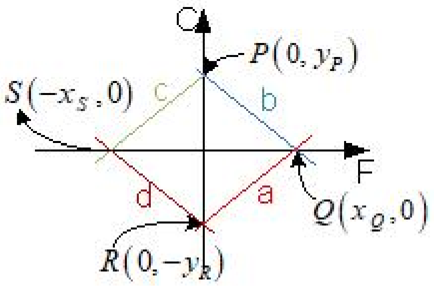
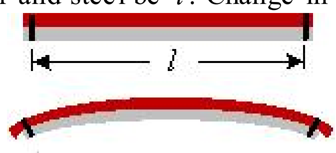
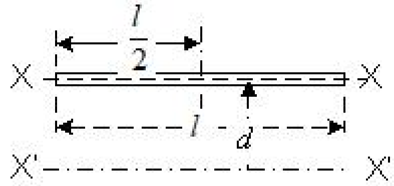
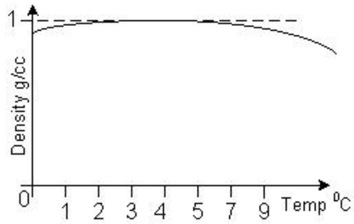
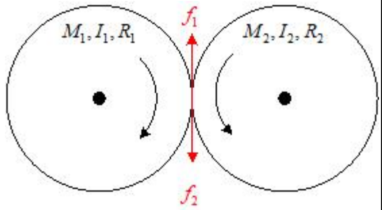
Heat : Illustrations to Solutions of Subjective Questions (Typical)

I-01	Let system X is at temperature t_X. Since it is not in thermal equilibrium with systems Y and Z therefore as per Zeroth Law of Thermodynamics (ZLT) $t_X \neq t_Y$ and $t_X \neq t_Z$, here t_Y and t_Z are temperatures of systems Y and Z respectively. Now condition for the systems Y and Z to be in thermal equilibrium necessary condition is $t_X = t_Z$, as per ZLT. This is neither evident from the given data, nor it is contradicted; the data is silent in respect of which is silent in respect t_Y and t_Z. Therefore, in the event of uncertainty ***correct option is (c).***
I-02	Relationship between Celsius and Farenheit temperatures is $\frac{F-32}{9}=\frac{C}{5} \Rightarrow C=\frac{5}{9}F-\frac{160}{9}$. This equation can be compared with general equation of line $y=mx+c$, where correpondence of variables is $y \to C$, $x \to F$, slope of line $m \to \frac{5}{9}$, and intercept on Y axis is $c \to -\frac{160}{9}$. Since, intercept on C-axis is negative, the line must be passing through point *R*. Through this point two lines **a** and **d** are passing having slopes $m_a = \frac{0-(-y_R)}{x_Q - 0} = \frac{y_R}{x_Q}$ and $m_d = \frac{(-y_R)-0}{0-(-x_S)-0} = -\frac{y_R}{x_S}$ respectively. Slope of the line of the given equation $m \to \frac{5}{9}$ is (+)ve; this is valid for line a only and hence, **curve representing the given relationship is (a).**  **N.B.:** Solution of this problem using basic concept of coordinate geometry will ensure that wrong choice is not made
I-03	Comparig two reference temperatures Freezing Point and boiling of water at NTP in all the scales would lead to the answer- <table><tr><td>Reference to water</td><td>Fahrenheit</td><td>Kelvin</td><td>Celsius</td><td>Platinum</td></tr><tr><td>Ice Point</td><td>32^0F</td><td>273 K</td><td>0^0C</td><td>0^0</td></tr><tr><td>Boiling point</td><td>212^0F</td><td>373 K</td><td>100^0C</td><td>100^0</td></tr></table> Since reference point in Celsius and Platinum linear scale have same values, therefore by either interpolation or extraploation any other temperature in these two scales shall also have same value. Acordingly, ***answer is option (d)***.
I-04	The ideal gas equation is $pv=nRT$. If volume of gas is fixed it leads to $p=kT \Rightarrow p-p_0=k(t-0)=kt$ at 0^0C. And at 100^0C, it would be $p_{100}-p_0=k(100-0)=100k$. These two equations can be combined into a ratio-proportion $\frac{p-p_0}{p_{100}-p_0}=\frac{t}{100} \Rightarrow t=\left(\frac{p-p_0}{p_{100}-p_0}\right)\times 100$. In this context analysis of each option is as under – (a) At low pressure and low temperature for a fixed volume of bulb quantity gas (*n*) will be limited. (b) At low temperature and high pressure quantity of gas (*n*) will increase as compared to that in option (a), this will reduce sensitivity of change in pressure. (c) At high temperature and low pressure quantity of gas (*n*) compared to that in option (a), this will increase

	sensitivity of change in pressure. (d) At high temperature and high pressure, quantity of gas (n) shall be comparable to that in option (a), and thus sensiyvity of change in pressure will not be much affected. Thus for greater sensitivity **option (c) would give best results**.
I-05	Relation ship for linear thermal expansion is $\Delta l = l_0 \alpha \Delta t \Rightarrow \alpha = \frac{\Delta l}{l_0 \Delta t} \Rightarrow [\alpha] = \frac{L}{LK} = K^{-1}$, as given. Likewise, for coefficient of volumetric expansion $\Delta v = v_0 \alpha \Delta t \Rightarrow \alpha = \frac{\Delta v}{v_0 \Delta t} \Rightarrow [\alpha] = \frac{L^3}{L^3 K} = K^{-1}$, as given. This is provided in ***option (a), and this is correct.***
I-06	Metal sheet with a circular hole when heated, it will undergo thermal expansion. Taking, a finite ring at the perimeter of the hole, it will undergo exmpansion $l_{\Delta t} = l(1+\alpha\Delta t) \Rightarrow 2\pi R_{\Delta t} = 2\pi R(1+\alpha\Delta t)$. It leads to $R_{\Delta t} - R = \alpha R \Delta t \Rightarrow \Delta R = \alpha R \Delta t$. Since, radius of hole is an absolute vaue is always (+)ve, coefficient of inear thermal expansion α is also (+)ve, and when sheet is heated Δt is also (+)ve. Thus RHS of the final expression of change in adius of the hole is (+), it means radius of the hole on heating would increase. Thus, ***option (a) is correct.***
I-07	Let distance between rivets of bimetallic strip made of two identical strips of copper and steel be l. Change in length of copper and steel srips when heated through a temperature Δt for copper and steel strips will be $\Delta l_{copper} = \alpha_{copper} l \Delta t$ and $\Delta l_{steel} = \alpha_{steel} l \Delta t$ respectively. It leads to $\frac{\Delta l_{copper}}{\alpha_{copper}} = \frac{\Delta l_{steel}}{\alpha_{steel}} = l\Delta t$. Accordingly, $\frac{\Delta l_{copper}}{\Delta l_{steel}} = \frac{\alpha_{copper}}{\alpha_{steel}}$. From the given data $\frac{\alpha_{copper}}{\alpha_{steel}} > 1$ and hence $\frac{\Delta l_{copper}}{\Delta l_{steel}} > 1$. The rivets since fix the ends, and therefore unequal expansion of strips will cause bending along arcs of different radius with a fixed angle such that $\frac{\Delta l_{copper}}{\Delta l_{steel}} = \frac{R_{copper}\theta}{R_{steel}\theta} = \frac{R_{copper}}{R_{steel}} > 1$.  This is possible only when bending of copper is on convex side. ***Hence, answer is option (b)***
I-08	Moment of inertia of a unform rod is $I = \frac{Ml^2}{12}$. If temperature of the rod is increase by Δt then its length with increases to $l_{\Delta t} = l(1+\alpha\Delta t)$ accordingly its moment of inertia would change to $I_{\Delta t} = \frac{M\left(l(1+\alpha\Delta t)\right)^2}{12}$ which leads to $I_{\Delta t} = \frac{Ml^2(1+\alpha\Delta t)^2}{12} \approx \frac{Ml^2}{12}(1+2\alpha\Delta t) = I(1+2\alpha\Delta t) = I + 2\alpha I \Delta t$. Thus inceasein moment of inertia of the rod is $\Delta I_{\Delta t} = I_{\Delta t} - I = (I + 2\alpha I \Delta t) - I = 2\alpha I \Delta t$. With this derivation, ***answer is option (c).***
I-09	Taking rod to be of circular cross-section of radius r, its moment of inertia is $I = \frac{mr^2}{2}$. On increase of temperature by Δt the radius would undergo thermal expansion and it would be $r_{\Delta t} = r(1+\alpha\Delta t)$. Accordingly, 

