EXPANSION OF SOLIDS

SYNOPSIS

INTRODUCTION :

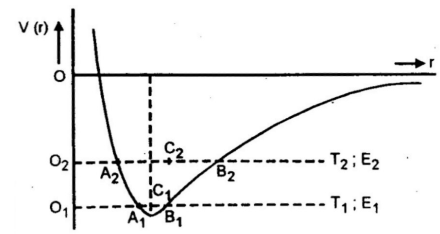
- Solid is a rigid body in which atoms are arranged in the form of a lattice.
- The interatomic force of attraction depends on the distance between atoms.
- At a specific temperature the atoms in a solid possess specific interatomic distances. Hence solids have a definite length, area and volume at a given temperature.
- On heating solids expand due to increase in interatomic spacing, which is a result of asymmetrical lattice vibrations.
- Isotropic solids expand equally in all directions.
  Eg. Metals and some alloys.
- Anisotropic solids have different expansions in different directions.
  Eg: Crystalline C_aCo_3, Galena.
- Substances which contract on heating are
  a) cast iron
  b) Type metal (Tin + lead)
  c) Silica Glass
  d) Rubber
  e) Ice
  f) Lead
- The molecules possess both KE and PE. So the KE and PE of molecules increase when the body is heated.
- The increase in KE may be in a) transslatory KE b) vibratory KE and c) rotary KE for fluid.
- In solids the increase in KE is in vibratory KE and rotatory KE.
- The increase of KE results in rise in temperature.

POTENTIAL ENERGY CURVE

- Due to the presence of Intermolecular attraction, the molecules possess PE.
- The atoms In a solid are arranged in a regular order called lattice.
- There exists a force of attraction between the atoms depending on the distance between them. Hence the atoms acquire potential energy.
- At a particular distance of separation the force of attraction is maximum - Imparting minimum potential energy and acquire stability.
- At equilibrium the atoms are in a specific state of vibration, at a particular distance of separation (r_o), making solid to have a definite size.
- The graph between the interatomic distance and potential energy is a curve called potential energy curve.

Molecular Explanation of thermal expansion

Thermal expansion of solids can be explained in terms of asymmetry in the intertomic potential energy curve, as shown in Fig.



At any given temperature T_1 and energy, say E_1, atoms vibrate with the interatomic separation oscillating between its minimum ($O_1 A_1$) and maximum ($O_1 B_1$). The equilibrium interatomic separation is the mean ($O_1 C_1$) of these values.
When the solid is heated to temperation T_2, the energy increases to E2 The atoms now vibrate with the interatomic separation oscillating between its minimum ($O_2 A_2$) and maximum ($O_2 B_2$). The equilibrium interatomic separation is mean $O_2 C_2$ of these values.
We find that $O_2 C_2 > O_1 C_1$ i.e. the equilibrium interatomic separation increases with temperature. This is the origin of thermal expansion of solids.

In case of gases, as temperature is raised, molecular impacts become harder causing an increase in pressure. The pressure can be kept constant only by expansion.

COEFFICIENTS OF EXPANSION:

- When a solid is heated the increase in length is called linear expansion.
- The ratio of increase in length of a solid per degree rise in temperature to its original length is called linear expansion coefficient.

$$\alpha = \frac{l_2 - l_1}{l_1 \times (t_2 - t_1)} /^0C$$

$l_2 = l_1 [1 + \alpha (t_2 - t_1)]$

The coefficient of linear expansion of a solid depends on the nature of the material only.

Ex: Iron - $\alpha = 12\times10^{-6} /^0 C$
Copper - $\alpha = 17\times10^{-6} /^0 C$
Brass - $\alpha = 18\times10^{-6} /^0 C$

The linear expansion of a solid depends on three factors.

$l_2 - l_1 = e = l_1 \alpha (t_2 - t_1)$

a) Its original length (l_1)
b) The nature of the material (a)
c) Change in temperature (t_2 - t_1)

- The increase in area is called areal expansion or superficial expansion.
- The ratio of increase in its area per degree rise in temperature to its original area is called areal expansion coefficient â

$$\beta = \frac{a_2 - a_1}{a_1 \times (t_2 - t_1)} /^0C$$

$a_2 = a_1[1 + \beta\ (t_2 - t_1)]$

- The increase in volume is called volume expansion or cubical expansion.
- The ratio of increase in its volume per degree rise in temperature to its original volume is called volume expansion coefficient γ.

$$\gamma = \frac{V_2 - V_1}{V_1 \times (t_2 - t_1)} /^0C$$

$V_2 = V_1[1 + \gamma\ (t_2 - t_1)]$

- The S.I. unit of $\alpha . \beta$ and γ is K^{-1}.
- The dimensional formula of α , β and γ is [$è^{-1}$]
- The values of α β and γ are same in centigrade and kelvin scale.
- Numerical value of expansion coefficient of a solid become 5/9 times when we use Fahrenheit scale instead of centigrade scale.

i.e. $\alpha /^0C \times \frac{5}{9} = \alpha /^0F$

Ex: The coefficient of linear expansion of a solid is $18x10^{-6}$ $/^0$ C. Its Value in Fahrenheit scale is

$18x10^{-6}$ $/^0$ C $\times \frac{5}{9}$ = 10 x 10^{-6} / ^{0}F

RELATION BETWEEN α , β and γ :

- For isotropic materials $\alpha : \beta : \gamma$ = 1:2:3

$\beta = 2\alpha \qquad \gamma = 3\beta/2$

$\gamma = 3\alpha \qquad \gamma = \alpha + \beta$

- For anisotropic materials γ is the sum of linear coefficients in three mutually perpendicular directions.

$\gamma = \alpha_x + \alpha_y + \alpha_z$.

APPLICATIONS :

- Between the rails a gap is left to allow for their expansion in summer. If **l** is the length of the rail and **t** is the change in temperature then the gap is given by l α t.
- Telephone wires are loosely connected between the poles, to allow for their contraction in winter.
- Concrete roads are laid in sections and gaps are provided between them to allow for expansion.
- Pipes used to convey steam from boiler must have loops to prevent cracking of pipes due to thermal expansion.
- Huge iron girders used in the construction of bridges and buildings are allowed to rest on rollers on either side providing scope for expansion. Hence the damage to the structure can be avoided.
- When a drop of water falls on a hot glass chimney, the portion of the spot where the water falls, contracts and due to uneven expansion of the glass it cracks.
- Pyrex glass is used to prepare test tubes for heating purpose because its linear expansion coefficient is small. (a = $3x10^{-6}\ {}^0C^{-1}$)
- Silica glass (quartz) is used for making bulbs of thermometer because of low linear expansion coefficient. (a = 0.5 $x10^{-6}\ {}^0C^{-1}$)
- Invar is an alloy of Iron - 63.8%, Nickel - 36% and Carbon - 0.2%. Invar has very low linear expansion coefficient so balance wheels in wrist watches, pendulums in clocks and standard scales are made of Invar steel.
- A cavity inside a solid behaves as if it is a solid for all thermal expansions and contractions.
- A hole is drilled at the center of a metallic plate. When plate is heated, the diameter of hole increases.
- When two holes are drilled on a metal plate and heated the distance between the holes increases.
- When a solid and hollow spheres with same outer radius made up of same metal are heated to same temperature then both expand equally.
- Platinum is used to seal glass because their coefficients of expansion are almost same.
- Steel is used in RCC because their coefficient of expansions are almost same.

- Generally, modulus of elasticity in solid decreases with increase in temperature.
- Moment of inertia of a body increases with increase in temperature.

SAME EXPANSION IN DIFFERENT RODS

- If two rods of different materials have the same deference between their lengths at all temperatures.

Then $l_1\alpha_1 = l_2\alpha_2$, $\frac{l_1}{l_2} = \frac{\alpha_2}{\alpha_1}$

if the constant deference in their lengths is x then

$$l_1 = \frac{x\alpha_2}{\alpha_1 \sim \alpha_2}, \quad l_2 = \frac{x\alpha_1}{\alpha_1 \sim \alpha_2}$$

This principle is used in grid Iron pendulum

- If an iron ring with a saw - cut is heated, the width of the gap increases.
- Thick glass tumbler cracks when hot liquid is taken into it because of unequal expansion.

- **BIMETALLIC STRIP :**

- Bimetallic strip works on the principle of differential expansion of metals.
- If a bimetallic strip made of brass and iron is heated brass bends on convex side.
- If it is cooled brass bends on concave side. The reason for this is expansion of brass is more than that of iron.
- Radius of curvature of a bimetallic strip.

$$R = \frac{d}{(\alpha_2 - \alpha_1)(t_2 - t_1)}$$

d =Thickness of bimetallic strip used.

a) as temperature sensor in thermometers and fire alarms.

b) As an automatic switch or circuit breaker in electric iron, refrigerators, incubators, thermostats, flash lights etc.,

c) As a balance wheel in wrist watches.

- **PENDULUM CLOCKS:**

Pendulum clocks lose or gain time as the length increases or decreases respectively.

The fractional change in time period = $\frac{\Delta T}{T} = \frac{\alpha\Delta t}{2}$

The loss or gain per day = $\frac{1}{2}\alpha\Delta t \times 86400$ Seconds.

% Time lost (or) gained = $\frac{1}{2}\alpha\Delta t \times 100$

Invar steel has very low a. So it is used in making pendulum clocks, balancing wheels and measuring tapes.

