PHYSICS

BOOKS - CHHAYA PHYSICS (BENGALI ENGLISH)

EXPANSION OF SOLIDS AND LIQUIDS

Numerical Examples

1. A steel is 1.5 m long at $20^\circ C$. What will be the increase in its length if it is heated up to $100^\circ C$? α for steel $= 11 \times 10^{-6\circ} C^{-1}$.

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2. The length of a zinc rod, when heated from $20^\circ C$ to $80^\circ C$, increase by 0.6 cm. If the coefficient of linear expansion of zinc is $27 \times 10^{-6^\circ} C^{-1}$, what is the initial length of the rod?

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3. The lengths of a copper rod are 200.166 cm and 200.664 cm at $50^\circ C$ and $200^\circ C$ respectively. What is the coefficient of linear expansion of copper?

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4. A brass rod has a length of 150 cm at $40^\circ C$. What will be its length at $100^\circ C$? The coefficient of linear expansion of brass is $18 \times 10^{-6} {}^\circ C^{-1}$.

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5. Coefficient of linear expansion of aluminium is 19×10^{-6} per degree celsius. What will be the value of this coefficient in Fahrenheit scale?

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6. At $30^\circ C$ the diameter of a brass disc is 8 cm. What will be the increase in surface area if it is heated to $80^\circ C$? α of brass $= 18 \times 10^{-6\circ} C^{-1}$.

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7. A rectangular copper block measures $20cm \times 12cm \times 3cm$. What will be the change in volume of the block when it is heated from $0^\circ C$ to $800^\circ C$? Coefficient of linear expansion of copper is $0.16 \times 10^{-4\circ} C^{-1}$.

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8. A lead bullet has a volume of $2.5cm^3$ at $0^\circ C$. Its volume increases by $0.021cm^3$ when heated to $98^\circ C$. Find the coefficient of linear expansion of lead.

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9. An aluminium sphere of diameter 20 cm is heated from $0^\circ C$ to $100^\circ C$. What will be its change in volume? Coefficient of linear expansion of aluminium $= 23 \times 10^{-6\circ} C^{-1}$.

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10. A piece of metal weighs $46g \times g$ in air. When immersed in a liquid of relative density 1.24, kept at $27^\circ C$, its weight is $30g \times g$. When the temperature of the liquid is raised to $42^\circ C$, the metal piece in it weighs $30.5g \times g$. At $42^\circ C$, the relative density of the liquid is 1.20. Find the coefficient of linear expansion of the metal.

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11. Density of glass at $10^\circ C$ is 2.6 $g \cdot cm^{-3}$ and that at $60^\circ C$ is $2.596g \cdot cm^{-3}$. What is the average

value of the coefficient of linear expansion of glass between these two temperatures?

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12. Two ends of a steel rod are rigidly fixed with two supports. At $30^\circ C$ its area of cross-section is 4 cm^2. How much force will be exerted on the supports by the ends of the rod if the temperature of the rod is raised by $60^\circ C$? [Young's modulus of steel $= 2.1 \times 10^{12} dyn \cdot cm^{-2}$ and its coefficient of linear expansion is $12 \times 10^{-6} {}^\circ C^{-1}$]

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13. Two ends of a wire are rigidly clamped. If its temperature is decreased by $10^{\circ}C$, find the change in the tension of the wire.

Area of cross-section of the wire $= 0.01cm^2$,

$\alpha = 16 \times 10^{-6\circ}C^{-1}, Y = 20 \times 10^{11} dyn.\ cm^{-2}$

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14. The difference in length of two metal rods A and B is 25 cm at all temperatures. Coefficients of linear expansion of the materials of A and B are $1.28 \times 10^{-5\circ}C^{-1}$ and $1.92 \times 10^{-5\circ}C^{-1}$ respectively. Find the length of each rod at $0^{\circ}C$.

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15. The difference in length of an iron rod and a copper rod at $50^\circ C$ is 2 cm. This difference remains the same also at $450^\circ C$. What are the lengths of the rods at $0^\circ C$? Given, α for iron $= 12 \times 10^{-6\circ} C^{-1}$ and α for copper $= 17 \times 10^{-6\circ} C^{-1}$.

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16. A metal scale measures correct reading at $25^\circ C$. A rod is measured to be 80 cm by the scale

at $15^{\circ}C$. What is the actual length of the rod? $(\alpha = 15 \times 10^{-6\circ}C^{-1})$

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17. A steel scale is error-less at $50^{\circ}F$. Using the scale, the length of a brass rod is found to be 1.5 m at $50^{\circ}C$. What is the true length of the rod at $100^{\circ}C$? (Coefficients of linear expansion of steel and brass are $11.2 \times 10^{-6\circ}C^{-1}$ and $18 \times 10^{-6\circ}C^{-1}$ respectively.)

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18. The brass scale of a barometer has no error at $0^{\circ}C$. α of brass $= 0.00002^{\circ}C^{-1}$. The reading of the barometer at $27^{\circ}C$ is 75 cm. What is the actual reading of the barometer?

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19. A steel ring is heated up to $95^{\circ}C$ to fit exacty on the outer surface of an iron cylinder of diameter 10 cm at $20^{\circ}C$. After fitting, the ring is cooled so that the system attains a temperature $20^{\circ}C$. What is the thermal stress of the ring? [Young's modulus of

steel $=21 \times 10^5 kg \cdot cm^{-2}$ and α for steel $= 12 \times 10^{-6\circ} C^{-1}.]$

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20. A metre scale made of steel is to be so graduated that at any temperature a reding of 1 mm should be correct up to 0.0005 mm. What can be the maximum allowed change in temperature while marking the millimetre gaps? Coefficient of linear expansion of steel $= 13.22 \times 10^{-6\circ} C^{-1}.$

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21. At $0^\circ C$, three rods of equal length form an equilateral triangle. Among the three rods, one is made of invar (with neligible expansion) and the other two rods are made of some other metal. When the triangle is heated up to $100^\circ C$, the angle between the two rods of the same metal changes to $\left(\frac{\pi}{3} - \theta\right)$. Show that the coefficient of linear expansion of the metal is $\frac{\sqrt{3}\theta}{200}{}^\circ C^{-1}$.

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22. On each surface of a solid cube, a uniform pressure p is applied. Calculate the temperature

rise of the solid cube so that its volume remains unaltered. Given, the coefficient of volume expansion of the material of the cube $= \gamma$ and its bulk modulus of elasticity = B.

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23. One end of a 100 cm long rod is fixed. At its free end a screw is attached and the pitch of the screw is 0.5 mm. The rod can move along its length on turning the screw. The screw has a circular scale with 100 divisions. It moves by one small scale division of 0.5 mm per turn. At $20^{\circ} C$, the pitch scale reads a little over zero and the circular scale reads

92. When the temperature is increased to $100^{\circ}C$, the pitch scale reading changes to a little above 4 divisions and the circular scale reading is 72. Find the coefficient of linear expansion of the material of the rod.

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24. Two rods of the same cross-sectional area are attached end to end forming a total length of 1 m, at $25^{\circ}C$. One rod in the combination is a 30 cm long copper rod. The composite rod, increases by 1.91 mm at $125^{\circ}C$. If the composite rod is rigidly fixed between two walls so that no change in length

may occur even with the rise in temperature, find the Young's modulus (Y) and the coefficient of linear expansion (α) for the second rod. α for copper $= 1.7 \times 10^{-5\circ} C^{-1}$, Y for copper $= 1.3 \times 10^{11} N \cdot m^{-2}$.

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25. An aluminium sphere at $20^\circ C$ is kept at 1 standard atmosphere pressure, in a pressure chamber covered with oil. What should be the rise in pressure on the sphere to keep its volume unchanged even at $35^\circ C$? Coefficient of linear expansion of aluminium, $\alpha = 23 \times 10^{6\circ} C^{-1}$ and

its bulk modulus of elasticity, $K = 7.7 \times 10^{10} N \cdot m^{-2}$.

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26. Two rods, each of coefficient of linear expansion α_2 and length l_2, form the two sides of an isosceles triangle and the base is formed by another rod of length l_1 and coefficient of linear expansion α_1. The base is fixed horizontally at its mid-point. What should be the relationship between l_1 and l_2 so that the distance of the vertex from the mid-point of the base, does not change for any increase in temperature?

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27. Two metal plates of length l_0 and width x are joined together at temperature t by rivetting them in such a way that the edges of the plates coincide. The coefficients of linear expansion of the materials of the plates are α_1 and $\alpha_2(\alpha_1 > \alpha_2)$. When the bimetallic strip is heated to $(t + \delta t)$ it bends and forms an arc of a circle. Find the radius of curvature of the strip.