	$I_{\Delta t}=\frac{mr_{\Delta t}^{2}}{2}=\frac{m\left(r\left(1+\alpha\Delta t\right)\right)^{2}}{2}=\frac{mr^{2}}{2}\left(1+2\alpha\Delta t+\alpha^{2}\left(\Delta t\right)^{2}\right)\approx I\left(1+2\alpha\Delta t\right)$. This approximation is based on the fact that $\alpha<<\Delta t$ and therefore $\alpha^{2}\left(\Delta t\right)^{2}\rightarrow 0$. Accordingly, $I_{\Delta t}=I+2\alpha I\Delta t$. Moment of inertia of a rod of length l and mass m is about an axis X'-X' parallel to axis of the rod X-X, and a distance d, as per *parallel axis theorem*, would be $I_{d}=I+\sum md^{2}\Delta l=I+md^{2}\int_{0}^{l}dl=I+md^{2}l$. And on increase of temperature by Δt by new moment of inertia would be $I_{d-\Delta t}=I_{\Delta t}+md^{2}l$. Thermal expansion of cross-section of rod is radially uniform and hence it will have no effect of change in temperature on d. Accordingly, change in moment of inertia is $\Delta I_{d-\Delta t}=I_{d-\Delta t}-I_{d}$. This simplifies into $\Delta I_{d-\Delta t}=\left(I\left(1+2\alpha\Delta t\right)+md^{2}l\right)-\left(I+md^{2}l\right)=2\alpha I\Delta t$. Thus ***answer is option (c).*** **N.B.:** In the problem radius is since not given it is assumed to be r. This is essential unless problem states thatit is a thin rod or a wire.
I-10	Density of water at 4^{0}C is $1\,g\cdot cc^{-3}$ and is highest, while density of water as it tends to solidifies at 0^{0}C or on heating decreases with increase of temperature. Further due to buoyancy water at the bottom would be denser than at 2^{0}C. Hence, answer ***is option (c).*** 
I-11	Coefficient of volumetric expansion of water γ_{W} is greater than of aluminium sphere γ_{A}. Let V is the volume of the sphere. Force of buyoancy is equal to the weight of ligquid disolaced by the sphere of aluminium for whose density is greater than water $\rho_{A}>>\rho_{W}$, but coefficient of voulmetric thermal expansion of liquids is much greater than metals $\gamma_{A}<\gamma_{W}$. In the instant case it is assumed that aluminium sphere is allowed to come in thermal equlibrium with water at 10^{0}C in which it is dipped. Therefore, force of buyoancy before heating is $F_{B}=V\rho_{W}g$. On increase of temperature by $\Delta t\,^{0}$C volume of sphere is $V_{\Delta t}=V\left(1+\gamma_{A}\Delta t\right)$, therefore it will eperience a force of buyoancy $F_{B\Delta t}=V_{\Delta t}\rho_{W\Delta t}g$. During heating there is volumetric expnasion of water also accoordingly density of water would be $\rho_{W\Delta t}=\frac{V\rho_{W}}{V\left(1+\gamma_{W}\Delta t\right)}=\frac{\rho_{W}}{\left(1+\gamma_{W}\Delta t\right)}$. Therefore, $F_{B\Delta t}=V\left(1+\gamma_{A}\Delta t\right)\left(\frac{\rho_{W}}{\left(1+\gamma_{W}\Delta t\right)}\right)g$. Using Binomial theorem it approximates to $F_{B\Delta t}=V\rho_{W}g\left(1+\gamma_{A}\Delta t\right)\left(1+\gamma_{W}\Delta t\right)^{-1}\approx F_{B}\left(1+\gamma_{A}\Delta t\right)\left(1-\gamma_{W}\Delta t\right)$. Since, despite $\gamma_{A}<\gamma_{W}$ both of them are quite small and hence $\gamma_{A}\cdot\gamma_{W}<<$ thus it leads to a further approzimation $F_{B\Delta t}\approx F_{B}\left(1-\left(\gamma_{W}-\gamma_{A}\right)\Delta t\right)$. Decrement factor $\left(\gamma_{W}-\gamma_{A}\right)>1$ associated with Δt will lead to $F_{B\Delta t}<F_{B}$. Therefore, ***answer is option (b).***
I-12	Since the two wheels are identical $M_{1}=M_{2}=M;\ I_{1}=I_{2}=I; R_{1}=R_{2}=R$. Let wheel has initial angual velocity $\omega_{1i}=-\omega$ i.e. in clockwise direction, and $\omega_{2i}=0$. Therefore initial kinetic of the system would be $KE_{i}=\frac{1}{2}I\omega_{i}^{2}+0=\frac{1}{2}I\omega_{i}^{2}$. 