Compensated pendulum length is always constant at all temperatures, so it shows correct time at all temperatures. Generally, compensated pendulums are made with invar steel, because of its very low "a."

a = Areal expansion coefficient

- **THERMAL STRESS:**

- When a metal rod is heated or cooled and is not allowed to expand or contract thermal stress is developed.
- Thermal force F=Y A α (t_2 - t_1). Thermal force is independent of length of rod.
- Thermal stress, σ = Y α (t_2 - t_1).

Y = Young's modulus

α = Coefficient of linear expansion

$t_2 - t_1$ = difference in temperature

A = area of cross section of the metal rod

For same thermal stress in two different roads heated through the same rise in temperature,

$Y_1 \alpha_1 = Y_2 \alpha_2$

- A metal scale calibrated at particular temperature does not give the correct measurement at any other temperature.

- When scale expands correction to be made $\Delta l = L\alpha\Delta t$ Correct reading $L + \Delta l$
- When scale contract correction to be made $\Delta l = L\alpha\Delta t$ Correct reading $L - \Delta l$

L= measured value

% error in the measurement = $100\alpha\Delta t$

Relation between faulty and correct length of body is given by

$$\frac{l_2 - l_1}{l_1} = (\alpha_b - \alpha_S)\Delta t$$

where l_1=length of body at $t_1{}^0$c where the scale is marked

l_2=length of body at $t_2{}^0$c where the measurement is made

α_b = coefficient of linear expansion of the body

α_s = coefficient of linear expansion of the scale

- **BAROMETER WITH BRASS SCALE :**

Relation between faulty and actual barometric height is given by

- $h_2 = h_1 (1+(\alpha_s - \gamma_{Hg}) (t_2-t_1))$

h_1= height of barometer at $t_1{}^0{}_c$ where the scale is marked.

- h_2= height of barometer at $t_2^0{}_c$ where the measurement is made.
- γ_{Hg} = real coefficient of expansion of mercury
- γ_s = Coefficient of linear expansion of scale

- **VARIATIONOF DENSITY OF A SOLID WITH TEMPERATURE.**

When as solid is heated its volume increases and hence its density decreases.

If d_1 and d_2 are densities of a solid at t_1^0C and

- t_2^0C, $d_1 = d_2\{1+\gamma\ (t_2 - t_1)\}$

If d_1 and d_0 are densities at t^0 C and 0^0 C.

$$d_1 = \frac{d_0}{(1+\gamma t)} (or) d_0 = (1+\gamma t)$$ (exact formula)

$d_1=d_0(1+\gamma\ t)$ (approximate formula)

- **PERCENTAGE CHANGES :**
- Fractional change in length = $\frac{l_2 - l_1}{l_1} = \alpha\Delta t$
- Percentage change in length =

$$\left(\frac{l_2 - l_1}{l_1}\right) \times 100 = \alpha\Delta t \times 100$$

- Percentage change in area

$$= \left(\frac{a_2 - a_1}{a_1}\right) \times 100 = \beta\Delta t \times 100$$

= 2xpercentage change in length.

- Percentage change in volume

$$= \left(\frac{v_2 - v_1}{v_1}\right) \times 100 = \gamma\Delta t \times 100$$

=3xpercentae change in length.

- Percentage changes does not depend on original dimensions of the body
- Two metal rods of coefficients of linear expenses α_1 and α_2 have same length at $\theta_1{}^0C$ and $\theta_2{}^0C$ respectably the common temperature at which they have same lengths is

$$\theta = \frac{\alpha_1\theta_1 - \alpha_2\theta_2}{\alpha_1 - \alpha_2}$$

CONCEPTUAL QUESTIONS

1. Solids expand on heating because
   1) The K.E. of the atoms increases.
   2) The P.E. of the atoms increases
   3) Total energy of the atoms increases.
   4) The K.E. of the atoms decreases.
2. Expansion during heating
   1) Occurs only in solids.
   2) Decreases the density of the material
   3) Occurs at the same rate for all liquids and gases.
   4) Increases the weight of the material.
3. When a metal bar is cooled, then which one of these statements is correct.
   1)Length, density and mass remain same.
   2)Length decreases, density increases but mass remains the Same
   3)Length and mass decrease but densityremains the same.
   4)Length and density decrease but mass remains the same.
4. When a metal bar is heated, the increase in length is greater, if
   1) The bar has large diameter
   2) The bar is long.
   3) The temperature rise large.
   4) Both 2 and 3.
5. A ring shaped piece of a metals heated, If the material expands, the hole will
   1) Contract 2) Expand 3) Remain same
   4) Expand or Contract depending on the width
6. A solid ball of metal has a spherical cavity inside it. The ball is cooled.The Volume of the cavity will
   1) decrease 2) increase
   3) remain same 4) have its shape changed
7. The substance which has negative coefficient of linear expansion is
   1) Lead 2) Aluminum 3) Iron 4) invar steel
8. Two spheres of same size are made of same material but one is hollow and the other is solid. They are heated to same temperature, then
   1) Both spheres will expand equally.
   2) Hollow sphere will expand more than solid one.
   3) Solid sphere will expand more than hollow one.
   4) Hollow sphere will expand double that of solid one
9. Two spheres of same size made of same material are given same amount of heat. Then.
   1) Both spheres will expand equally.
   2) Hollow sphere will expand more than solid one.
   3) Solid sphere will expand more than hollow one.
   4) Solid sphere will expand three times that of hollow sphere.
10. The linear expansion of a solid depends on
    1) Its original length
    2) Nature of the material and temperature difference.
    3) The nature of the material only
    4) Both 1 and 2
11. The coefficient of linear expansion of a solid depends upon
    1) the unit of length
    2) the nature of the material only
    3) the nature of the material and temperature
    4) Both 1 and 2
12. If α_c and α_k denote the numerical values of coefficient of linear expansions of the solid , expressed per ^{0}C and per Kelvin respectively, then.
    1) $\alpha_c > \alpha_k$ 2) $\alpha_c < \alpha_k$ 3) $\alpha_c = \alpha_k$ 4) $\alpha_c = 2\alpha_k$

13. If α_c and α_f denote the numerical values of coefficient of linear expansion of a solid, expressed per ^{0}C and per ^{0}F respectively, then
1) $\alpha_c > \alpha_f$ 2) $\alpha_f > \alpha_c$
3) $\alpha_f = \alpha_c$ 4) $\alpha_f + \alpha_c = 0$

14. The coefficient of linear expansion of a metal rod is 12x10^{-6} / ^{0}C, its value in per $_0$C, its value in per ^{0}F
1 . $\frac{20}{3}\times10^{-6}/^0F$ 2. $\frac{15}{4}\times10^{-6}/^0F$
3. $21.6\times10^{-6}/^0F$ 4. $12\times10^{-6}/^0F$

15. The coefficient of volume expansion is
1) equal to the coefficient of linear expansion.
2) Twice the coefficient of linear expansion
3) Equal to the sum of coefficients of linear and superficial expansions.
4) Twice the coefficient of areal expansion.

16. The coefficient of linear expansion of a solid is experimentally determined by.
1) Mechanical lever method
2) Optical lever method
3) Spherometer method
4) All the above

17. Always platinum is fused into glass, because
1) Platinum is good conductor of heat
2) Melting point of platinum is very high
3) They have equal specific heats
4) Their coefficients of linear expansion are equal

18. Two metal strips that constitute a bimetallic strip must necessarily differ in their.
1) length 2) mass
3) coefficient of linear expansion 4) resistivity

19. Thermostat is based on the principle of
1) equal expansion of two rods of different lengths.
2) Different expansion of two rods of different lengths.
3) Different expansion of two rods of same length
4) Equal expansion of two rods of same length.

20. A pendulum clock shows correct time at 0^0 C. At a higher temperature the clock.
1) loses time 2)gains time
3) neither loses nor gains time 4)will not operate

21. To keep the correct time modern day watches are fitted with balance wheel made of
1) Steel 2) Platinum 3) Invar 4)Tungsten

22. A brass disc fits into a hole in an iron plate. To remove the disc.
1) the system must be cooled
2) the system must be heated
3) the plate may be heated (or) cooled
4) the disc must be heated

23. When hot water is poured on a glass plate, it breaks because of
1) unequal expansion of glass
2) equal contraction of glass
3) unequal contraction of glass
4) glass is delicate

24. When the temperature of a body increases
1) density and moment of inertia increase
2) density and moment of inertia decrease
3) density decreases and moment of inertia increases.
4) Density increases and moment of inertia decreases.

