Thermal Properties of Matter

OBJECTIVE TYPE QUESTIONS

Multiple Choice Questions (MCQs)

1. Two spheres of the same material have radii 1 m and 4 m and temperatures 4000 K and 2000 K respectively. The energy radiated per second by the first sphere is
(a) greater than that by the second
(b) less than that by the second
(c) equal in both cases
(d) the information is incomplete to draw any conclusion

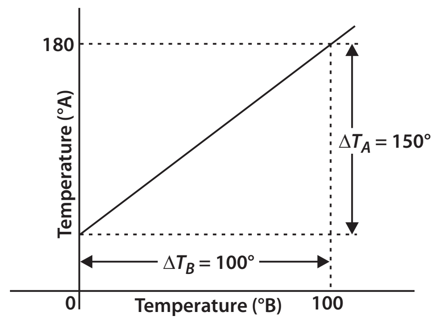
2. A bimetallic strip is made of aluminium and steel ($\alpha_{Al} > \alpha_{steel}$). On heating, the strip will
(a) remain straight
(b) get twisted
(c) will bend with aluminium on concave side
(d) will bend with steel on concave side.

3. On a temperature scale Y, water freezes at – 160°Y and boils at – 50°Y. On this Y scale, a temperature of 340 K would be read as : (colder freezes at 273 K and boils at 373 K)
(a) – 106.3°Y (b) – 96.3°Y
(c) – 86.3°Y (d) – 76.3°Y

4. Driver of truck gets his steel petrol tank filled with 75 L of petrol at 10°°C. If α_{steel} is 24×10^{-6}/°°C and γ_{petrol} is 9.9×10^{-4}/°°C, the overflow of petrol at 30°C is
(a) 1.35 L (b) 1.38 L
(c) 1.45 L (d) 1.48 L

5. A uniform metallic rod rotates about its perpendicular bisector with constant angular speed. If it is heated uniformly to raise its temperature slightly
(a) its speed of rotation increases
(b) its speed of rotation decreases
(c) its speed of rotation remains same
(d) its speed increases because its moment of inertia increases

6. The graph between two temperature scales A and B is shown in figure. Between upper fixed point and lower fixed point there are 150 equal division on scale A and 100 on scale B. The relationship for conversion between the two scales is given by

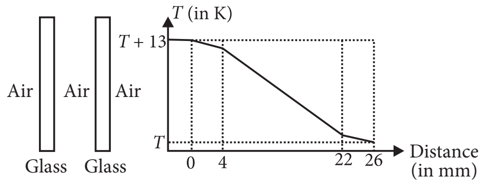


(a) $\frac{T_A - 180}{100} = \frac{T_B}{150}$ (b) $\frac{T_A - 30}{150} = \frac{T_B}{100}$
(c) $\frac{T_B - 180}{150} = \frac{T_A}{100}$ (d) $\frac{T_B - 40}{100} = \frac{T_A}{180}$

7. A one litre flask contains certain quantity of mercury. If the volume of air inside the flask remains the same at all temperatures then the volume of mercury in the flask is (volume expansion coefficient of mercury is 20 times that of flask)
(a) 100 cc (b) 50 cc (c) 200 cc (d) 150 cc

8. An ideal gas is expanding such that PT^2 = constant. The coefficient of volume expansion of the gas is
(a) $\frac{1}{T}$ (b) $\frac{2}{T}$ (c) $\frac{3}{T}$ (d) $\frac{4}{T}$

9. The figure shows a cross-section of a double glass unit of a window on a vertical wall. A graph of the temperatures at different points within the unit is given below. The temperature difference across the unit is 13 K. It has a cross-sectional area of 1.3 m^2 and the rate of heat flow through it is 65 W. Then the correct statement is (Glass has a thermal conductivity of 1 W m^{-1} K^{-1})



(a) The unit is in steady state and in thermal equilibrium.
(b) The unit is in steady state but not in thermal equilibrium.
(c) The unit is not in steady state but is in thermal equilibrium.
(d) The unit neither in steady state nor in thermal equilibrium.

10. Two rods of different materials having coefficients of linear expansion α_1 and α_2 and Young's modulus Y_1 and Y_2 respectively are fixed between two rigid massive walls. The rods are heated such that they undergo the same increase in temperature. There is no bending of rods. If $\alpha_1 : \alpha_2 = 2 : 3$, the thermal stress developed in the two rods are equal provided $Y_1 : Y_2$ equal to

(a) 2 : 3 (b) 4 : 9
(c) 1 : 2 (d) 3 : 2

11. Two rods, one of aluminium and the other made of steel, having initial lengths l_1 and l_2 are connected together to form a single rod of length $(l_1 + l_2)$. The coefficient of linear expansion of aluminium and steel are α_a and α_s respectively. If the length of each rod increases by the same amount, when their temperatures are raised by T°C, then the ratio $\frac{l_1}{l_1 + l_2}$ is

(a) $\frac{\alpha_s}{\alpha_a}$ (b) $\frac{\alpha_a}{\alpha_s}$
(c) $\frac{\alpha_s}{\alpha_a + \alpha_s}$ (d) $\frac{\alpha_a}{\alpha_a + \alpha_s}$

12. The triple point of carbon dioxide is 216.55 K the corresponding temperature on the celsius and Fahrenheit scale is

(a) 56.45°C, –69.61°F (b) –56.45°C, 69.61°F
(c) 56.45°C, 69.61°F (d) –56.45°C, –69.61°F

13. To increase the length of brass rod by 2% its temperature should increase by ($\alpha = 0.00002$ °C^{-1})

(a) 800 °C (b) 900 °C
(c) 1000 °C (d) 1100 °C

14. The quantities of heat required to raise the temperatures of two copper spheres of radii r_1 and r_2 ($r_1 = 1.5r_2$) through 1 K are in the ratio of

(a) $\frac{27}{8}$ (b) $\frac{9}{4}$ (c) $\frac{3}{2}$ (d) 1

15. Find the stress developed inside a tooth cavity filled with copper when hot tea at temperature of 57°C is drunk. (Take temperature of tooth to be 37°C, $\alpha = 1.7 \times 10^{-5}$ °C^{-1} and bulk modulus for copper = 140×10^9 N m^{-2})

(a) 1.43×10^8 N m^{-2} (b) 4.13×10^8 N m^{-2}
(c) 2.12×10^4 N m^{-2} (d) 3.12×10^4 N m^{-2}

16. A 10 kW drilling machine is used to drill a bore in a small aluminium block of mass 8 kg. Find the rise in temperature of the block is 2.5 minutes, assuming 50% power is used up is heating the machine itself or lost to the surrounding.
(Specific heat of aluminium = 0.91 J g^{-1} × °C^{-1})

(a) 100 °C (b) 103 °C (c) 150 °C (d) 155 °C

17. The densities of two substances are in the ratio 2 : 3 and their specific heats are 0.12 and 0.09 CGS units respectively. The ratio of their thermal capacities per unit volume is

(a) 8 : 9 (b) 1 : 2 (c) 3 : 2 (d) 4 : 9

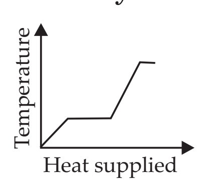
18. 22320 cal of heat is supplied to 100 g of ice at 0° C. If the latent heat of fusion of ice is 80 cal g^{-1} and latent heat of vaporization of water is 540 cal g^{-1}, the final amount of water thus obtained and its temperature respectively are

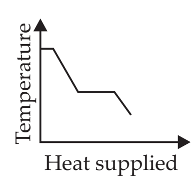
(a) 8 g, 100°C (b) 100 g, 90°C
(c) 92 g, 100°C (d) 8 g, 100°C

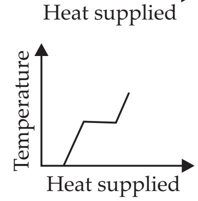
19. Two absolute scale A and B have triple points of water defined to be at 200 A and 350 B. The relation between T_A and T_B is

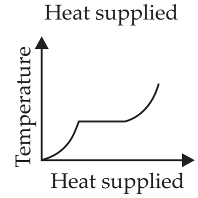
(a) $T_A = 4/7\ T_B$ (b) $T_B = 4/7\ T_A$
(c) $T_A = 2/7\ T_B$ (d) $T_B = 2/7\ T_A$

20. A block of ice at –10°C is slowly heated and converted to steam at 100°C. Which of the following curves represents the phenomena qualitatively?

(a) 

(b) 

(c) 

(d) 

21. 0.1 m^3 of water at 80°C is mixed with 0.3 m^3 of water at 60°C. The final temperature of the mixture is

(a) 65°C (b) 70°C (c) 60°C (d) 75°C

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

(a) 4g (b) 6g (c) 8g (d) 10g

23. An aluminium sphere is dipped into water. Which of the following is true?

(a) Buoyancy will be less in water at 0 °C than that in water at 4 °C.

(b) Buoyancy will be more in water at 0 °C than that in water at 4 °C.

(c) Buoyancy in water at 0 °C will be same as that in water at 4 °C.

(d) Buoyancy may be more or less in water at 4 °C depending on the radius of the sphere.

24. As the temperature is increased, the time period of a pendulum

(a) increases as its effective length increases even though its centre of mass still remains at the centre of the bob.

(b) decreases as its effective length increases even though its centre of mass still remains at the centre of the bob.

(c) increases as its effective length increases due to shifting of centre of mass below the centre of the bob.