	When the two wheels are brought in contact they will experience a force of friction such that, f_1 will tend to retard wheel 1 i.e. decrease magnitude ω_1 with an angular retardation such that $I\alpha = fR \Rightarrow \alpha = \frac{fR}{I}$ and f_2 will accelerate wheel 2 i.e. increase magnitude of ω_2 with an angular acceleration $\alpha = \frac{fR}{I}$. This will continue until $\omega_1 = \omega_2$. In this process at any time t when $\omega_1 > \omega_2$ kinetic energies of the two wheels would be $KE = \frac{1}{2}I\omega_1^2 + \frac{1}{2}I\omega_2^2$. Here, $\omega_{1t} = \omega_{1i} - \alpha t = \omega_{1i} - \frac{fR}{I}t$ and $\omega_{2t} = \omega_{2i} + \alpha t = 0 + \frac{fR}{I}t = \frac{fR}{I}t$. In the process angular displacement of the two wheels are $\theta_{1t} = \omega_{1i}t + \frac{1}{2}\alpha t^2 = \omega_{1i}t + \frac{fR}{2I}t^2$ and $\theta_{2t} = \omega_{2i}t + \frac{1}{2}\alpha t^2 = \frac{fR}{2I}t^2$, respetively. Thus frictional work done during this on wheel 1 is $W_{f1} = 2\pi R\theta_{1t}f = 2\pi R\left(\omega_{1i}t + \frac{fR}{2I}t^2\right)f$ and that on wheel 2 is $W_{f2} = 2\pi R\theta_{2t}f = 2\pi R\left(\frac{fR}{2I}t^2\right)f$. Thus for wheel 1, at time t shall be $KE_{1t} = \frac{1}{2}I\omega_{1t}^2 = KE_{1i} - W_{f1} = \frac{1}{2}I\omega_i^2 - 2\pi R\left(\omega_{1i}t + \frac{fR}{2I}t^2\right)f$ and kinetic energy of wheel 2 at that instant shall be $KE_{2t} = KE_{2i} + W_{f2} = \frac{1}{2}I\omega_{2t}^2 = 2\pi R\left(\frac{fR}{2I}t^2\right)f$. Thus, kinetic energy of the wheels decreases. It leads to $\Delta KE_1 = \Delta KE_{1t} - \Delta KE_{1i} = \left(\frac{1}{2}I\omega_i^2 - 2\pi R\left(\omega_{1i}t + \frac{fR}{2I}t^2\right)f\right) - \frac{1}{2}I\omega_i^2$. It leads to $\Delta KE_1 = -2\pi R\left(\omega_{1i}t + \frac{fR}{2I}t^2\right)f$, here (-)ve sign is indicative of the fact that kinetic energy of the system decreases with time. ***This makes, option (a) true***. The ΔKE_1 lost is converted into heat energy as per Joules experiment and dissipated in rise of temperature of wheels or into the environment. Hence total energy remains same, ***that makes option (b) false***. Mechanical energy of the system comprise of kinetic energy and potential energy. Since, nothing in the description of the experiment signifies change of height of the two wheels, and hence $\Delta PE_1 = 0$, therefore, $\Delta TME_1 = \Delta KE_1 + \Delta PE_1 = \Delta KE_1 = -2\pi R\left(\omega_{1i}t + \frac{fR}{2I}t^2\right)f$. Since, magnitude of ΔTME is (-)ve, hence total mechanical energy of the system reduces. ***This makes option (c) to be correct.*** The loss of kinetic energy as per Joules experiment is since converted in to heat energy, it increases molecular activity, i.e increase of internal energy and not decrease; ***this makes option (d) incorrect.*** ***Thus correct answer is option (a) and (c).*** ***N.B:*** This problem involves largely integration of concepts of mechanics. Yet, taking problems from basics lead to a thought process involving an integrated approach.
I-13	Bodies A and B are identical having mass m, and at any instant B is in a train with velocity $\vec{V}_{B,G} = \vec{V}$ while A is placed on the platform such that $\vec{V}_{A,G} = 0$. Therefore, kinetic energy of A is $KE_{B,G} = \frac{1}{2}mV^2$, while kinetic

	energy of A from the ground is $KE_{A,G} = 0$. Thus $KE_{B,G} > KE_{A,G}$, which ***makes option (a) correct***. Total energy of A comprises of potential and kinetic energy. Since platform and train are at sime height they shall have same potential energy therefore $TE_A = KE_A + PE_A + IE_A = KE_A; TE_B = KE_B + PE_B + IE_B = KE_B$. Internal energy is associated with heat content of the two bodies in same ambient conditions, which are stated to be identical hence they shall alo be equal like that of potential energy. Thus $TE_A > TE_B$, ***this makes option (b) correct***. Mechanical energy a system comprises of sum of potential and kinetic energy. Potential energies both the bodies being same as discussed above $KE_B > KE_A \Rightarrow ME_B > ME_A$, ***this makes option (c) correct***. Internal energy of the two identical bodies in same ambient condition being equal ***makes option (d) incorrect***. ***Thus, correct answer is option (a), (b) and (c).***
I-14	**Size of a degree in Mercury scale:** $t = al + b;\ a = \frac{t_2 - t_1}{l_2 - l_1} = \frac{100 - 0}{l_{100} - l_0} = \frac{100}{l_{100} - l_0};\ b = -al_0$ but it depends upon coefficient of expansion of mercury in range of ice point and steam point. But, it becomes non-uniform (nonlinear) over a wide range of temperature. ***This non-lineaerity of scale changes size of a degree of temperature on the mercury scale .*** **Size of a degree in Celsius scale :** It is based on dividing ice-point and steam-pointin 100 equal part each of which represents a degree. But, devising this scale requires some substance whose property changes linearly over the range. But, the ***Celsius scale has uniform size of a degree..*** **Size of a degree in Absolute scale :** This is also called Kelvin's scale where absoute 0K is that temperature at which hermal motion as per thermodynamics ceases and it is 273.16 K below triple point of water which is 0.01^0C. This is unformly extrapolated and is therefore ***size of a degree in Absolute scale remains uniform***. **Size of a degree in Ideal Gas scale :** The ideal gas equation $PV = nRT$ demonsrates $p \propto T$ practically for all gases with difference across gases decreasing with reduction in quantity of gas. This is achieved by filling gas in the bulb of *constant volume gas thermometer* at high temperature and low pressure. ***This gives uniform size of degree.*** ***The above analysis lead to options (c), and (d) as answer.***
I-15	In adbatic process there is no exchange of heat of the system with the environment. Let heat of the system be $H = H_w + H_s = m_w s_w t_{wi} + m_s s_s t_{si}$. After placing the solid object inside water, temperature of the water falls say by $\Delta t_w \Rightarrow t_{wi} - \Delta t_w = t_{wf}$. Then it should satisfy that $m_w s_w t_{wi} + m_s s_s t_{si} = m_w s_w \left(t_{wi} + \Delta t_w\right) + m_s s_s \left(t_{si} + \Delta t_s\right)$. It leads to $0 = m_w s_w \Delta t_w + m_s s_s \Delta t_s$, this is possible only when sign of Δt_s is opposite to that of Δt_w. Since, temperature of water decreases i.e. sign of Δt_w is (-)ve hence sign of Δt_s must be (+)ve i.e. temperaure of solid must increase. Hence, **answer is (a).**
I-16	Time period of pendulum is $T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow T \propto \sqrt{l}$, in this length of pendulum increases with length as per equation $l_{\Delta t} = l\left(1 + \alpha\Delta t\right)$ here coefficient of linear expansion α is(+)ve and for increase of temperature Δt is also (+)ve. Hence, $l_{\Delta t} > l$. Accordingly, $\frac{T_{\Delta t}}{T} = \sqrt{\frac{l_{\Delta t}}{l}} > 1$. Hence time period of the pendulum will increase but