25. In balance wheel of watch, the factors that make its oscillations uniform are
1) tension in hair spring
2) moment of inertia of balance wheel
3) Both 1 and 2 4) Neither 1 nor 2

26. A rectangular metal plate has two circular holes drilled in a symmetric manner as shown in the figure. If the metal plate is uniformly heated, which of the marked distances x, y, z will increase ?
1) x, y 2) y, z 3) x, z 4) x, y and z

27. When a metal ring is heated
1) he inner radius decreases and outer radius increases
2) The outer radius decreases and inner radius increases
3) Both inner and outer radii increase
4) Both inner and outer radii decrease

28. The material whose elasticity remains constant even when the temperature is changed is
1) Bimetallic strip 2) invar steel
3) Elinvar 4) Alnico

29. To withstand the shapes of concave mirrors against temperature variations used in high resolution telescope, they are made of
1) Quartz 2) Flint glass
3) Crown glass 4) Combination of Flint and Silica

30. The holes through which the fish plates are fitted to join the rails are oval in shape because
1) Bolts are in oval shape
2) To allow the movement of rails in the direction of length due to change in temperature.
3) To make the fitting easy and tight
4) Only oval shape holes are possible

31. A semicircular metal ring subtends an angle of 180^0 at the center of the circle. When it is heated, this angle
1) remains constant 2) increases slightly
3) decreases slightly 4) becomes 360^0

32. The diameter of a metal ring is D and the coefficient of linear expansion is a . If the temperature of the ring is increased by 1^0 C, the circumference and the area of the ring will increase by
1) $\pi D\alpha$, $2\pi D\alpha$ 2) $2\pi D\alpha$, $\pi D^2\alpha$
3) $\pi D\alpha$, $\frac{\pi D\alpha}{2}$ 4) $\pi D\alpha$, $\frac{\pi D^2\alpha}{2}$

33. The moment of Inertia of a uniform thin rod about its perpendicular bisector is I. If the temperature of the rod is increased by q the moment of Inertia about perpendicular bisector increases by (coefficient of linear expansion of material of the rod is a
1) Zero 2) $I\alpha$q 3) 2 $I\alpha$q 4) 3 $I\alpha$q

34. A piece of glass is heated to a high temperature and then allowed to cool. If it cracks, a probable reason for this is the following property of glass
1)low thermal conductivity 2)high thermal conductivity
3)high specific heat 4) high melting point

35. If L_1 and L_2 are the lengths of two rods of coefficients of linear expansion α_1 and α_2 respectively the condition for the difference in lengths to be constant at all temperatures is

1) $L_1\alpha_1 = L_2\alpha_2$ 2) $L_1\alpha_2 = L_2\alpha_1$
3) $L_1\alpha_1^2 = L_2\alpha_2^2$ 4) $L_1\alpha_2^2 = L_2\alpha_1^2$

36. An Iron ball is heated. The percentage increase will be largest in

1) diameter 2) Surface area 3) Volume 4) density

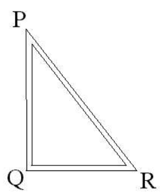
37. The coefficients of linear expansion of P and Q are α_1 and α_2 respectively. If the coefficient of cubical expansion of 'Q' is three times the coefficient of superficial expansion of P, then which of the following is true ?

1) $\alpha_2 = 2\alpha_1$ 2) $\alpha_1 = 2\alpha_2$ 3) $\alpha_2 = 3\alpha_1$ 4) $\alpha_1 = 3\alpha_2$

38. The substance which contracts on heating is

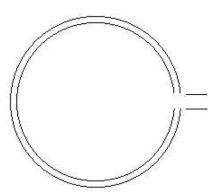
1) Silica glass 2) Iron
3) Invar steel 4) Aluminum

39. PQR is a right angled triangle made of brass rod bent as shown. If it is heated to a high temperature the angle PQR.



1) increases 2) decreases
3) remains same 4) becomes 135^0

40. An iron ring has a gap as shown in the figure. If the ring is uniformly heated to a higher temperature the width of gap.



1) remains same 2) increases
3) decreases
4) may increase or decrease

KEY

01) 1	02) 2	03) 2	04) 4	05) 2
06) 1	07) 1	08) 1	09) 2	10) 4
11) 2	12) 3	13) 1	14) 1	15) 3
16) 4	17) 4	18) 3	19) 3	20) 1
21) 3	22) 1	23) 1	24) 3	25) 3
26) 4	27) 3	28) 3	29) 1	30) 2
31) 1	32) 4	33) 3	34) 1	35) 1
36) 3	37) 1	38) 1	39) 3	40) 2

LEVEL - 1

1) A wire of length 100cm increases in length by 10^{-2} m when it is heated through 100^0 C. The coefficient of linear expansion of the material of the wire expressed in /K units is

1) -1 X 10^{-6} / K 2) 1 X 10^4 / K
3) 1 X 10^{-4} / K 4) 10^{-2} / K

2) A metal plate of area 1.2 m^2 increases its area by 2.4 X 10^{-4} m^2 when it is heated from 0^0 C to 100^0 C. The coefficient of cubical expansion of the metal expressed in per ^{0}C is

1) 2 X 10^{-6} 2) 4 X 10^{-6} 3) 6 X 10^{-6} 4) 3 X 10^{-6}

3) The length of a metal rod at 10^0C is 1m. Its coefficient of linear expansion is 12 X 10^{-6} /^{0} C.
The temperature to which it must be heated so that the expansion in it is 12mm is

1) 1000^0 C 2) 820^0 C 3) 1010^0 C 4) 101^0 C

4) The length of each rail is 10m. The coefficient of linear expansion of steel is 12 X 10^{-6} /^{0} C and the range of variation of temperature at the given place is 15^0 C. The gap to be left between the rails is

1) 0.0001 m 2) 0.018 m 3) 0.0012 m 4) 0.0018 m

5) Two metal rods have coefficients of linear expansion 1.1 X 10^{-5} /^{0} C and 1.65 X 10^{-5} /^{0} C respectively. The difference in lengths is 10cm at all temperatures. Their initial lengths must be respectively.

1) 40 cm and 50 cm 2) 40 cm and 30 cm
3) 50 cm and 60 cm 4) 30 cm and 20 cm

6) A clock while keeps correct time at 30^0 C has a pendulum rod made of brass. The number of seconds it gains (or) loses per second when the temperature falls to 10^0 C is
[a of brass = 18 X 10^{-6} /^{0} C]

1) 18 X 10^{-6} sec 2) 18 X 10^{-5} sec
3) 0.0018 sec 4) 0.018 sec

7) An iron bar whose cross sectional area is 4cm^2 is heated from 0^0C and 100^0C. The force required to prevent the expansion of the rod is
[Y of Iron = 2 X 10^{12} dyne / cm^2
α of Iron = 12 X 10^{-6} /^{0}C]

1) 0.96 X 10^8 N 2) 0.96 X 10^7 N
3) 9.6 X 10^7 N 4) 96 X 10^3 N

8) The density of a substance at 0^0C is 10 g/c.c. and at 100^0C and at 100^0C its density is 9.7g/c.c. The coefficient of linear expansion of the substance is.

1. 10^{-4}/^{0}C 2. 3x10^{-4}/^{0}C 3. 6x10^{-4}/^{0}C 4. 9x10^{-4}/^{0}C

9) The coefficient of linear expansion of a metal is 1x10^{-5}/^{0}C. The percentage increase in area of a square plate of that metal when it is heated through 100^0C is

1) 0.02% 2) 0.1% 3) 0.001% 4) 0.2%

10) The coefficient of superficial expansion of rod is 4x10^{-5}/^{0} C. The percentage increase in the volume of a cube of that metal when it is heated from 0^0C to 100^0 C is

1) 0.4% 2) 0.8% c) 1.2% d) 0.6%

11) A steel rod of length 0.5km is used in the construction of a bridge. It has to withstand a temperature change of 40^0C. The gap that is allowed for its expansion is [a = 10^{-6}/^{0}C]

1) 0.02cm 2) 0.02mm 3) 2m 4) 20 mm

12) A rod is found to be 200 cm long at 40^{0}C and 200.24 cm at 100^{0}C. The coefficient of cubical expansion of the material is
1) 2x10^{-5}/^{0}C 2) 6x10^{-5}/^{0}C 3) 3x10^{-5}/^{0}C 4) 4x10^{-5}/^{0}C

13) A metal rod having α =10x10^{-6}/^{0}C has a length of 250 cm at 40^{0}C. The temperature at which it can be shortened by 1mm.
1) 80^{0}C 2) -40^{0}C 3) 0^{0}C 4) 40^{0}C

14) The coefficient of linear expansion of brass is 19x10^{-6}/^{0}C. If the volume of brass vessel at 0^0 C is 19x10^{-6}/^{0}.C If the volume of brass vessel at 0^0 C is 150 cc, its volume at 100^0 C
1) 150.86cc 2) 149.14 cc 3) 150 cc 4) 207 cc

15) The radius of a metal sphere is 100 cm at 0^0 C and 101 cm at 100^0 C. The coefficient of volume expansion of metal is
1) 10^{-4} /^oC 2) 3×10^{-4} /^oC
3) 2×10^{-4} /^oC 4) 1.5×10^{-4} /^oC

16) The invar volume of a brass sphere is 1000 cc at 0^{0}C. Its volume at 100^{0}C is (α =18x10$^{-6/0}$C)
1) 1000 cc 2) 994.6 cc 3) 1005.4 cc 4) 100.54 cc

17) A brass sheet is 25 cm long and 8 cm broad at 0^0 C. Its area at 100^{0}C is (α = 18 x10^{-6} /^{0} C)
1) 207.2 cm^2 2) 200.72 cm^2
3) 272 cm^2 4) 2000.72 cm^2

18) A brass rod of cross section 2 cm X 2 cm is heated through 10^{0}C and prevented from expansion. The thermal force exerted on the clamp is
(For brass, α = 2 X 10^{-5} /^{0} and Y = 2 X 10^{10} P)
1) 160 N 2) 1600 N 3) 100 N 4) 8000 N

19) An iron tyre 100 cm in diameter is to be fitted on to a wooden wheel of 100.4 cm in diameter if a of Iron is 1 X10^{-5} /^{0} C, the temperature increase required for this purpose is
1) 40^0 C 2) 100^0 C 3) 400^0 C 4) 1000^0 C

20) A hole of 4 cm in diameter is made in a brass plate at a temperature of 20^0 C. The diameter of the hole when the temperature of plate is increased to 100^0 C is (α = 20 X 10^{-6} /^{0} C)
1) 4.64 cm 2) 4.064 cm 3) 4.00064 cm 4) 4.0064 cm

21) The pendulum of a clock is made of brass. If the clock keeps correct time at 20^0 C how many seconds per day will it loose at 35^0 C (α for brass = 2 X 10^{-5} /^{0} C)
1) 12.96 s 2) 1.29 s 3) 129.6 s 4) 8.64 s