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28. One end of a 600 cm long steel bar is fixed rigidly and the other end rests on a lever, 10 cm away from its fulcrum. The lever turns through 2° when the bar is heated up to $50^\circ C$. Find the increase in length of the bar and its coefficient of linear expansion.

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29. Three rods of equal length at $0^\circ C$, are connected with one another to form an equilateral triangle ABC [Fig. 5.10]. Coefficient of linear expansion for the rod AB is α and that for the other

two rods is β. What will be the increment in the measure of the angle at C if the triangle is heated to $t^{\circ}C$?

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30. A steel wire with a cross-sectional area $0.4mm^2$ is fixed tightly at $20^{\circ}C$ between two rigid supports. If the temperature falls to $0^{\circ}C$, what will be the tension on the string? Given, for steel, Y $= 2 \times 10^{12} dyn \cdot cm^{-2}$ and $\alpha = 12 \times 10^{-6\circ} C^{-1}$.

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31. Structure of an equilateral triangle ABC is made using three thin rods. Another rod AD connects the vertex A with D, the mid-point of BC. Coefficient of linear expansion for AB and AC is α and that for the base BC is β. Show that, if the coefficient of linear expansion for the rod AD is $\frac{1}{3}(4\alpha - \beta)$, the arms of the system will not show any tendency to bend, for a small rise in temperature.

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32. A thin square metal plate has side of length l_0. When the temperature of the plate is raised from

$0^\circ C$ to $100^\circ C$, its length increased by 1%. What is the percentage increase in area of the plate in this case?

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33. Coefficient of apparent expansion of mercury with respect to glass is $153 \times 10^{-6\circ} C^{-1}$. Find the coefficient of linear expansion (α_g) of glass where coefficent of real expansion of mercury is $180 \times 10^{-6\circ} C^{-1}$.

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34. A liquid has a coefficient of apparent expansion, $18 \times 10^{-5\circ} C^{-1}$ for an iron container, and $14.46 \times 10^{-5\circ} C^{-1}$ for an aluminium container. If the coefficient of linear expansion of aluminium is $2.38 \times 10^{-5\circ} C^{-1}$, find that of iron.

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35. A thin long glass tube of uniform cross-section contains 1 m long mercury thread at $0^\circ C$. At $100^\circ C$, the mercury thread increases by 16.5 mm. If the coefficient of real expansion of mercury is

$0.000182^{\circ}C^{-1}$, find the coefficient of linear expansion of glass.

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36. The internal volume of a glass flask is Vcm^3. What volume of mercury should be kept in the flask so that the volume of the empty space over mercury in the flask remains constant at all temperatures? Coefficient of volume expansion of mercury $= 1.8 \times 10^{-4^{\circ}}C^{-1}$ and coefficient of linear expansion of glass $= 9 \times 10^{-6^{\circ}}C^{-1}$.

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37. The volume expansion coefficients of glass and mercury are $2.4 \times 10^{-5\circ} C^{-1}$ and $1.8 \times 10^{-4\circ} C^{-1}$ respectively. What volume of mercury should be kept in the flask so that the volume of the empty space over mercury in the flask remains constant at all temperatures?

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38. The internal volume of a glass flask is $540 cm^3$. What volume of mercury should be kept in the flask so that the volume of the empty space remains

constant at any temperature? Real expansion of mercury $= 1.8 \times 10^{-4^\circ} C^{-1}$ and volume expansion of glass $= 2.5 \times 10^{-5^\circ} C^{-1}$.

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39. The volume of the bulb of a mercury thermometer is 1 cm^3 at $0^\circ C$, and it is filled with mercury at that temperature. The tube attached to the bulb has an area of cross-section 0.1 mm^2. If the coefficient of apparent expansion of mercury is $16 \times 10^{-5^\circ} C^{-1}$, find the length up to which mercury expands in the tube, when the bulb is immersed in boiling water.

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40. 1 g water has a volume of 1 cm^3 at $4^\circ C$. Its volume at $60^\circ C$ is $1.0169 cm^3$. Calculate the average coefficient of real expansion of water between these two temperatures.

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41. Masses of 10 cm^3 of water are 9.998 g and 10 g at $0^\circ C$ and $4^\circ C$ respectively. Find the average coefficient of real expansion of water within the range of these temperatures.

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42. Density of mercury at $0^\circ C$ is $13.5955 g \cdot cm^{-3}$. If the coefficient of linear expansion of mercury is $0.000061^\circ C^{-1}$, find its density at $60^\circ C$.

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43. Density of mercury at $15^\circ C$ is $13.56 g \cdot cm^{-3}$ and its coefficient of real expansion is $18 \times 10^{-5\circ} C^{-1}$. What will be the mass of $600 cm^3$ of mercury at $130^\circ C$? What will be the volume of 600 g of mercury at $130^\circ C$?

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44. Density of mercury is $13.6g \cdot cm^{-3}$ at $0^{\circ}C$. What will be the volume of 100 g of mercury at $100^{\circ}C$? Coefficient of real expansion of mercury $\frac{1}{5550}{}^{\circ}C^{-1}$.

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45. A piece of metal weighs $50g$ in air. It weighs $45g$ when immersed in a liquid at $25^{\circ}C$, and $45.1g$ at $100^{\circ}C$. If the coefficient of linear

expansion of the metal is $12 \times 10^{-6\circ} C^{-1}$, find the coefficient of real expansion of the liquid.

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46. A glass rod weighs $90g \times g$ in air. It weighs $49.6g \times g$ when immersed in a liquid at $12^\circ C$, and $51.9g \times g$ at $97^\circ C$. Find the real expansion coefficient of the liquid. [Volume expansion coefficient of glass $= 2.4 \times 10^{-5\circ} C^{-1}$]

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47. Apparent weights of a solid in a liquid are $50g$ and $52g$ at $25^\circ C$ and $75^\circ C$ respectively. If the coefficient of linear expansion of the solid is $\alpha_s = 6.6 \times 10^{-6^\circ} C^{-1}$, and γ for the liquid is $7.3 \times 10^{-4^\circ} C^{-1}$, what is the real weight of the solid in air?

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48. A sphere of mass 266.5 g and of diameter 7 cm floats on a liquid. When the liquid is heated to $35^\circ C$ the sphere starts sinking in the liquid. If the density of the liquid at $0^\circ C$ is $1.527g \cdot cm^{-3}$,

find its coefficient of volume expansion. Neglect the expansion of the sphere.

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49. A piece of metal weighs $46g \times g$ in air. It weighs $30g \times g$ in a liquid of specific gravity 1.24 at $27^\circ C$. At $42^\circ C$, when the specific gravity of the liquid is 1.20, the weight of the piece immersed in it is $30.5g \times g$. Find the coefficient of linear expansion (α) of the metal.

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50. The area of cross-section of the capillary tube of a mercury thermometer is A_0 and the volume of the bulb filled with mercury is V_0 at $0^\circ C$. Find the length of the mercury column in the capillary tube as the bulb is heated to $t^\circ C$. Coefficient of linear expansion of glass is α and coefficient of volume expansion of mercury is β.

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51. A 1 L flask contains some mercury. It is observed that the volume of air in the flask remains unchanged at all temperatures. What is the volume

of mercury in the flask? Coefficient of linear expansion of the material of the flask $= 9 \times 10^{-6\circ} C^{-1}$ and coefficient of real expansion of mercury $= 1.8 \times 10^{-4\circ} C^{-1}$

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52. A barometer with a brass scale reads 75.34 cm at $25^\circ C$. The scale was graduated at $20^\circ C$. What will be the reading of the barometer at $0^\circ C$? Coefficient of linear expansion α for brass $= 18 \times 10^{-6\circ} C^{-1}$ and coefficient of linear expansion γ for mercury $= 18 \times 10^{-5\circ} C^{-1}$.

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53. Coefficients of volume expansion of benzene and wood are $1.2 \times 10^{-3\circ} C^{-1}$ and $1.5 \times 10^{-4\circ} C^{-1}$ respectively. Their respective densities at $0^\circ C$ are $900 kg \cdot m^{\cdot -3}$ and $880 kg \cdot m^{-3}$. Find the temperatures at which wood will just immerse in benzene.

