# PHYSICS

## BOOKS - ARIHANT PHYSICS (HINGLISH)

## TEMPERATURE AND THERMAL EXPANSION

### Others

**1.** In a temperature scale X ice point of water is assigned a value of $20^{\circ}$ X and the boiling point of water is assigned a value of $220^{\circ}$ X . In another scale Y the ice point of water is assigned a value of $-20^{\circ}$ Y and the boiling point is given a value of $380^{\circ}$ Y. At what temperature the numerical value of temperature on both the scales will be same?

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**2.** The length of the mercury column in a mercury-in- glass thermometer is 5.0 cm at triple point of water. The length is 6.84 cm at the steam point. If length of the mercury column can be read with a precision of 0.01 cm, can this thermometer be used to distinguish between the ice point and the triple point of water?

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**3.** What effect the following changes will makes to the range, sensitivity and responsiveness of a mercury in glass thermometer – (a) Increase in size of the bulb. (b) Increase in diameter of the capillary bore. (c) Increase in length of the stem. (d) Use of thicker glass for the bulb.

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**4.** The focal length of a spherical mirror is given by $f = \frac{R}{2}$ , where R is radius of curvature of the mirror. For a given spherical mirror made of steel the focal length is f = 24.0 cm. Find its new focal length if temperature increases by $50^\circ C$. Given = $\alpha_{\text{Steel}} = 1.2 \times 10^{-5} .^\circ C^{-1}$

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**5.** A glass rod when measured using a metal scale at $30^\circ C$ appears to be of length 100 cm. It is known that the scale was calibrated at $0^\circ C$. Find true length of the glass rod at (a) $30^\circ C$ $(b) 0^\circ C$

$\alpha_{\text{steel}} = 8 \times 10^{-6} .^\circ C^{-1}$ and $\alpha_{\text{Metal}} = 26 \times 10^{-6} .^\circ C^{-1}$

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**6.** A pendulum based clock keeps correct time in an aeroplane flying uniformly at a height h above the surface of the earth. The cabin temperature inside the plane is $10^\circ C$. The same pendulum keeps correct time on the surface of the earth when temperature is $30^\circ C$. Find the coefficient of linear expansions of the material of the pendulum. You can assume that h ltlt R (radius of the earth)

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**7.** A liquid having coefficient of volume expansion $\gamma_0$ is filled in a cylindrical glass vessel. Glass has a coefficient of linear expansion of $\alpha_g$. The liquid along with the container is heated to raise their temperature by $\Delta T$. Mass of the container is negligible. (a) find relationship between $\alpha_g$ and $\gamma_0$ if it was found that the centre of mass of the system did not move due to heating.

(b) Find relationship between $\alpha_g$ and $\gamma_0$ if the fraction of volume of the container occupeid by the liquid does not change due to heating.

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**8.** A water in glass thermometer has density of water marked on its stem [Density of water is the thermometric property in this case]. When this thermometer is dipped in liquid A the density of water read is 0.99995 g $cm^3$. Thereafter it is dipped in liquid B and the reading remains unchanged. Maximum density of water is 1.00000 g $cm^{-3}$. (a) Can we say that liquid A and B are necessarily in thermal equilibrium? (b) If two liquids are mixed and the thermometer is inserted in the mixture, the height of water column in stem is found to change (i.e. reading is different from 0.99995 g $cm^{-3}$). Has the height increased or decreased?

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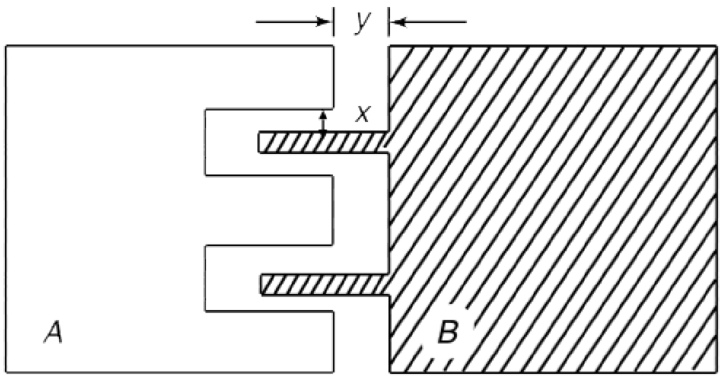
**9.** Two metal plates A and B made of same material are placed on a table as shown in the figure. If the plates are heated uniformly, will the gap indicated by x and y in the figure increase or decrease?