22) A clock pendulum keeps correct time at 25^{0}C. If the pendulum is made of steel whose α = 1 X 10^{-5} /^{0} C, how many seconds per day will it gain or loose when used at 40^{0}C
1) 12.96 s 2) 6.48 s 3) 3.24 s 4) 8.64 s

23) A steel rod of cross section 1 mm^2 is prevented from expansion by heating through 10^0 C. The thermal force developed in it is
(Y = 2 X 10^{11} N/m^2; α = 10^{-5} /^{0}C)
1) 20N 2) 2N 3) 200 N 4) 0.2 N

24) What force should be applied to the ends of steel rod of a cross sectional area 10 cm^2 to prevent it from elongation when heated form 273 K to 303 k? (α of steel 10^{-5} ^{0}C^{-1}, Y = 2 X 10^{11} N/m^2)
1) 2x10^{4}N 2) 3x10^{4}N 3) 6x10^{4}N 4) 12x104 N

25) The inner diameter of a brass ring at 273 K is 5 cm. To what temperature should it be heated for it to accommodate a ball 5.01 cm in diameter. (α = 2X10^{-5} /^{0} C)
1) 273 K 2) 372 K 3) 437 K 4) 173K

26) A metal sheet having size of 0.6 X 0.5 m^2 is heated from 293 K to 520^0 C. The final area of the hot sheet is . {α of metal = 2 X 10^{-5} /^{0} C]
1) 0.306 m^2 m 2) 0.0306 m^2 3) 3.06 m^2 4) 1.02m^2

KEY

01) 3	02) 4	03) 3	04) 4
05) 4	06) 2	07) 4	08) 2
09) 4	10) 4	11) 4	12) 2
13) 3	14) 1	15) 2	16) 3
17) 2	18) 2	19) 3	20) 4
21) 1	22) 2	23) 1	24) 3
25) 2	26) 1		

LEVEL- 2

1) when a rod is heated from 25^{0}C to 75^{0}C, it expands by 1 mm. When a rod of same material but with 4 times the length is heated from 25^{0}C to 50^{0}C. The increase in length is
1) 1mm 2) 1.5mm 3)1.6mm 4) 2 mm

2) A crystal has linear coefficients 0.00004/^{0}C, 0.00005/^{0}C, 0.00006/^{0}C. Coefficient of cubical expansion of the crystal is
1)0.000015/^{0}C 2) 0.00015/^{0}C
3) 0.00012/^{0}C 4) 0.00018/^{0}C

3) A solid sphere and a hollow sphere of same material have same mass. When they are heated by 50^{0}C, increase in volume of solid sphere is 5c.c. The expansion of the hollow sphere is
1) 5 c.c. 2) More than 5 c.c.
3) less than 5 c.c. 4) Zero

4) A bimetal made of copper and iron strips welded together is straight at room temperature. It is held vertically so that the iron strip is towards the left hand and copper strip is towards right hand. The bimetal strip is then heated. The bimetal strip will
1) remain straight 2) Bend towards right
3) Bend towards left 4) Have no change

5) A wire of length 60 cm. Is bent into a circle with a gap of 1 cm. At its ends. On heating it by 100^{0}C, the length of the gap increases to 1.02 cm. α of material of wire is
1) 2x10^{-4}/^{0}C 2) 4x10^{-4}/^{0}C 3) 6x10^{-4}/^{0}C 4) 1x10^{-4}/^{0}C

6) A brass rod at 30^{0}C is observed to be 100cm long when measured by a steel scale which is correct at 0^{0}C. α for steel is 12 X 10^{-6} /^{0} C and α for brass is 19 X 10^{-6} /^{0} C and α for brass is 19X 10^{-6} /^{0} C. The correct length of brass rod at 0^{0}C is
1) 100.021 cm 2) 99.979 cm
3) 100.042 cm 4) 99.958 cm

7) A brass rod and a steel rod are both measured at 0^0C. Their lengths are found to be 150 cm and 150.2 cm respectively. At what common temperature will their lengths be equal. (α_{steel} = 12 X10^{-6}/^{0} C, α brass =18X 10^{-6}/^{0} C)
1) 111.4^{0}C 2) 167.^{0}C 3) 222.2^{0}C 4) 278.3^{0}C

8) When the temperature of a metal sphere increases by 100^{0}C, its surface area increases by 0.2%. Coefficient of cubical expansion of the sphere is
1) 5x10^{-6}/^{0}C 2) 10x10^{-6}/^{0}C
3) 20x10^{-6}/^{0}C 4) 30x10^{-6}/^{0}C

9) A crystal has a coefficient of expansion 13 X 10^{-7}/^{0} C in one direction and 231 X 10^{-7}/^{0} C in every direction at right angles to it. Then the cubical coefficient of expansion is
1) 257x10^{-7}/^{0}C 2) 462x10^{-7}/^{0}C
3) 244x10^{-7}/^{0}C 4) 475x10^{-7}/^{0}C

10) A brass scale gives correct length at 0^{0}C. If the temperature be 25^{0}C and the length read by the scale is 10 cm. Then the actual length will be
1) more than 10 cm 2) less than 10 cm
3) equal to 10 cm 4) we can not say

11 . B_1 is the bulk modulus of cube at t_1^{0}C and B_2 is the bulk modulus at $(t_1 + 30)^0$C then
1) B_1=B_2 2) B_2<B_1 3) B_2 > B_1 4) B_1-B_2=30

12. A metal sphere is heated from 0^{0}C to 100^{0}C. The change in volume of 10cm radius is (γ =6.3 X 10^{-5}/^{0} C)
1) 1026.4cc 2) 26.4cc 3) 2.64cc 4) 264.3cc

13. The diameter of iron wheel is 1cm. If its temperature is increased by 700^{0}C What is the increase in circumference of the wheel ? (a=12 X 10^{-6}/^{0} C)
1) 0.0264 cm 2) 0.264 cm 3) 2.64 cm 4) 26.4 cm

14. An iron matel rod is to maintain an accuracy of one part per million. The coefficient of linear expansion of iron is 1 X 10^{-5}/^{0} C. The minimum variations in temperature of the rod could be
1) ± 1^{0}C 2) ± 5^{0}C 3) ±0.1^{0}C 4) ± 0.01^{0}C

15. Two rods of different materials having coefficients of thermal expansion α_1, α_2 and young's modulus y_1, y_2 respectively are fixed between two rigid walls. The rods are heated such that they undergo the same increase in temperature. There is no bending of rods. If $\alpha_1 : \alpha_2$ =2:3, thermal stress developed in the rods are equal provided y_1:y_2 is equal to
1) 2:3 2) 1:1 3) 3:2 4) 4:9

16. A cube of edge (L) and coefficient of linear expansion (a) is heated by 1^{0}C. Its surface area increases by
1) 6αL^2 2) 8αL^2 3) 12αL^2 4) 2αL^2

17. Brass scale of a Barometer gives correct reading at 0^{0}C. coefficient of linear expansion of brass is 18 X 10^{-6}/^{0}C. If the barometer reads 76cm at 20^{0}C, the correct reading is (γ_{Hg}=18 X 10^{-5}/^{0} C)
1) 76.426 cm 2) 75.7cm
3) 76.642 cm 4) 76.264 cm

KEY

1) 4	2) 2	3) 2	4) 3
5) 1	6) 2		
7) 3	8) 4	9) 4	10) 1
11) 2	12) 2		
13) 1	14) 3	15) 3	16) 3
17) 2			

HINTS

1. $\frac{e_1}{l_1\Delta t_1} = \frac{e_2}{l_2\Delta t_2}$

2. $\gamma = \alpha_x + \alpha_y + \alpha_z$

3. $\Delta v \propto v$ Mass is same, volume is more for hollow sphere.

4. More a metal bend on convex shape when heated

5. $\alpha = \frac{l_2 - l_1}{l_1\Delta t}$ (gap can be taken as l_1)

6. l_0=l_1[1-(α_b-α_s)t]

7. t^0C= l_1-l_2/ ($l_1\alpha_1$-$l_2\alpha_2$)

8. $\beta = \frac{\Delta A}{A\Delta t}, \gamma = \frac{3\beta}{2}$

9. $\gamma = \alpha_x + (\alpha_y + \alpha_z)$

11. $k = \frac{\text{Normal stress}}{\text{Bulk strain}} = \frac{\text{Normal stress}}{\gamma\delta t}$

12. Where $V = \frac{4}{3}\Pi r^3$

13. Increase is circumference = $\pi D\alpha\Delta t$ where D = diameter of the wheel

14. $\frac{\Delta l}{l}$ = 1/10^6

15. $\frac{Y_1\Delta l_1}{l} = \frac{Y_2\Delta l_2}{l}$

16. $\Delta A = A\beta\Delta t$

17. True value =scale reading $\left[l - (\gamma - \alpha)\Delta t\right]$

LEVEL - 3

1) The initial lengths of two rods A and B are in the ratio 3:5 and coefficients of linear expansion are in the ratio 5:3. If the rods are heated from 34^0C to 65^0C, the ratio of their expansion will be
1) 1:1 2) 3:5 3) 1:2 4) 2:3

2) When a thin rod of length 'l' is heated from t^0_1C to t^0_2 C length increases by 1%. If plate of length 2l and breadth 'l' made of same material is heated form t^0_1 C to t^0_2 C, percentage increase in area is
1) 1 2) 2 3) 3 4) 4

3) A steel tape is calibrated at 20^0C. when the temperature of the day is -10^0C, the percentage error in the measurement with the tape is (α =12 X 10^{-6} /^{0} C)
1) 3.6% 2) 0.36% 3) 0.18% 4) 0.036%

