Physicsaholics

DPP – Thermal Expansion

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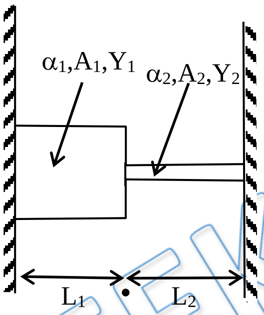
Q 1. Two elastic rods are joined between fixed supports as shown in the figure. Condition for no change in the lengths of individual rods with the increase of temperature is – (a_1,a_2 = linear expansion coefficient, A_1, A_2 = Area of rods, Y_1,Y_2 = young modulus)



(a) $\frac{A_1}{A_2} = \frac{\alpha_1 Y_1}{\alpha_2 Y_2}$ (b) $\frac{A_1}{A_2} = \frac{L_1\alpha_1 Y_1}{L_2\alpha_2 Y_2}$
(c) $\frac{A_1}{A_2} = \frac{L_2\alpha_2 Y_2}{L_1\alpha_1 Y_1}$ (d) $\frac{A_1}{A_2} = \frac{\alpha_2 Y_2}{\alpha_1 Y_1}$

Q 2. An iron tyre is to be fitted onto a wooden wheel 1.0 metre in diameter. The diameter of the tyre is 6 mm, smaller than that of the wheel. The tyre should be heated so that its temperature increases by a minimum of (given coefficient of volume expansion of iron is 3.6 x 10^{-5}/°C)
(a) 167°C (b) 334°C (c) 500°C (d) 1000°C

Q 3. When a block of iron floats in mercury at 0°C, a fraction K_1 of its volume is submerged, while at the temperature 60°C, a fraction K_2 is seen to be submerged. If the coefficient of volume expansion of iron is γ_{Fe}, and that of mercury γ_{Hg}, then the ratio K_1 / K_2 can be expressed as –
(a) $\frac{1+60\gamma_{Fe}}{1+60\gamma_{Hg}}$ (b) $\frac{1-60\gamma_{Fe}}{1+60\gamma_{Hg}}$ (c) $\frac{1+60\gamma_{Fe}}{1-60\gamma_{Hg}}$ (d) $\frac{1+60\gamma_{Hg}}{1+60\gamma_{Fe}}$

Q 4. Two rods one of aluminium and the other made of steel, having initial length l_1 and l_2 are connected together to form a single rod of length $l_1 + l_2$. The coefficients of linear expansion for aluminium and steel are a_a and a_s respectively. If the length of each rod increases by the same amount when their temperature are raised by t°C, then find the ratio $l_1/(l_1 + l_2)$ –
(a) a_s / a_a (b) a_a/a_s
(c) a_s /(a_a + a_s) (d) a_a /(a_a + a_s)

Q 5. An iron ball is heated. The percentage increase will be the largest in –

(a) diameter (b) surface area
(c) volume (d) density

Q 6. Two holes of unequal diameters d_1 and d_2 ($d_1>d_2$) are cut in a metal sheet. If the sheet is heated–
(a) Both d_1 and d_2 will decrease
(b) Both d_1 and d_2 will increase
(c) d_1 will increase, d_2 will decrease
(d) d_1 will decrease, d_2 will increase

Q 7. Two rods of lengths l_1 and l_2 are made of materials whose coefficient of linear expansions are a_1 and a_2. If the difference between two lengths is independent of temperature–
(a) $\frac{\ell_1}{\ell_2} = \frac{\alpha_1}{\alpha_2}$ (b) $\frac{\ell_1}{\ell_2} = \frac{\alpha_2}{\alpha_1}$
(c) $\ell_2^2\alpha_1 = \ell_1^2\alpha_2$ (d) $\frac{\alpha_1^2}{\ell_1} = \frac{\alpha_2^2}{\ell_2}$