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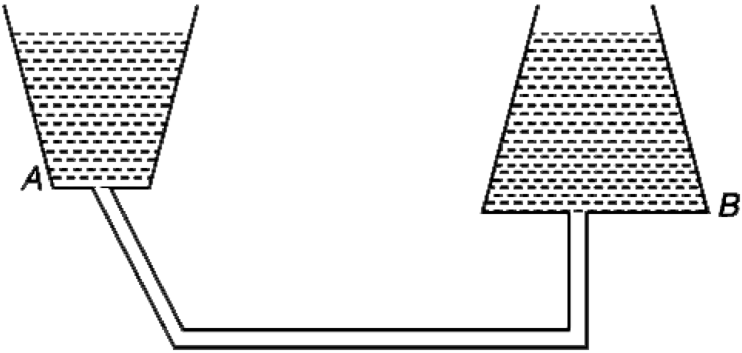
**10.** Containers A and B contain a liquid up to same height. They are connected by a tube (see figure). (a) If the liquid in container A is heated, in which direction will the liquid flow through the tube. (b) If the liquid in the container B is heated in which direction will the liquid flow through the tube? Assume that the containers do not expand on heating.

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11. Height of mercury in a barometer is $h_0 = 76.0$ cm at a temperature of $\theta_1 = 20^\circ C$. If the actual atmospheric pressure does not change, but the temperature of the air, and hence the temperature of the mercury and the tube rises to $\theta_2 = 35^\circ C$, what will be the height of mercury column in the barometer now? Coefficient of volume expansion of mercury and coefficient of linear expansion of glass are

$\gamma_{Hg} = 1.8 \times 10^{-4} . ^\circ C^{-1}, \alpha_g = 0.09 \times 10^{-4} . ^\circ C^{-1}$

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**12.** In the last problem if the scale for reading the height of mercury column is marked on the glass tube of the barometer, what reading will it show when temperature rises to $\theta_2 = 35^\circ C$ ?

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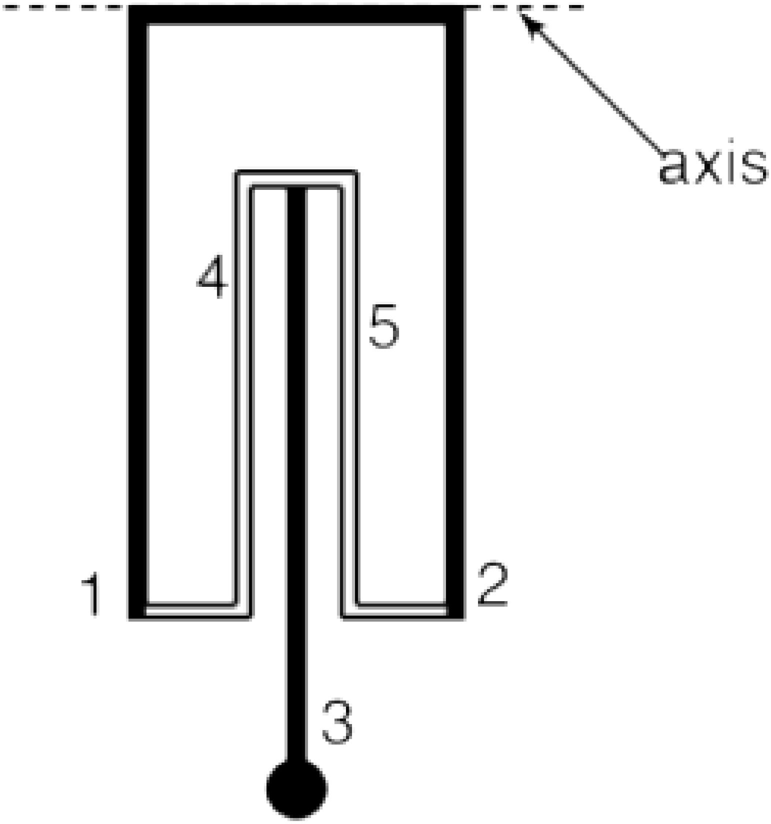
**13.** Pendulum of a clock consists of very thin sticks of iron and an alloy. At room temperature the iron sticks 1 and 2 have length $L_0$ each. Length of each of the two alloy sticks 4 and 5 is 0 and the length of iron stick 3 (measured up to the centre of the iron bob) is $l_0$. Thickness of connecting strips are negligible and mass of everything except the bob is negligible. The pendulum oscillates about the horizontal axis shown in the figure. It is desired that the time period of the pendulum should not change even if temperature of the room changes. Find the coefficient of linear expansion ($\alpha$) of the alloy if the coefficient of linear expansion for iron is $\alpha_0$.