4) Distance between two places is 200km. α of metal is 2.5 X 10^{-5} /^{0} C. Total space that must be left between steel rails to allow for a change of temperature from 36^0F to 117^0F is
1) 2.25 km 2) 0.225 km
3) 22.5 km 4) 0.0225 km

5) Coefficients of linear expansions of two metals are in the ratio 3:4. The ratio of initial lengths of rods so that the expansions may be equal when heated through the same range of temperature is
1) 3:4 2) 4:3 3) 1:1 4) 4:1

6) Coefficient of cubical expansion of a metal cube is γ. Increase in temperature for which the volume of the cube increases by 5% is
1) 0.05 γ 2) 0.5 γ 3) 0.5/γ 4) 0.05/γ

7) The temperature of a thin uniform rod increases by t. Its moment of inertia '*I*' about an axis perpendicular to its length increases by
1) 0 2) αIt 3) $2\alpha It$ 4) $\alpha^2 It$

8) In a grid iron pendulum, there are 3 iron rods and 4 brass rods, Length of each brass rod is 50 cm. α of iron is 12 X 10^{-6} /^{0}C and α of Brass is 18X10^{-6}/^{0}C. Length of each iron rod is
1) 50 cm 2) 100cm 3) 120 cm 4) 60 cm

9) Coefficient of linear expansion of a crystal in 3 mutually perpendicular directions are 8.5X10^{-6}/^{0}C, 10.5X10^{-6}/^{0}C, 11X10^{-6}/^{0}C. If mass of crystal is 25gm, its volume at 60^0c is (given density at 0^0C is 5 g/cc)
1) 5.009 c.c. 2) 4.991 c.c. 3) 5.9 c.c. 4) 5.999 c.c.

10) A brass rod and a lead rod each 80 cm long at 0^0c, are clamped together at one end with their free ends coinciding. The separation of the free ends of the rods, if the system is placed in steam bath is
$(\alpha_{pb} = 28\times10^{-6}\ /^oC, \alpha_{br} = 18\times10^{-6}\ /^oC)$
1) 0.2 mm 2) 0.8 mm 3) 1.4 mm 4) 1.6 mm

11) A pendulum clock runs fast by 5 seconds per day at 20^0c and goes slow by 10 seconds per day at 35^0C. It shows correct time at a temperature of
1) 27.5^0C 2) $25.^0$C 3) $30.^0$C 4) $33.^0$C

12) A sphere of coefficient of linear expansion α, mass 'm' and radius 'r' is spinning about an axis through its diameter with an angular velocity 'ω' when it is heated such that its temperature increases by Δ t, the angular velocity becomes.
1) $\omega(1+\alpha\Delta t)^2$ 2) $\dfrac{\omega}{(1+\alpha\Delta t)^2}$
3) $\omega(1+\alpha\Delta t)$ 4) $\omega\alpha\Delta t$

13) Two uniform bars of lengths L_1 and L_2 with coefficient of linear expansions α_1 and α_2 are joined to form a longer rod of length L_1+L_2. The effective coefficient of linear expansion of the composite bar is
1) $\dfrac{L_1+L_2}{L_1\alpha_1+L_2\alpha_2}$ 2) $\dfrac{L_1\alpha_1+L_2\alpha_2}{L_1+L_2}$
3) $\dfrac{L_1\alpha_1-L_2\alpha_2}{L_1+L_2}$ 4) $\dfrac{L_1-L_2}{L_1\alpha_1-L_2\alpha_2}$

14) A steel tape is calibrated at 20^0C. It is used to measure a length of an object on a hot summer day when the temperature is 40^0C. If measured length is 5m, the actual length is(a=1X10^{-5} /^{0}C)
1) 5.001m 2) 5.01 m 3) 5.1 m 4) 4.99 m

15) A solid sphere of radius r and mass m is spinning about a diameter as axis with a speed ω_0. The temperature of the sphere increases by 100^0C without any other disturbance. If the coefficient of linear expansion of material of sphere is 2 X 10^{-4} /^{0} C, the ratio of angular speed at 100^0C and ω_0 is
1) 1:1 2) 1:1.04 3) 1.04:1 4) 1:1.02

16) A bimetallic strip of brass and steel, each having thickness of 1cm at 20^0C, is heated to 120^0C. It bends with brass on the outer side. The radius of curvature of the curved surface is (α brass = 18X10^{-6}/^{0} C, α steel = 12 x10^{-6}/^{0} C)
1) 16.67 m 2) 16.67cm 3) 16.67 mm 4) 3.33m

17) A uniform solid brass cylinder of mass M=0.5 Kg and radius R=0.03m is placed in frictionless bearings and set to rotate about its geometrical axis with an angular velocity of 60 rad/s. After the cylinder has reached the specified state of rotation, it is heated without any mechanical contact from room temperature 20^0C to 100^0C. The fractional change in angular velocity of the cylinder is (α =2X10^{-5}/^{0}C)
1) -3.2x10^{-3} 2) 3.2x10^{-3} 3) 2.3x10^{-3} 4) -2.3x10^{-3}

18) The diameter of a metal ring is D and the coefficient of linear expansion α. If the temperature of the ring is increased by 1^0C , the circumference and the area fo the ring will increase by
1) $\pi D\alpha,\ 2\pi D\alpha$ 2) $2\pi D\alpha,\ \pi D^2\alpha$
3) $\pi D\alpha,\ \dfrac{\pi D\alpha}{2}$ 4) $\pi D\alpha,\ \dfrac{\pi D^2\alpha}{2}$

19) Two rods of the same length, have radii in the ratio 3:4. Their densities are respectively 8000 and 9000 kg/m^3. Their specific heats are in the ratio of 2:3. When the same amount of heat is supplied to both, the changes in their lengths are in the ratio. (If their linear coefficients are in the ratio 5:6)
1) 1:1 2) 5:2 3) 5:12 4) 12:5

20) If the coefficient of the linear expansion changes from α_1 to α_2 linearly in a rod of length 'l', the increase in length for 10^0C rise of temperature is

1) $5l(1+\alpha_1\alpha_2)$ 2) $5l(\alpha_1+\alpha_2)$

3) $5l(\alpha_1-\alpha_2)$ 4) $5l^2(1+\alpha_1\alpha_2)$

KEY

1.1	2. 2	3.4	4.2
5.2	6.4		
7.3	8.2	9.1	10.2
11.2			12.2
13.2	14.1	15.2	16.1
	17.1	18.4	19.2
20.2			

HINTS

1 $\frac{e_1}{e_2}=\frac{l_1\alpha_1}{l_2\alpha_2}\frac{\Delta t_1}{\Delta t_2}\Delta t_1=\Delta t_2$

3 $\frac{\Delta l}{l}\times 100=\alpha\Delta t\times 100$

4 $l_1-l_2=l_1\alpha\Delta t$

5 $\frac{l_1}{l_2}=\frac{\alpha_1}{\alpha_2}=\frac{4}{3}$

6 $\Delta t=\frac{V_2-V_1}{\gamma V_1}$

7 $I\propto l^2$

$\frac{\Delta I}{I}=2.\frac{\Delta l}{l}=2\alpha\Delta t$

8 $n_1 l_1 \alpha_1=n_2 l_2 \alpha_2$

9 $\gamma=\alpha_x+\alpha_y+\alpha_z$

$V_0=\frac{m}{d_0}$

$V_t=V_0\left[l+\gamma t\right]$

10. $e_2-e_1=l_1\left[\left(\alpha_2-\alpha_1\right)\right]$

11. $\frac{1}{2}\alpha\left(35-t\right)\times 86400=10$

$\frac{1}{2}\alpha\left(t-20\right)\times 86400=5$

13. Rods connected in series

$\left(l_1\alpha_1+l_2\alpha_2\right)\Delta t=\left(l_1+l_2\right)\propto\Delta t$

14. $t_2^0C>t_1^0C$

Actul length $=L+L\alpha\Delta t$

15. $I_1 w_1=I_2 w_2$

$R_1^2 w=R_2^2 w_2$

$$\frac{w_1}{w_2}=\left(\frac{R_2}{R_1}\right)^2=\frac{1}{\left(1+\alpha\Delta t\right)^2}$$

16. $R=\frac{d}{\left(\alpha_b-\alpha_s\right)\Delta t}$

17. $I_1 w_1=I_2 w_2$

$\frac{\Delta w}{w}=\frac{-\Delta I}{I}=-2\alpha\Delta t$

20. $\alpha=\frac{\alpha_1+\alpha_2}{2}$

$\Delta l=l\alpha\Delta t=\frac{\alpha_1+\alpha_2}{2}\times l\times 10$

$=5l\left(\alpha_1+\alpha_2\right)$

PREVIOUS EAMCET QUESTIONS

1. A metallic solid sphere is rotating about is diameter as axis of rotation. If the temperature is increased by 200^0C, the percentage increased in its moment of inertia is (coefficient of linear expansion of the metal = $10^{-5}/^0$C)
[EAMCET 2004 E]

1. 0.1 2. 0.2 3. 0.3 4. 0.4

2. A thin brass sheet at 10^0C and thin steel sheet at 20^0C have the same surface area. The common temperature at which both would have the same area (coefficient of linear expansion for brass and steel are respectively 19 x $10^{-6}/^0$C and 11 x $10^{-6}/^0$C)
[EAMCET 2003 M]