Q 8. Three rods of equal length are joined to form an equilateral triangle ABC. D is midpoint of AB. The coefficient of linear expansion is a_1 for AB, and a_2 for AC and BC. If the distance DC remains constant for small changes in temperature-
(a) $a_1 = a_2$ (b) $a_1 = 2a_2$
(c) $a_1 = 4a_2$ (d) $a_1 = \frac{1}{2}a_2$

Q 9. A uniform metal rod is used as a bar pendulum. If the room temperature rises by 10ºC, and the coefficient of linear expansion of the metal of the rod is 2×10^{-6} per ºC, the period of the pendulum will have percentage increase of-
(a) -2×10^{-3} (b) -1×10^{-3} (c) 2×10^{-3} (d) 1×10^{-3}

Q 10. A vessel is partly filled with a liquid. Coefficient of cubical expansion of material of the vessel and liquid are g_V and g_L respectively. If the system is heated, then volume unoccupied by the liquid will necessarily-
(a) Remain unchanged if $g_V = g_L$
(b) Increase if $g_V = g_L$
(c) Decrease if $g_V = g_L$
(d) None of these

Q 11. The volume of the bulb of a mercury thermometer at 0ºC is V_0 and cross-section of the capillary is A_0. The coefficient of linear expansion of glass is a_g perºC and the cubical expansion of mercury g_m per ºC. If the mercury just fills the bulb at 0ºC, what is the length of mercury column in capillary at TºC-
(a) $\frac{V_0T(\gamma_m+3\alpha_g)}{A_0(1+2\alpha_gT)}$ (b) $\frac{V_0T(\gamma_m-3\alpha_g)}{A_0(1+2\alpha_gT)}$
(c) $\frac{V_0T(\gamma_m+2\alpha_g)}{A_0(1+3\alpha_gT)}$ (d) $\frac{V_0T(\gamma_m-2\alpha_g)}{A_0(1+3\alpha_gT)}$

Q 12. A beaker is completely filled with water at 4°C.If expansion in beacker is negligible, It must overflow –
(a) when heated but not when cooled

(b) when cooled but not when heated
(c) both when heated or cooled
(d) neither when heated nor when cooled

