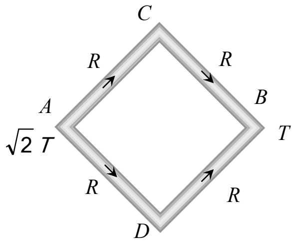
$$\Rightarrow \int_{r_1}^{r_2} \frac{dr}{r^2} = -\frac{4\pi K}{H}\int_{T_1}^{T_1} dT$$

Which on integration and simplification gives

$$H = \frac{dQ}{dt} = \frac{4\pi K r_1 r_2 (T_1 - T_2)}{r_2 - r_1} \Rightarrow \frac{dQ}{dt} \propto \frac{r_1 r_2}{(r_2 - r_1)}$$

37. (c) Similar to Q.No.26

Temperature difference between C and D is zero.



Graphical Questions

1. (c) Rate of cooling $\left(-\frac{dT}{dt}\right) \propto$ emissivity (e)

From graph, $\left(-\frac{dT}{dt}\right)_x > \left(-\frac{dT}{dt}\right)_y \Rightarrow e_x > e_y$

Further emissivity (e) $\propto$ Absorptive power (a) $\Rightarrow a_x > a_y$

($\because$ good absorbers are good emitters).

2. (b) According to Wien's law $\lambda_m \propto \frac{1}{T}$ and from the figure $(\lambda_m)_1 < (\lambda_m)_3 < (\lambda_m)_2$ therefore $T_1 > T_3 > T_2$.

3. (d) $\frac{A_T}{A_{2000}} = \frac{16}{1}$ (given)

Area under $e_\lambda - \lambda$ curve represents the emissive power of body and emissive power $\propto T^4$

(Hence area under $e_\lambda - \lambda$ curve) $\propto T^4$

$\Rightarrow \frac{AT}{A_{2000}} = \left(\frac{T}{2000}\right)^4 \Rightarrow \frac{16}{1} = \left(\frac{T}{2000}\right)^4 \Rightarrow T = 4000K.$

4. (c) According to Wein's law $\lambda_m \propto \frac{1}{T} \Rightarrow \nu_m \propto T$.

As the temperature of body increases, frequency corresponding to maximum energy in radiation (ν_m) increases this is shown in graph (c).

5. (c) According to Wein's displacement law.

6. (b) For θ-t plot, rate of cooling $=\frac{d\theta}{dt}=$ slope of the curve.

At $P, \frac{d\theta}{dt}=\tan\phi_2=k(\theta_2-\theta_0)$, where k = constant.

At $Q \frac{d\theta}{dt}=\tan\phi_1=k(\theta_1-\theta_0) \Rightarrow \frac{\tan\phi_2}{\tan\phi_1}=\frac{\theta_2-\theta_0}{\theta_1-\theta_0}$

7. (a) According to Wein's displacement law

$\lambda_m \propto \frac{1}{T} \Rightarrow \lambda_{m_2} < \lambda_{m_1} \quad (\because \; T_1 < T_2)$

There fore I–λ graph for T_2 have lesser wavelength (λ_m) and so curve for T_2 will shift towards left side.

8. (d) Area under given curve represents emissive power and emissive power $\propto T^4 \Rightarrow A \propto T^4$

$$\Rightarrow \frac{A_2}{A_1}=\frac{T_2^4}{T_1^4}=\frac{(273+327)^4}{(273+27)^4}=\left(\frac{600}{300}\right)^4=\frac{16}{1}$$