	not in direct proportion. ***Thus answer is (b).***
I-17	Given that markings on a mercury thermometer for Ice Point 0^0C is 20^0 and Steam point 100^0C is 80^0. Since markings on a thermometer is of unform size in its range Therefore, by ratio-proportion $\frac{80-20}{100-0}=\frac{32-20}{\theta-0}\Rightarrow\frac{60}{100}=\frac{12}{\theta}\Rightarrow\theta=\frac{12}{0.6}=20^0\text{C}$. ***Thus answer is 20^0C.***
I-18	Triple point temperature is 273.16 K which corresponds to 0.01^0Cand pressure registered in constant volume thermometer is given to be 1.500×10^4Pa and at normal boiling point which corresponds to 100^0C is 2.050×10^4 Pa. Then by ratio and proportion $T=\frac{2.050\times10^4}{1.500\times10^4}\times273.16=\frac{2.050}{1.500}\times273.16$. Here while reporting answer it essential to note number of significant digits in the given data which is 4, while number of significant digits in triple point of water is 5. Therefore answer shall be reported in minimum number of significant digits among the multipliers. Accordingly, though as per calculations $T=373.27767$ the answer shall be 373.3 K. ***Thus answer is 373.3 K.*** N.B.: Here convention of significant digits is required to be used. This care is essential when data is given.
I-19	Triple point temperature is 273.16 K at which let pressure is measured to be P_0 and at melting point of lead T measured pressure is $2.20\times P_0$. Therefore, by ratio proportion $\frac{T}{273.16}=\frac{2.2\times P_0}{P_0}\Rightarrow T=273.16\times2.2$. It leads to , $T=600.952=601$. It is based on convention of Significant digits which is minimum Three in case of pressure. Accordingly, answer is 601 K. ***Thus answer is 373.3 K.***
I-20	Solving this question requires understanding Callender's compensated constant pressure air thermometer, and in its final form that $T=\frac{V}{V-v'}T_0$, which is based on ideal gas equation applied to fixed quantity of gas contained in the bulb of the the thermometer. Here, $V=1800\,\text{cc}$ is the volume of each of the bulbs both measuring bulb and reference bulb, $v'=200\,\text{cc}$ is the volume of mercury poured out during measurement and $T_0=273\,\text{K}$ is temperature of the ice bath. Accordingly, $T=\frac{1800}{1800-200}\times273.15\,\text{K}=307.305\,\text{K}$. In the given data minimum SGs are Three and hence ***answer will be*** $T=307\,\text{K}$**.**
I-21	Principle of platinum resistance thermometer is based on its principle of thermal coefficient of resistance, $R_t=R_0(1+\alpha t)$and taking its measured resistance R_0 and R_{100} at two reference temperatures 0^0 and 100^0 such that, $t=\frac{R_t-R_0}{R_{100}-R_0}\times100=\frac{86-80}{90-80}\times100=\frac{6}{10}\times100=60^0$ **.** ***Thus answer is*** 60^0. **N.B.:** In Platinum Scale temperature measured to be N is indicated simply as N^0 it would be incorrect to indicate it as N^0 C
I-22	There are three variables and with given data of resistances corresponding to three points of temperature on Clius scale it is possible to formulate three equations and this satisfies condition of sufficiency of data. Accordingly, Three equation are, which lead to virtually Two equations and Two variables to be determined – $R_0=20.0$ … (1) $R_{100}=27.5=20.0(1+\alpha\times100+\beta\times100^2)\Rightarrow0.375=1\times10^2\alpha+1\times10^4\beta$ … (2)

	$R_{420} = 50.0 = 20.0\left(1+\alpha\times420+\beta\times420^2\right) \Rightarrow 1.50 = 4.20\times10^2\alpha+17.6\times10^4\beta$ ... (3) Solving, $(2)\times4.2-(3)$ we get $1.575-1.5=\left(4.2\times10^4-17.62\times10^4\right)\beta \Rightarrow 0.075=-13.4\times10^4\beta$, thus we get $\beta=-\frac{75}{13.4}\times10^{-7}=-5.59\times10^{-7}\ {}^0\text{C}^{-2}$ Substituting, value of β in (2) we get $0.375=1\times10^2\alpha+1\times10^4\times\left(-5.59\times10^{-7}\right)=10^2\alpha-5.59\times10^{-3}$. This reduces to $\alpha=3.75\times10^{-3}+0.0559\times10^{-3}=3.80\times10^{-3}$. ***Thus values of*** R_0, α ***and*** β ***are 20.0 Ω,*** $3.80\times10^{-3}\ {}^0\text{C}^{-1}$, $-5.59\times10^{-7}\ {}^0\text{C}^{-2}$ ***respectively.*** **N.B:** In this principle of rounding LSG is used extensively.
I-23	Thermal expansion of metal is expressed as $l_t=l_0\left(1+\alpha t\right)$. Taking coefficient of thermal expansion is taken to be uniform, the reference length is $l=1$ cm and refrence temperature to be $t=20^0$C, the formula can be written as $l_{\Delta t}=l\left(1+\alpha\Delta t\right)\Rightarrow l_{\Delta t}=1\left(1+1.1\times10^{-5}\times(-10)\right)=1\left(1-1.1\times10^{-4}\right)=1-0.00011=0.99989$ cm. Hence answer is 0.99989 cm. **N.B.:** In this case since distance is asked, rounding of LSG is not done.
I-24	Thermal expansion in length of track Δl for change of temprature through Δt = 30^{0}C (=48-18) is derived from $l_{\Delta t}=l\left(1+\alpha\Delta t\right)\Rightarrow \Delta l=l_{\Delta t}-l=\alpha l\Delta t=12.0\times30\times1.1\times10^{-5}=358.9\times10^{-5}=3.589\times10^{-3}$ m. It equates to $\Delta l=0.4$ cm. ***Hence answer is 0.4 cm.***
I-25	Given that at reference temperature 20^{0}C length of two separate meter scales of aluminium and steel are $l_{a\Delta t}=l\left(1+\alpha_a\Delta t\right)$ and $l_{s\Delta t}=l\left(1+\alpha_s\Delta t\right)$ respectively. There fore ratio of centimeter of two scales for any change of temperature would $\frac{l_{a\Delta t}}{l_{a\Delta t}}=\frac{l\left(1+\alpha_a\Delta t\right)}{l\left(1+\alpha_s\Delta t\right)}=\frac{1+\alpha_a\Delta t}{1+\alpha_s\Delta t}$ Therefore, at 0^{0}C, 40^{0}C and 100^{0}C value of Δt is (-) 20^{0}C, 20^{0}C and 80^{0}Caccordingly, For case 1 where $\Delta t=-20^0C$: $\frac{l_{a(-20)}}{l_{a(-20)}}=\frac{1-20\times2.3\times10^{-5}}{1-20\times1.1\times10^{-5}}=\frac{1-0.00046}{1-0.00022}=\frac{0.99954}{0.99978}=0.999759=0.99976$, For case 2 where $\Delta t=20^0C$: $\frac{l_{a(20)}}{l_{a(20)}}=\frac{1+20\times2.3\times10^{-5}}{1+20\times1.1\times10^{-5}}=\frac{1+0.00046}{1+0.00022}=\frac{1.00046}{1.00022}=1.000239=1.00024$, For case 2 where $\Delta t=80^0C$: $\frac{l_{a(20)}}{l_{a(20)}}=\frac{1+80\times2.3\times10^{-5}}{1+80\times1.1\times10^{-5}}=\frac{1+0.00184}{1+0.00088}=\frac{1.00184}{1.00088}=1.000959=1.00096$, At the end of each case answer is given. N.B: (1) The required answers are ratio of lengts and hence it does not have either unit or dimension. (2) Ratio is asked of Aluminium-centimeter and steel-centrimeter, but thermal coefficient of expansion of the metals are given in reverse order. This should be taken care of while these coefficients.
I-26	The stated experiment demands an accuracy upto 0.055mm in 1 mm, i.e. permissible error per mm is 0.0945. Accuracy of the metre scale is stnadardized at 20^{0}C. Taking standard relatioship of linear thermal expansion, $l_{\Delta t}=l\left(1\pm\alpha\Delta t\right)\Rightarrow\frac{l_{\Delta t}}{l}=1\pm\alpha\Delta t\Rightarrow\alpha\Delta t=\frac{l_{\Delta t}}{l}-1\Rightarrow\pm\alpha\Delta t=\frac{l_{\Delta t}-l}{l}=\frac{\Delta l}{l}\Rightarrow\pm\Delta t=\frac{\Delta l}{\alpha l}$. Using the given data