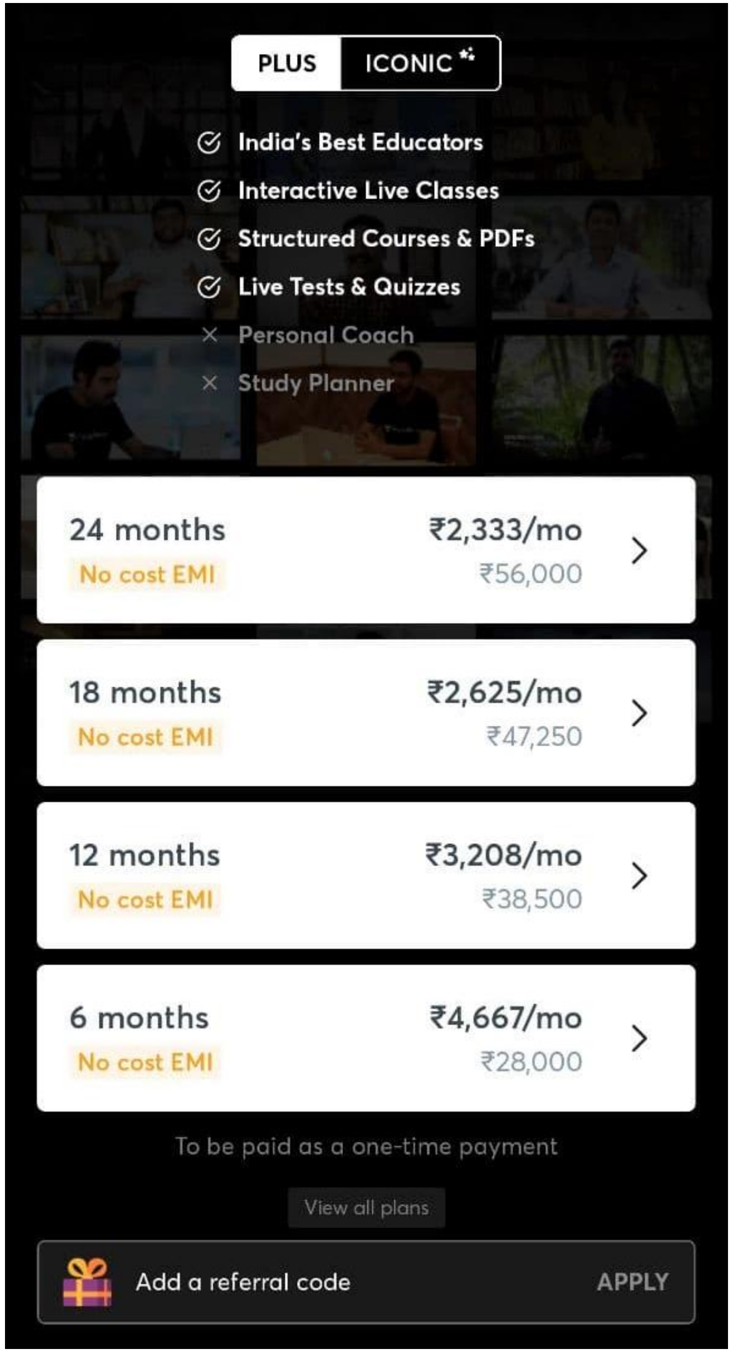
Q 13. Match The Column

Column I	Column II
(A) When temperature increases then time period of pendulum [rod is of metal]	(P) Decrease
(B) When temperature decreases then time period of pendulum [rod is of metal]	(Q) Increase
(C) A cavity is inside of metal sphere then on increasing the temperature	(R) Same
(D) Radius of A hole in a circular plate on increasing temperature	(S) Can't say anything

Answer Key

Q.1 d	**Q.2 c**	**Q.3 a**	**Q.4 c**	**Q.5 c**
Q.6 b	**Q.7 b**	**Q.8 c**	**Q.9 d**	**Q.10 b**
Q.11 b	**Q.12 c**			