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54. A metal piece of density $8g \cdot m^{-3}$ is suspended from a wooden hook by an weightless string. The tension in the string is $56g \times g$. What will be the tension in the string, if the system is immersed in a liquid at $40^{\circ}C$? The surrounding temperature during the experiment is $20^{\circ}C$. At $20^{\circ}C$ the specific gravity of the liquid is 1.24. The coefficients of volume expansion of the liquid and the metal are $4 \times 10^{-5\circ}C^{-1}$ and $8 \times 10^{-4\circ}C^{-1}$ respectively.

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55. A body, at $4^{\circ}C$, floats with 0.98 part of its volume immersed in water. At what temperature the body will just immerse in water? Coefficient of real expansion of water $= 3.3 \times 10^{-4^{\circ}}C^{-1}$. Neglect expansion of the solid body.

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56. A solid at $0^{\circ}C$ floats with 98% of its volume immersed in a liquid. The solid floats completely immersed when the temperature is raised to $25^{\circ}C$. If the coefficient of volume expansion of the solid is

$2.6 \times 10^{-6^\circ} C^{-1}$, find the coefficient of real expansion of the liquid .

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57. A mercury thermometer contains $0.4 cm^3$ of mercury at $0^\circ C$. The diameter of the capillary tube of the thermometer is 0.2 mm. What should be the length of the scale to measure temperatures between $0^\circ C$ to $100^\circ C$? The coefficient of apparent expansion of mercury $= 1.7 \times 10^{-4^\circ} C^{-1}$.

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58. A and B are two thermometers made of glass and both contains the same liquid. Both thermometers have spherical bulbs. The internal diameter of the bulb of A is 7.5 mm and radius of the capillary tube is 1.25 mm. The corresponding values for B are 6.2 mm and 0.9 mm. Find the ratio of the lengths between two consecutive graduations in thermometers A and B.

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59. A container is filled up to the brim with 500 g of water and 1000 g of mercury. When 21200 cal of

heat is supplied to the system, 3.52 g of water flows out of the container. Neglecting the expansion of the container, find the coefficient of real expansion of mercury. Given, volume expansion coefficient of water $= 1.5 \times 10^{-4\circ} C^{-1}$, density of mercury $= 13.6 g \cdot cm^{-3}$, density of water $1 g \cdot cm^{-3}$ and specific heat capacity of mercury $= 0.03 cal \cdot g^{-1} \cdot {}^{\circ} C^{-1}$.

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60. A glass bulb is filled in at $0^{\circ} C$ by 350 g of mercury. When a few steel balls are put in the bulb, it can then hold only 265 g of mercury. When the

bulb is heated to $100^{\circ}C$, with the steel balls in mercury, 5 g of mercury flows out. Find the coefficient of linear expansion of steel. Given, the coefficient of real expansion of mercury $= 18 \times 10^{-5^{\circ}} C^{-1}$. Neglect expansion of glass.

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61. Between two similar thermometers, one is filled with mercury and another with alcohol of the same volume at $0^{\circ}C$. The gap for each degree in the mercury thermometer is l and that in the alcohol thermometer is l'. Show that $\frac{l}{l'} = \frac{\gamma - 3\alpha}{\gamma_1 - 3\alpha}$ where $\gamma =$ coefficient of real

expansion of mercury, $\gamma_1 =$ coefficient of real expansion of alcohol and $\alpha =$ coefficient of linear expansion of glass.

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62. A cylindrical container contains some liquid. The coefficient of linear expansion of the material of the container is α. When the container is heated it is observed that the liquid level inside the container remains unchanged. What is the volume expansion coefficient of the liquid?

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63. A body weighs W_0 in air. Its apparent weights in a liquid at $t_1{}^\circ C$ and $t_2{}^\circ C$ are W_1 and W_2 respectively. If the coefficient of volume expansion of the material of the body is γ, find the coefficient of real expansion of the liquid.

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64. Using two different containers A and B, the coefficients of apparent expansion of a liquid are found to be γ_1 and γ_2 respectively. If the coefficient of linear expansion of the material A is α, find that of the material B.

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65. A hollow iron ball floats completely immersed in water at $10^{\circ} C$ temperature. What will happen if the temperature of both of them is raised to $50^{\circ} C$?

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Section Related Questions

1. Define the coefficient of volume expansion of a solid.

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2. Establish the relation between the coefficient of linear expansion and surface expansion of a solid.

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3. What is thermal stress? Obtain the expression for thermal stress.

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4. What is invar? Write down one of its uses.

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5. Show how density of a liquid varies with temperature. Or, Establish the relation between the density of al liquid and the coefficient of its real expansion.

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6. A solid body is immersed in a liquid. How does the apparent weight of the body change due to rise in temperature of the liquid?

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Highger Order Thinking Skill Hots Questions

1. Is it possible to maintain a constant difference in the lengths of a brass rod and a steel rod, at all temperatures?

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2. A brass disc is stuck in a hole of a steel plate. Should you heat the system to free the disc from the hole? Given, α for brass

$= 19 \times 10^{-6} {}^{\circ} C^{-1}$ and α for steel $= 12 \times 10^{-6} {}^{\circ} C^{-1}$.

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3. An isosceles triangle is made of three zinc rods. Will there be any change in its base angles with the rise in temperature? Give reasons for your answer.

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4. A copper plate and an iron plate of the same volume are riveted together. Explain the likely

observations, when the system is heated.

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5. An iron rod is fitted along the diameter of a circular iron ring. Explain, whether the ring remains circular or not, when the system is heated.

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6. Two rods of different materials are of the same length and cross-sectional area. They are joined lengthwise and rigidly fixed between two walls. The

materials of the two rods have different thermal and mechanical properties. What should be the relation between the Young's moduli and the coefficients of linear expansion of the two materials so that the position of the junction point of the rods does not alter even when heated?

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7. If the other factors remain unaltered, does the change in the volume of a solid , with the change in temperature, depend on the presence of a hole in the solid? Answer with reason.

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8. A solid and a hollow cylinder of the same size and made of the same material are heated for the same change of temperature. Will the expansions be the same? Explain your answer.

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9. The difference in lengths of two rods, made up of different materials, remains constant at all temperatures. Show that their lengths at $0^{\circ}C$ are

inversely proportional to their coefficients of linear expansion.

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10. The difference in lengths of two rods, made up of different materials, remains constant at all temperatures. Show that their lengths at $0^\circ C$ are inversely proportional to their coefficients of linear expansion.

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11. A platinum wire can easily be sealed to a glass bulb while a copper wire wire cannot. Why?

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12. Electric wires are hung between two consecutive poles with a slight sag, instead of stretching them out fully. Give reasons.

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13. An aluminium rod of length l_1 and an iron rod of length l_2 are joined lengthwise to form a single rod of length $(l_1 + l_2)$. Coefficients of linear expansion of aluminium and iron are α_a and α_s respectively. If both the rods expand equally for a rise in temperature t find the ratio between l_1 and $(l_1 + l_2)$.

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14. On being heated, the length of each side of a cube increases by 2%. What is the percentage increase in the volume of the cube?

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15. Coefficient of linear expansion along one edge of a cube-shaped crystal is α_1, but that along a perpendicular direction is α_2. Find the coefficient of volume expansion of the crystal.

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16. The length of each side of a skeleton cube (made up of rods) at $0^\circ C$ is l_0. Taking any vertex of the cube as the origin, the coefficients of linear expansion of the rods along x, y, z-axes or parallel to

them are α_1, α_2 and α_3 respectively. Show that the equivalent coefficient of volume expansion of the skeleton cube is $\alpha_1 + \alpha_2 + \alpha_3$.

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17. When the temperature of a body increases from t to $t + \Delta t$, the moment of inertia of it increases from I to $I + \Delta I$. If the coefficient of linear expansion of the body is α, then show that $\frac{\Delta I}{I} = 2\alpha\Delta t$.

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18. The apparent coefficient of expansion of a liquid when heated in a copper vessel is C and when heated in a silver vessel is S. If A is the linear coefficient of expansion of copper, then show that the linear coefficient of expansion of silver is $\frac{C+3A-S}{3}$.

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19. A liquid in a container is heated suddenly. At first the liquid level goes down a little and then the level begins to rise. Explain why.

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20. What will be the effect of using water in place of mercury, in a thermometer for measuring the temperatures in the range of $0^{\circ}C \text{ to } 10^{\circ}C$?

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21. If mercury is kept in a glass vessel and in a copper vessel separately, will the coefficient of apparent expansion in both cases be the same ? If not, in which case will it be greater ? Coefficients of volume expansion of glass and copper are

$25 \times 10^{-6} {}^{\circ} C^{-1}$ and $50 \times 10^{-6} {}^{\circ} C^{-1}$

respectively.