(d) decreases as its effective length remains same but the centre of mass shifts above the centre of the bob.

25. Two metal rods 1 and 2 of same lengths have same temperature difference between their ends. Their thermal conductivities are K_1 and K_2 and cross sectional areas A_1 and A_2, respectively. If the rate of heat conduction in 1 is four times that in 2, then

(a) $K_1A_1 = 4K_2A_2$ (b) $K_1A_1 = 2K_2A_2$

(c) $4K_1A_1 = K_2A_2$ (d) $K_1A_1 = K_2A_2$

26. A body A of mass 0.5 kg and specific heat 0.85 J g^{-1} K^{-1} is at a temperature of 60°C. Another body B of mass 0.3 kg and specific heat 0.9 J g^{-1} K^{-1} is at a temperature of 90°C. When they are connected through a conducting rod, heat will flow from

(a) A to B

(b) B to A

(c) heat can't flow

(d) first from A to B, then B to A

27. The coefficient of expansion of a crystal in one direction (x-axis) is 2.0×10^{-6} K^{-1} and that in the other two perpendicular (y-and z-axes) direction is 1.6×10^{-6} K^{-1}. What is the coefficient of cubical expansion of the crystal?

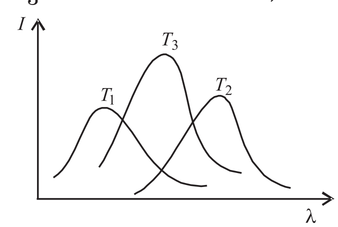
(a) 1.6×10^{-6} K^{-1} (b) 1.8×10^{-6} K^{-1}

(c) 2.0×10^{-6} K^{-1} (d) 5.2×10^{-6} K^{-1}

28. A faulty thermometer reads freezing point and boiling point of water as –5 °C and 95 °C respectively. What is the correct value of temperature as it reads 60 °C on faulty thermometer?

(a) 60 °C (b) 65 °C (c) 64 °C (d) 62 °C

29. The plots of intensity of radiation versus wavelength of three black bodies at temperatures T_1, T_2 and T_3 are shown. Then,



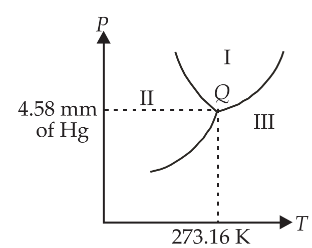
(a) $T_3 > T_2 > T_1$ (b) $T_1 > T_2 > T_3$

(c) $T_2 > T_3 > T_1$ (d) $T_1 > T_3 > T_2$

30. If the temperature of hot black body is raised by 5%, rate of heat energy radiated would be increased by how much percentage?

(a) 12% (b) 22% (c) 32% (d) 42%

31. In the phase diagram shown, the point Q corresponds to the triple point of water. The regions I, II and III respectively correspond to phases



(a) liquid, solid, vapour

(b) solid, liquid, vapour

(c) liquid, vapour, solid

(d) solid, vapour, liquid

32. Which of the following statement does not hold good for thermal radiation?

(a) The wavelength changes when it travels from one medium to another.

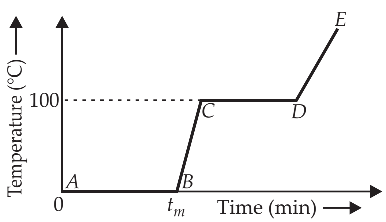
(b) The frequency changes when it travels from one medium to another.

(c) The speed changes when it travels from one medium to another.

(d) They travel in straight line in a given medium.

33. Refer to the plot of temperature versus time showing the changes in the state of ice on heating (not to scale).

Which of the following is correct?



(a) AB represents ice and water are not in the thermal equilibrium.

(b) At B water starts boiling.

(c) At C all the water gets converted into steam.

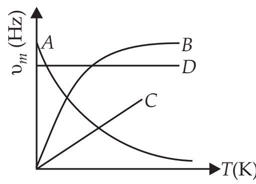
(d) CD represents water and steam in equilibrium at boiling point.

34. Three stars A, B, C have surface temperatures T_A, T_B and T_C. A appears bluish, B appears reddish and C appears yellowish. We can conclude that

(a) $T_A > T_C > T_B$ (b) $T_A > T_B > T_C$

(c) $T_B > T_C > T_A$ (d) $T_C > T_B > T_A$

35. Which one of the following is $\upsilon_m - T$ graph for perfectly black body? υ_m is the frequency of radiation with maximum intensity and T is the absolute temperature.



(a) A (b) B (c) C (d) D

Case Based MCQs

Case I : Read the passage given below and answer the following questions from 36 to 40.

Specific Heat Capacity

Heat capacity of a substance is defined as $H = \frac{\Delta Q}{\Delta T} = ms$, where ΔQ is amount of head supplied to the substance to change its temperature from T to $T + \Delta T$.

Specific heat capacity is the amount of heat per unit mass absorbed or given off to change its temperature by one unit. $S = \frac{1}{m}\frac{\Delta Q}{\Delta T} = \frac{H}{m}$

It depends on the nature of substance and its temperature.

36. Which one of the following substances has highest specific heat capacity at room temperature and atmospheric pressure?

(a) Water

(b) Ice

(c) Aluminium

(d) Mercury

37. Heat capacity of a substance is infinite. It means

(a) heat is given out.

(b) heat is taken in.

(c) no change in temperature whether heat is taken in or given out.

(d) all of these.

38. Water is used as a coolant because

(a) it has lower density.

(b) it has low specific heat.

(c) it has high specific heat.

(d) it is easily available.

39. Calorie is defined as the amount of heat required to raise the temperature of 1 g of water by 1°C and it is defined under which of the following conditions?

(a) From 14.5°C to 15.5°C at 760 mm of Hg

(b) From 98.5°C to 99.5°C at 760 mm of Hg

(c) From 13.5°C to 14.5°C at 76 mm of Hg

(d) From 3.5°C to 4.5°C at 76 mm of Hg

40. Find the thermal capacity of 40 g of aluminum. (s = 0.2 cal/g K)

(a) 168 J/°C (b) 672 J/°C

(c) 840 J/°C (d) 33.6 J/°C

Case : II Read the passage given below and answer the following questions from 41 to 45.

Thermal Expansion

The increase in the dimensions of a body due to the increase in its temperature is called thermal expansion. Thermal expansion is present in solids, liquids and gases. In the case of solids, the increase will be in length, area and volume. In liquids and gases, only expansion in volume is possible as they do not possess any fixed shape. In the case of gases, the state of a gas at any instant is dependent on its volume, pressure and temperature. Hence a gas can be heated at constant volume or at constant pressure. The property of thermal expansion of substance is different for different substances and it also depends on the state of the substance viz, solid, liquid or gas.

Relation between α, β and γ

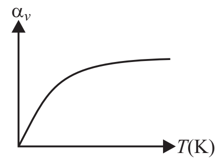
The three coefficients of thermal expansion are related as $\alpha = \frac{\beta}{2} = \frac{\gamma}{3}$.

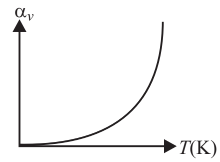
41. There is a hole in the middle of a copper plate. When heating the plate, diameter of hole would

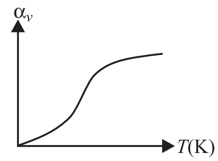
(a) always increase (b) always decrease

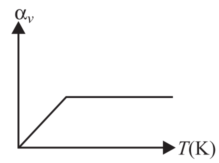
(c) remains the same (d) none of these

42. Which of the following graphs correctly shows variation of coefficient of volume expansion of copper as a function of temperature?

(a)


(b)


(c)


(d)


43. Two spheres *A* and *B* are made of the same material and have the same radius. Sphere *A* is hollow and sphere *B* is solid. Both the spheres are heated to the same temperature. Which of the following is correct?

(a) *A* expands more than *B*.

(b) *A* expands less than *B*.

(c) Both the spheres expand equally.

(d) Data is insufficient.

44. The coefficient of volume expansion of liquid is γ. The fractional change in its density for ΔT rise in temperature is

(a) $\gamma \Delta T$ (b) $\frac{\Delta T}{\gamma}$

(c) $1 + \gamma \Delta T$ (d) $1 - \gamma \Delta T$

45. If α, β and γ are coefficients of linear, superficial and volume expansion respectively, then

(a) $\frac{\beta}{\alpha} = \frac{1}{2}$ (b) $\frac{\beta}{\gamma} = \frac{2}{3}$

(c) $\frac{\gamma}{\alpha} = \frac{3}{2}$ (d) $\frac{\beta}{\alpha} = \frac{\gamma}{\beta}$

Assertion & Reasoning Based MCQs

For question numbers 46-55, two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of A

(b) Both A and R are true but R is NOT the correct explanation of A

(c) A is true but R is false

(d) A is false and R is also false

46. Assertion (A) : The density of water is maximum at 4° C.

Reason (R) : The volume of water decreases while heating from 0°C to 4°C.

47. Assertion (A) : The coefficient of volume expansion has dimension K^{-1}.

Reason (R) : The coefficient of volume expansion is defined the change in volume per unit volume per unit change in temperature.

48. Assertion (A) : When a solid iron ball is heated, percentage increase is its volume is largest.
Reason (R) : Coefficient of superficial expansion is twice that of linear expansion where as coefficient of volume expansion is three time of linear expansion.