	the desired temperature variayion is $\Delta t=\pm\frac{0.055}{\left(1\times10^{3}\right)\left(1.1\times10^{-5}\right)}=\pm5$. ***Thus, range of temperature within the desired accuracy is*** $20\pm5=15^{0}\text{C to }25^{0}\text{C}$ ***is the answer.***
I-27	Equation for thermal volumetric coefficient of expansion is $v_t=v_0\left(1+\gamma t\right)$, as per the given data $\rho_0=0.998$ g.cm^{-3} at 0^{0}C and $\rho_4=1.000$ g.cm^{-3} at 4^{0}C . Therefore, $\lambda=\frac{v_t-v_0}{v_0 t}=\frac{v_4-v_0}{4v_0}$, here density $\rho=\frac{m}{v}\Rightarrow v=\frac{m}{\rho}$. Accordingly, $\lambda=\frac{\frac{1}{\rho_t}-\frac{1}{\rho_0}}{\frac{1}{\rho_0}t}=\frac{\rho_0-\rho_t}{\rho_t t}=\frac{0.998-1}{1\times4}=-\frac{0.002}{4}=-5\times10^{-4}\,{}^{0}\text{C}$. **Thus answer is** $-5\times10^{-4}\,{}^{0}\text{C}$.
I-28	Time period of pendulum is $T=2\pi\sqrt{\frac{l}{g}}$. It is standardised at 20^{0}C at a place where $g=9.800\,\text{m}\cdot\text{s}^{-2}$ accordingly, $T=2\pi\sqrt{\frac{l}{9.800}}$. At another place where $g=9.788\,\text{m}\cdot\text{s}^{-2}$ at certain temperature t it gives same time period i.e. $T=2\pi\sqrt{\frac{l_t}{9.788}}=2\pi\sqrt{\frac{l\left(1+\alpha\Delta t\right)}{9.788}}$, considering linear thermal expansioon of the rod length. Comparing the two time periods it leads to $2\pi\sqrt{\frac{l}{9.800}}=2\pi\sqrt{\frac{l\left(1+\alpha\Delta t\right)}{9.788}}\Rightarrow\frac{1}{9.800}=\frac{1+\alpha\Delta t}{9.788}$. Accordingly, $\frac{9.788}{9.800}-1=1.2\times10^{-5}\times\Delta t\Rightarrow\Delta t=-\frac{0.012}{9.800\times1.2}\times10^{5}=-\frac{1.2}{9.800\times1.2}\times10^{3}=-102.04$. This leads to $\Delta t=-102.04=t-20\Rightarrow t=20-102.04=-82.04=-82\,{}^{0}\text{C}$. This is considering rounding of SGs. ***Thus answer is -82^{0}C.***
I-29	At 10^{0}C diameter of the whole is 2.000 cm in aluminium plate with $\alpha_a=2.3\times10^{-5}\,{}^{0}\text{C}^{-1}$ and diameter of solid sphere with $\alpha_s=1.1\times10^{-5}\,{}^{0}\text{C}^{-1}$ is 2.005 cm. On heating an infinitesimal ring permeter of the hole would undergo thermal expansion which would be $p_{\Delta t}=p\left(1+\alpha_a\Delta t\right)\Rightarrow2\pi\left(r+\Delta r\right)=2\pi r\left(1+\alpha_a\Delta t\right)$. Thus, $r_{p\Delta t}=r_p+\Delta r_p=r_p\left(1+\alpha_a\Delta t\right)$. Likewise, volumetric expansion of sphere $v_{s\Delta t}=v_s\left(1+\gamma_s\Delta t\right)$. Therefore, $\frac{4}{3}\pi r_{s\Delta t}{}^{3}=\frac{4}{3}\pi r_s^{3}\left(1+3\alpha_s\Delta t\right)$. Since, $\Delta t<<$, it leads to $r_{s\Delta t}=r_s\left(1+3\alpha_s\Delta t\right)^{\frac{1}{3}}=r_s\left(1+\frac{1}{3}\times3\alpha_s\Delta t\right)=r_s\left(1+\alpha_s\Delta t\right)$. For the sphere to be able to pass through is limiting condition is $r_{p\Delta t}=r_{s\Delta t}\Rightarrow r_p\left(1+\alpha_a\Delta t\right)=r_s\left(1+\alpha_s\Delta t\right)$. This leads to $r_p\left(1+\alpha_a\Delta t\right)=r_s\left(1+\alpha_s\Delta t\right)\Rightarrow\left(r_p\alpha_a-r_s\alpha_s\right)\Delta t=r_s-r_p\Rightarrow\Delta t=\frac{r_s-r_p}{r_p\alpha_a-r_s\alpha_s}$. Substituting values $\Delta t=\frac{r_s-r_p}{r_p\alpha_a-r_s\alpha_s}=\frac{2.005-2.000}{2.000\times2.3\times10^{-5}-2.005\times1.1\times10^{-5}}=\frac{0.005\times10^{5}}{4.6000-2.2055}=\frac{500}{2.3945}=208.8=209$. It implies that, for initial temperature of 10^{0}C $\Delta t=t-10\Rightarrow t=10+\Delta t=10+209=219\,{}^{0}\text{C}$. ***Thus answer is 219^{0}C.*** **N.B.:** In the instant case, perimeter of the hole in the plate undergoes linear expansion, while sphere undergoes volumetric expansion. But, in final analysis, it reduces to linear expansion of the radius of the hole and sphere. This intuition is developed through solving of problems from first principle,in first stage.