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**14.** Two samples of a liquid have volumes 400 cc and 220 cc and their temperature are $10^\circ C$ and $110^\circ C$ respectively. Find the final temperature and volume of the mixture if the two samples are mixed.

Assume no heat exchange with the surroundings. Coefficient of volume expansion of the liquid is $g = 10^{-3}.^{\circ}C^{-1}$ and its specific heat capacity is a constant for the entire range of temperature.

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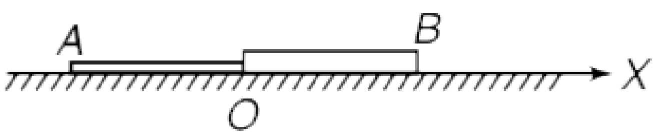
**15.** A composite bar has two segments of equal length L each. Both segments are made of same material but cross sectional area of segment OB is twice that of OA. The bar is kept on a smooth table with the joint at the origin of the co - ordinate system attached to the table. Temperature of the composite bar is uniformly raised by $\Delta\theta$. Calculate the x co-ordinate of the joint if coefficient of linear thermal expansion for the material is $\alpha^{\circ}C^{-1}$

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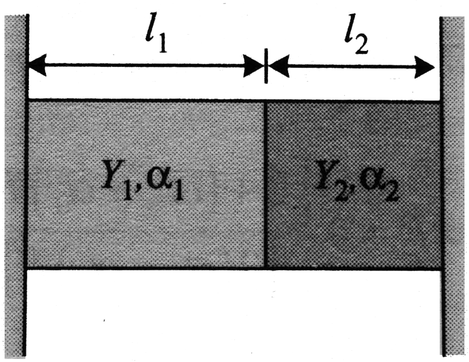
**16.** Two rods of different metals having the same area of cross section A are placed between the two massive walls as shown is Fig. The first rod has a length $l_1$, coefficient of linear expansion $\alpha_1$ and Young's modulus $Y_1$. The correcsponding quantities for second rod are $l_2$, $\alpha_2$ and $Y_2$. The temperature of both the rods is now raised by $t^\circ C$.

i. Find the force with which the rods act on each other (at higher temperature) in terms of given quantities.

ii. Also find the length of the rods at higher temperature.

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**17.** Two rods of equal cross-sections, one of copper and the other of steel are joined to from a composite rod of length $2.0m$ at $20^\circ C$ the length of the copper rod is $0.5m$. When the temperature is raised to $120^\circ C$, the length of composite rod increases to $2.002m$. If the composite rod is fixed between two rigid walls and thus not allowed to expand, it is found that the length of the component rod also do not change with increase in temperature. Calculate the Young's modulus of steel. Given Young's modulus of copper $= 1.3 \times 10^{11} N / m^2$ the coefficient of linear expansion of copper $\alpha_C = 1.6 \times 10^{-5} / .^\circ c$