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22. A wooden block floats in water keeping a volume V of it above the surface, at $0^{\circ} C$. If the temperature of water is slowly raised from $0^{\circ} C$ to $20^{\circ} C$, what will be the change in the value of V ?

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23. What will be the difference observed when one heats mercury and water from $0^{\circ} C$?

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24. Ice is formed on the top surface of a lake. Temperature of air above ice is $-15^{\circ} C$, (i) What is the temperature of the water layer just below ice? (ii) Find the maximum possible temperature at the bottom of the lake.

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25. A beaker is filled up to its brim with a liquid of density $1.5g \cdot cm^{-3}$. A piece of ice is floating on the liquid. Does the liquid overflow due to melting of ice?

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26. A container si filled up to its brim with water with a piece of ice floating on it [Fig 5.15(a)]. State the effect on the level of water in it container when ice melts completely, if the initial temperature of water was (i) $0^{\circ}C$ (ii) $4^{\circ}C$ and (iii) above $4^{\circ}C$.

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27. A body, immersed in a liquid, is suspended from the left arm of a hydrostatic balance, and is balanced by putting measuring weights on the scale pan at the right arm. If the liquid with the body in it is heated, will the equillibrium be disturbed?

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28. State the factors on which the coefficients of expansion of a liquid depend.

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29. Is the apparent expansion coefficient of a liquid a constant?

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30. Which one of the following graphs in Fig. 5.16 correctly represents the change of density of water with temperature?

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31. If the coefficient of volume expansion of glass would have been equal to the coefficient of real expansion of mercury, a mercury thermometer would not be active-explain.

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Exercise Multiple Choice Questions

1. When a hollow metallic sphere is heated, the volume of the cavity inside that sphere

A. remains the same

B. decreases

C. increases

D. N/A

Answer: C

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2. If a solid metallic sphere is heated, which of the following quantities undergoes the highest percentage increase?

A. length

B. area

C. volume

D. density

Answer: C

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3. A steel scale gives correct reading at $10^{\circ} C$. If the length of a rod is measured with the help of that scale at $30^{\circ} C$ then the measured length will be

A. equal to the actual length

B. less than the actual length

C. more than the actual length

D. N/A

Answer: B

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4. A platinum wire can easily be sealed in glass, because for glass and platinum

A. densities are equal

B. melting points are equal

C. specific heats are equal

D. coefficients of linear expansion are equal

Answer: D

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5. The ratio of lengths of two iron rods is 1:2 and that of their cross-sectional area is 2:3. What will be the ratio of their expansions in volume for the same rise in temperature?

A. $1:2$

B. $1:3$

C. $2:3$

D. $4:6$

Answer: B

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6. Three rods of iron form an isosceles triangle. What will be the change in the base angles of that triangle due to a rise in its temperature?

A. no change will occur

B. both the base angles will increase but the vertical angle will decrease

C. both the base angles will decrease but the vertical angle will increase

D. no conclusion can be arrived at

Answer: A

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7. A brass disc just fits inside the hole of an iron plate. To loosen the disc from the hole easily, which of the following operations would be more

convenient? (coefficient of linear expansion of brass is more than that of iron).

A. the junction should be heated

B. the junction should be cooled

C. the junction should be hammered without heating or cooling it

D. the junction should be heated first and then it should be dipped in water

Answer: B

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8. An aluminium rod (coefficient of linear expansion α_1) of length l_1 at $0^\circ C$ is welded with a steel rod (coefficient of linear expansion α_2) of length l_2 to form a composite rod of length $(l_1 + l_2)$. If, when heated through $t^\circ C$, each rod increases in length by the same amount, then the value of $\frac{l_1}{l_1 + l_2}$ will be

A. $\frac{\alpha_1}{\alpha_2}$

B. $\frac{\alpha_2}{\alpha_1}$

C. $\frac{\alpha_1}{\alpha_1 + \alpha_2}$

D. $\frac{\alpha_2}{\alpha_1 + \alpha_2}$

Answer: D

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9. Coefficient of linear expansion of brass is $19 \times 10^{-6^\circ} C^{-1}$. If the area of a circular brass disc at $0^\circ C$ is 25 cm^2, then at $80^\circ C$ its area will be

A. 25.038 cm^2

B. 25.076 cm^2

C. 25.114 cm^2

D. 25.38 cm^2

Answer: B

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10. The length of each steel rail of a line at $10^\circ C$ is 25 m. What gap should be maintained between two successive rails so that up to $50^\circ C$ they will not be strained? [coefficient of linear expansion of steel $= 11 \times 10^{-6\circ} C^{-1}$]

A. 5.5 mm

B. 8.25 mm

C. 11 mm

D. 1.65 mm

Answer: C

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11. Two similar iron and copper strips are riveted together at $20^\circ C$. What will be the nature of curvature of this bimetallic strip at $0^\circ C$ and $100^\circ C$? (coefficient of linear expansion of copper is more than that iron)

A. at both the temperatures the copper plate will be on the convex side

B. at both the temperatures the iron plate will be on the convex side

C. at $0^{\circ}C$ the copper plate will be on the convex side but at $100^{\circ}C$, it will be on the concave side

D. at $0^{\circ}C$ the iron plate will be on the convex side but at $100^{\circ}C$, it will be on the concave side.

Answer: D

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12. In which of the following cases a bimetallic strip is not used?

A. sealing of a platinum wire in glass

B. thermostat

C. fire alarm

D. compensated balance wheel of a watch

Answer: A

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13. The length of a brass rod is to be measured at different temperatures. For this, the accuracy will be the highest if the scale is made of which material?

A. wood

B. steel

C. brass

D. platinum

Answer: A

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14. Young's modulus for the material of a rod is Y and its coefficient of linear expansion is α. A rod of length l and cross-section A of this material is kept in between two rigid supports and its temperature is increased by $t^{\circ}C$. The force developed inside the rod is

A. $lAY\alpha t$

B. $AY\alpha t$

C. $lY\alpha t$

D. $Y\alpha t$

Answer: B

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15. Two rods of the same length are kept in between two rigid supports and their temperatures are increased by the same amount. What will be the relation between the Young's moduli and coefficients of linear expansion of the rods, for equal thermal stresses generated in them?

A. $\frac{Y_1}{Y_2} = \frac{\alpha_1}{\alpha_2}$

B. $\frac{Y_1}{Y_2} = \sqrt{\frac{\alpha_1}{\alpha_2}}$

C. $\frac{Y_1}{Y_2} = \frac{\alpha_2}{\alpha_1}$

D. $\frac{Y_1}{Y_2} = \sqrt{\frac{\alpha_2}{\alpha_1}}$

Answer: C

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16. When the temperature of a metallic sphere is increased by $40^{\circ}C$ then its volume increases by 0.24%. Coefficient of linear expansion of the metal in $^{\circ}C^{-1}$ is

A. 2×10^{-5}

B. 6×10^{-5}

C. 18×10^{-5}

D. 1.2×10^{-5}

Answer: A

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17. The ratio of the lengths of two metallic rods is 2:3 and the ratio of the coefficients of linear expansion of their materials is 4:3. The ratio of their linear expanions for the same rise in temperature is

A. $1:2$

B. $2:3$

C. $3:4$

D. $8:9$

Answer: D

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18. A steel scale gives correct reading at $t_1{}^\circ C$. With the help of this scale the distance between two points measures $l' \text{ and } t_2{}^\circ C$. If the coefficient of linear expansion of steel is α then the actual length l between the two points is

A. $l = l'$

B. $l = l'[1 + \alpha(t_2 - t_1)]$

C. $l = l'[1 - \alpha(t_2 - t_1)]$

D. $l = \frac{l'}{1 + \alpha(t_2 - t_1)}$

Answer: B

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19. Two spheres of the same material have the same radius but one is hollow while the other is solid. Both spheres are heated to same temperature. Then

A. the solid sphere expands more

B. the hollow sphere expands more

C. expansion is same for both

D. nothing can be said about their relative expansion if their masses are not given

Answer: C

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20. When a rod is heated but prevented from expanding the stress developed is independent of

A. material of the rod

B. rise in temperature

C. length of the rod

D. none of the above

Answer: C

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21. At some temperature T, a bronze pin is a little large fit into a hole drilled in a steel block. The change in temperature required for an exact fit is minimum when (coefficient of linear expansion of bronze is grearter than that of steel)

A. only the block is heated

B. both block and pin are heated together

C. both block and pin are cooled together

D. only the pin is cooled

Answer: D

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22. When water is heated from $0^{\circ}C$ to $50^{\circ}C$, density of water

A. remains the same

B. decreases continually

C. increases continually

D. increases at first and then decreases

Answer: D

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23. Due to anomalous expansion of water from $0^\circ C$ to $4^\circ C$, in cold countries

A. entire water in a lake freezes to ice

B. no part of water in a lake freezes to ice

C. aquatic animals can survive

D. oxygen content of water increases

Answer: C

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24. The relation between real and apparent expansion of a liquid is

A. real expansion = apparent expansion

B. real expansion $<$ apparent expansion

C. real expansion $>$ apparent expansion

D. depending on the nature of the liquid, sometimes apparent expansion and sometimes real expansion is greater

Answer: C

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25. How many coefficients of expansion of a liquid is used in practice?