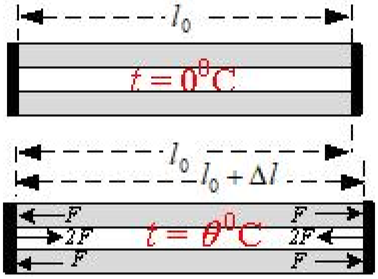
I-30	Let the vessel at 20^0C be of cylindrical cross-section A and height H, then volume of vessel is $V_c = A\times H$ here A is area and H is height of vessel. $V_c = A\times H$, On heating through a temperature Δt, volume shall be $V_{ct} = A_t\times H_t = \left(A\left(1+\beta_g\Delta t\right)\right)\times\left(H\left(1+\alpha_g\Delta t\right)\right) AH\left(1+2\alpha_g\Delta t\right)\left(1+\alpha_g\Delta t\right) = V_c\left(1+3\alpha_g\Delta t+2\times\alpha_g{}^2\times(\Delta t)^2\right)$. Since, $\alpha_g << \Delta t$, the expression reduces to $V_{ct} = V_c\left(1+3\alpha_g\Delta t\right)$. Volume of mercury on thermal expansion of mercury is $V_{mt} = V\left(1+\gamma_m\Delta t\right) = V\left(1+3\alpha_m\Delta t\right)$, Let V is the volume of mercury poured into vessel, then volume of empty space is $V_e = V_c - V$. On heating through a temperature Δt, volume of vessel and mercury are increasing since both have (+)ve coefficient of linear expansion. Then for satisfying given condition $V_e = V_c - V = V_{ct} - V_{mt}$. It leads to a general form $V_c - V = V_c\left(1+3\alpha_g\Delta t\right) - V\left(1+3\alpha_m\Delta t\right) \Rightarrow V + 3\alpha_m V\Delta t - V = V_c + 3\alpha_g V_c\Delta t - V_c \Rightarrow 3\alpha_m V\Delta t = 3\alpha_g V_c\Delta t$. It leads to $V = \frac{\alpha_g}{\alpha_m}V_c = \frac{9\times10^{-6}}{1.8\times10^{-4}}\times10^3 = 5\times10 = 50$ cc. ***Thus answer is 50 cc of mercury.***
I-31	Let V_W be volume of piece of wood, therefore mass of wood shall be $m_W = V_W\rho_W \Rightarrow \rho_W = \frac{m_W}{V_W}$. At temperature t volume of of wood would be $V_{Wt} = V_W\left(1+\gamma_W t\right)$, here instead of Δt we have taken t since reference temperature is 0^0C. Therefore, density of wood at temperature t would be $\rho_{Wt} = \frac{m_W}{V_W\left(1+\gamma_W t\right)} = \frac{\rho_W}{1+\gamma_W t}$ and likewise of benzene it would be $\rho_{Bt} = \frac{m_B}{V_B\left(1+\gamma_B t\right)} = \frac{\rho_B}{1+\gamma_B t}$. For the would to just sink necessary condition is that $\rho_{Wt} = \rho_{Bt} \Rightarrow \frac{\rho_W}{1+\gamma_W t} = \frac{\rho_B}{1+\gamma_B t}$. Accordingly, it leads to $\rho_W\left(1+\gamma_B t\right) = \rho_B\left(1+\gamma_W t\right) \Rightarrow \left(\rho_W\gamma_B - \rho_B\gamma_W\right)t = \rho_B - \rho_W$, It leads to $t = \frac{\rho_B - \rho_W}{\rho_W\gamma_B - \rho_B\gamma_W}$. On substituting values given $t = \frac{900-800}{800\times1.5\times10^{-3} - 900\times1.2\times10^{-3}} = \frac{100}{1200-1080}\times10^3 = \frac{100}{120}\times10^3 = 0.833\times10^3 = 83\,^0$C. ***Thus answer is 83^{0}C.***
I-32	Basic defintion of strain is equal to ratio of change in length to original length, before force is applied. This makes an external force a necessary condition for development of strain. In the instant case the rod is kept on the table and free to undergo thernmal expnasion without any external force. Thermal expansion and elongation of application of an external force are two independent phenomenon. And hence thermal expansion will not produce and strain in the rod. ***Hence, answer is Zero.*** **N.B.:** As a hint to the above solution, information in respect of coefficient of thermal expansion, and external force, area of cross-section of rod and Young's Modulus of elasticity is not given. Even if these data are provided it is redubndant and only to test conceptual clarity of student.
I-33	In the instant case it is of thermal contraction and $l_0 = l_{20}\left(1+\alpha\left(0-20\right)\right) \Rightarrow \Delta l = l_0 - l_{20} = -20\alpha l_{20}$. Since two ends if the wire are fixed, and therefore, to retain original length l_{20}, the thermally contracted length l_{20} with undergo elastic elongation such that strain is $= \frac{\Delta l}{l_0}$ and stress is $p = \frac{T}{A}$, here T is the tension and A is the area of

cross-section of the wire. Thus, as per Hooke's Laws modulus of elasticity $Y=\frac{p}{\frac{\Delta l}{l}}=\frac{\frac{T}{A}}{\frac{20\alpha l_{20}}{l_0}}\approx\left.\frac{\frac{T}{A}}{\frac{20\alpha l_{20}}{l_{20}}}\right|_{l_0\approx l_{20}}$.

This leads to $Y=\frac{T}{20\alpha A}\Rightarrow T=20\alpha YA$. On substituting values, $T=20\times\left(1.2\times10^{-5}\right)\times\left(2.0\times10^{11}\right)\times\left(0.5\times10^{-6}\right)$. It solves into $T=20\times1.2\times2.0\times0.5=24$ N. ***Thus answer is 24 N.***

N.B.: Approximation $l_0\approx l_{20}$ is based on consideration that change in length in thermal contraction is insignificant as compared to original length of the wire.

I-34 In this problem Two processes are concurrent- (a) thermal expansion of both the aluminium and steel rods, which is uneven due to difference in α depite same length at 0^0C, (b) as a result of uneven expansion rod undergoing higher thermal expansion will exert a tensile force on the rod undergoing lesser thermal expansion. This, in absence of any external force, will cause a reaction as per Newton's Third Law of motion.



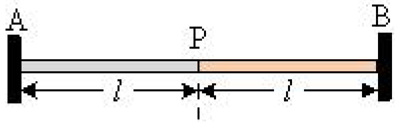
Free length of steel rod after thermal expansion at θ^0C is $l_{s\theta}=l_0\left(1+\alpha_s\theta\right)$ and for aluminium rod it would be $l_{a\theta}=l_0\left(1+\alpha_a\theta\right)$. Taking $\alpha_a>\alpha_s\Rightarrow l_{a\theta}>l_{a\theta}$, steel rod would experience a tensile stress and aluminum rod will experiece a compressive stress such that it settles down at some length l_0' such that $l_{s\theta}<l_0'<l_{s\theta}$.