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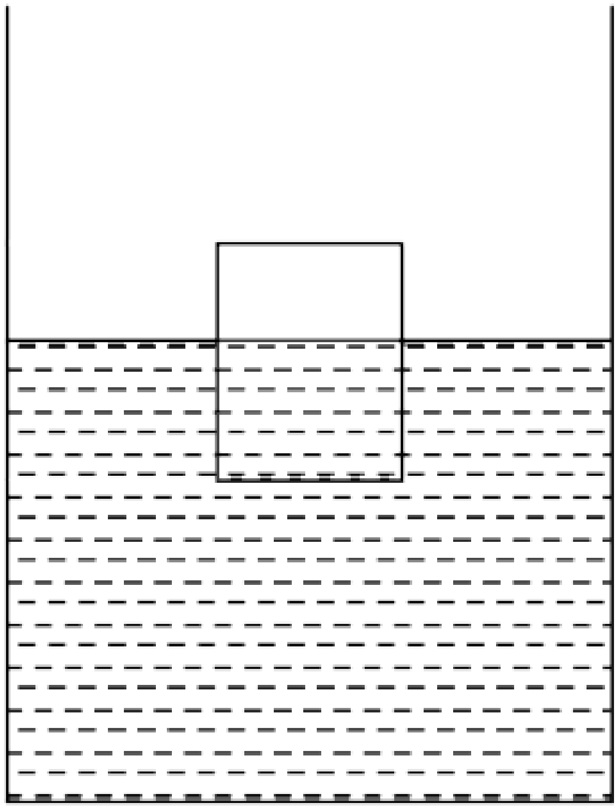
**18.** A beaker contains a liquid of volume $V_0$. A solid block of volume V floats in the liquid with 90% of its volume submerged in the liquid. The whole system is heated to raise its temperature by $\Delta\theta$. It is observed that the height of liquid in the beaker does not change and the solid in now floating with its entire volume submerged. Calculate $\Delta\theta$. It is given that coefficient of volume expansion of the solid and the glass (beaker) are $\gamma_s$ and $\gamma_g$ respectively.



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**19.** Assume that the coefficient of linear expansion of the material of a rod remains constant, equal to $\alpha^\circ C^{-1}$ for a fairly large range of temperature. Length of the rod is $L_0$ at temperature $\theta_0$. (a) Find the length of the rod at a high temperature $\theta$. (b) Approximate the answer obtained in (a) to show that the length of the rod for small changes in temperature is given by $L = L_0[1 + \alpha\ (\delta - \delta_0)]$

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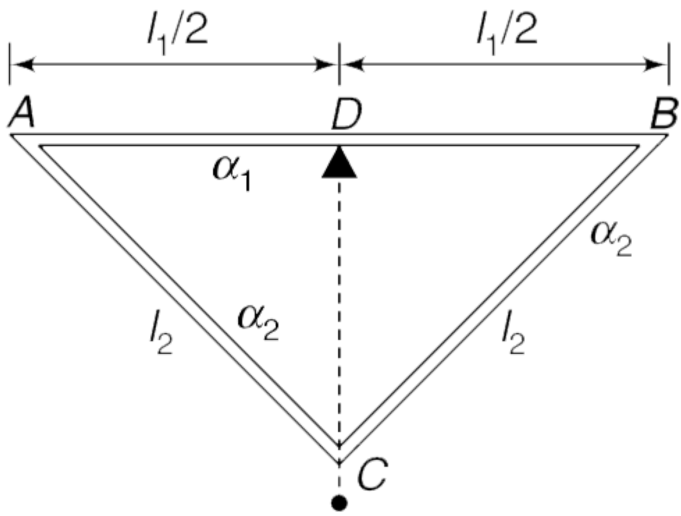
**20.** In a compensated pendulum a triangular frame ABC is made using two different metals. AB of length $l_1$ is made using a metal having coefficient of linear expansion $\alpha_1$. BC and AC of length $l_2$ each have coefficient of linear expansion $\alpha_2$. A heavy bob is attached at C. Pendulum can oscillate about the pivot D. Find $\frac{l_2}{l_1}$ so that distance of bob from the pivot point D does not change with change in temperature.

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**21.** A thin uniform rod of mass M and length l is rotating about a frictionless axis passing through one of its ends and perpendicular to the rod. The rod is heated uniformly to increases its temperature by $\Delta\theta$. Calculate the percentage change in rotational kinetic energy of the rod. Explain why the answer is not zero. Take coefficient of linear expansion of the material of the rod to be $\alpha$.