1.-3.75 ^{0}C 2. -2.75^{0}C 3. 2.75 ^{0}C 4. 3.75 ^{0}C

3. Two marks on a glass rod, 10 cm apart, are found to increase their distance by 0.08 mm, when the rod is heated from 0^0C to 100^0C. A flask made of the same glass as that of rod measures a volume 1000 c.c. at 0^0C. The volume, it measures at 100ºC in C.C is (EAMCET 2002, M)

1) 1002.4 2) 1004.2 3) 1006.4 4) 1008.2

4. A metallic wire with tension T and at temperature 30^0C vibrates wit hits fundamental frequency of 1kHz. The same wire with the same tension but at 10^0C temperature vibrates with a fundamental frequency of 1.001 kHz. The coefficient of linear expansion of the wire is (EAMCET 2002, E)

1) 2x$10^{-4}/^0$C 2) 1.5x$10^{-4}/^0$C

3) 1x$10^{-4}/^0$C 4) 0.5x$10^{-4}/^0$C

5. A steel meter scale is to be ruled so that millimeter intervals are accurate within about 5×10^{-5} mm at a certain temperature. The maximum temperature variation allowable during the ruling is (Coefficient of linear expansion of steel = 10×10^{-6} K^{-1}) (EAMCET 2001, E)
1) 2^0C 2) 5^0C 3) 7^0C 4) 10^0C

6. When the temperature of a body increases form t to t + Δt, its moment of inertia increases from I to I + ΔI. The coefficient of linear expansion of the body is α. The ratio ΔI/I is : (2001, M)
1) Δt/t 2) 2 Δt/t 3) $\alpha\Delta$t 4) $2\alpha\Delta$t

7. If a cylinder of diameter 1.0cm at 30^0C is to be slid into a hole of diameter 0.9997 cm in a steel plate at the same temperature, the minimum required rise in the temperature of the plate is: (Coefficient of linear expansion of steel=$12\times10^{-6}/^0$C) (EAMCET 2001, M)
1) 25^0C 2) 35^0C 3) 45^0C 4) 55^0C

8. Two metal rods A and B are having their initial lengths in the ratio 2:3 and coefficients of linear expansion in the ratio 3:4. When they are heated through the same temperature difference, the ratio of their linear expansion is (2000, M)
1) 1:2 2) 2:3 3) 3:4 4) 4:3

9. The length of a metal rod at 0^0C is 0.5m. When it is heated, its length increases by 2.7mm. The final temperature of rod is (coeff. of linear expansion of metal = $90\times10^{-6}/^0$C) [2000, M]
1) 20^0C 2) 30^0C 3) 40^0C 4) 60^0C

10. Density of a substance at 0^0C is 10 gm/cc and at 100^0C its density is 9.7 gm/cc. The coefficient of linear expansion of the substance is ————/^{0} C [EAMCET' 98, M]
1) 10^{-4} 2) 3×10^{-4} 3) 19.7×10^{-3} 4) 10^{-3}

11. A steel bridge in a town is 200m long. The minimum temperature in winter in the town is 10^0C and the maximum in summer is 40^0C. The change in length of the bridge from winter to summer is
(a_{steel} = 11 $\times10^{-6}$ /^{0} C) [EAMCET' 98 E]
1) 3.3cm 2) 6.6cm 3) 6.6m 4) 3.3m

12. A clock with an iron pendulum keeps correct time at 15^0C. If the room temperature rises to 20^0C, the error in seconds per day will be (coefficient of linear expansion for iron is 0.000012/^{0}C) [EAMCET' 97]
1) 2.5sec 2) 2.6sec 3) 2.4sec 4) 2.2sec

13. The variation of density of a solid with temperature is given by the formula [EAMCET' 94 M]
1) $d_2=\frac{d_1}{1+\gamma(t_2-t_1)}$ 2) $d_2=\frac{d_1}{1-\gamma(t_2-t_1)}$
3) $d_2=\frac{d_1}{1-2\gamma(t_2-t_1)}$ 4) $d_2=\frac{d_1}{1+2\gamma(t_2-t_1)}$

14. The coefficient of volume expansion is [EAMCET' 96M]
1) twice the coefficient of linear expansion.
2) Twice the coefficient of real expansion.
3) Thrice the coefficient of real expansion.
4) Thrice the coefficient of linear expansion

15. The coefficient of linear expansion of brass and steel are α_1 and α_2. If we take a brass rod of length l_1 and steel rod of length l_2 at 0^0C their difference in length (l_2-l_1). Will remain the same at all temperatures if [EAMCET' 95M]
1) $\alpha_1 l_2 = \alpha_2 l_1$ 2) $\alpha_1 l_2^2 = \alpha_2 l_1^2$
3) $\alpha_1^2 l_2 = \alpha_2^2 l_1$ 4) $\alpha_1 l_1 = \alpha_2 l_2$

16. When a metal sphere is heated maximum percentage increase occurs in its [EAMCET' 94M]
1) Density 2) Surface area 3) Radius 4) Volume

17. The balance wheel of a watch is made of [EAMCET' 94E]
1) Brass 2) Invar 3) Steel 4) Platinum

18 When a copper ball is heated the largest percentage increase will occur in its [92M]
1) Diameter 2) Area 3) Volume 4) Density

19. Upon heating, the length of the side of a cube changes by 2% the volume of the cube changes by [EAMCET' 92E]
1) 1% 2) 6% 3) 0.5% 4) 4%

20. A 2 meter long aluminum pipe at 27^0C is heated until it is 2.0024 at 77^0C. The coefficient of linear expansion of aluminum is [EAMCET' 92E]
1) $12\times10^{-6}/^0$C 2) $24\times10^{-6}/^0$C
3) $6\times10^{-6}/^0$C 4) None

21. There is a circular hole in a metal plate, what happens to the radius of the hole, when the plate is heated? [EAMCET' 85]
1) Increases 2) Decreases
3) Unchanged 4) depends upon metal

22. The length of each steel rail is 10m in winter. The coefficient of linear expansion of steel is 0.000012/^{0}C and the temperature increases by 15^0C in summer. The gap to be left between the rails [EAMCET' 84]
1) 0.0018m 2) 0.0012m 3) 0.0022m 4) 0.05m

23. At 0^0C, a square steel bar of 1 cm side, is rigidly clamped at both ends so that its length cannot increase. Young's modulus of steel is 20×10^{10} Nm^{-2} and its coefficient of linear expansion is 11×10^{-6} /^{0}C. When the temperature is raised to 10^0C, the force exerted on the clamp is
1) 1100N 2) 2200N 3) 3300N 4) 4400N

24. A metal rod having a linear coefficient of expansion 2×10^{-5} /^{0} C has a length 1m at 25^0C, the temperature at which it is shortened by 1 mm is [EAMCET' 83]
1) 50^0C 2) -50^0C 3) -25^0C 4) -12.5^0C

25. If the coefficient of linear expansion of glass is 0.000009, the coefficient of cubical expansion of glass is [EAMCET' 81]
1) 0.0000027 2) 0.000027 3) 0.00027 4) 0.000018

26. The relation between the coefficient of real expansion (γ_r) and coefficient of apparent expantion (γ_a) of a liquid and the coefficient linear expantion (α_g) of the material of the container is: [EAMCET'05]
1) $\gamma_r=\alpha_g+\gamma_\alpha$ 2) $\gamma_r=\alpha_g+3\gamma_\alpha$
3) $\gamma_r=3\alpha_g+\gamma_\alpha$ 4) $\gamma_r=3(\alpha_g+\gamma_\alpha)$

KEY

1.4	2.1	3.1	4.3
5.2	6.4	7.1	8.1
9.4	10.1	11.2	12.2
13.1	14.4	15.4	16.4
17.2	18.3	19.2	20.2
21.1	22.1	23.2	24.3
25.2	26. 3		

ASSERTION, REASON

1. **Assertion (A):** A thick and thin metallic rods of same material heated through same rise of temperature then thermal stress is same.
Reason (R): Thermal stress is independent of area of cross section.
1.A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

2. **Assertion (A):** An iron ball strucked in a brass plate is removed by heating the system.
Reason (R): The coefficient of linear expansion of brass is more than that of iron.
1. A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

3. **Assertion (A):** Invar steel is used to prepare clock pendulum.
Reason (R): The coefficient of linear expansion of invar steel is Infinity.
1. A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

4. **Assertion (A):** When hot water is poured in a thick glass tumbler then the tumbler breaks.
Reason (R): Glass is a bad conductor of heat
1. A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

5. **Assertion (A):** To have same difference between the lengths of two metallic rods their initial lengths of 0ºC should be in the inverse ratio of their coefficient of linear expansion.
Reason (R): If the lengths of two metallic rods at 0º C are in the inverse ratio of their coefficient of linear expansion then the change in the lengths due to same rise of temperature is same.
1. A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

6. **Assertion (A)**: When a bimetallic strip made of iron and brass is heated then it bends in the form of concave towards Brass.
Reason (R): The coefficient of linear expansion of iron is less than brass.
1. A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

7. **Assertion (A):** A solid on heating undergoes expansion only because of increasing the amplitude of the simple oscillators.
Reason (R): A solid on heating undergoes expansion only because of increasing the inter atomic distance.
1. A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

8. **Assertion (A):** A mettallic plate containing circular hole is heated then the size of the hole increases.
Reason (R): The expansion of the solid always takes place readily outwards.
1. A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

9. **Assertion (A):** The linear expansion dose not depend on nature of the material, initial length, and rise in temperature.
Reason (R): The coefficient of linear expansion depends on nature of the material and system of

temperature.

1. A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

10. Assertion (A): Platinum is used to fuse into glass tube.

Reason (R): Both platinum and glass have almost same values of coefficient of linear expansion.

1. A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

11. **Assertion (A):** A thin rod and a thick rod made of same material having same length are heated throuhg same range of themperature. Then both the rods expand equally.