A. 1

B. 2

C. 3

D. 4

Answer: B

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26. The coefficient of real expansion of a liquid is γ and the coefficient of apparent expansion is γ'. Units of these are

A. both $^{\circ}C^{-1}$

B. both $m^3 \cdot {}^{\circ}C^{-1}$

C. $^{\circ}C^{-1}$ for γ and $m^3 \cdot {}^{\circ}C^{-1}$ for γ'

D. $m^3 \cdot {}^{\circ}C^{-1}$ for γ and $^{\circ}C^{-1}$ for γ'

Answer: A

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27. If a liquid having coefficient of volume expansion α, kept in a container having coefficient of linear expansion $\frac{\alpha}{3}$, is heated, then the level of the liquid will

A. rise

B. fall

C. remain the same

D. remain almost the same

Answer: C

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28. The coefficient of volume expansion of a liquid is

A. positive for all liquids

B. negative for all liquids

C. negative for water from $0^\circ C$ to $4^\circ C$ but positive for other liquids

D. negative for water from $0^\circ C$ to $4^\circ C$ but negative for other liquids

Answer: C

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29. A vessel is partly filled with a liquid at $0^\circ C$. The condition for which the volume of the remaining part of the vessel remains unchanged is

A. expansion of the entire vessel = real expansion of the liquid in the vessel

B. expansion of the remaining part of the vessel = real expansion of the liquid in the vessel

C. expansion of the entire vessel = apparent expansion of the liquid in the vessel

D. expansion of the remaining part of the vessel = apparent expansion of the liquid in the vessel

Answer: A

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30. Apparent weight of a body immersed in water at $20^\circ C$ is W_1. When temperature is increased to $40^\circ C$, the apparent weight becomes W_2. In this case

A. for different solids W_2 may be greater than or less than W_1

B. W_2 is always equal to W_1

C. W_2 is always less than W_1

D. W_2 is always greater than W_1

Answer: D

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31. Apparent weights of a body immersed in a liquid at the temperature t_1 is W_1 and temperature t_2 is W_2. Coefficients of volume expansion of the liquid and the solid are γ and γ_s respectively. The value of $W_2 - W_1$ will be

A. proportional to $(\gamma - \gamma_s)(t_2 - t_1)$

B. proportional to $\dfrac{\gamma - \gamma_s}{t_2 - t_1}$

C. proportional to $\dfrac{t_2 - t_1}{\gamma - \gamma_s}$

D. proportional to $\dfrac{1}{(\gamma - \gamma_s)(t_2 - t_1)}$

Answer: A

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32. Apparent weight of a piece of metal immersed in water at $0^\circ C$ is 100 g and at $50^\circ C$ is 100.5 g. What will be the apparent weight at $20^\circ C$?

A. 100.1 g

B. 100.2 g

C. 100.3 g

D. 100.4 g

Answer: B

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33. A block of wood is floating on water. If the temperature is increased the apparent weight of the block of wood

A. will remain the same

B. will increase

C. will decrease

D. may increase or decrease

Answer: A

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34. The coefficient of apparent expansion of a liquid for two different vessels A and B are γ_1 and γ_2 respectively. If the coefficient of linear expansion of the material of the vessel A is α, then the coefficient of linear expansion of the material of the vessel B will be

A. $\frac{\alpha\gamma_1\gamma_2}{\gamma_1+\gamma_2}$

B. $\frac{\gamma_1-\gamma_2}{2\alpha}$

C. $\frac{\gamma_1 - \gamma_2 + \alpha}{3}$

D. $\frac{\gamma_1 - \gamma_2}{3} + \alpha$

Answer: D

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35. A glass is fully with water at $4^\circ C$. Water overflows when the glass is

A. cooled but not when heated

B. heated but not when cooled

C. both cooled or heated

D. first heated then cooled

Answer: C

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36. Weight of a piece of metal immersed in alcohol at $0^\circ C$ is W_1 and at $59^\circ C$ is W_2. The coefficient of volume expansion of the metal is less than the coefficient of volume expansion of alcohol. If the density of the metal is greater than that of alcohol then

A. $W_1 > W_2$

B. $W_1 = W_2$

C. $W_1 < W_2$

D. $W_2 = \frac{W_1}{2}$

Answer: C

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37. The coefficient of volume expansion of a liquid is γ and its density at $0^\circ C$ is ρ. If the temperature is increased to $t^\circ C$ then the change in density will be

A. $\frac{\rho(1-\gamma t)}{\gamma t}$

B. $-\frac{\rho(1+\gamma t)}{\gamma t}$

C. $\frac{\rho\gamma t}{1-\gamma t}$

D. $-\frac{\rho\gamma t}{1-\gamma t}$

Answer: D

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38. Surface of a lake is at $2^\circ C$. Find the temperature of the bottom of the lake

A. $2^\circ C$

B. $3^\circ C$

C. $4^\circ C$

D. $1^\circ C$

Answer: C

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39. The coefficients of real expansion of a liquid is γ and the coefficient of linear expansion of the material of the containing vessel is α. Then the condition for no apparent expansion of the liquid in that vessel is

A. $\gamma = \alpha$

B. $\gamma = 3\alpha$

C. $\gamma < \alpha$

D. $\gamma > 3\alpha$

Answer: B

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40. Two vessels are filled with water at the same temperature. If one vessel is heated and the other is cooled, then in both the cases water overflows. The initial temperature of water in both the vessels was

A. $273^\circ C$

B. 273 K

C. $277^\circ C$

D. 277 K

Answer: D

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41. The coefficient of real expansion of mercury is γ and the coefficient of linear expansion of glass is α. The mercury thread, enclosed in a glass tube of uniform bore, expands linearly due to rise in

temperature. The effective coefficient of expansion will be

A. $\frac{\gamma}{3}$

B. $\frac{\gamma - 3\alpha}{3}$

C. $\frac{\gamma - 2\alpha}{3}$

D. $\gamma - 2\alpha$

Answer: D

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42. The coefficient of volume expansion of mercury is $18 \times 10^{-5\circ} C^{-1}$ and the coefficient of linear expansion of copper and glass are $17 \times 10^{-6\circ} C^{-1}$ and $9 \times 10^{-6\circ} C^{-1}$ respectively. If mercury is kept first in the copper vessel and then in the glass vessel, then

A. coefficient of apparent expansion of mercury in the first case will be less

B. coefficient of apparent expansion of mercury in the first case will be greater

C. coefficient of real expansion of mercury in the first case will be less

D. coefficient of real expansion of mercury in the first case will be greater

Answer: A

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43. To measure the height of the mercury column in a barometer, a brass-scale is attached with it. Coefficient of real expansion of mercury is γ and coefficient of linear expansion of brass is α. Due to

rise in temperature, the effective coefficient at which the barometer reading increases is

A. γ

B. $\gamma + \alpha$

C. $\gamma - \alpha$

D. $\gamma - 2\alpha$

Answer: C

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44. A uniform pressure p is applied on each face of a solid cube. What will be the rise in temperature of the cube so that it regains its original volume? (Given, bulk modulus = B and coefficient of volume expansion = γ for the material of the cube.)

A. $\frac{p}{(B-p)r}$

B. $\frac{pr}{B}$

C. $\frac{pB}{r}$

D. $\frac{Br}{p}$

Answer: A

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Exercise Very Short Answer Type Questions

1. What is the unit of the coefficient of linear expansion of a substance?

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2. What is the relation between the coefficient of linear expansion (α) and the coefficient of volume expansion (γ) of a solid?