49. Assertion (A) : A beaker is completely filled with water at 4°C. It will overflow, both when heated or cooled.
Reason (R) : There is expansion of water below and above 4°C.

50. Assertion (A) : Thermal conductivity depends on nature of material of the wall.
Reason (R) : When temperature difference across the two sides of a wall is increased, its thermal conductivity increases.

51. Assertion (A) : Snow is better insulator than ice.
Reason (R) : Snow contains air packet and air is good insulator of heat.

52. Assertion (A) : A body with large reflectivity is a poor emitter.
Reason (R) : Poor absorbers of heat are poor emitters.

53. Assertion (A) : For a perfectly black body, absorption coefficient and emission coefficient is one.
Reason (R) : Perfect absorbers are perfect emitters.

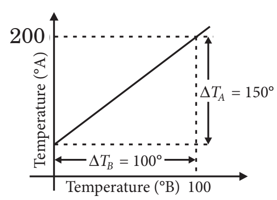
54. Assertion (A) : Greater is the coefficient of thermal conductivity of a material, smaller is the thermal resistance of a rod of that material.
Reason (R) : Thermal resistance is the ratio of temperature difference between the ends of the conductor and rate of flow of heat.

55. Assertion (A) : In the upper part of the atmosphere the temperature of air is of the order of 1000 K, even then it is quite cold there.
Reason (R) : The heat density of upper atmosphere is very high.

SUBJECTIVE TYPE QUESTIONS

Very Short Answer Type Questions (VSA)

1. The graph between two temperature scales A and B is shown in figure. Between upper fixed point and lower fixed point there are 150 equal division on scale A and 100 on scale B. What is the relationship for conversion between the two scales ?



2. Two identical rectangular strips, one of copper and the other of steel, are riveted to form a bimetallic strip. What will happen on heating ?

3. Thermal conductivity of air is less than that of felt but felt is a better heat insulator in comparison to air. Why?

4. The temperature on a Fahrenheit scale is 98.6°F? What is the corresponding temperature on a Kelvin scale?

5. The temperature gradient in a rod 0.5 m long is 40 °C per metre. The temperature of the hotter end is 30 °C. What is the temperature of its colder end?

6. Why does a metal bar appear hotter than a wooden bar at the same temperature? Equivalently it also appears cooler than wooden bar if they are both colder than room temperature.

7. How does running hot water on a jar lid loosen it ?

8. What is the temperature of the triple-point of water on an absolute scale whose unit interval size is equal to that of the Fahrenheit scale?

9. Why are we advised to store medicines below 86 °F ?

10. Specific heat of aluminium metal is 24.4 J/mole K. Express the specific heat in J/kg K.

Short Answer Type Questions (SA-I)

11. Two absolute scales A and B have triple points of water defined to be 100 A and 250 B. What is the relation between T_A and T_B?

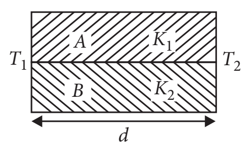
12. The volume of a metal block changes by 0.12%, when it is heated through 40°°C. Find the coefficient of linear expansion for material of block.

13. Show that the coefficient of area expansions, $(\Delta A/A)/\Delta T$, of a rectangular sheet of the solid is twice its linear expansivity, α_1.

14. A lead bullet strikes against a fixed steel plate with a velocity 200 m s^{-1}. If the impact is perfectly inelastic and the heat produced is equally shared between the bullet and the target, what is the rise in temperature of the bullet?
(specific heat capacity of lead = 125 J kg^{-1} K^{-1})

15. 0.15 kg of ice at 0°C is mixed with 0.30 kg of water at 50°C in a container. Find the resultant temperature. Given the Latent heat of fusion of ice = 3.35×10^5 J/kg and c_{water} = 4200 J kg^{-1} K^{-1}.

16. Two rods A and B of different materials are welded together as shown in figure. Their thermal conductivities are K_1 and K_2. Find the thermal conductivity of the composite rod.



17. The density of water at 20°C is 998 kg/m^3 and at 40°C is 992 kg/m^3. Find the coefficient of volume expansion of water.

18. The specific heat of many solids at low temperatures varies with absolute temperature T according to the relations $S = DT^3$, where D is a constant. What is the heat energy required to raise the temperature of a mass m of such a solid from T_1 = 20 K to T_2 = 30 K ?

19. Draw experimental curves between wavelength λ and intensity of radiation E_λ emitted by a black body maintained at different constant temperatures.

20. Two ideal gas thermometers A and B use oxygen and hydrogen respectively. The following observations are made :

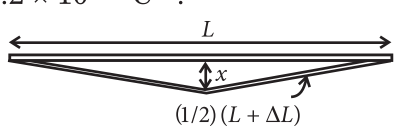
Temperature	**Pressure thermometer *A***	**Pressure thermometer *B***
Triple-point of water	1.250×10^5 Pa	0.200×10^5 Pa
Normal melting point of sulphur	1.797×10^5 Pa	0.287×10^5 Pa

(a) What is the absolute temperature of normal melting point of sulphur as read by thermometers A and B ?

(b) What do you think is the reason behind the slightly difference in answers of thermometers A and B ? (The thermometers are not faulty). What further procedure is needed in the experiment to reduce the discrepancy between the two readings ?

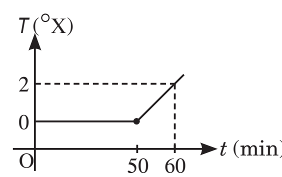
Short Answer Type Questions (SA-II)

21. A rail track made of steel having length 10 m is clamped on a railway line at its two ends. On a summer day due to rise in temperature by 20°C, it is deformed as shown in figure. Find x (displacement of the centre) if coefficient of linear expansion of steel is, $\alpha_{steel} = 1.2 \times 10^{-5}$ °C^{-1}.



22. Define the terms heat capacity and water equivalent. Give their CGS and SI units.

23. A calorimeter contains 10 kg of water and some ice. Variation of temperature with time, when the calorimeter is heated over a slow burner is as shown in graph. Ignoring heat absorbed by calorimeter, find the amount of ice present.



24. Differentiate between three modes of heat transmission.

25. A brass wire 1.8 m long at 27°C is held taut with little tension between two rigid supports. If the wire is cooled to a temperature of –39°C, what is the tension developed in the wire, if its diameter is 2.0 mm? Coefficient of linear expansion of brass = 2.0×10^{-5} K^{-1}; Young's modulus of brass = 0.91×10^{11} Pa.

26. Find the ratio of heat required to raise the temperatures of two copper spheres of radii r_1 and r_2 ($r_1 = 2.5r_2$) through 1 K.

27. (a) Calorimeters are made of metals not glass. Why ?

(b) What is calorimetry ?

(c) Which has the highest specific heat capacity : hydrogen or water?

28. Explain briefly the anomalous expansion of water. How the fishes can survive in the extreme winter when lakes ponds are frozen?

29. (a) On what factors does the amount of heat flowing through a body [conductivity] depend? Obtain the expression for the heat conducted.

(b) Define coefficient of thermal conductivity. Write its SI unit.

(c) Define thermal conductivity.

30. During summers in India, one of the common practice to keep cool is to make ice balls of crushed ice, dip it in flavoured sugar syrup and sip it. For this a stick is inserted into crushed ice and is squeezed in the palm to make it into the ball. Equivalently in winter, in those areas where it snows, people make snow balls and throw around. Explain the formation of ball out of crushed ice or snow in the light of P–T diagram of water.

31. What is the effect of pressure on melting point of a substance? What is the regelation. Give its one practical application.

Long Answer Type Questions (LA)

32. Explain why?

(a) A body with large reflectivity is a poor emitter?

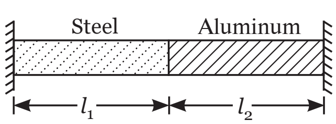
(b) A brass tumbler feels much colder than a wooden tray on a chilly day?

(c) The Earth without its atmosphere would be inhospitably cold?

(d) Heating systems based on circulation of steam are more efficient in warming a building than those based on circulation of hot water?

33. What is meant by coefficient of linear expansion, superficial expansion and cubical expansion ? Derive the relationship between them.

34. Two rods one of steel and other of aluminium is equal to cross-sectional area are joined together and the free ends are fixed between two rigid supports as shown in the figure.



Temperature of surroundings is increased by 100°C. If displacement of joint rods is ($N^2/10$) mm, then find the value of N with the help of following table.

Metal	Coefficient of expansion α(°C^{-1})	Young's modulus Y(Nm^{-2})	Length l(m)
Steel	1.2×10^{-5}	20×10^{10}	20
Aluminium	2.4×10^{-5}	7×10^{10}	7

35. According to Stefan's law of radiation, a black body radiates energy σT^4 from its unit surface area every second where T is the surface temperature of the black body and $\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4} is known as Stefan's constant. A nuclear weapon may be thought of as a ball of radius 0.5 m. When detonated, it reaches temperature of 10^3 K and can be treated as a black body.

(a) Estimate the power it radiates.

(b) If surrounding has water at 30 °C, how much water can 10% of the energy produced evaporate in 1 s?

[$s_w = 4186.0$ J kg^{-1} K^{-1}, $L_v = 22.6 \times 10^5$ J kg^{-1}]

(c) If all this energy U is in the form of thermal radiation, corresponding momentum is $p = U/c$. How much momentum per unit time does it impart on unit area at a distance of 1 km?