Ans. 13) A $\to$ Q; B $\to$ P; C $\to$ Q; D $\to$ Q



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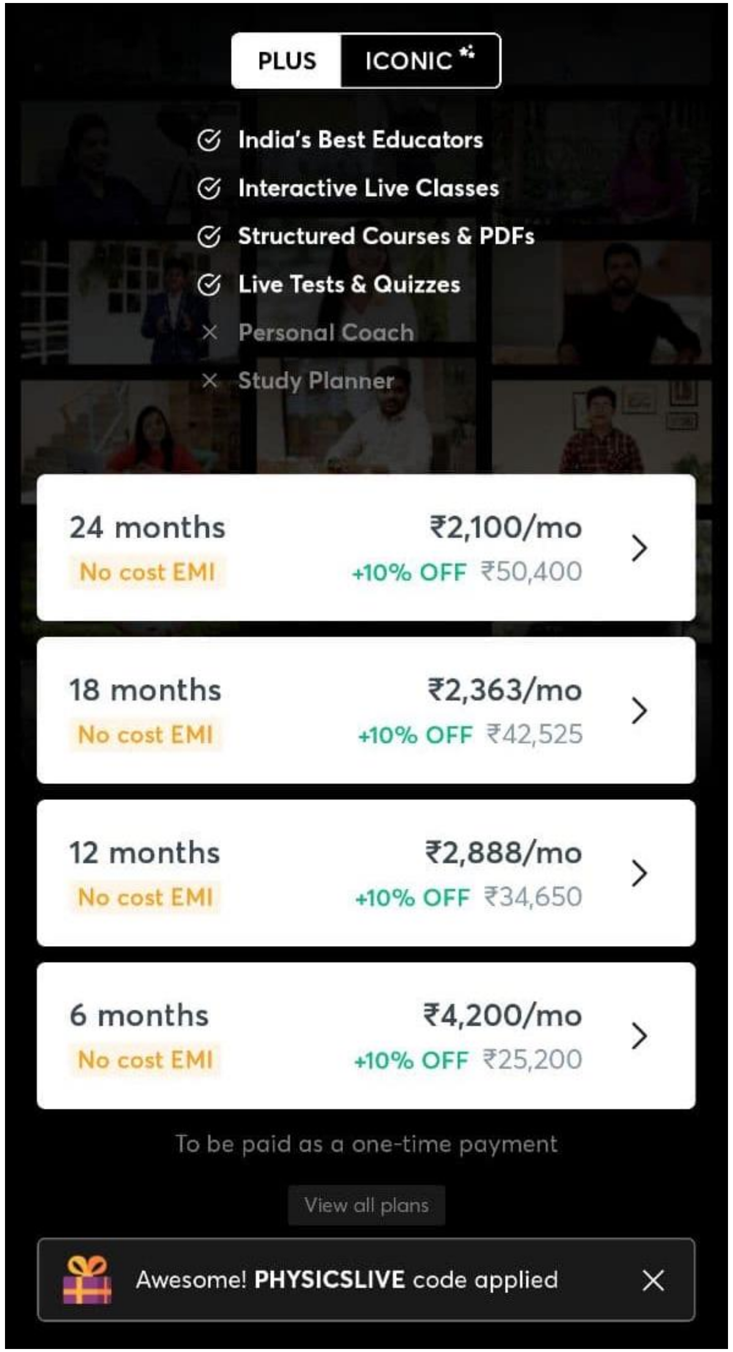

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Physics DPP - Solution

DPP- 1 Thermal Expansion

By Physicsaholics Team

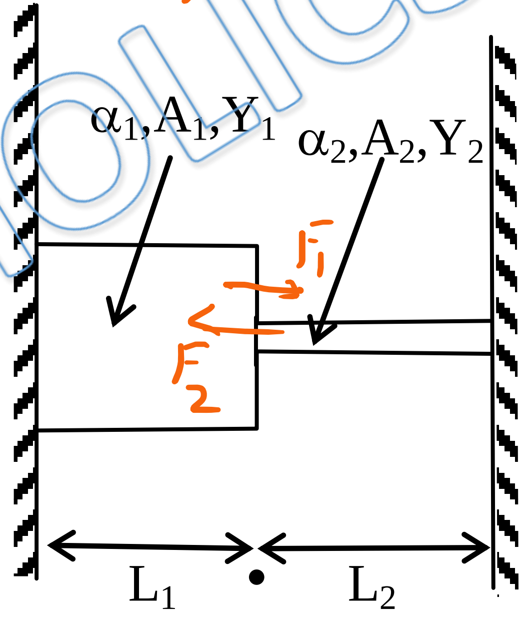
Q1) Two elastic rods are joined between fixed supports as shown in the figure. Condition for no change in the lengths of individual rods with the increase of temperature is – (a_1,a_2 = linear expansion coefficient, A_1, A_2 = Area of rods, Y_1,Y_2 = young modulus)

$F_1 = F_2$ in equilibrium

$\Rightarrow Y_1 A_1 \alpha_1 \Delta T = Y_2 A_2 \alpha_2 \Delta T$

$\Rightarrow \frac{A_1}{A_2} = \frac{Y_2 \alpha_2}{Y_1 \alpha_1}$

formula of thermal stress $= Y \alpha \Delta T$



(a) $\frac{A_1}{A_2} = \frac{\alpha_1 Y_1}{\alpha_2 Y_2}$ (b) $\frac{A_1}{A_2} = \frac{L_1 \alpha_1 Y_1}{L_2 \alpha_2 Y_2}$