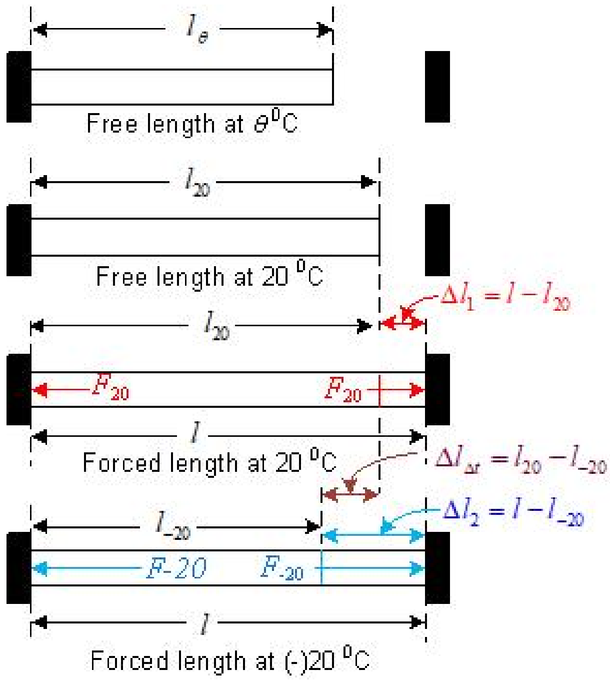
In this problem aluminium rod is sandwitched between Two steel rods. Therefore, unlike bimetallic strip it will not bend on thermal expansion, rather it will remian straight. And total tensile stress experienced by steel rods due to greater elongation of aluminium rod will equal to total compressive force experienced by aluminium rod due to lesser expansion of steel rod.

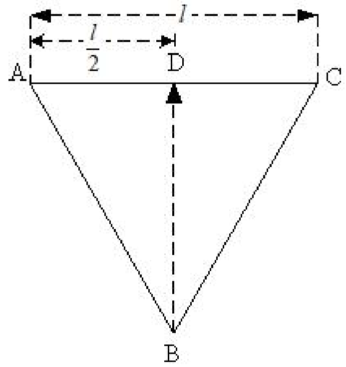
Tensile elongation or compression is as per Hooke's Law is $Y\frac{\frac{F}{A}}{\frac{\Delta l}{l}}\Rightarrow F=Y\frac{\Delta l}{l}A$. Given that all the rods of same cross-section also and therefore tensile force on steel rods shall be $F_s=Y_s\frac{\Delta l_s}{l}2A=2Y_s\frac{\Delta l_s}{l}A$ a. Since there are two steel rods in parallel and hence their effectivearea would het added i.e. doubled. But, for aluminium rod the compressive force would be $F_a=Y_a\frac{\Delta l_a}{l}A$. Here $\Delta l_s=l-l_{s\theta}=l-l_0\left(1+\alpha_s\theta\right)$, and likewise, . $\Delta l_a=l_{a\theta}-l=l_0\left(1+\alpha_a\theta\right)-l$. In a state of equilibrium $F_s=F_a\Rightarrow 2Y_s\frac{\Delta l_s}{l}A=Y_a\frac{\Delta l_a}{l}A\Rightarrow 2Y_s\Delta l_s=Y_a\Delta l_a$. Substituting the values $2Y_s\left(l-l_0\left(1+\alpha_s\theta\right)\right)=Y_a\left(l_0\left(1+\alpha_a\theta\right)-l\right)$, This simplifies into an expression as under -

$$\left(2Y_s+Y_a\right)l=l_0\left(2Y_s\left(1+\alpha_s\theta\right)+Y_a\left(1+\alpha_a\theta\right)\right)=l_0\left(\left(2Y_s+Y\right)+\left(2\alpha_sY_s+\alpha_aY_a\right)\theta\right)\Rightarrow l=l_0\left(1+\frac{2\alpha_sY_s+\alpha_aY}{2Y_s+Y}\theta\right)$$

Thus answer is $l_0\left[1+\frac{\alpha_a\mathrm{Y}_a+2\alpha_s\mathrm{Y}_s}{\mathrm{Y}_a+2\mathrm{Y}_s}\theta\right]$.

I-35	Let r_{20} is the radius of the steel ball at 20^0C then its volune is $V_{20}=\frac{4}{3}\pi r_{20}{}^3$. The volumetric thermal expansion when heated to 1200C i.e. $\Delta t=100^0\text{C}$ shall be $V_{120}=\frac{4}{3}\pi\left(r_{20}\left(1+\alpha\Delta t\right)\right)^3\approx\frac{4}{3}\pi r_{20}{}^3\left(1+3\alpha\Delta t\right)=V_{20}\left(1+3\alpha\Delta t\right)$, since $\alpha <<$, neglecting all higher power of α. To keep the volume constant on heating the ball has to undergo volumetric compression fron V_{120} to V_{20}. Such that $\gamma=\frac{p}{\frac{\Delta V}{V}}\Rightarrow p=\gamma\frac{\Delta V}{V}=\gamma\frac{V_{20}-V_{120}}{V_{120}}=\lambda\frac{V_{20}-V_{20}\left(1+3\alpha\Delta t\right)}{V_{20}\left(1+3\alpha\Delta t\right)}=\lambda\frac{3\alpha\Delta t}{1+3\alpha\Delta t}\approx 3\alpha\lambda\Delta t\big\vert_{3\alpha\Delta t<<1}$. Substituting the values, $p=3\times\left(1.2\times10^{-5}\right)\times\left(1.6\times10^{11}\right)\times100=5.76\times10^8=5.8\times10^8$ Pa, This is the external pressure, and therefore as per Newton's Tghird law of motion, for ball to be in a state of equilibrium internal pressure would be 5.8×10^8 Pa ***this is the answer.***
I-36	Moment of inertia of any solid body at 0^0C is expressed as $I_0=\frac{\sum mr_0{}^2}{\sum m}=\frac{\sum mr_0{}^2}{M}$. On heating of the object by $\theta^0\text{C}$, all radial distances will experience thermal expnasion such that $r_0\rightarrow r_\theta\Rightarrow I_\theta=\frac{\sum mr_\theta{}^2}{M}$. Accordingly $I_\theta=\frac{\sum m\left(r_0\left(1+\alpha\theta\right)\right)^2}{M}\approx\frac{\sum mr_0^2\left(1+2\alpha\theta\right)}{M}=\frac{\sum mr_0{}^2}{M}\left(1+2\alpha\theta\right)=I_0\left(1+2\alpha\theta\right)$, ignoroning terms containing hiher power of α, being infintesimal. **Hence proved.**
I-37	Time period of a torsional pendulom is $T=2\pi\sqrt{\frac{I}{k}}$, here $I=\frac{Mr^2}{2}$ and k are moment of inertia of the disk and torsional constant of the suspension wirestring of the disc. Accordingly, at 5^0C, $T_5=2\pi\sqrt{\frac{Mr_5{}^2}{2k}}=\pi\sqrt{\frac{2M}{k}}r_5$, and at 45^0C, $T_{45}=2\pi\sqrt{\frac{Mr_{45}{}^2}{2k}}=\pi\sqrt{\frac{2M}{k}}r_{45}=\pi\sqrt{\frac{2M}{k}}r_5\left(1+\alpha\left(45-5\right)\right)=\pi\sqrt{\frac{2M}{k}}r_5\left(1+40\alpha\right)$. Thus percentage change time period $\Delta t\%=\frac{T_{45}-T_5}{T_5}\times100=\frac{\pi\sqrt{\frac{2M}{k}}r_5\left(1+40\alpha\right)-\pi\sqrt{\frac{2M}{k}}r_5}{\pi\sqrt{\frac{2M}{k}}r_5}\times100=40\times100\times2.4\times10^{-5}$. It leads to $\Delta t\%=\left(4\times10^3\right)\times\left(2.4\times10^{-5}\right)=9.6\times10^{-2}\ \%$, Thus answer is $\Delta t\%=9.6\times10^{-2}\ \%$
I-38	Let rod between points AP has coefiicient of linear expansion and Young's Modulus of elasticity be α_1 and Y_1 and for rod between points P and B be α_2 and Y_2 respectively.Each have initial length l  On heating of rods through at temperature θ the legth of the two rods would be $l_{1\theta}=l\left(1+\alpha_1\theta\right)$ and $l_{2\theta}=l\left(1+\alpha_2\theta\right)$. For Point P to remain at the same position each of the rod has to undergo elastic compression $\Delta l_1=l_{1\theta}-l=l\left(1+\alpha_1\theta\right)-l=\alpha_1 l\theta$ and likewise, $\Delta l_2=l_{2\theta}-l=\alpha_2 l\theta$.

