CBSE

THERMAL PROPERTIES OF MATTER WS 10
Class 11 - Physics

Section A

1. A 200- cm^3 glass flask is filled to the brim with mercury at 20°C. How much mercury overflows when the temperature of the system is raised to 100° C.The coefficient of linear expansion of the glass is 0.40×10^{-5}/°C. Coefficient of volume expansion of mercury is 1.82×10^{-4}/°C. **[1]**

    a) 2.3 cm^3

    b) 2.5 cm^3

    c) 2.7 cm^3

    d) 2.9 cm^3

2. A steel railroad track has a length of 30.000 m when the temperature is 0.0°C. Suppose that the ends of the rail are rigidly clamped at 0.0°C so that expansion is prevented. What is the thermal stress set up in the rail if its temperature is raised to 40.0°C? $\alpha-$ steel = 11×10^{-6} (°C)$^{-1}$ Y-steel = 20GPa? **[1]**

    a) $8.4 \times 10^6 N/m^2$

    b) $8.1 \times 10^7 N/m^2$

    c) $9.1 \times 10^7 N/m^2$

    d) $8.8 \times 10^6 N/m^2$

3. A brass rod of length 50 cm and diameter 3.0 mm is joined to a steel rod of the same length and diameter. What is the change in length of the combined rod at 250 °C, if the original lengths are at 40.0 °C? The ends of the rod are free to expand (Co-efficient of linear expansion of brass = $2.0 \times 10^{-5} K^{-1}$, steel = $1.2 \times 10^{-5} K^{-1}$). **[1]**

    a) 0.38 cm.

    b) 0.42 cm.

    c) 0.34 cm.

    d) 0.36 cm.

4. The radius of a metal sphere at room temperature T is R, and the coefficient of linear expansion of the metal is α. The sphere is heated a little by a temperature ΔT so that its new temperature is T + ΔT. The increase in the volume of the sphere is approximately **[1]**

    a) $2\pi R\alpha\Delta T$

    b) $4\pi R^3 \alpha \Delta T/3$

    c) $4\pi R^3 \alpha \Delta T$

    d) $\pi R^2 \alpha \Delta T$

5. When a body is heated, then maximum rise will be in its **[1]**

    a) surface area

    b) density

    c) volume

    d) length

6. The volume of a gas at 20°C is 100 cm^3 at normal pressure. If it is heated to 100° C, its volume becomes 125 cm^3 at the same pressure, then volume coefficient of the gas (at normal pressure) is **[1]**

    a) 0.0033/°C

    b) 0.0021/°C

    c) 0.0030/°C

    d) 0.0025/°C

7. A surveyor uses a steel measuring tape that is exactly 50.000 m long at a temperature of 20°C. The markings on **[1]**

the tape are calibrated for this temperature.

  i. What is the length of the tape when the temperature is 35°C?

  ii. When it is 35°C, the surveyor uses the tape to measure a distance. The value that she reads off the tape is
    35.794 m. What is the actual distance? $\alpha = 1.2 \times 10^{-5}$°C

    a) 50.008 m, 35.600 m   b) 50.009 m, 35.800 m

    c) 50.007 m, 35.750 m   d) 50.010 m, 35.900 m

8.   A large steel wheel is to be fitted on to a shaft of the same material. At 27 °C, the outer diameter of the shaft is **[1]** 8.70 cm and the diameter of the central hole in the wheel is 8.69 cm. The shaft is cooled using 'dry ice'. At what temperature of the shaft does the wheel slip on the shaft? Assume the coefficient of linear expansion of the steel to be constant over the required temperature range: $\alpha_{\text{steel}} = 1.20 \times 10^{-5}\ \text{K}^{-1}$.