(c) $\frac{A_1}{A_2} = \frac{L_2 \alpha_2 Y_2}{L_1 \alpha_1 Y_1}$ ✓(d) $\frac{A_1}{A_2} = \frac{\alpha_2 Y_2}{\alpha_1 Y_1}$

Q2) An iron tyre is to be fitted onto a wooden wheel 1.0 metre in diameter. The diameter of the tyre is 6 mm, smaller than that of the wheel. The tyre should be heated so that its temperature increases by a minimum of (given coefficient of volume expansion of iron is 3.6 x 10^{-5}/°C)

$\alpha = \gamma/3 = 1.2 \times 10^{-5}$

$\Delta l = l_0 \alpha \Delta T$

$\Rightarrow \quad 6mm = (1m - 6mm)\alpha \Delta T \Rightarrow \Delta T = \frac{6 \times 10^{-3}}{1 \times 1.2 \times 10^{-5}}$

$= 500°C$

(a) 167°C (b) 334°C (c) 500°C (d) 1000°C

Q3) When a block of iron floats in mercury at 0ºC, a fraction K_1 of its volume is submerged, while at the temperature 60ºC, a fraction K_2 is seen to be submerged. If the coefficient of volume expansion of iron is γ_{Fe}, and that of mercury γ_{Hg}, then the ratio K_1 / K_2 can be expressed as –

Volume merged $= \frac{\rho_s}{\rho_l} = K_1$

at 60°C

$$K_2 = \frac{\rho_s}{1 + \gamma_{Fe}\Delta T} \times \frac{1 + \gamma_{Hg}\Delta T}{\rho_l} = \frac{K_1(1 + 60\gamma_{Hg})}{1 + 60\gamma_{Fe}}$$

(a) ✓ $\frac{1+60\gamma_{Fe}}{1+60\gamma_{Hg}}$ (b) $\frac{1-60\gamma_{Fe}}{1+60\gamma_{Hg}}$ (c) $\frac{1+60\gamma_{Fe}}{1-60\gamma_{Hg}}$ (d) $\frac{1+60\gamma_{Hg}}{1+60\gamma_{Fe}}$

$$\Rightarrow \frac{K_1}{K_2} = \frac{1 + 60\gamma_{Fe}}{1 + 60\gamma_{Hg}}$$

Q4) Two rods one of aluminium and the other made of steel, having initial length l_1 and l_2 are connected together to form a single rod of length $l_1 + l_2$. The coefficients of linear expansion for aluminimum and steel are a_a and a_s respectively. If the length of each rod increases by the same amount when their temperature are raised by t°C, then find the ratio $l_1/(l_1 + l_2)$ –

$$\Delta l = l_1 \alpha_1 \Delta T = l_2 \alpha_2 \Delta T$$

$$\frac{l_1}{l_1 + l_2} = \frac{1}{1 + l_2/l_1} = \frac{1}{1 + \alpha_1/\alpha_2} = \frac{\alpha_2}{\alpha_1 + \alpha_2} = \frac{a_s}{a_a + a_s}$$

(a) a_s / a_a

(b) a_a/a_s

(c) $a_s /(a_a + a_s)$ ✓

(d) $a_a /(a_a + a_s)$

Q5) An iron ball is heated. The percentage increase will be the largest in –

$\Delta V = V_0 \gamma \Delta T$

% Increment in volume $= \frac{\Delta V}{V_0} \times 100 = 100 \gamma \Delta T$

" " " diameter $= 100 \alpha \Delta T$

" " " surface area $= 100 \beta \Delta T$

(a) diameter

(b) surface area

(c) volume ✓

(d) density

Since $\gamma > \beta > \alpha$

% Increment in volume will be maximum.