ANSWERS

OBJECTIVE TYPE QUESTIONS

1. **(c) :** The energy radiated per second E by a sphere of radius R at temperature T kelvin is given by

$$E = e\sigma A T^4$$

As both spheres are of the same material, so their emissivities will be equal.

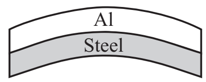
$\therefore$ $E_1 = e\sigma 4\pi(1)^2 \times (4000)^4 = e\sigma\pi \times 1024 \times 10^{12}$ J/s

and $E_2 = e\sigma 4\pi\,(4)^2\,(2000)^4 = e\sigma\pi \times 1024 \times 10^{12}$ J/s

Thus, $E_1 = E_2$

How σ is a Stefan's constant

2. **(d) :** Since $\alpha_{Al} > \alpha_{steel}$, so on heating the bimetallic strip, aluminium strip will expand more than that of steel strip.



Due to it, steel strip will bend on concave side.

3. **(c) :** Let T_Y be the temperature on Y scale corresponding to T_K on kelvin scale.

Since the temperature scale is assumed to be linear slop in two cases will be same. Hence,

$$\therefore \quad \frac{T_Y - (-160)}{-50 - (-160)} = \frac{T_K - 273}{373 - 273} \quad \text{or} \quad \frac{T_Y + 160}{-50 + 160} = \frac{340 - 273}{100}$$

or $\quad 100(T_Y + 160) = 110(67)$ or $T_Y = -86.3°\ Y$

4. **(b) :** Change in volume of petrol,

$$\Delta V_p = V\gamma_p\,\Delta T = V \times 9.9 \times 10^{-4} \times 20 = 1.98 \times 10^{-2}\ V$$

Change in volume of steel tank,

$$\Delta V_s = V\gamma_s\,\Delta T = V \times 3 \times 24 \times 10^{-6} \times 20 \quad [\because\ V_s = 3\alpha_s]$$

$$= 1.44 \times 10^{-3}\ V = 0.144 \times 10^{-2}\ V$$

Volume of petrol overflowing,

$$\Delta V_p - \Delta V_s = (1.98 - 0.144) \times 10^{-2}\ V$$

$$= 1.836 \times 10^{-2} \times 75 = 1.38 \text{ L}$$

5. **(a) :** When the rod is heated uniformly to raise its temperature slightly, its moment of inertia (I) increases. Since angular momentum, $L = I\omega$, ω (angular speed) decreases to conserve L.

6. **(b) :** From the graph

For the scale A,

Lower fixed point = 30°A

Upper fixed point = 180°A

For the scale B,

Lower fixed point = 0°B

Upper fixed point = 100°B

$\therefore$ The relationship between the two scales A and B is given by

$$\frac{T_A - 50}{150} = \frac{T_B - 0}{100} = \frac{T_B}{100}$$

7. **(b) :** Let V_{flask} and $V_{mercury}$ be the volume of flask and volume of mercury inside it. Respectively as the volume of air inside the flask remains the same at all temperatures, this is possible only if the volume expansion of flask will be equal to that of mercury.

i.e. $\Delta V_{flask} = \Delta V_{mercury}$ or $V_{flask}\gamma_{flask}\,\Delta T = V_{mercury}\,\gamma_{mercury}\,\Delta T$

or $\quad V_{mercury} = \dfrac{V_{flask}\,\gamma_{flask}}{\gamma_{mercury}}$

Here, $V_{flask} = 1$ L $= 1000$ cc, $\dfrac{\gamma_{flask}}{\gamma_{mercury}} = \dfrac{1}{20}$

$$\therefore \quad V_{mercury} = (1000 \text{ cc})\left(\frac{1}{20}\right) = 50 \text{ cc}$$

8. **(c) :** PT^2 = constant (Given) ...(i)

According to ideal gas equation,

$$PV = nRT \quad \text{or} \quad P = \frac{nRT}{V}$$

Substituting this value of P in (i), we get

$$\left(\frac{nRT}{V}\right)T^2 = \text{constant} \quad \text{or} \quad \frac{T^3}{V} = \text{another constant}$$

Differentiating both sides, we get

$$\frac{1}{V}3T^2\,dT - \frac{T^3}{V^2}dV = 0$$

or $\quad 3dT = \dfrac{T}{V}dV \quad$ or $\quad \dfrac{1}{V}\left(\dfrac{dV}{dT}\right) = \dfrac{3}{T}$ ...(ii)

According to definition of the coefficient of volume expansion of the gas is

$$\gamma = \frac{1}{V}\left(\frac{dV}{dT}\right) \qquad ...(iii)$$

From (ii) and (iii), we get $\gamma = \dfrac{3}{T}$

9. **(b) :** Temperature is not same every where so unit is not in thermal equilibrium but heat is flowing at constant rate.

10. **(d) :** From the formula for thermal stress

$$\left(\frac{F}{A}\right)_1 = \alpha_1 Y_1 \Delta T \qquad ....(i)$$

$$\left(\frac{F}{A}\right)_2 = \alpha_2 Y_2 \Delta T \qquad ....(ii)$$

(Since, temperature ΔT is same)

Dividing (i) by (ii), we get

$$\frac{(F/A)_1}{(F/A)_2} = \frac{\alpha_1 Y_1}{\alpha_2 Y_2}$$

For thermal stress to be equal, $\alpha_1 Y_1 = \alpha_2 Y_2$

or $\quad \dfrac{Y_1}{Y_2} = \dfrac{\alpha_2}{\alpha_1} = \dfrac{3}{2} \qquad \left(\text{As } \dfrac{\alpha_1}{\alpha_2} = \dfrac{2}{3}\right)$

11. (c) : As $\Delta l_1 = \Delta l_2$ $\therefore$ $\alpha_a l_1 \Delta T = \alpha_s l_2 \Delta T$

or $\frac{l_2}{l_1} = \frac{\alpha_a}{\alpha_s}$ or $\frac{l_2}{l_1} + 1 = \frac{\alpha_a}{\alpha_s} + 1$ or $\frac{l_2 + l_1}{l_1} = \frac{\alpha_a + \alpha_s}{\alpha_s}$

$\therefore$ $\frac{l_1}{l_1 + l_2} = \frac{\alpha_s}{\alpha_a + \alpha_s}$

12. (d) : As $T_C = (T - 273)°C$

$= 216.55 - 273 = -56.45\,°C$

Also, $T_F = \frac{9}{5}T_C + 32 = \frac{9}{5} \times (-56.45) + 32$

$= -101.61 + 32 = -69.61°F$

13. (c) : $\frac{\Delta L}{L} = 2\% = \frac{2}{100}$

Given, $\alpha = 0.00002\,°C^{-1}$

As $\Delta L = \alpha L \Delta T$

or $\Delta T = \frac{\Delta L}{\alpha L} = \frac{2}{100 \times 0.00002} = \frac{1}{0.001}$

$= 10^3 = 1000\,°C$

14. (a) : Here, $r_1 = 1.5\, r_2 = \frac{3}{2} r_2 \Rightarrow \frac{r_1}{r_2} = \frac{3}{2}$

Quantity of heat required to raise the temperature of copper sphere of radius r_1 through 1 K is

$$Q_1 = m_1 s_{Copper} \Delta T = \left(\frac{4}{3}\pi r_1^3 \rho_{Copper}\right) \times s_{Copper} \times 1$$

or $Q_1 = \frac{4}{3}\pi r_1^3 \rho_{Copper} s_{Copper}$ ...(i)

Quantity of heat required to raise the temperature of copper sphere of radius r_2 through 1 K is

$$Q_2 = m_2 s_{Copper} \Delta T = \frac{4}{3}\pi r_2^3 \rho_{Copper} \times s_{Copper} \times 1$$

or $Q_2 = \frac{4}{3}\pi r_2^3 \rho_{Copper} s_{Copper}$ ...(ii)

Divide (i) by (ii), we get $\frac{Q_1}{Q_2} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{3}{2}\right)^3 = \frac{27}{8}$

15. (a) : Volumetric strain in tooth cavity

$= \frac{\Delta V}{V}$

Let γ be the coefficient of volume expansion with the change in temperature ΔT °C.

Change in volume is

$\Delta V = \gamma V \Delta T$

or $\frac{\Delta V}{V} = \gamma \Delta T$

Thermal stress in tooth cavity

$= \beta \times$ volumetric strain $= \beta \times \gamma \Delta T$

$= \beta \times 3\alpha \Delta T$ $(\because \gamma = 3\alpha)$

$= 140 \times 10^9 \times 3 \times 1.7 \times 10^{-5} \times (57°C - 37°C)$

$= 1.43 \times 10^8$ N m^{-2}.