    a) – 69 °C   b) – 79 °C

    c) – 89 °C   d) – 59 °C

9.   A composite rod made of copper ($\alpha = 1.8 \times 10^{-5}\ \text{K}^{-1}$) and steel ($\alpha = 12 \times 10^{-5}\ \text{K}^{-1}$) is heated. Then **[1]**

    a) it bends with steel on concave side   b) data is insufficient

    c) it does not expand   d) it bends with copper on concave side

10.   **Assertion (A):** Rubber contract on heating. **[1]**

  Reason (R): In rubber as temperature increases, the amplitude of transverse vibrations increases more than the amplitude of longitudinal vibrations.

    a) Both A and R are true and R is the correct   b) Both A and R are true but R is not the
       explanation of A.   correct explanation of A.

    c) A is true but R is false.   d) A is false but R is true.

11.   **State True or False:** **[1]**

   (a)   When a metal plate with a hole is heated up, the metal expands and the hole shrinks. **[1]**

12.   **Fill in the blanks:** **[1]**

   (a)   Water has _____ volume and _____ density at 4°C **[1]**

13.   A bimetallic strip consists of metals X and Y. It is mounted rigidly at the base as shown below: **[1]** The metal X has a higher coefficient of expansion compared to that for metal Y. When the bimetallic strip is placed in a cold bath,
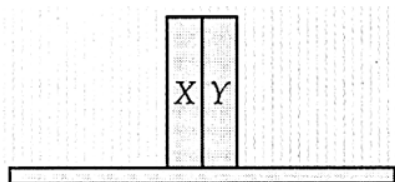
    a) it will bend towards the left   b) it will bend towards the right

    c) it will neither bend nor shrink   d) it will not bend but shrink

14.   The diameters of steel rods A and B having the same length are 2 cm and 4 cm respectively. They are heated **[1]** through 100° C. What is the ratio of increase of length of A to that of B?

15.   Why is a gap left between the ends of two railway lines in a railway track? **[1]**

16.   Why are loops provided in long metal pipes used for carrying oil and any other liquid over long distances? **[1]**

17. A brass disc fits snugly in a hole in a steel plate. Should we heat or cool the system to loosen the disc from the hole. **[1]**

18. A cylinder of diameter 1.0 cm at 30°C s to be slid into a hole in a steel plate. The hole has a diameter of 0.99970 cm at 30°C. To what temperature must the plate be heated? For steel, a = 1.1×10^{-5} °C^{-1}. **[1]**

19. Why is invar used in making a clock pendulum? **[1]**

20. Two rods, one of aluminum 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 coefficients of linear expansion for aluminium and steel are α_a and α_g respectively. If the length of each rod increases by the same amount when their temperatures are raised by t°C, then find the ratio $\frac{l_1}{(l_1+l_2)}$. **[1]**

21. The density of mercury is 13.6 g cm^{-3} at 0° C and its coefficient of cubical expansion is 1.82×10^{-4} °C^{-1}. Calculate the density of mercury at 50° C. **[1]**

22. A liquid of cubical expansivity γ is heated in a vessel having linear expansivity $\frac{\gamma}{3}$. What would be the effect on the level of the liquid? **[1]**

23. Density ρ, mass m and volume V are related as $\rho = \frac{m}{V}$. Prove that $\gamma = -\frac{1}{\rho}\frac{d\rho}{dT}$. **[1]**

Section B

24. Two rods of different metals of coefficient of linear expansion α_1 and α_2 and initial lengths I_1 and I_2 respectively are heated to the same temperature, Find relation in α_1, α_2, I_1 and I_2 such that difference between their lengths remains constant at any temperature. **[2]**

25. Two large holes are cut in a metal sheet. If the sheet is heated, how will the distance between the two holes increase or decrease on heating? **[2]**

26. Why does the density of solid | liquid decreases with rise in temperature? **[2]**

27. What is invar? What is its speciality and what is its use? **[2]**

28. State Stefan-Boltzmann law. Write the CGS and SI units of Stefan-Boltzmann constant. **[2]**

29. A metallic ball has a radius of 9.0 cm at 0°C. calculate the change in its volume when it is heated to 90°C. Given that the coefficient of linear expansion of metal of ball is 1.2×10^{-5} K^{-1}. **[2]**