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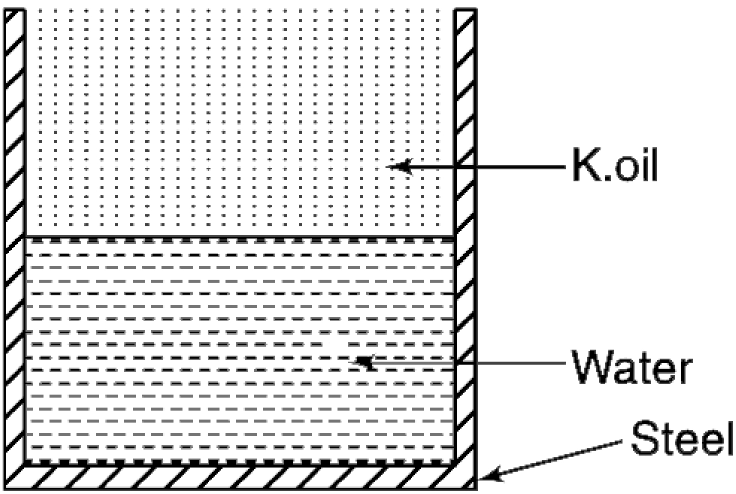
**22.** (a) A steel tank has internal volume $V_0$ (= 100 litre). It contains half water ( volume = $\frac{V_0}{2}$ ) and half kerosene oil at temperature $\theta_1 = 10^\circ C$ Calculate the mass of kerosene that flows out of the tank at temperature of $\theta_2 = 40^\circ C$. Coefficient of cubical expansion for different substances are:

$\gamma_k = 10^{-3}.^\circ C^{-1}, \gamma_w = 2 \times 10^{-4}.^\circ C^{-1}, \gamma_{\text{steel}} = 1.2 \times 10^{-5}.^\circ C^{-1}$

. density of kerosene at $10^\circ C$ is $\rho_1 = 0.8 kg$ /litre.

(b) In the last problem the height of water in the container at $\theta_1 = 10^\circ C$ is $H_1 = 1.0 m$. Find the height of water at $\theta_2 = 40^\circ C$.

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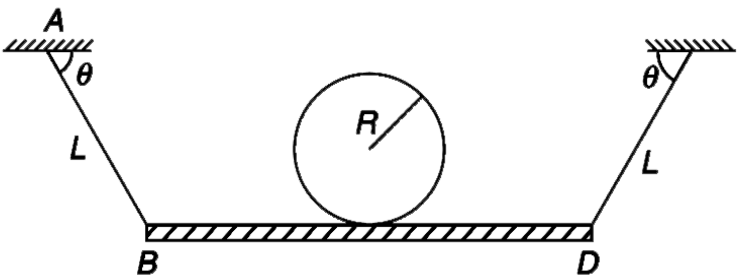
**23.** A metal cylinder of radius R is placed on a wooden plank BD. The plank is kept horizontal suspended with the help of two identical string AB and CD each of length L. The temperature coefficient of linear expansion of the cylinder and the strings are $a_1$ and $a_2$ respectively. Angle q shown in the figure is $30^\circ$. It was found that with change in temperature the centre of the cylinder did not move. Find the ratio $\frac{\alpha_1}{\alpha_2}$, if it is know that L = 4R. Assume that change in value of $\theta$ is negligible for small temperature changes

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**24.** A vernier calliper has 10 divisions on vernier scale coinciding with 9 main scale divisions. It is made of a material whose coefficient of linear expansion is $\alpha = 10^{-3} .^{\circ} C^{-1}$. At $0^{\circ} C$ each main scale division = 1mm. An object has a length of 10 cm at a temperature of $0^{\circ} C$ and its material has coefficient of linear expansion equal to $\alpha_1 = 1 \times 10^{-4} .^{\circ} C^{-1}$. The length of this object is measured using the said vernier calliper when room temperature is $50^{\circ} C$. (a) Find the reading on the main scale and the vernier scale (b) The same object is measured (at $50^{\circ} C$) using a wooden scale whose least count is 1mm. Write the measured reading using this scale assuming it to be correct at all temperature.