16. (b) : Here, $P = 10$ kW $= 10^4$ W, $m = 8$ kg

time, $t = 2.5$ minute $= 2.5 \times 60 = 150$ s

Specific heat, $s = 0.91$ J g^{-1} C^{-1}

Total energy $= P \times t = 10^4 \times 150 = 15 \times 10^5$ J

As 50% of energy is lost,

$\therefore$ Energy available, $\Delta Q = \frac{1}{2} \times 15 \times 10^5 = 7.5 \times 10^5$ J

As $\Delta Q = ms\Delta T$

$$\Delta T = \frac{\Delta Q}{ms} = \frac{7.5 \times 10^5}{8 \times 10^3 \times 0.91} = 103\ °C$$

17. (a) : $\frac{\text{Thermal capacity } (S)}{\text{Volume } (V)} = s\frac{m}{V} = s\rho$

$\therefore$ $\frac{S_1 / V_1}{S_2 / V_2} = \frac{s_1 \rho_1}{s_2 \rho_2} = \frac{0.12}{0.09} \times \frac{2}{3} = \frac{8}{9}$

18. (c) : Heat required to convert 100 g of ice at 0°C to water at 100°C

$= (100\text{ g})(80\text{ cal g}^{-1}) + (100\text{ g})(1\text{ cal g}^{-1}\,°C^{-1})(100°C)$

$= 8000$ cal $+ 10000$ cal $= 18000$ cal

But 22320 cal of heat is supplied, so remaining amount of heat

$= 22320$ cal $- 18000$ cal $= 4320$ cal

Let the amount of water evaporated by remaining heat be m. Then

$m(540\text{ cal g}^{-1}) = 4320$ cal

or $m = \frac{4320\text{ cal}}{540\text{ cal g}^{-1}} = 8$ g

Thus the final amount of water obtained at 100°C

$= 100$ g $- 8$ g

$= 92$ g.

19. (a) : Here, triple point of water on scale $A = 200A$

Triple point of water on scale $B = 350B$

$200A = 350B = 273.16$ K (given)

or $1A = \frac{273.16}{200}$ K and $1B = \frac{273.16}{350}$ K

If T_A and T_B represent the triple point of water on scales A and B, then

$$\frac{273.16}{200}T_A = \frac{273.16}{350}T_B$$

or $\frac{T_A}{T_B} = \frac{200}{350}$ or $T_A = \frac{4}{7}T_B$

20. (a) : When heat is supplied the temperature of ice increases from –10°C to 0°C. It is represented by a straight line inclined to heat axis. At 0°C the heat is used in converting ice into water at 0°C. This stage is represented by horizontal straight portion. After that temperature of water rises from 0°C to 100°C. It is represented by a straight line inclined to heat axis. At 100°C, the heat is used in converting water into steam. The graph is represented by horizontal straight line. Thus option (a) is correct.

21. (a) : Density of water = 10^3 kg/m^3

Let the final temperature of the mixture be T.

Assuming no heat transfer to or from container.

Heat lost by water at 80°C = $0.1 \times 10^3 \times s_{water} \times (80 - T)$

Heat gained by water at 60°C = $0.3 \times 10^3 \times s_{water} \times (T - 60)$

According to the principle of calorimetry

heat lost = heat gain

$\therefore \quad 0.1 \times 10^3 \times s_{water} \times (80 - T) = 0.3 \times 10^3 \times s_{water} \times (T - 60)$

or $\quad 1 \times (80 - T) = 3 \times (T - 60)$ or $4T = 260$

or $T = \frac{260}{4}$°C $= 65$°C

22. (c) : $[m \times 2100 \times 5 + 1 \times 3.36 \times 10^5] \times 10^{-3} = 420$

where m is in grams.

or $\quad m \times 2100 \times 5 \times 10^{-3} + 336 = 420$

or $\quad m \times 2100 \times 5 \times 10^{-3} = 84$ or $m = \frac{84}{2100 \times 5 \times 10^{-3}} = 8$ g

23. (a) : As buoyancy at 0°C, $F_b = V\rho_0 g$ and

buoyancy at 4°C, $F'_b = V\rho_4 g$,

$\frac{F_b}{F'_b} = \frac{\rho_0}{\rho_4} < 1$ (density of water at 4°C is maximum)

i.e., $F_b < F'_b$

24. (a) : Time period of the simple pendulum is

$$T = 2\pi\sqrt{\frac{L}{g}} \qquad \text{... (i)}$$

where L is the effective length of the pendulum. With increase in temperature, the effective length (L) of simple pendulum increases even though its centre of mass still remains at the centre of the bob.

From (i), $T \propto \sqrt{L}$

So T increases as temperature increases.

25. (a) : Let L be length of each rod.

Rate of heat flow in rod 1 for the temperature difference ΔT is

$$H_1 = \frac{K_1 A_1 \Delta T}{L}$$

Rate of heat flow in rod 2 for the same difference ΔT is

$$H_2 = \frac{K_2 A_2 \Delta T}{L}$$

As per question, $H_1 = 4H_2$

$\therefore \quad \frac{K_1 A_1 \Delta T}{L} = 4\frac{K_2 A_2 \Delta T}{L}$ or $K_1 A_1 = 4K_2 A_2$

26. (b) : Here, $m_A = 0.5$ kg, $s_A = 0.85$ J g^{-1} K^{-1}, $T_A = 60$°C, $m_B = 0.3$ kg, $s_B = 0.9$ J g^{-1} K^{-1} and $T_B = 90$°C

Heat always flows from a body of higher temperature to a body of lower temperature. Since the body B is at a higher temperature, therefore heat will flow from body B to A.

27. (d) : Coefficient of cubical expansion is

$\gamma = \alpha_x + \alpha_y + \alpha_z = \alpha_x + 2\,\alpha_y \qquad (\because \alpha_y = \alpha_z)$

$= 2.0 \times 10^{-6} + 2 \times 1.6 \times 10^{-6} = 5.2 \times 10^{-6}$ K^{-1}

Hence the correct choice is (d).

28. (b) : $\frac{X - LFP}{UFP - LFP}$ = constant (for all temperature scales)

where, LFP $\longrightarrow$ Lower fixed point

UFP $\longrightarrow$ Upper fixed point

$$\frac{X - (-5)}{95 - (-5)} = \frac{C - 0}{100 - 0} \Rightarrow \frac{60 + 5}{95 + 5} = \frac{C}{100} \Rightarrow C = 65\ \text{°C}$$

29. (d) : According to Wien's law if λ is the wavelength at maximum intensity λT = constant.

$\therefore$ Shorter the wavelength of the peak, greater the temperature for intensity vs λ graph.

($\lambda_{max.}$ is not maximum wavelength but λ at maximum intensity)

$T_1 > T_3 > T_2$

30. (b) : According to Stefan's law, the rate of energy radiated by a black body at absolute temperature T is

$E = A\sigma T^4$

When the temperature of the body is raised by 5%, its new temperature becomes

$$T' = T + \frac{5}{100}T = \frac{21}{20}T \quad \therefore \quad \frac{E'}{E} = \left(\frac{T'}{T}\right)^4 = \left(\frac{21}{20}\right)^4 = (1.05)^4$$

% increase in rate of heat energy $= \frac{E' - E}{E} \times 100\%$

$= \left(\frac{E'}{E} - 1\right) \times 100\% = [(1.05)^4 - 1] \times 100\% = 22\%$

31. (a) : In the given P-T diagram,

Region I - Liquid

Region II - Solid

Region III- Vapour

32. (b) : Thermal radiation travels in straight lines, like light. Thermal radiation obeys the law of refraction. Hence, when it travels from one medium to another, its wavelength and speed changes whereas frequency remains unchanged as frequency is the characteristics of source of thermal radiation.

33. (d) : In the given graph, AB represents no change in temperature with time. It means ice and water are in thermal equilibrium. BC shows the change in temperature with time. CD represents a constant temperature (100°C) with time. It means, water and steam are in thermal equilibrium at boiling point.

34. (a) : The appearance of a star depends on the wavelength (λ_m) at which it radiates maximum energy. This depends inversely on the surface temperature (T) of the star. Now, $\lambda_{blue} < \lambda_{yellow} < \lambda_{red}$. Thus, star A (bluish) radiates the shortest wavelength and must be at the highest temperature, while star B (reddish) must be at the lowest temperature.

35. (c) : According to Wien's displacement law

$\lambda_m T = b$

In terms of frequency, $\frac{c}{\upsilon_m}T = b$ or $\upsilon_m = \frac{c}{b}T$

Hence, the $\upsilon_m - T$ graph is a straight line as shown by curve *C*.

36. (a) :

Substances	**Specific heat capacity**
Water	4186 J kg^{-1} K^{-1}
Ice	2060 J kg^{-1} K^{-1}
Aluminium	900 J kg^{-1} K^{-1}
Mercury	140 J Kg^{-1} K^{-1}

Water has the highest specific heat capacity.

37. (c) : Infinite thermal capacity implies that there would be practically no change in temperature whether heat is taken in or given out.

38. (c) : Owing to its high specific heat, water is used as a coolant in automobile radiators as well as a heater in hot water bags.

39. (a) : 1 calorie is the amount of heat required to raise the temperature of 1 g of water from 14.5°C to 15.5°C at 760 mm of Hg.

40. (d) : Thermal capacity = $ms = 40 \times 0.2 = 8$ cal/°C
$= 4.2 \times 8 = 33.6$ J/°C

41. (a) : A metal expands on heating. Therefore, diameter of the hole increases always.

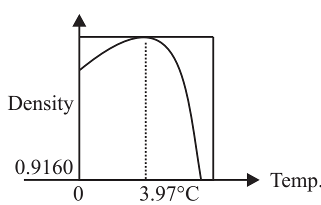
42. (c)

43. (c) : A cavity in a material expands in exactly the same way as if the cavity were filled with material. Thus, both spheres will expand by the same amount.

44. (a)

45. (b) : As $\beta = 2\alpha$ and $\gamma = 3\alpha$ $\quad \therefore \quad \frac{\beta}{\gamma} = \frac{2\alpha}{3\alpha} = \frac{2}{3}$

46. (b) : Individual water molecules are all present at the maximum distance from adjacent molecule due to hydrogen bonding. Hence water exhibits its minimum density when it is in the form of ice. The transformation of ice to water is accompanied by the breaking of some of the hydrogen bonds, leading to a dramatic increase in density. Its density is minimum at 0°C and maximum at 4°C.