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3. A bimetallic strip made up of brass and iron remains linear at $20^{\circ}C$. When the temperature is decreased to $0^{\circ}C$, the strip bends.Which material remains on the convex side of the bent strip?

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4. Coefficient of linear expansion of platinum is $9 \times 10^{-6\circ}C^{-1}$. What will be the value of this coefficient when the temperature is expressed in Fahrenheit unit?

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5. If the coefficient of linear expansion of iron is $0.0000067^{\circ} F^{-1}$, then what is its value in celsius scale?

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6. Due to rise in temperature, if each side of a copper cube increases by 0.1%, then find out the increase in volume of that cube.

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7. Write down the variation of density of a solid with increase in temperature.

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8. Thermal expansion of invar is _____ than that of all other metals or alloys. [Fill in the blank]

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9. Between the coefficient of apparent expansion (γ') and the coefficient of real expansion (γ) of a

liquid which one is a characteristic property of the liquid?

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10. A glass vessel is filled with water up to its brim. Now, what will happen if temperature is increased?

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11. At what temperature density of water will be the maximum?

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12. How does density of a liquid change with temperature?

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13. At what temperature under standard atmospheric pressure, the density of pure water will be the maximum?

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14. Real expansion of a liquid = apparent expansion of the liquid + volume expansion of the _____. [Fill in the blank]

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15. Coefficient of real expansion of water from $0^{\circ}C$ to $4^{\circ}C$ is _____. [Fill in the blank]

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16. Usually the thermal expansion of a liquid is greater than the thermal expansion of an equal volume of a solid'. State whether the statement is true or false.

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17. Usually the thermal expansion of a liquid is greater than the thermal expansion of an equal volume of a gas'. State whether the statement is true or false.

Watch Video Solution

18. What is the density of pure water at $4^{\circ} C$ in SI?

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Exercise Short Answer Type Questions I

1. Coefficient of linear expansion of iron is $12 \times 10^{-6 \circ} C^{-1}$ - explain the statement.

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2. A metal scale does not show correct reading at all temperatures' - explain.

Watch Video Solution

3. Explain why thin glass beakers are used to boil water.

Watch Video Solution

4. During the construction of long bridges, why are the two ends of a bridge not fixed rigidly in the

concrete?

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5. Explain why a tightly fitted metal cap of a glass bottle can be opened by heating it slightly.

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6. A beaker is filled to the brim with water at $4^{\circ}C$. What will you notice if the temperature is (i) increased and (ii) decreased?

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7. Is the coefficient of apparent expansion of a liquid fixed?

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8. What change will be observed if both mercury and water are heated from $0^\circ C$?

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Exercise Short Answer Type Questions Ii

1. If a hollow iron tube is heated, then do the following quantities increase or decrease : (i) volume, (ii) density, (iii) internal diameter, and (iv) external diameter?

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2. A brass disc is fitted tightly into the bore of a steel plate. Should you apply heat in order to remove the disc from the bore? Given that α of brass $= 19 \times 10^{-6\circ} C^{-1}$ and that of steel $= 12 \times 10^{-6\circ} C^{-1}$.

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3. Give three practical examples of the utilization of expansion of solids.

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4. The top of a lake is frozen. Air just above the ice layer is at $-15^{\circ}C$. What is the temperature of the water layer just below ice? Comment on the maximum possible temperature at the bottom of the lake.

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5. Show that the change in density ρ of a liquid, due to rise in temperature Δt, can be written as $\Delta\rho = -\rho\gamma\Delta t$ [$\gamma =$ coefficient of real expansion of the liquid].

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Exercise Problem Set I

1. If the temperature of a rod of length 2 m is increased by $100^\circ C$, what will be its increase in length? Given, α for the rod $= 0.000012^\circ C^{-1}$.

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2. When the temperature of a 3 m long iron rod is increased from $0^\circ C$ to $200^\circ C$, the rod increases in length by 7.2 mm. Determine the coefficient of linear expansion of iron.

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3. Due to rise in temperature of a brass rod by $100^\circ C$, its length increases by 0.5 cm. What was the initial length of the rod? α for brass $= 19 \times 10^{-6 \circ} C^{-1}$.

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4. The lengths of an iron and a zinc rod at $0^\circ C$ are 25.55 cm and 25.5 cm respectively. At what temperature will their lengths be equal? Coefficients of linear expansion of iron and zinc are $10 \times 10^{-6\circ} C^{-1}$ and $30 \times 10^{-6\circ} C^{-1}$ respectively.

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5. The length of the steel structure of a bridge is 0.5 km and it has to withstand temperature change from $44^\circ F$ to $116^\circ F$. What allowance should be

kept for its expansion if the coefficient of linear expansion of steel is $1 \times 10^{-5^{\circ}} C^{-1}$?

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6. A steel tape 1 m long is correctly calibrated for a temperature of 27.0 $^{\circ}C$. 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 $^{\circ}C$. 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 $27.0^{\circ}C$? Coefficient of linear expansion of steel $= 1.20 \times 10^{-5} K^{-1}$.

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7. An iron sphere is to be passed through a circular brass ring. At $20^{\circ}C$, the diameter of the sphere is 25 cm and the internal diameter of the ring is 24.9 cm. If both the sphere and the ring are heated together, at what temperature will the sphere just pass through the ring? α for iron $= 1.2 \times 10^{-5\circ} C^{-1}$ and α for brass $= 2 \times 10^{-5\circ} C^{-1}$.

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8. Diameter of a brass disc at $30^{\circ}C$ is 10 cm. What will be the increase in area of the disc at $70^{\circ}C$? α for brass $= 18 \times 10^{-6\circ}C^{-1}$.

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9. Prove that, the expansion of volume V of a solid due to a rise Δt in temperature is $\Delta V = 3\alpha V \cdot \Delta t$. Here, $\alpha =$ coefficient of linear expansion of the solid.

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10. Densities of glass at $10^{\circ}C$ and $60^{\circ}C$ are $2.6g \cdot cm^{-3}$ and $2.596g \cdot cm^{-3}$ respectively. What is the average coefficients of linear expansion of glass in between these two temperatures?

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11. A square metal plate of side 100 cm at $0^{\circ}C$, has a circular hole of diameter 40 cm in the middle of it. At what temperature, will each side by 101 cm long? What will be the diameter of the hole at that temperature? α for the metal $= 12.5 \times 10^{-6^{\circ}}C^{-1}$

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12. The coefficient of apparent expansion of a liquid in a brass vessel is $14.6 \times 10^{-5^\circ} C^{-1}$. What will be the coefficient of apparent expansion of that liquid when it is in iron vessel? α for brass $= 18 \times 10^{-6^\circ} C^{-1}$ and α for iron $= 12 \times 10^{-6^\circ} C^{-1}$.

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13. Volume of the bulb of a thermometer is 1 cm^3. Each degree division of that thermometer should

be 5 mm long. What will be the cross-sectional area of the thermometer tube? Coefficient of apparent expansion of mercury with respect to glass is $1.6 \times 10^{-4\circ} C^{-1}$.

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14. The bulb and the stem of a mercury-in-glass thermometer contains 1 cm^3 of mercury up to the zero mark. If the internal diameter of the stem is 0.3 mm, what is the length of a degree celsius on the scale? Coefficient of real expansion of mercury $= 18 \times 10^{-5\circ} C^{-1}$ and coefficient of linear expansion of glass $= 8 \times 10^{-6\circ} C^{-1}$.

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15. Masses of $10cm^3$ of water at $0^\circ C$ and $4^\circ C$ are 9.998 g and 10 g respectively. Calculate the coefficient of real expansion of water in this range of temperature.

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16. A capilllary glass tube of uniform bore contains a thread of mercury 1 m long at $0^\circ C$. When temperature is raised to $100^\circ C$, the thread is found to be 16.5 mm longer. If the coefficient of real

expansion of mercury is $= 18.2 \times 10^{-5\circ} C^{-1}$, then what will be the coefficient of linear expansion of glass?

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17. A closed glass bulb contains some mercury. Volumes of the empty space of the bulb at $0^\circ C$ and $40^\circ C$ are 1 cm^3 and 0.98 cm^3 respectively. Determine the volume of mercury. Assume that α for glass $= 7.2 \times 10^{-6\circ} C^{-1}$ and γ for mercury $= 1.81 \times 10^{-4\circ} C^{-1}$.