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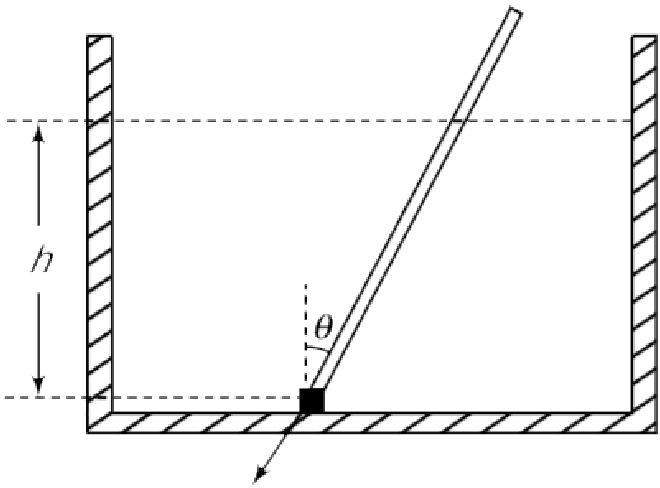
**25.** A rectangular tank contains water to a height h. A metal rod is hinged to the bottom of the tank so that it can rotate freely in the vertical plane. The length of the rod is L and it remains at rest with a part of it lying above the water surface. In this position the rod makes an angle $\theta$ with the vertical. Assume that $y = \cos\theta$ and find fractional change in value of y when temperature of the system increases by a small value $\Delta T$. Coefficient of linear expansion of material of rod and the tank are $\alpha_1$ and $\alpha_2$ respectively. Coefficient of volume expansion of water is $\lambda$. What is necessary condition for $\theta$ to increase?

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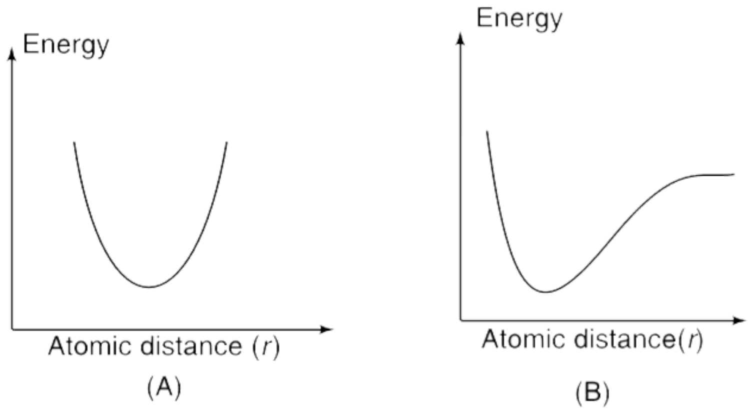
**26.** In the given figure graph B shows the variation of potential energy versus atomic separation (r) in a material. Argue qualitatively to show that if the potential energy graph was a symmetrical one as depicted in graph A, there would have been no thermal expansion on heatin

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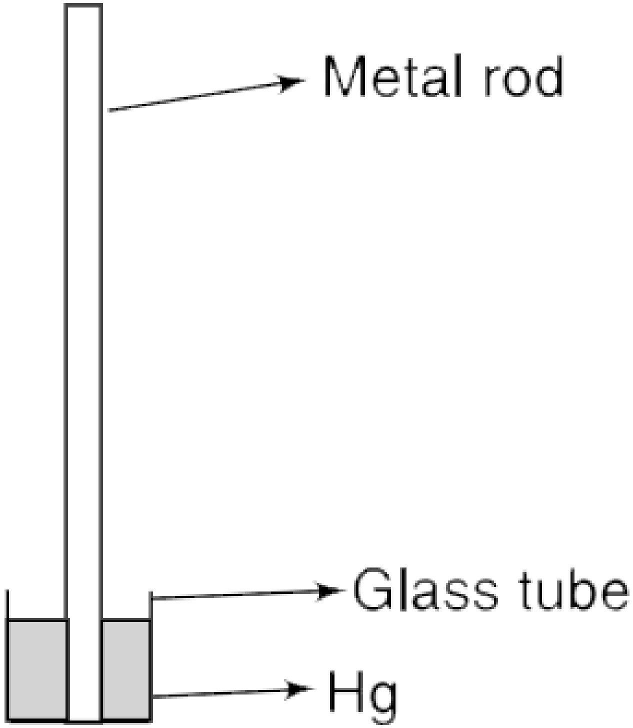
**27.** In design of a compensated pendulum, a light metal rod of length $L_0$ = 1.0 m is attached to a glass tube filled with mercury. Neglecting the mass of the glass tube as well, calculate the height of mercury column in the glass tube so that centre of mass of this system does not rise or fall with temperature Given :

$\lambda_{)}\, Hg) = 1.82 \times 10^{-4} K^{-1}$, $\alpha_{\text{glass'})=9xx10^(-6),alpha_(}m\eta l = 1.2 \times 10^{-5} K^{-1}$

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