30. A clock having a brass pendulum beats seconds at 30°C. How many seconds will it lose or gain per day when temperature falls to 10°C? Given a for brass = 1.9×10^{-5} °C^{-1}. **[2]**

31. Due to the change in mains voltage, the temperature of an electric bulb rises from 3000 K to 4000 K. What is the percentage rise in electric power consumed? **[2]**

32. There are two spheres of same radius and material at same temperature but one being solid while the other hollow. Which sphere will expand more if **[2]**

    i. they are heated to the same temperature

    ii. same amount of heat is given to each of them?

33. A steel wire of 2.0 mm ^{2} cross-section is held straight (but under no tension) by attaching it firmly to two points a distance 1.50 m apart at 30°C. If the temperature now decreases to 5°C and if the two points remain fixed, what will be the tension in the wire? **[2]**

    Given that Young's modulus of steel = 2×10^{11} Nm^2 and coefficient of thermal expansion of steel a =1.1×10^{-5}/ °C.

34. a. Why the brake drums of a car are heated when it moves down a hill at constant speed? **[2]**
    b. Why pendulum clocks generally go faster in winter and slow in Summer?

35. When a block of iron floats in mercury at 0°C, a fraction k_1 of its volume is submerged, while at the temperature 60° C, a fraction k_2 is seen to be submerged. If the coefficient of volume expansion of iron is γ_{Fe} and that of mercury is γ_{Hg}, then find the ratio k_1/k_2. **[2]**

36. Find out the increase in moment of inertia I of a uniform rod (coefficient of linear expansion α) about its perpendicular bisector when its temperature is slightly increased by $\triangle$T. **[2]**

37. One litre flask contains some mercury. It is found that at different temperatures, the volume of air inside the flask remains the same. What is the volume of mercury in this flask? Given α for glass = 9×10^{-6} °C^{-1} and γ for mercury = 1.8×10^{-4} °C^{-1}. **[2]**

38. The brass scale of a barometer gives correct reading at 0°C. Coefficient of linear expansion of brass is 2.0×10^{-5}/°C. The barometer reads 75.00 cm at 27°C. What is the true atmospheric pressure at 27°C? **[2]**

39. Thick bottomed drinking glasses frequently crack if hot water is poured into them. Why? **[2]**

40. The design of some physical apparatus requires that there be a constant difference in length at any temperature between iron and copper cylinders laid side by side. What should be the length of the cylinders at 0°C for the difference in length to be 10 cm at all temperatures? Given! a for iron = 1.1×10^{-5} °C^{-1} and for copper = 1.7×10^{-5} °C^{-1}. **[2]**

41. A steel scale measures the length of a copper rod as 80 cm when both are at 20° C, the calibration temperature of the scale. What would the scale read for the length of the rod when both are at 40° C? Given α for steel = 1.1×10^{-5} °C^{-1} and α for copper = 1.7×10^{-5} °C^{-1}. **[2]**

42. Prove that the coefficient of cubical expansion of an ideal gas at constant pressure is equal to the reciprocal of its absolute temperature. **[2]**

43. The coefficient of volume expansion of glycerine is 49×10^{-5} °C^{-1}. What is the fractional change in its density for a 30°C rise in Temperature? **[2]**

Section C

44. A thin rod having length L_0 at 0°C and coefficient of linear expansion α has its two ends maintained at temperatures θ_1 and θ_2, respectively. Find its new length. **[3]**

45. The coefficient of volume expansion of glycerin is $49 \times 10^{-5} \text{K}^{-1}$. What is the fractional change in its density for a 30 °C rise in temperature? **[3]**

46. Develop a relation between the co-efficient of linear expansion, co-efficient superficial expansion and coefficient of cubical expansion of a solid. **[3]**