Reason (R): The linear expandsion $e = l\alpha\Delta t$

1. A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

12. Assertion (A): A thin rod and a thick rod made of same material having same length are given same amount of heat θ. Then the thin rod expands more.

Reason (R): The linear expansion depends upon initial length of the rod only .

1. A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

13. Assertion (A): The co-efficient of linear expansion of a metal rod ix $12x10^{-6}/^{o}C$. If the length of the metal rod is measured in kilometre instead of cm, the α value is again $24\times10^{-6}/^{0}C$.

Reason (R): α is independent of unit of lengh.

1. A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

14. Assertion (A): A platinum wire can be sealed through glass. But a brass one cannot be sealed through glass.

Reasion (R): Co-efficient of linear expansion of platinum and that of Brass have different values.

1. A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

15. Assertion (A): Two rods of the same material have the same lengths but diametres are in the ration of 1:2. If 1000 cal of heat are supplied to the two rods sperately the ratio of their linear expansion is 8:1.

Reasion (R): The linear expansion $e = l\alpha\Delta t$

1. A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

16. Assertion (A): The linear expansion of metal wire is 1% when it is heated from T_1 ºC to T_2ºC. If a thin plate of same metal of dimension 2L x L was heated from T_1ºC to T_2ºC, then the areal expansion is 3%.

Reasion (R): The percentage of areal expansion=2 x% linear expansion. The % expansions are independent of original dimensions.

1. A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

17. Assertion (A): In a grid iron pendulum, there are 3 iron rods and 4 brass rods. Length of each brass rod is 50cm. α of iron is $12\times10^{-6}/^{o}C$ and α of brass is $18\times10^{-6}/^{o}C$. Length of each iron rod is 50cm.

Reasion (R): For grid iron pendulum

$n_1 l_1 \alpha_1 + n_2 l_2 \alpha_2 = 1$

1. A and R are correct and R is correct explanation for A
2. explanation for A
3. A is true and R is false
4. A is wrong and R is true.

19. Assertion (A): A metre scale measures correct lengths at 0ºC. Using this scale, length of an object is measured as 15m at 40ºC. Then the correct length of that object is $\left(\alpha = 20\times10^{-6}/^{o}C\right)$ 15.012m.

Reasion (R): True length = scale reading

1. A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

20. Assertion (A): A solid sphere $\left(\alpha = 2\times10^{-4}/^{o}C\right)$ of radiuc 'r' is spinning about its diametre as axis with an angular speed w. If the temperature of sphere increases by 100ºC, the ratio of new angular speed to original angular speed is 25:26

Reasion (R): Moment of inertia $I\infty\omega$

1. A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

21. Assertion (A): The linear co-efficents of expansion of a crystal along three perpendicualr axes are $\alpha, \frac{-\alpha}{2}, \frac{\alpha}{5}$. Its volume co-efficient is $\frac{7\alpha}{10}$

Reasion (R): for anisotropic solids $r = \alpha x + \alpha y + \alpha z$.

1. A and R are correct and R is correct explanation for A
2. A and R are correct and R is not correct explanation for A
3. A is true and R is false
4. A is wrong and R is true.

KEY

1.1	2.1	3.3	4.1
5.1	6.47.1	8.1	9.4
10.1	11.1	12.3	13.4
14.3	15.1	16.4	17.3
18.4	19.3	20.3	21.1

ASSIGNMENT -I

Instruction for Questions:

In each of the following questions, a statment of Assertion (A) is given followed by a corresponding statement of reason (R) just below it. Of the statment marks the correct answer.

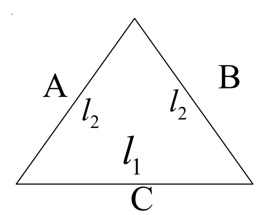
1) Both 'A' and 'R' are true and 'R' is the correct explanation of 'A'
2) Both 'A' and 'R' are true and 'R' is not the correct explanation of 'A'
3) 'A' is true and 'R' is false.
4) 'A' is false and 'R' is true

1. A): Metals expand equally in all directions.
R): Meals are isotropic
2. A): The expansion depends on temperature difference to which it is raised, initial dimensions and the meterial.
R): The coefficient of expansions depends on the material.
3. A): Invar is used in metal tapes, balance wheels and pendulum clocks.
R): The coefficient of linear expansion of invar is very low.
4. A): In a bimetallic strip, the element with more linear expansion coefficient will eccupy the outer side of curvature.
R): For all meterials, the cubical expansion coefficient is three times the linear expansion coefficent.
5. A): The percentage change in area per degree rise of a body is variable.
R): The percentage change in area per degree rise of a surface of a body when heated is 200 α where α is the coefficient of linear expansion.
6. A): When an iron sphere with a spherical cavity is heated, the volume of the cavity increases.
R): The molecular distance increases on heating.
7. A): Some substances like cast iron and rubber contract on heating.
R): In the case of some substances in which molecules vibrate longitudinally and transversely, the amplitude of transverse vibrations increases.
8. A): When the temperature is measured in Fahrenheit the value of 'd' becomes 5/9th of the value when the temperature measured in celsius.
R): 5 degree difference in celsius is equal to 9 degree difference in Fahrenheit.
9. A): Thermal expansion of solids is essentially due to the anharmonicity of lattice oscillations.
R): The potential energy curve of anharmonic oscillators is symmertric parabola.

10. A): The change in length when a wire of length one unit is heated to 1 degree temperature rise is equal to coefficient of linear expansion.
R): Coefficient of linear expansions is equal in all directions in the case of a crystal.
11. A): When a metal rod is heated, percentage increase in its volume is largest.
R): Coefficient volume expansion is 3 times that of linear expansion and 1.5 times that of areal expansion.
12. A): When a solid is heated, it expands.
R): The 'PE-interatomic spacing' curve for solids is asymetric.
13. A): In summer, the pendulum clock runs slow.
R): As temperature increases, length of the pendulum decreases and time period decreases.
14. A): A brass disc fits snugly in the hole of the iron plate. To remove the disc the combination must be heated.
R): A coefficient linear expansion of brass is more than that of iron.
15. A): Bottles filled with water, when kept in deep freezer, break.
R): Water expands on freezing.
16. A): When a circular disc with a hole is heated, the diameter of the hole increases.
R): The distance between the molecules at the periphery of the hole increases as solid expands.
17. A): If hot liquid is poured in thick glass tumbler it breaks.
R): Temperature distribution is not uniform in thick bodies leading to differential expansion.
18. A): When a Bimetalic strip made up of Brass and Iron is heated then brass lies on convex side.
R): Due to lower value of coefficient of linear expansion, brass aquires convex side.
19. A): In the case of a crystal of $\alpha, \beta\, and\, \gamma$ are the coefficients of linear expansions along the three axes then the coefficient of cubical expansion is $3\alpha + 3\beta + 3\gamma$.
R): With usual notaion $\frac{\alpha}{1} = \frac{\beta}{2} = \frac{\gamma}{3}$
20. A): The moment of inertia (I) of a body decreases with increase of temperature.
R) With useal notation the change in moment of inertia is $2\alpha I dT$.
21. A): When a copper ring with a gap in circumference is heated the gap increases.
R): On heating the molecular distance increases.
22. A): The thermal stress produced in a rod is independent of length of th rod.
R): The fractional change is length is constant for a given meterial for a given rise in temperature.
23. A): Thin silica glass containers are used to heat the liquids.
R): The coefficient of expansion of silica glass is negligibly small.
24. A): The pendulum clocks may gain or lose time due to seasonal changes.
R): Due to expansion the effective length of pendulum changes.
25. A): Platinum is used to fuse into glass rods.
R): Both platinum and glass have almost same values of coefficient of linear expansion.
26. A): When a solid iron ball is heated, the percentage change in its volume is greatest.
R): $\beta = 2\alpha\; and\; \gamma = 3\alpha$ where the symbols have their usual meaning.

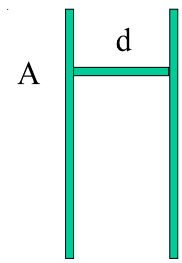
SELF TEST FOR LEVEL -III

1. Two rods of the same length have radii in the ratio 3:4. Their densities are respectively 8000 kg/m^3 and 9000 kg/m^3. Their specific heats are in the ratio 2:3. When the same amount of heat is supplied to both, the changes in their lengths are in the ratio, if their linear coefficients are in the ratio 5:6
1) 1:1 2) 5:2 3) 5:12 4) 12:5
2. A thin circular plate of area 200 cm^2 has a hole of circumference 10π cm at 20ºC. On heating the plate to 40ºC, the diameter of the hole will be $(\alpha = 0.000012 / K)$
1) less than 10 cm 2) 10cm
3) 10.0024 cm 4) 9.9976cm
3. Three rods, A,B,C are arranged to form an isoscele traingle. A, B are made of the same material of linear coefficent α_2, and C is made of material of linear coefficient α_1. The altitude of the triangle is the same at all temperatures. Then

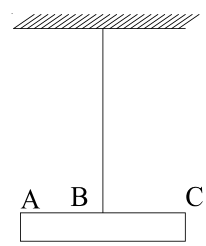


1) $l_2 = \frac{l_1}{2}\sqrt{\alpha_1 / \alpha_2}$ 2) $l_2 = \frac{2l_1}{\sqrt{4\alpha_2}}$
3) $l_2 = \frac{l_1}{2\sqrt{\alpha_1\alpha_2}}$ 4) $l_2 = \frac{l_1}{2}\sqrt{\frac{\alpha_2}{\alpha_1}}$