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Exercise Problem Set Ii

1. The difference in lengths of an iron and a copper rod, both at $50^\circ C$ and $450^\circ C$, is 2 cm. What are the lengths of the two rods at $0^\circ C$? [Given, $\alpha_{Fe} = 12 \times 10^{-6\circ} C^{-1}$ and $\alpha_{Cu} = 17 \times 10^{-6\circ} C^{-1}$]

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2. Two rods of thickness d and of length l are riveted. If the temperature is increased by θ, what will be the average radius of curvature of the combination? Coefficient of linear expansion of the materials of the two rods are α_1 and α_2.

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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 $250^\circ C$, if the original lengths are at $40.0^\circ C$? The ends of the rod are free to expand

(coefficient of linear expansion of brass $= 2.0 \times 10^{-5} K^{-1}$, steel $= 1.2 \times 10^{-5} K^{-1}$).

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4. The weight of a glass rod in air is $90g \times g$. Its apparent weight in a liquid at $12^{\circ} C$ is $49.6g \times g$, and at $97^{\circ} C$ is $51.9g \times g$. Determine the coefficient of real expansion of the liquid. Coefficient of volume expansion of glass $= 2.4 \times 10^{-5 \circ} C^{-1}$.

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5. A specific gravity bottle is completely filled with mass m of a liquid at $0^\circ C$. If it is heated to $t^\circ C$, then what mass of the liquid will be expelled? Coefficient of real expansion of the liquid $= \gamma$ and coefficient of linear expansion of the material of the bottle $= \alpha$.

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6. The mean value of the coefficient of real expansion of mercury is $18.2 \times 10^{-5\circ} C^{-1}$. Density of mercury at $20^\circ C$ is $13.55g \cdot cm^{-3}$. At what

higher temperature, will the error in the measurement of density be 1%?

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7. A piece of iron having a square cross-section has a length of 30 cm, and it floats on mercury at $0^\circ C$. If the temperature is raised to $100^\circ C$, then what additional length of the piece will be immersed? Density of mercury at $0^\circ C = 13.6g \cdot cm^{-3}$, density of iron at $0^\circ C = 7.6g \cdot cm^{-3}$, coefficient of real expansion of mercury $= 1.82 \times 10^{-4\circ} C^{-1}$ and coefficient of volume expansion of iron $= 3.51 \times 10^{-5\circ} C^{-1}$.

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8. With the help of a graduated cylinder made of ordinary glass, volume can be measured accurately at $10^{\circ}C$. If it is used at $70^{\circ}C$, what will be the percentage error in the measurement? Coefficient of linear expansion of glass $= 9 \times 10^{-6\circ}C^{-1}$.

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9. A solid body floats in a liquid at $50^{\circ}C$, being completely submerged in it. What fraction of the volume of the body would be submerged when it is

cooled to $0^\circ C$? The coefficient of volume expansion for the solid is $0.3 \times 10^{-5} K^{-1}$ and that of the liquid is $8.0 \times 10^{-5} K^{-1}$.

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10. An aluminium sphere of diameter 10 cm is submerged in glycerine of density $1.26 g \cdot cm^{-3}$ at $20^\circ C$. Calculate the change in apparent weight of the sphere when the glycerine is heated to $100^\circ C$. Coefficient of volume expansion of glycerine $= 5 \times 10^{-4 \circ} C^{-1}$ and that of linear expansion of aluminium $= 2.5 \times 10^{-6 \circ} C^{-1}$.

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Exercise Host Numerical Problems

1. Two metaliic strips of different metals are riveted together to form a composite metallic strip of thickness 0.1 cm. If the strip is heated to $100^{\circ}C$, what will be the radius of curvature of the strip? Given, the values of α of the two metals are $18 \times 10^{-6\circ}C^{-1}$ and $12 \times 10^{-6\circ}C^{-1}$.

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2. Two copper rods and one aluminium rod of the same length are joined together to form an equilateral triangle ABC. A rod AD of another material connects the vertex A to the mid-point D of the base (aluminium) rod of the triangle. For small rise in temperature of the system there will be no tendency for the sides of the triangle to buckle. Determine the coefficient of linear expansion of the material of the rod AD. Given, α for copper $= 16 \times 10^{-6\circ} C^{-1}$ and α for aluminium $= 26 \times 10^{-6\circ} C^{-1}$.

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3. The cross-sectional area of a steel rod of length 25 cm is 0.8 cm^2. What tension will be required to increase the length of the rod, equal to the increase due to its rise in temeprature by $10^\circ C$?

For steel, $Y = 2 \times 10^{12} dyn \cdot cm^{-2}$ and $\alpha = 10^{-5\circ} C^{-1}$.

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4. The temperature of a steel rod is increased by $15^\circ C$.To resist its expansion in length, what stress should be applied? Young's modulus (Y) for steel

$= 2 \times 10^{12} dyn \cdot cm^{-2}$ and its coefficient of linear expansion, $\alpha = 1.2 \times 10^{-5\circ} C^{-1}$.

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5. The inner circumference of a steel tyre is 157 cm. It is to be fitted on a ring of diameter 50 cm. Find the temperature up to which the tyre is to be heated to fit it on the ring. When cooled, what force will be exerted by the tyre on unit surface area of the ring? For steel $Y = 2.1 \times 10^{12} dyn \cdot cm^{-2}$, $\alpha = 12 \times 10^{-6\circ} C^{-1}$.

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6. A piece of metal floats on mercury. The coefficients of volume expansion of the metal and mercury are γ_1 and γ_2 respectively. If their temperature is increased by ΔT, then by what factor does the fraction of the volume of metal submerged in mercury change?

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Entrance Corner Assertion Reason Type

1. Statement I : A brass disc just fits in a hole in a steel plate. The system must be cooled to loosen

the disc from the hole.

Statement II : The coefficient of linear expansion for brass is greater than the coefficient of linear expansion for steel.

A. Statement I is true, statement II is true , statement II is a correct explanation for statement I.

B. Statement I is true, statement II is true , statement II is not a correct explanation for statement I.

C. Statement I is true, statement II is false.

D. Statement is false, statement II is true.

Answer: A

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2. Statement I: A beaker is completely filled with water at $4^{\circ}C$. It will overflow, both when heated or cooled.

Statement II : There is expansion of water below and above $4^{\circ}C$.

A. Statement I is true, statement II is true , statement II is a correct explanation for statement I.

B. Statement I is true, statement II is true , statement II is not a correct explanation for statement I.

C. Statement I is true, statement II is false.

D. Statement is false, statement II is true.

Answer: A

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3. Statement I : The coefficient of real expansion of the liquid is independent of the nature of container.

Statement II : $\gamma_r = \gamma_a + \gamma_v$ where $\gamma_r =$

coefficient of real expansion, $\gamma_a =$ coefficient of expansion and $\gamma_v =$ coefficient of apparent expansion of vessel.

A. Statement I is true, statement II is true , statement II is a correct explanation for statement I.

B. Statement I is true, statement II is true , statement II is not a correct explanation for statement I.

C. Statement I is true, statement II is false.

D. Statement is false, statement II is true.

Answer: B

4. Statement I : The coefficient of apparent expansion can be negative.

Statement II : Coefficient of real expansion of a liquid can be less than the coefficient of expansion of vessel.

A. Statement I is true, statement II is true , statement II is a correct explanation for statement I.

B. Statement I is true, statement II is true , statement II is not a correct explanation for statement I.

C. Statement I is true, statement II is false.

D. Statement is false, statement II is true.

Answer: A

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5. Statement I : A solid and a hollow sphere of same material when heated through the same temperature, will expand by the same amount.

Statement II : The change in volume is independent of the original mass but depends on original volume.