	As per Hooke's law for rod AP, $Y_1 = \dfrac{\frac{F}{A}}{\frac{\Delta l_1}{l_{1\theta}}} = \dfrac{Fl_{1\theta}}{A\Delta l_1} = \dfrac{Fl_{1\theta}}{A\alpha_1 l\theta} \approx \dfrac{Fl}{A\alpha_1 l\theta} \Rightarrow Y_1\alpha_1 = \dfrac{F}{A\theta}$, likewise for rod PB $Y_1 = \dfrac{\frac{F}{A}}{\frac{\Delta l_1}{l_{1\theta}}} \Rightarrow Y_2\alpha_2 = \dfrac{F}{A\theta}$, Thus for the Two rods $\dfrac{F}{A\theta} = Y_1\alpha_1 = Y_2\alpha_2$, ***Thus answer is*** $Y_1\alpha_1 = Y_2\alpha_2$.
I-39	Let free length of rod at θ^0C be l_θ the fixed streched length of the rod be l_0. Free length of the rod at 20^{0}C is $l_{20} = l_\theta\left(1+\alpha\left(20-\theta\right)\right)$. This rthemally expanded rod is subjected to force of 5000 N to fix it between two rigid ends at a distance l This will create an elastic elongation in the rod $\Delta l_1 = l - l_{20} = l - l_\theta\left(1+\alpha\left(20-\theta\right)\right)$.  As per Hooke's Law $\dfrac{\Delta l}{l} = \dfrac{p}{Y} \Rightarrow \Delta l = \dfrac{pl}{Y} = \dfrac{Fl}{AY}$. Thus elastic elongation in the rod of cross-section $150\times10^{-6}\text{m}^2$ is N.m^{-2} under a stress $\sigma_1 = \dfrac{5000}{150\times10^{-6}} = 33.3\times10^6$. N.m^{-2} Now keeping the ends of the lod fixed at distance l the system is cooled to (-)20^{0}C. Therefore freelength of rod will change to $l_{-20} = l_\theta\left(1+\alpha\left(-20-\theta\right)\right)$. Thus total themal contraction in free length of the rod is $\Delta l_{\Delta t} = 40\times l_\theta\times\alpha$. Thus, elastic elongation in the rod with it length fixed at l is $\Delta l_2 = \Delta l_1 + \Delta l_{\Delta t}$. Thus, rod will experience an additional stress to undertake an elastic elongation $\Delta l_{\Delta t}$ such that $\Delta p = \Delta l_{\Delta t}\left(\dfrac{Y}{l_\theta}\right) = 40\alpha l_\theta\left(\dfrac{Y}{l_\theta}\right) = 40\alpha Y$. It solves into $\Delta\sigma = 40\times\left(11.7\times10^{-6}\right)\times\left(2.00\times10^{11}\right) = 9.36\times10^7$ N.m^{-2}. Thus stress at -200C would be $\sigma_2 = \sigma_1 + \Delta\sigma$, it solves to $\sigma_2 = 33.3\times10^6 + 93.6\times10^6 = 126.9\times10^6 = 127\times10^6$ N.m^{-2} **N.B.:** Though $l_{-20} < l_\theta < l_{20}$, but due to coefficient of thermal expansion being very small for elastic elongation $_{-20} \approx l_\theta \approx < l_{20}$ In addition principle of significant digits is used in reporting the answer.

I-40	Given that length of sides AB=BC=CA=*l*. Linear coefficient of thermal expansion of the rd BC is α_1 and of sides AB and AC are α_2. In normal condition when the formation is equilateral triangle, $(BD)^2=(AB)^2+(AD)^2$, from property of Pythagoras Theorem, i.e. $BD=\sqrt{AB^2\text{-}AD^2}=\sqrt{l^2-\left(\frac{l}{2}\right)^2}=\frac{\sqrt{3}}{2}l$. On rise of temperature by θ^0C, rods of length AB and AD will undergo thermal linaer expansion, the distance will be $BD'=\sqrt{\left(l\left(1+\alpha_2 t\right)\right)^2-\left(\frac{l\left(1+\alpha_1 t\right)}{2}\right)^2}=l\sqrt{1+2\alpha_2 t-\frac{1+2\alpha_1 t}{4}}$, ignoring terms of higher order of α_1 and α_2. It is given that BD remains unchanged on heading and therefore on equating BD=BD' $\Rightarrow \left(BD\right)^2=\left(BD'\right)^2$, it leads to $\frac{3}{4}l^2=\left(\frac{3}{4}+\left(2\alpha_2-\frac{1}{2}\alpha_1\right)t\right)^2 l^2$ to this is possible only when $2\alpha_2-\frac{1}{2}\alpha_1=0 \Rightarrow \alpha_1=4\alpha_2$. This is the answer. 
I-41	Thermal expansion in rod of length L is $\Delta L_1=L\alpha\Delta\theta$ and in rod of length $2L$ is, $\Delta L_2=2L\alpha\Delta\theta$ total change in composite rod of length $3L$ is $\Delta L=\Delta L_1+\Delta L_2=L\alpha\theta+4L\alpha\theta=5L\alpha\theta$. Since, coefficient of expansion is $\alpha=\frac{\Delta l}{l\Delta\theta}=\frac{\Delta L}{3L\Delta\theta}=\frac{5\alpha L\Delta\theta}{3L\Delta\theta}=\frac{5}{3}\alpha$. ***This is the answer***.