47. A steel tape 1m long is correctly calibrated for a temperature of 27.0 °C. The length of a steel rod measured by this tape is found to be 63.0 cm on a hot day when the temperature is 45.0 °C. What is the actual length of the steel rod on that day? What is the length of the same steel rod on a day when the temperature is 27.0 °C? Coefficient of linear expansion of steel = 1.20×10^{-5} K^{-1}. **[3]**

48. What do you mean by coefficients of apparent and real expansion of a liquid? How are they related? **[3]**

49. Calculate the stress developed inside a tooth cavity filled with copper when hot tea at temperature of 57°C is drunk. You can take body (tooth) temperature to be 37° C and α = 1.7×10^{-5}/K. Bulk modulus for copper = 140×10^9 N/m^2. **[3]**

50. What is meant by coefficient of linear expansion and coefficient of cubical expansion? Derive relationship between them. **[3]**

51. An ice cube of mass 0.1 kg at 0°C is placed in an isolated container which is at 227°C. The specific heat S of the **[3]**

container varies with temperature T according to the empirical relation S = A + BT, where A = 100 cal/kg-K and B = 2×10^{-2} cal/kg-K^2. If the final temperature of the container is 27°C, determine the mass of the container. (Latent heat of fusion of water = 8×10^4 call kg. Specific heat of water = 10^3 cal /kg-K).

52. Discuss the anomalous expansion of water. Give its practical importance. **[3]**

53. Mention three applications of thermal conductivity in daily life. **[3]**

54. Briefly explain, what do you mean by the terms thermal strain and thermal stress? Write expressions for them. **[3]**

55. Show that the coefficient of volume expansion for a solid substance is three times its coefficient of linear expansion. **[3]**

56. How does the density of a solid affected when the solid is heated? Derive the mathematical relation. **[3]**

57. How does the coefficient of cubical expansion of a substance vary with temperature? Draw γ versus T curve for copper. **[3]**

Section D

Question No. 58 to 62 are based on the given text. Read the text carefully and answer the questions: **[5]**

All three states of matter (solid, liquid and gas) expand when heated. Thermal expansion can be defined as the change in the length, width, height, or volume of any material on changing the temperature. It is a well-known phenomenon now that substances expand on heating and contract on cooling


58. A pendulum clock shows the correct time at a definite temperature. At a higher temperature the clock

    a) neither gains nor loses time   b) gain time

    c) loses times   d) Remain same

59. Gaps are left between railway tracks because

    a) look good to leave the gap   b) it is customary to leave the gap

    c) gaps give the space to the tracks to expand in the summer   d) gaps hold the track firmly

60. When a copper ball is heated, the largest percentage increase will occur in its

    a) All of these   b) Area

    c) Diameter   d) Volume

61. Expansion during heating

    a) decrease the weight of the material   b) occurs only in solid

    c) increase the weight of the material   d) decrease the density of the material

62. If the length of the cylinder on heating increases by 2%, the area of the base will increase by:

    a) 4%   b) 2%

    c) 5%   d) 3%

63. An equilateral triangle ABC is formed by two Cu rods AB and BC and one Al rod. It is heated in such a way that temperature of each rod increases ΔT. Find change in the angle ABC. [Coefficient of linear expansion for Cu is α_1] ,Coefficient of linear expansion for Al is α_2]. **[5]**

64. On what factors does the rate of heat conduction in a metallic rod in the steady state depend? Write the necessary **[5]** expression and hence define the coefficient of thermal conductivity. Write its units and dimensions also.

65. We would like to prepare a scale whose length does not change with temperature. It is proposed to prepare a unit **[5]** scale of this type whose length remains, say 10 cm. We can use a bimetallic strip made of brass and iron each of different length whose length (both components) would change in such a way that difference between their lengths remain constant. If $\alpha_{iron} = 1.2 \times 10^{-5}$/ K and $\alpha_{\text{brass}} = 1.8 \times 10^{-5}$ what should we take as length of each strip?