4. A composite rod is made up of two metals A and B of linear coefficients 0.000012 and 0.000018/K. When the rod is heated from 20 to 100ºC the increase of length of the rod is 0.912 mm. If the length of rod A is 50cm, that of B is
1) 42 cm 2) 75 cm 3) 33.3 cm 4) 30 cm
5. A scale is constructed so that it is correct at 20ºC. If the perecentage error in any measurement of length with it should not exceed 0.05%, what is the maximum temperature at which length can be measured with it ? $(\alpha = 0.000012/K)$
1) 12 ºC 2) 124 ºC 3) 62 ºC 4) 22 ºC
6. A cube of side 20cm at 20ºC is heated to 120ºC. It is made of material whose lineear coefficient of expansions is 0.000012 /K. The increase in volume of the cube is
1) 19.2 cm^3 2) 14.4 cm^3 3) 9.6 cm 4) 28.8 cm^3
7. In the above problem the increase in surface area of the cube is
1) 5.76 cm^2 2) 0.96 cm^2 3) 3.84 cm^2 4) 2.88 cm^2
8. A pendulum consists of a bob suspended by a steel wire of linear coefficient 0.000011/K. If it beats seconds at 20ºC, on a day when the temperature is 40 ºC,
1) it loses 19 seconds 2) it gains 19 seconds
3) it loses 9.5 seconds 4) it gains 9.5 seconds
9. A pendulum loses 26 seconds at 40ºC and gains 12 seconds at 10ºC. It keeps correct time at
1) 30.5ºC 2) 19.5ºC 3) 25ºC 4) 15ºC
10. The diameter of steel rod at 25ºC is 3 cm. A brass ring at 25ºC has an internal diameter 2.992 cm. At what common temperature the ring just slides on the rod. Linear coefficients of expansion for steel and brass are respectively 11 x 10^{-6} and 19 x 10^{-6}/K
1) 260.5ºC 2) 360.5ºC 3) 160.5ºC 4) 560.5ºC
11. A sphere is heated from 0 to 100ºC. Its moment of inertia increases by (if a of the material of the sphere is 0.000011/K)
1) 0.1% 2) 0.2% 3) 0.3% 4) 0.25%
12. A block 10 x 10 x 10 cm (density 8 g/c.c; specific heat 0.1 cal/g/K) is supplied with 32000 cal. Its volume increases by (linear coefficent of expansion 0.000012 / K)
1) 1.44 c.c 2) 2.88 c.c 3) 0.72 c.c 4) 0.48 c.c
13. A composite bar of length $(l_1 + l_2)$ is made from two bars of lengths l_1 and l_2 and linear coefficients a_1, a_2 respectively. The effective linear coefficent of expansions of the composite rod is
1) $\frac{l_1\alpha_1 - l_2\alpha_2}{l_1 - l_2}$ 2) $\frac{l_1\alpha_1 + l_2\alpha_2}{l_1 + l_2}$
3) $l_1 l_2 \alpha_1 \alpha_2$ 4) $\frac{l_1\alpha_1 + l_2\alpha_2}{l_1 + l_2}$
14. A parallel plate capacitor with spacer as shown in the figure is to be made that its capacitance is to remain constant with any samll changes of temperature. If the plates are made of material of linear coefficient α_1 and the spacer is of material of linear coefficient α_2 the condition is



1) $a_2^2 = \frac{\alpha_1^2}{9}$ 2) $a_1^2 = \frac{\alpha_2^2}{9}$ 3) $2\alpha_1 = \alpha_2$ 4) $2\alpha_2 = \alpha_2$
15. A composite rod made of two rods AB and BC are joined at B. The rods are of equal lenth at room temperature and have equal masses. The coefficient of linear expansion α of AB is more than that of BC. The composite rod is suspended horizontally by means of a thread at B. When the rod is heated,



1) it remains horizontal
2) tilts down on the side AB
3) tilts down on the side BC
4) begins to rotate.

KEY

1.2	2.3	3.4	4.4
5.3	6.4	7.1	8.3
9.2	10.2	11.2	12.1
13.2	14.3	15.2	

MORE THAN ONE CHOICE ANSWER – ASSIGNMENT

1. A metal rod is shaped into a ring with a small gap. If this is heated
   a) The length of the rod will increase.
   b) The gap will decrease.
   c) The gap will increase
   d) The diameter of the ring will increase in the same ration as the length of the rod.
   1) a,b,c 2) b,c,d 3) a,c,d 4) a,b,d
2. Substances which are easily compressible have.
   a) High expansion coefficients
   b) Low expansion coefficients
   c) High melting points
   d) Low melting points
   1) a,c 2) a,d 3) b,c 4) b,d
3. If l is the length of rod, Δt the range of temperature and α the coefficient of linear expansion, then arrange the linear expansions for the following combinations in the decreasing order
   a) l, Δt, α b) l/2,3 Δt, $\alpha/4$
   c) 2l, $\Delta t/3$, 2α d) 3l, $\Delta t/2$, $\alpha/2$
   1) a,c,b,d 2) b,a,c,d 3) d,a,c,b 4) c,a,d,b
4. Substances which have negative coefficients of expansion are a) Lead b) Type metal c) Wax d) Platinium
   1) b.c 2) a,d 3) b,d 4) c,d
5. A bolt is passed through a pipe and a nut is just tightened. Coefficients of linear expansion for bolt and pipe material are X and Y respectively, If the assembly is heated then.
   a) a tensile stress will be induced in the bolt if X < Y
   b) a compressive stress will be induced in the bolt if X < Y
   c) a compressive stress will be induced in the bolt if X = Y
   d) No stress will be induced in the bolt if X > Y
   1) a,c 2) c,d 3) a,d 4) a,b
6. Which of the following statements are correct ?
   a. bimetal is used in metal thermometer
   b. Bimetals are use to generate electricity.
   c. Bimetal relays are used to open or close electric circuits
   d. Bimetal is used in thermostats for regulating heating or cooling of rooms.
   1) a,b 2) c,b 3) d,b 4) a,c,d
7. Arrange the coefficients of volume expansion of the given substances in the decreasing order
   a) Ordinary glass b) Pyrex glass
   c) Ethyl alcohol d) Mercury
   1) a,b,c,d 2) d,a,c,b 3) b,a,c,d 4) c,d,a,b
8. A rod is clamped between two rigid supports. When it cools, the thermal stress developed
   a. Is dependent of Young's modulus of the material of the rod
   b. Is Independent of cross-sectional area
   c. Is inversely proportional to temperature range.
   d. Is independent of the coefficient of linear expansion.
   1) b,c 2) a,b 3) c,d 4) a,d

KEY

1) 3	2) 2	3) 4	4) 3
5) 4	6) 4	7) 4	8) 2

MATCHING QUATIONS

1. List I List II

a. Anisotropic cubical block — e. Minimum coefficient of Linear expansion
b. Isotropic Solid — f. Negative coefficient of linear expansion
c. Paraffin Wax — g. $\gamma = \alpha + \beta$
d. Invar — h. $\gamma = \dfrac{\beta_1 + \beta_2 + \beta_3}{2}$

1. a-h, b-g, c-f, d-e 2. a-g, b-h, c-f, d-e
3. a-f, b-g, c-h, d-e 4. a-h, b-e, c-f, d-g

2. List I List II

a. Thermal stress — e. $n_1 l_1 a_1 = n_2 l_2 a_2$
b. Radius of circular arc of heated bimetallic strip — f. $\dfrac{d}{(\alpha_2 - \alpha_1)\Delta t}$
c. Loss (or) gain in time of wall clock pendulum — g. $y \infty \Delta t$
d. Grid iron pendulum — h. $\dfrac{1}{2} \infty \Delta t$

1. a-e, b-f, c-h, d-g   2. a-g, b-h, c-f, d-e
3. a-g, b-f, c-h, d-e   4. a-g, b-h, c-e, d-f

3. **List I** | **List II**

List I	List II
a. Percentage change in solids	e.Independent of Original Dimension
b.Percent change in area	f.Minimum
c.Percent change in Volume	g.2 x percentage change in length
d.Percent change in density of a solid	h. $\frac{3}{2}$ x percentage change in area

1. a-g, b-e, c-h, d-f   2. a-e, b-g, c-h, d-f
3. a-e, b-g, c-f, d-h   4. a-f, b-g, c-h, d-e

4. **List I** **List II**

numerical value of

List I	List II
a. $\alpha / {}^0C$ of a Solid	e.equal to $\alpha / {}^0C + / {}^0C$
b. $\alpha / {}^0F$ of a Solid	f.equal to $\alpha / {}^0C$ of the solid
c. α / k of a Solid	g.equal to $\alpha / {}^0C \times \frac{9}{5}$
d. $\gamma / {}^0C$ of a Solid	h.equal to $\alpha / {}^0F \times \frac{5}{9}$

1. a-e, b-g, c-f, d-h   2. a-h, b-f, c-g, d-e
3. a-e, b-f, c-g, d-h   4. a-h, b-g, c-f, d-e

5. **List I** **List II**

List I	List II
a.Linear expansion	e. 2/3 x Coefficient of cubical expansion
b.Coefficient of Linear expansionsion material	f.Depends on dimen tempera ture
c.Percentage increase in Linear expansion of the solid	g.Independent of original dimension
d.Coefficient of superficial expansion of the solid	h.Depends on materiel only

1. a-e, b-g, c-h, d-f   2. a-e, b-h, c-g, d-f
3. a-h, b-e, c-g, d-f   4. a-f, b-h, c-g, d-e

KEY

1) 1   2) 3   3) 2   4) 4
5) 4