47. (a) : As, $\gamma = \frac{\Delta V}{V \Delta T}$ *i.e.*, units of coefficient of volume expansion is K^{-1}.

48. (a) : As $\beta = 2\alpha$ and $\gamma = 3\alpha$, *i.e.*, coefficient of volume expansion of solid is three time coefficient of linear expansion and 1.5 times the coefficient of superficial expansion, on heating a solid iron ball, percentage increase in its volume is largest.

49. (a) : Water has maximum density at 4°C. On heating above 4°C or cooling below 4°C, density of water decreases and its volume increases. Therefore, water overflows in both the cases.

50. (c) : Thermal conductivity of the wall depends on nature of material of the wall and not on temperature difference across its two sides.

51. (a) : When the temperature of the atmosphere reaches below 0°C, then the water vapours present in air, instead of condensing, freeze directly in the form of minute particles of ice. Many particles coalesce and take cotton-like shape which is called snow. Thus snow contains air packets in which convection currents cannot be formed. Hence snow is a good heat insulator. In ice there is no air.

52. (a) : According to Kirchhoff's law, the ratio of emissive power to the absorptive power corresponding to a particular wavelength and at any given temperature is always a constant for all bodies. This constant is equal to emissive power of a perfectly black body at the same temperature and corresponding to the same wavelength. $\frac{e_\lambda}{a_\lambda} = E_\lambda$.

If $e\lambda$ is small, $a\lambda$ is also small and vice-versa because E_λ is constant. Hence poor emitter are poor absorbers.

53. (a) : By definition, $a = 1$ for a perfectly black body. According to Kirchoff's law, good absorbers are good emitters. Therefore $e = 1$.

54. (b) : By definition, $R = \frac{\theta_1 - \theta_2}{H} = \frac{d}{KA}$, *i.e.*, $R \propto \frac{1}{K}$.

Thus greater the coefficient of thermal conductivity of a material, smaller is the thermal resistance of the rod of that material. Also thermal resistance is analogy to electrical resistance. In reverse of this greater the thermal resistance, better will be the thermal insulation and poorer will be the thermal conduction.

55. (c) : Heat sensation depends upon the quantity of heat absorbed by the skin. As we go up in the atmosphere, the number of air-molecules per unit volume goes on decreasing. Hence the total energy related to molecules per unit volume goes on decreasing. Thus, in the upper part of the atmosphere the heat density is low although the translational kinetic energy per molecule is quite large. Due to low heat density one feels coldness.

SUBJECTIVE TYPE QUESTIONS

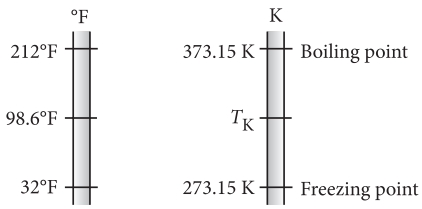
1. From the graph, for the scale *A*,
Lower fixed point = 50°A
Upper fixed point = 200°A
For the scale *B*,
Lower fixed point = 0° B
Upper fixed point = 100° B
$\therefore$ The relationship between the two scales *A* and *B* is given

by $\dfrac{T_A - 50}{150} = \dfrac{T_B - 0}{100} = \dfrac{T_B}{100}$

2. The coefficient of linear expansion is more for copper than for steel. As such, when the bimetallic strip is heated, it will bend in such a way that the copper strip will occupy the convex side, *i.e.*, the outer side.

3. Free air is able to transmit heat by convection currents. But in case of felt, there are fine holes which trap air and do heat allow its movement. Obviously, convection currents cannot be set in the felt.

4.



Let T_K be temperature on Kelvin scale corresponding to 98.6°F on Fahrenheit scale. Then

$$\frac{98.6 - 32}{212 - 32} = \frac{T_K - 273.15}{373.15 - 273.15}$$

or $$\frac{66.6}{180} = \frac{T_K - 273.15}{100}$$

or $$T_K = \frac{66.6}{180} \times 100 + 273.15 = 310.2\text{ K}$$

5. As temperature gradient $= \dfrac{T_1 - T_2}{x}$,

where, $T_1 = 30$ °C, $x = 0.5$ m, $T_2 = ?$

Temperature of colder end = 30 – 0.5 × 40 = 10 °C

6. Since the conductivities of metals are very high compared to wood. So on touching a hot metal with a finger, heat flows faster to the finger from metal and feels the heat.

Similarly, when one touches a cold metal the heat from the finger to the metal bar from the body.

7. The metal expands more than the glass and consequently lid pulls away from the jar.

The hot water helps the metal to expand.

8. The unit interval size of Fahrenheit scale is

212 – 32 = 180 divisions

Also we know that the unit interval size of absolute scale is 100.

∴ Triple point of water on an absolute scale having 180 divisions is given by

$$T = \frac{273.16}{100} \times 180 = 491.69$$

9. A temperature of 86° F is equal to 30° C. Above this temperature, chemical reactions may take place resulting in a change in the composition of the medicine. The medicine may then become ineffective or even harmful.

10. Specific heat of aluminium metal

= 24.4 J/mole K

$= \dfrac{24.4}{27} \times 1000 \text{ J/kg K} = 904 \text{ J/kg K} \approx 900 \text{ J/kg K}.$

11. Here, triple point of water on scale, $A = 100\,A$

triple point of water on scale, $B = 250\,B$

triple point of water on kelvin scale = 273.16 K

According to question

$$100\,A = 250\,B = 273.16\text{ K}$$

$$1\,A = \frac{273.16}{100}\text{K},\ 1\,B = \frac{273.16}{250}\text{K}$$

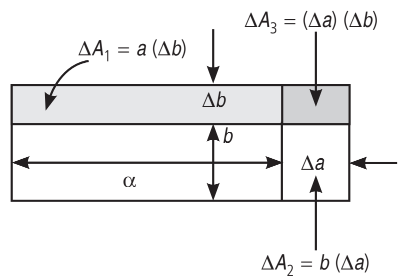
If T_A and T_B represent the triple point of water on two scales A and B, then

$$\frac{273.16}{100}T_A = \frac{273.16}{250}T_B,\ \frac{T_A}{T_B} = \frac{100}{250} = \frac{2}{5},\ T_A = \frac{2}{5}T_B$$

12. $\gamma = \dfrac{\Delta V}{V\Delta T} = \dfrac{0.12}{100} \times \dfrac{1}{40} = \dfrac{0.0012}{40} = 3 \times 10^{-5}\ °C^{-1}$

So, $\alpha = \dfrac{\gamma}{3} = \dfrac{3 \times 10^{-5}}{3} = 1 \times 10^{-5}\ °C^{-1}$

13.



Consider a rectangular sheet of the solid material of length a and breadth b as shown in figure. When the temperate increases by ΔT, a increases by $\Delta a = \alpha_1 a\,\Delta T$ and b increases by $\Delta b = \alpha_1 b\,\Delta T$. From figure the increase in area

$\Delta A = \Delta A_1 + \Delta A_2 + \Delta A_3$

$\Delta A = a\,\Delta b + b\,\Delta a + (\Delta a)(\Delta b)$

$= a\,\alpha_1 b\,\Delta T + b\alpha_1\,a\,\Delta T + (\alpha_1)^2\,ab\,(\Delta T)^2$

$= \alpha_1\,ab\,\Delta T\,(2 + \alpha_1\,\Delta T) = \alpha_1\,A\Delta T\,(2 + \alpha_1\,\Delta T)$

Since $\alpha_1 \simeq 10^{-5}\ K^{-1}$, from the product $\alpha_1\,\Delta T$ for fractional temperature is small in comparison with 2 and may be neglected.

Hence $\left(\dfrac{\Delta A}{A}\right)\dfrac{1}{\Delta T} \simeq 2\alpha_1$

14. Since the target is fixed, both bullet and plate will be finally at rest.

The kinetic theory is converted into low energy.

But recries half of his heat energy and its temperature rises.