Q6) Two holes of unequal diameters d_1 and d_2 ($d_1 > d_2$) are cut in a metal sheet. If the sheet is heated–

fill the hole with removed metal discs. increase the temperature and remove discs.

diameter of hole = diameter of disc

(a) Both d_1 and d_2 will decrease

(b) Both d_1 and d_2 will increase ✓

(c) d_1 will increase, d_2 will decrease

(d) d_1 will decrease, d_2 will increase

⇒ diameters of both holes increase.

Q7) Two rods of lengths ℓ_1 and ℓ_2 are made of materials whose coefficient of linear expansions are α_1 and α_2. If the difference between two lengths is independent of temperature–

difference between lengths is constant.

⇒ increment in length is same for both

⇒ $l_1 \alpha_1 \Delta T = l_2 \alpha_2 \Delta T$ ⇒ $\frac{l_1}{l_2} = \frac{\alpha_2}{\alpha_1}$

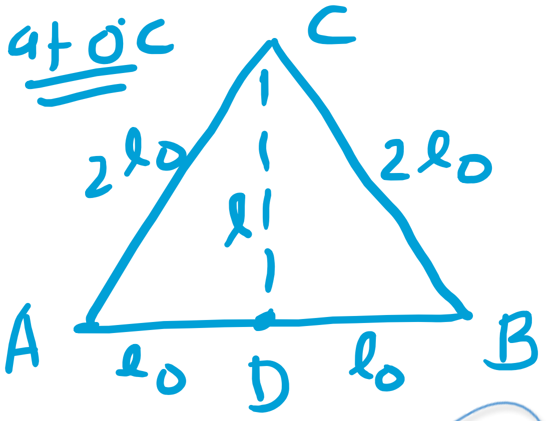
(a) $\frac{\ell_1}{\ell_2} = \frac{\alpha_1}{\alpha_2}$

(b) $\frac{\ell_1}{\ell_2} = \frac{\alpha_2}{\alpha_1}$ ✓

(c) $\ell_2^2\alpha_1 = \ell_1^2\alpha_2$

(d) $\frac{\alpha_1^2}{\ell_1} = \frac{\alpha_2^2}{\ell_2}$

Q8) Three rods of equal length are joined to form an equilateral triangle ABC. D is midpoint of AB. The coefficient of linear expansion is α_1 for AB, and α_2 for AC and BC. If the distance DC remains constant for small changes in temperature-



Let length of BD is x and that of BC is y at temperature T.

$x^2 + l^2 = y^2 \Rightarrow 2x\Delta x = 2y\Delta y$

$\Rightarrow l_0 \times l_0 \alpha_1 \Delta T = 2l_0 \cdot 2l_0 \alpha_2 \Delta T$

$\Rightarrow \alpha_1 = 4\alpha_2$

(a) $\alpha_1 = \alpha_2$

(b) $\alpha_1 = 2\alpha_2$

✓(c) $\alpha_1 = 4\alpha_2$

(d) $\alpha_1 = \frac{1}{2}\alpha_2$

Q9) A uniform metal rod is used as a bar pendulum. If the room temperature rises by 10ºC, and the coefficient of linear expansion of the metal of the rod is 2×10^{-6} per ºC, the period of the pendulum will have percentage increase of-

$$T = 2\pi\sqrt{l/g} \Rightarrow \frac{\Delta T}{T} = \frac{1}{2} \times \frac{\Delta l}{l} = \frac{1}{2}\frac{l\alpha\Delta T}{l}$$

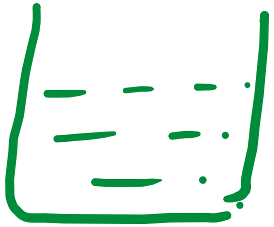
$$\% \text{ increment in } T = 100 \times \frac{1}{2} \times \alpha\Delta T = 100 \times \frac{1}{2} \times 2 \times 10^{-6} \times 10$$

$$= 10^{-3}$$

(a) -2×10^{-3} (b) -1×10^{-3} (c) 2×10^{-3} (d) 1×10^{-3} ✓

Q10) A vessel is partly filled with a liquid. Coefficient of cubical expansion of material of the vessel and liquid are γ_V and γ_L respectively. If the system is heated, then volume unoccupied by the liquid will necessarily-