66. The electrical resistance in ohms of a certain thermometer varies with temperature according to the approximate **[5]** law: R = R_0 [1 + α(T - T_0)]

   The resistance is 101.6 Ω at the triple-point of water 273.16 K, and 165.5Ω at the normal melting point of lead (600.5 K). What is the temperature when the resistance is 123.4Ω?

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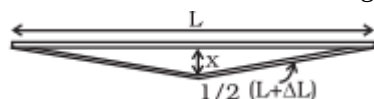
   On a summer day due to rise in temperature by 20° C, it is deformed as shown in figure. Find *x* (displacement of the centre) if α_{steel} = 1.2 $\times$ 10^{-5} /°C.

68. A hole is drilled in a copper sheet. The diameter of the hole is 4.24 cm at 27.0 °C. What is the change in the **[5]** diameter of the hole when the sheet is heated to 227 °C? Coefficient of linear expansion of copper $= 1.70 \times 10^{-5} \mathrm{K}^{-1}$.

69. What is meant by coefficient of linear expansion, superficial expansion and cubical expansion? Derive the **[5]** relationship between them.

70. We would like to make a vessel whose volume does not change with temperature (take a hint from the problem **[5]** above). We can use brass and iron ($\gamma_{brass} = 6 \times 10^{-5} K^{-1} \gamma_{iron} = 3.55 \times 10^{-5} K^{-1}$) to create a volume of 100 cm^3. How do you think you can achieve this?

71. A brass wire of length 1.8 m at 27 °C is held tight with little tension between two rigid supports. If the wire is **[5]** cooled to a temperature of -39 °C. What is the tension developed in the wire, if its diameter is 2.0 mm? Co-efficient of linear expansion of brass $= 2.0 \times 10^{-5} \mathrm{K}^{-1}$; Young's modulus of brass $= 0.91 \times 10^{11} \mathrm{Pa}$.

72. Draw a labelled P-T diagram of water. Explain its behavior, when both pressure P and temperature T are above **[5]** and below the triple point. Give the importance of the triple point.

73. A brass rod of length 50 cm and diameter 3.0 mm is joined to a steel rod of the same length and diameter. What **[5]** is the change in length of the combined rod at 250 °C, if the original lengths are at 40.0 °C? Is there a 'thermal stress' developed at the junction? The ends of the rod are free to expand (Co-efficient of linear expansion of brass = $2.0 \times 10^{-5} K^{-1}$, Co-efficient of linear expansion of steel = $1.2 \times 10^{-5} K^{-1}$).

74. Show that the coefficient of area expansion, $\frac{\frac{\Delta A}{A}}{\Delta T}$, of a rectangular sheet of the solid is twice its linear **[5]** expansivity, α_1.

75. **Read the case study given below and answer any four subparts:** **[5]**

   All three states of matter (solid, liquid and gas) expand when heated. Thermal expansion can be defined as the change in the length, width, height, or volume of any material on changing the temperature. It is a well-known

phenomenon now that substances expand on heating and contract on cooling

i. A pendulum clock shows the correct time at a definite temperature. At a higher temperature the clock

    a. loses times

    b. gain time

    c. neither gains nor loses time

    d. none of these

ii. Gaps are left between railway tracks because:

    a. gaps hold the track firmly

    b. gaps give the space to the tracks to expand in the summer

    c. It is customary to leave the gap

    d. none of these

iii. When a copper ball is heated, the largest percentage increase will occur in its:

    a. Diameter

    b. area

    c. volume

    d. all of the above

iv. Expansion during heating:

    a. occurs only in solid

    b. increase the weight of the material

    c. decrease the density of the material

    d. none of these

v. If the length of the cylinder on heating increases by 2 %, the area of the base will increase by:

    a. 2%

    b. 3%

    c. 4%

    d. 5%