As $ms\Delta T = \dfrac{1}{2}\left(\dfrac{1}{2}mv^2\right)$

$\therefore \quad \Delta T = \frac{v^2}{4s} = \frac{(200)^2}{4 \times 125} = \frac{4 \times 10^4}{4 \times 125} = 80°C$

15. Let the resultant temperature be θ°C.

Heat lost by 0.30 kg water when its temperature falls from 50°C to θ°C

$= mc_{water}\,\Delta T = 0.30 \times 4200 \times (50 - \theta) = 1260\,(50 - \theta)$ J

Heat required to melt 0.15 kg ice into water at 0°C

$= mL_f = 0.15 \times 3.35 \times 10^5 = 0.5025 \times 10^5$ J

Heat required to raise temperature of 0.15 kg water from 0°C to θ°C $= mc_{water}\,\Delta T$

$= 0.15 \times 4200 \times (\theta - 0) = 630\,\theta$ J

By principle of calorimetry,

Heat gained = Heat lost

$0.5025 \times 10^5 + 630\,\theta = 1260\,(50 - \theta)$

$50.25 \times 10^3 + 630\,\theta = 63000 - 1260\,\theta$

$1890\,\theta = 63 \times 10^3 - 50.25 \times 10^3$

$1890\,\theta = 12.75 \times 10^3$

$\theta = 6.7$°C

16. Equivalent thermal conductivity of the composite rod in parallel combination will be,

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

17. As $\rho_{T_2} = \frac{\rho_{T_1}}{(1 + \gamma\Delta T)} = \frac{\rho_{T_1}}{1 + \gamma(T_2 - T_1)}$

Here, $T_1 = 20$°C, $T_2 = 40$°C, $\rho_{20°C} = 998$ kg/m^3, $\rho_{40°C} = 992$ kg/m^3

$\therefore \quad 992 = \frac{998}{1 + \gamma(40 - 20)}$ or $992 = \frac{998}{1 + 20\gamma}$

or $992(1 + 20\gamma) = 998$ or $1 + 20\gamma = \frac{998}{992}$

or $20\gamma = \frac{998}{992} - 1 = \frac{6}{992}$ or $\gamma = \frac{6}{992} \times \frac{1}{20}$

$= 3 \times 10^{-4}$/°C

18. As $\Delta Q = mS\Delta T$

$$\therefore \quad Q = \int \Delta Q = \int_{T_1}^{T_2} mS\Delta T$$

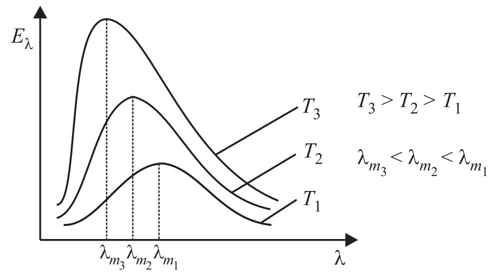
Here, $S = DT^3$, $T_1 = 20$ K and $T_2 = 30$ K

$$\therefore \quad Q = \int_{20}^{30} mDT^3 dT = mD\int_{20}^{30} T^3 dT = mD\left[\frac{T^4}{4}\right]_{20}^{30}$$

$$= \frac{mD}{4}[(30)^4 - (20)^4] = \frac{mD}{4} \times 10^4[81 - 16]$$

$$= \left(\frac{65}{4}\right) \times 10^4\,Dm = 162500\,Dm$$

19.



As the temperature of the body increases, the wavelength at which the spectral intensity (E_λ) is maximum shifts towards left. Therefore it is also called Wien's displacement law.

20. (a) Let T be the melting point of sulphur.

The triple point of water, $T_{tr} = 273.16$ K

For thermometer A : $P_{tr} = 1.25 \times 10^5$ Pa

$P = 1.797 \times 10^5$ Pa

$$\therefore \quad T_A = \frac{P}{P_{tr}} \times t_r = \frac{1.797 \times 10^5}{1.250 \times 10^5} \times 273.16$$

$= 392.69$ K

For thermometer B : $P_{tr} = 0.200 \times 10^5$ Pa

$P = 0.287 \times 10^5$ Pa

$$T_B = \frac{P}{P_{tr}} \times T_{tr} = \frac{0.287 \times 10^5}{0.200 \times 10^5} \times 273.16$$

$= 391.98$ K

(b) The discrepancy arises because the gases are not perfectly ideal. To reduce the discrepancy, readings should be taken at lower pressure as in that case, the gases approach to the ideal gas behaviour.

21. From figure, $x^2 = \left(\frac{L + \Delta L}{2}\right)^2 - \left(\frac{L}{2}\right)^2$

$$\Rightarrow \quad x = \sqrt{\left(\frac{L + \Delta L}{2}\right)^2 - \left(\frac{L}{2}\right)^2}$$

$$= \sqrt{\left(\frac{L}{2}\right)^2 + \frac{2L\Delta L}{4} + \left(\frac{\Delta L}{2}\right)^2 - \left(\frac{L}{2}\right)^2}$$

Since ΔL is a small quantity, the term with $(\Delta L)^2$ being very small can be neglected.

$$\therefore \quad x = \sqrt{\frac{L\Delta L}{2}} = \sqrt{\frac{L(L\alpha\Delta T)}{2}} = L\sqrt{\frac{\alpha\Delta T}{2}}$$

Given, $L = 10$ m, $\alpha = 1.2 \times 10^{-5}$ °C^{-1}, $\Delta T = 20$ °C

Hence, $x = 10\sqrt{\frac{1.2 \times 10^{-5} \times 20}{2}}$

$= 10 \times 1.1 \times 10^{-2}$ m $= 0.11$ m $= 11$ cm

22. The heat capacity of a substance can be defined by the amount of heat required to change its temperature by one degree. It is also called thermal capacity which is a physical property of matter.

The SI unit of heat capacity is low per kelvin and the unit of heat capacity in CGS is calorie/°C.

The water equivalent of a body is defined as the mass of water which requires the same amount heat as is required by the given body for the same rise of temperature.

Water equivalent = Mass × Specific heat

or $w = mc$

The CGS unit of water equivalent is g and the SI unit is kg.

23. Energy is absorbed at a constant rate P. For the period from 50 min to 60 min, $Q = mC\,\Delta T$

$\Rightarrow$ $P(10\text{ min}) = (10\text{ kg} + m_{ice})(4186)(20 - 0)$

$\Rightarrow$ $P(10\text{ min}) = (83.7 + (8.37)\,m_{ice}) \times 10^3$ ...(i)

From 0 to 50 min, $Q = m_{ice} \cdot L_f$

$\Rightarrow$ $P(50\text{ min}) = m_{ice}(3.33 \times 10^5)$ ...(ii)

From eqns. (i) and (ii), we have

$$\frac{m_{ice}(3.33\times10^5)}{50} = \frac{(83.7+(8.37)m_{ice})10^3}{10}$$

$\Rightarrow$ $m_{ice} = 1.44$ kg

24.

	Conduction	Convection	Radiation
1.	It is the transfer of heat by direct physical contact.	It is the transfer of heat by the motion of a fluid.	It is the transfer of heat by electromagnetic waves.
2.	It is due to temperature difference. Heat flows from high temperature region to low temperature region.	It is due to difference in density. Heat flows from low density region to high density region.	It occurs from all bodies at temperatures above 0 K.
3.	It occurs in solids through molecular collisions, without actual flow of matter.	It occurs in fluids by actual flow of matter.	It can take place at large distances and does not heat the intervening medium.
4.	It is a slow process.	It is also a slow process.	It propagates at the speed of light.

25. Here $l_1 = 1.8$ m, $t_1 = 27°C$, $t_2 = -39°C$

$\therefore$ $\Delta T = T_2 - T_1 = -39 - 27 = -66°C = -66$ K

l_2 = length at T_2°C

For brass, $\alpha = 2 \times 10^{-5}\text{ K}^{-1}$, $Y = 0.91 \times 10^{11}$ Pa

Diameter of wire, $d = 2.0\text{ mm} = 2.0 \times 10^{-3}$ m

If A be the area of cross-section of the wire, then

$$A = \frac{\pi d^2}{4} = \pi(10^{-3})^2\text{ m}^2$$

If F be the tension developed in the wire, then using the relation

$$Y = \frac{F/A}{\Delta l / l}, \text{ we get } \Delta l = \frac{Fl}{AY}$$

Also $\Delta l = l\,\alpha\,\Delta T \;\therefore\; \frac{Fl}{AY} = \alpha l \Delta T$

or $F = \alpha\,\Delta\,T\,AY$

$$= 2\times10^{-5}\times(-66)\times\frac{22}{7}\times(10^{-3})^2\times0.91\times10^{11}$$

$= -3.8 \times 10^2$ N

Negative sign indicates that the force is inwards due to the contraction of the wire.

26. Here, $r_1 = 2.5 r_2 = \frac{5}{2} r_2$

Quantity of heat required to raise the temperature of copper sphere of radius r_1 through 1 K is

$$Q_1 = m_1 s_{Copper}\,\Delta T = \left(\frac{4}{3}\pi r_1^3 \rho_{Copper}\right) \times s_{Copper} \times 1$$

$$= \frac{4}{3}\pi r_1^3 \rho_{Copper}\, s_{Copper} \quad ...(i)$$

Quantity of heat required to raise the temperature of copper sphere of radius r_2 through 1 K is

$$Q_2 = m_2 s_{Copper}\,\Delta T = \frac{4}{3}\pi r_2^3 \rho_{Copper} \times s_{Copper} \times 1$$

$$= \frac{4}{3}\pi r_2^3 \rho_{Copper} s_{Copper} \quad ...(ii)$$

Divide (i) by (ii), we get $\frac{Q_1}{Q_2} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{5}{2}\right)^3 = \frac{125}{8}$

27. (a) This is because metals are good conductors of heat and have low specific heat capacity.

(b) The branch of physics that deals with the measurement of heat is called calorimetry.

(c) Hydrogen has the highest specific heat capacity (not molar specific heat capacity). Its value is 14400 J $\text{kg}^{-1}\text{ K}^{-1}$

28. Water shows unusual expansion, when it is cooled from from 4 °C to 0 °C degree. The unusual behaviour of water, when it expands below 4° C to 0° C is called anomalous expansion of water. The anomalous expansion of water helps preserve aquatic life during very cold weather. When temperature falls, the top layer of water in a pond contracts, becomes denser and sinks to the bottom. A circulation is thus set up until the entire water in the pond reaches its maximum density at 4°C. If the temperature falls further, the top layer expands and remains on the top till it freezes. Thus even though the upper layer are frozen the water near the bottom is at 4°C and the fishes etc. can survive in it easily.