Let $\gamma_V = \gamma_L = \gamma$



At $T = T_0$

Capacity $= V_0$

Volume of liquid $= V_1$

(a) Remain unchanged if $\gamma_V = \gamma_L$

(b) Increase if $\gamma_V = \gamma_L$ ✓

(c) Decrease if $\gamma_V = \gamma_L$

(d) None of these

At $T_0 + \Delta T$

Capacity $= V_0 \gamma \Delta T$

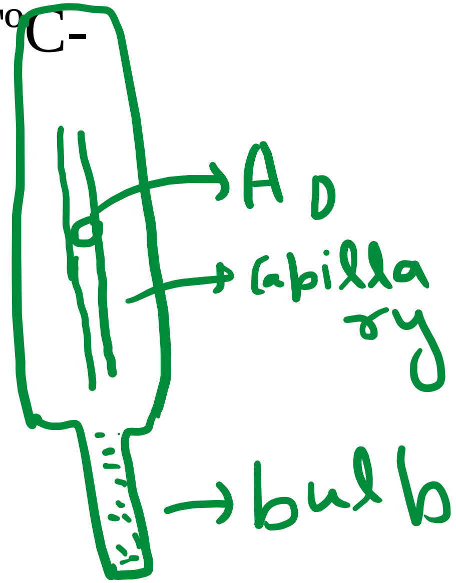
Volume of liquid $= V_1 \gamma \Delta T$

Empty space $= (V_0 - V_1)\gamma \Delta T$

Empty space will increase on increasing temperature.

Q11) The volume of the bulb of a mercury thermometer at 0ºC is V_0 and cross-section of the capillary is A_0. The coefficient of linear expansion of glass is α_g perºC and the cubical expansion of mercury γ_m per ºC. If the mercury just fills the bulb at 0ºC, what is the length of mercury column in capillary at TºC-

At T°C → volume of mercury = $V_0 \gamma_m T$
" " bulb = $V_0 \, 3\alpha_g T$



(a) $\frac{V_0 T(\gamma_m + 3\alpha_g)}{A_0(1+2\alpha_g T)}$

(b) $\frac{V_0 T(\gamma_m - 3\alpha_g)}{A_0(1+2\alpha_g T)}$ ✓

(c) $\frac{V_0 T(\gamma_m + 2\alpha_g)}{A_0(1+3\alpha_g T)}$

(d) $\frac{V_0 T(\gamma_m - 2\alpha_g)}{A_0(1+3\alpha_g T)}$

excess volume of Hg = $V_0(\gamma_m - 3\alpha_g)T$

Area of capillary = $A_0(1 + 2\alpha_g T)$

Height of Hg in capillary = $\frac{V_0(\gamma_m - 3\alpha_g)T}{A_0(1+2\alpha_g T)}$

Q12) A beaker is completely filled with water at 4°C.If expansion in beacker is negligible, It must overflow -

(a) when heated but not when cooled

(b) when cooled but not when heated

✓ (c) both when heated or cooled

(d) neither when heated nor when cooled

Due to abnormal expansion of water, water has maximum density at 4°C. If we change the temperature (increase or decrease) its volume will increase.

Q13) Match The Column

Column I	Column II
(A) When temperature increases then time period of pendulum [rod is of metal]	(P) Decrease
(B) When temperature decreases then time period of pendulum [rod is of metal]	(Q) Increase
(C) A cavity is inside of metal sphere then on increasing the temperature	(R) Same
(D) Radius of A hole in a circular plate on increasing temperature	(S) Can't say anything

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$= 2\pi\sqrt{\frac{l_0(1+\alpha\Delta T)}{g}}$$

Increment in size of cavity is similar to that of material.

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