A. Statement I is true, statement II is true , statement II is a correct explanation for statement I.

B. Statement I is true, statement II is true , statement II is not a correct explanation for statement I.

C. Statement I is true, statement II is false.

D. Statement is false, statement II is true.

Answer: A

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Entrance Corner Multiple Correct Answers Type

1. If α, β and γ are coefficients of linear, surface and volume expansion respectively, then

A. $(\beta/\alpha) = (1/2)$

B. $(\beta/\gamma) = (2/3)$

C. $(\gamma/\alpha) = (3/1)$

D. $(\beta/\alpha) = (\gamma/\beta)$

Answer: B::C

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2. In case of a metal scale

A. the distance between any two scale divisions does not vary with temperature

B. the distance between any two scale divisions increases in the ratio of $1:(1+\alpha t)$ at higher temperature

C. the distance between any two scale divisions is higher than the true distance in the ratio $(1+\alpha t):1$ at a lower temperature

D. none of the above

Answer: A::B::C

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3. If the temperature of a rod is increased from θ to θ' thermal strain in it will depend on

A. Young's modulus, y

B. coefficient of linear expansion, α

C. temperature difference, $\left(\theta' - \theta\right)$

D. none of these

Answer: A::C

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4. Two identical beakers A and B are filled with water to the same level at $4^{\circ}C$. If A is heated while B is cooled, then

A. water level in A will rise

B. water level in B will rise

C. water level in A will fall

D. water level in B will fall

Answer: A::D

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5. Due to thermal expansion, with rise in temperature

A. metallic scale reading becomes less than the true value

B. pendulum clock becomes fast

C. a floating body sinks a little more

D. the weight of a body in a liquid increases

Answer: B::C

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6. A bimetallic strip is formed out of identical strips one of copper and the other of brass. The coefficients of linear expansion of the two metals are α_c and α_B. On heating the temperature of

the strip goes up by ΔT and the strip bends to form an arc of radius of curvature R. Then R is

A. proportional to ΔT

B. inversely proportional to ΔT

C. proportional to $|\alpha_B - \alpha_C|$

D. inversely proportional to $|\alpha_B - \alpha_C|$

Answer: A::B

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7. A uniform metallic circurlar disc of mass M and radius R, mounted on frictionless bearings, is rotating at an angular speed ω about an axis passing through its centre and perpendicular to its plane. The temperature of the disc is then increased by Δt. If α is the coefficient of linear expansion of the metal.

A. the moment of inertia increases by $MR^2\alpha\Delta t$

B. the moment of inertia remains unchanged

C. the angular velocity increases by $2\alpha\omega\Delta t$

D. the angular velocity decreases by $2\alpha\omega\Delta t$

Answer: A::D

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Entrance Corner Comprehension Type

1. A copper collar is to fit tightly about a steel shaft that has a diameter of 6 cm at $20^\circ C$. The inside diameter of the copper collar at that temperature is 5.98 cm.

To what temperature must the copper collar be raised so that it will just slip on the steel shaft,

assuming the steel shaft remains at $20^\circ C$? $\left(\alpha_{\text{cooper}} = 17 \times 10^{-6} K^{-1}\right)$

A. $324^\circ C$

B. $21.7^\circ C$

C. $217^\circ C$

D. $32.4^\circ C$

Answer: C

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2. A copper collar is to fit tightly about a steel shaft that has a diameter of 6 cm at $20^\circ C$. The inside diameter of the copper collar at that temperature is 5.98 cm.

The tensile stress in the copper collar when its temperature returns to $20^\circ C$ is $\left(Y = 11 \times 10^{10} N \cdot m^{-2}\right)$

A. $1.34 \times 10^{5} N \cdot m^{-2}$

B. $3.68 \times 10^{-12} N \cdot m^{-2}$

C. $3.68 \times 10^{8} N \cdot m^{-2}$

D. $1.24 \times 10^{-12} N \cdot m^{-2}$

Answer: C

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3. A copper collar is to fit tightly about a steel shaft that has a diameter of 6 cm at $20^\circ C$. The inside diameter of the copper collar at that temperature is 5.98 cm.

If the breaking stress of copper is 230 $N \cdot m^{-2}$ at what temperature will the copper collar break as it cools?

A. $20^\circ C$

B. $47^\circ C$

C. $94^\circ C$

D. $217^\circ C$

Answer: C

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Entrance Corner Integer Type

1. A composite rod is made by joining a copper rod, end to end, with a second rod of a different material but of same cross-section. At $25^\circ C$, the

composite rod is 1 m in length of which the length of the copper rod is 30 cm. At $125^\circ C$ the length of the composite rod increases by 1.91 mm. The coefficient of linear expansion of copper is $\alpha = 1.7 \times 10^{-5\circ} C^{-1}$ and that of the second rod is $\beta = n \times 10^{-5\circ} C^{-1}$. Find the value of n.

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2. The volume of a metal sphere increases by 0.24% when its temperature is raised by $40^\circ C$. The coefficient of linear expansion of the metal is $n \times 10^{-5\circ} C^{-1}$. Find the value of n.

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3. The coefficient of real expansion of mercury is $18 \times 10^{-5^\circ} C^{-1}$. A thermometer has a bulb of volume $10^{-6} m^3$ and the cross-section of the stem is 0.002 cm^2. Assuming the bulb to be filled with mercury at $0^\circ C$, find the length (in cm) of the mercury column at $100^\circ C$.

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4. A thin copper wire of length l increases in length by 1% when heated from $0^\circ C$ to $100^\circ C$. If a thin

copper plate of area $2l \times l$ is heated from $0^\circ C$ to $100^\circ C$, find the percentage increase in its area.

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Examination Archive Wbchse

1. The liquid with co-efficient of volume expansion (γ) is filled in a container of a material having the co-efficient of linear expansion α. If the liquid overflows on heating then

A. $\gamma = 3\alpha$

B. $\gamma > 3\alpha$

C. $\gamma < 3\alpha$

D. $\gamma > 3\alpha^3$

Answer: B

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2. How does the moment of inertia of a body change with temperature?

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3. When a copper sphere is heated, which physical quantity of the sphere will show maximum percentage change?

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Examination Archive Wbjee

1. A metal rod is fixed rigidly at two ends so as to prevent its thermal expansion. If L, α and Y respectively denote the length of the rod, coefficient of linear thermal expansion and Young's modulus of its material, then for an increase in

temperature of the rod by ΔT, the longitudinal stress developed in the rod is

A. inverse proportional to α

B. inversely proportional to Y

C. directly proportional to $\frac{\Delta T}{Y}$

D. independent of L

Answer: D

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2. A solid rectangular sheet has two different coefficients of linear expansion α_1 and α_2 along its length and breadth respectively. The coefficient of surface expansion is $(\text{for } \alpha_1 t << 1, \alpha_2 t << 1)$

A. $\frac{\alpha_1 + \alpha_2}{2}$

B. $2(\alpha_1 + \alpha_2)$

C. $\frac{4\alpha_1\alpha_2}{\alpha_1 + \alpha_2}$

D. $\alpha_1 + \alpha_2$

Answer: D

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Examination Archive Jee Main

1. The pressure that has to be applied to the ends of a steel wire of length 10 cm to keep its length constant when its temperature is raised by $100^{\circ}C$ is (For steel, Young's modulus is $2 \times 10^{11} N \cdot m^{-2}$ and coefficient of linear expansion is $1.1 \times 10^{-5} K^{-1}$)

A. $2.2 \times 10^{8} Pa$

B. $2.2 \times 10^{9} Pa$

C. $2.2 \times 10^{7} Pa$

D. $2.2 \times 10^{6} Pa$

Answer: A

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2. A pendulum clock loses 12 s a day if the temperature is $40^\circ C$ and gains 4 s a day if the temperature is $20^\circ C$. The temperature at which the clock will show correct time, and the coefficient of linear expansion (α) of the metal of the pendulum shaft are respectively

A. $25^\circ C \quad \text{and} \quad 1.85 \times 10^{-5} / ^\circ C$

B. $60^\circ C \quad \text{and} \quad 1.85 \times 10^{-4} / ^\circ C$

C. $30^\circ C$ and $1.85 \times 10^{-3}/^\circ C$

D. $55^\circ C$ and $1.85 \times 10^{-2}/^\circ C$

Answer: A

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3. An external pressure P is applied on a cube at $0^\circ C$ so that it is equally compressed from all sides. K is the bulk modulus of the material of the cube and α is its coefficient of linear expansion. Suppose we want to bring the cube to its original size by heating. The temperature should be raised by :

A. $3PK\alpha$

B. $\frac{P}{3\alpha K}$

C. $\frac{P}{\alpha K}$

D. $\frac{3\alpha}{PK}$

Answer: B

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Examination Archive Neet

1. Coefficient of linear expansion of brass and steel rods are α_1 and α_2. Lengths of brass and steel

rods are l_1 and l_2 respectively. If $(l_2 - l_1)$ is maintained same at all temperatures, which one of the following relations holds good?

A. $\alpha_1 l_2^2 = \alpha_2 l_1^2$

B. $\alpha_1^2 l_2 = \alpha_2^2 l_1$

C. $\alpha_1 l_1 = \alpha_2 l_2$

D. $\alpha_1 l_2 = \alpha_2 l_1$

Answer: C

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1. Show that the coefficient of superficial expansion of a rectangular sheet of the solid is twice its coefficient of linear expansion.

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2. What do you mean by anomalous behaviour of water? How it can be helpful for the survival of aquatic creatures in polar region?

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