29. (a) The amount of heat Q flowing through a body depends on various factors

(i) It is directly proportional to the cross-sectional area A.

(ii) It is directly proportional to the temperature difference

$(T_1 - T_2)$ between the opposite faces.

(iii) It is directly proportional to time t for which the heat flows.

(iv) It is inversely proportional to thickness x of the block, and.

(v) It depends on the nature of the material of the block.

$$\therefore \quad Q \propto \frac{A(T_1 - T_2)t}{x} \quad \text{or} \quad Q = \frac{KA(T_1 - T_2)t}{x}$$

(b) Thermal conductivity is the ability of a given material to conduct or transfer heat. It is donated by K. Materials with high thermal conductivity are used in heat sinks and materials with low values of K used as thermal insulators.

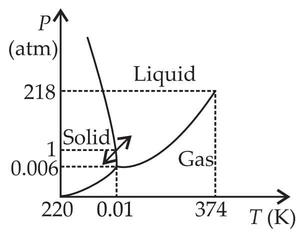
$$K = \frac{Qd}{A\Delta T}$$

It SI unit is $m^{-1} K^{-1}$.

Its SI unit is $J\ s^{-1}\ m^{-1}\ K^{-1}$ or $W\ m^{-1}\ K^{-1}$.

(c) The ability of material to conduct the heat through it is known as thermal conductivity.

30. Refer to the P-T diagram of water and double headed arrow. Increasing pressure at 0°C and 1 atm takes ice into liquid state and decreasing pressure in liquid state at 0°C and 1 atm takes water to ice state.



When crushed ice is squeezed, some of it melts, filling up gap between ice flakes. Upon releasing pressure, this water freezes binding all ice flakes making the ball more stable.

31. Effect of pressure on melting point : The melting point of those substances which expand on melting (*e.g.*, paraffing wax, phosphorus, sulphur, etc.) increases with the increase in pressure while the melting point of those substances which contract on melting (*e.g.*, ice, cast iron, bismuth etc.) decreases with increase in pressure.

Regelation : The phenomenon in which ice melts when pressure is increased and again freezes when pressure is removed is called regelation.

Example : Skating is possible due to the formation of water layer below the skates. Water is formed due to the increase of pressure and it acts as a lubricant.

32. (a) We know that $a + r + t = 1$

Where a, r and t are absorbance, reflectance and transmittance respectively of the surface of the body, t is also called emittance (e). Also according to Kirchhoff's law $e \propto a$, that is good absorbers are good emitters and hence poor reflectors and vice-versa *i.e.*, if r is large (*i.e.*, large reflectively) a is smaller and hence e is smaller *i.e.*, poor emitter.

(b) The thermal conductivity of brass is high *i.e.*, brass is a good conductor of heat. So when a brass tumbler is touched, heat quickly flows from human body to the tumbler. Consequently, the tumbler appears colder. On the other hand, wood is a bad conductor of heat. So heat does not flow from the human body to the wooden tray, thus it appears relatively hotter.

(c) Gases are generally insulators. The Earth's atmosphere acts like an insulating blanket around it and does not allow heat to escape out but reflects it back to the Earth. If this atmosphere is absent, then the Earth would naturally be colder as all its heat would have escaped out.

(d) This is because steam has much higher heat capacity (540 cal g^{-1}) than the heat capacity of water (80 cal g^{-1}) at the same temperature. Thus heating systems based on circulation of steam are more efficient than those based on circulation of hot water.

33. Coefficient of linear expansion : It is defined as the increase in length per unit original length per degree rise in temperature.

$$\alpha = \frac{\text{Increase in length}}{\text{Original length} \times \text{Rise in temperature}}$$

$$\alpha = \frac{L_T - L_0}{L_0 \times \Delta T} \quad \text{or} \quad L_T = L_0 (1 + \alpha\Delta T)$$

Coefficient of area expansion : It is defined as the increase in surface area per unit original surface area per degree rise in temperature.

$$\beta = \frac{\text{Increase in area}}{\text{Original area} \times \text{Rise in temperature}}$$

$$\beta = \frac{A_T - A_0}{A_0 \times \Delta T} \quad \text{or} \quad A_T = A_0(1 + \beta\Delta T)$$

Coefficient of volume expansion : It is defined as the increase in volume per unit original volume per degree rise in temperature.

$$\gamma = \frac{\text{Increase in volume}}{\text{Original volume} \times \text{Rise in temperature}}$$

$$\gamma = \frac{V_T - V_0}{V_0 \times \Delta T} \quad \text{or} \quad V_T = V_0(1 + \gamma\Delta T)$$

Consider a cube of side l. Its original volume is $V = l^3$

Suppose the cube is heated so that its temperature increases by ΔT. Its each side will become

$l' = l(1 + \alpha\,\Delta T)$

The new volume of the cube will be

$V' = l'^3 = l^3(1 + \alpha\,\Delta T)^3$

$\quad = V(1 + 3\alpha\,\Delta T + 3\alpha^2\,\Delta T^2 + \alpha^3\,\Delta T^3)$

As α is small, so the terms containing α^2 and α^3 can be neglected. Then $V' = V(1 + 3\alpha\,\Delta T)$

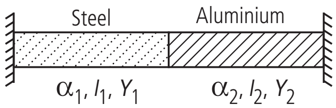
By the definition of the coefficient of cubical expansion,

$$\gamma = \frac{V' - V}{V\Delta T} = \frac{V(1+3\alpha\Delta T) - V}{V\Delta T} = 3\alpha$$

Similarly, it can be prove that $\beta = 2\alpha$

Hence $\frac{\alpha}{1} = \frac{\beta}{2} = \frac{\gamma}{3}$.

34. If allowed to expand the rods increase in length by $l_1\alpha_1 T$ and $l_2\alpha_2 T$. Because of walls, there is no free expansion. If one expands, the other would compress. Let the junction shift by x towards steel side (towards left).



Then, length of steel rod is $(l_1 - x)$ and length of aluminium rod is $(l_2 + x)$

In equilibrium, let thermal stress in rods are σ_1 and σ_2

Then, $\sigma_1 = \frac{Y_1 A(-x + l_1\alpha_1 T)}{l_1}$

and $\sigma_2 = \frac{Y_2 A(x + l_2\alpha_2 T)}{l_2}$

At the joint in equilibrium, forces due to thermal stress balances each other.

$\Rightarrow \quad F_1 = F_2 \Rightarrow \frac{F_1}{A} = \frac{F_2}{A}$

$\Rightarrow \quad \sigma_1 = \sigma_2$

$\Rightarrow \quad \frac{Y_1 A(-x + l_1\alpha_1 T)}{l_1} = \frac{Y_2 A(x + l_2\alpha_2 T)}{l_2}$

$\Rightarrow \quad x(Y_2 l_1 + Y_1 l_2) = l_1 l_2 (Y_1\alpha_1 - Y_2\alpha_2)T$

$\Rightarrow \quad x = \frac{l_1 l_2 (Y_1\alpha_1 - Y_2\alpha_2)\cdot T}{Y_2 l_1 + Y_1 l_2}$

Substituting the values, we get

$$x = \frac{\left[100\times7\times20(1.2\times10^{-5}\times20\times10^{10} - 2.4 \times 10^{-5}\times7\times10^{10})\right]}{(20\times7\times10^{10} + 7\times20\times10^{10})}$$

$$= \frac{100\times7\times20\times10^{4}(240-168)}{2\times20\times7\times10^{10}}$$

$x = 36 \times 10^{-4}$ m $= 36 \times 10^{-4} \times 10^{3}$ mm $= 3.6$ mm

$\therefore \quad \frac{N^2}{10} = 3.6$

$\Rightarrow \quad N^2 = 36$ or $N = 6$

35. (a) Radius of the ball, $r = 0.5$ m

$\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}, $T = 10^6$ K

Surface area of nuclear weapon,

$A = 4\pi r^2 = 4 \times 3.14 \times (0.5)^2 = 3.14$ m^2

$\therefore$ Power radiated, $P = (\sigma T^4)A$

$= 5.67 \times 10^{-8} \times (10^6)^4 \times 3.14 = 1.8 \times 10^{17}$ W

(b) Energy radiated, $E = P \times t$

$= 1.8 \times 10^{17}$ W $\times$ 1 s $= 1.8 \times 10^{17}$ J

Q = 10% of $E = 1.8 \times 10^{16}$ J

Also, $Q = mc_w \Delta T + mL_v = m(c_w\Delta T + L_v)$

Here, $c_w = 4186$ J kg^{-1} K^{-1}

$L_v = 22.6 \times 10^5$ J kg^{-1}

$\Delta T = 100 - 30 = 70$ °C $= 70$ K

$\therefore \quad m = \frac{Q}{(c_w\Delta T + L_v)} = \frac{1.8\times10^{16}}{4186\times70 + 22.6\times10^5}$

$= \frac{1.8\times10^{16}}{25.53\times10^5} = 7\times10^9$ kg

(c) $\because \quad p = \frac{U}{c}$

The radiation spread in an area of $4\pi r^2$

Here, r = 1 km $= 10^3$ m

Momentum imparted per unit time on a unit area at a distance r,

$= \frac{(U/c)}{4\pi r^2 t} = \frac{U}{4\pi c r^2 t} = 4\pi c r^2$

$= \frac{1.8\times10^{17}}{4\times3.14\times3\times10^8\times10^6} = 47.7$ N m^{-2}