Exercise-1

Marked Questions can be used as Revision Questions.

PART - I : SUBJECTIVE QUESTIONS

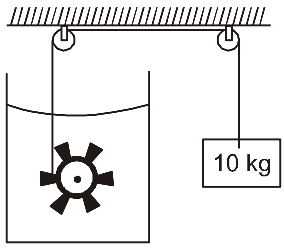
Section (A) : Calorimetry

A-1. In the following equation calculate the value of H.
1 kg steam at 200ºC = H + 1 kg water at 100ºC (S_{steam} = Constant = 0.5 Cal/gm°C)

A-2. From what height should a piece of ice (0°C) fall so that it melts completely? Only one-quarter of the energy produced is absorbed by the ice as heat. (Latent heat of ice = 3.4×10^5 J kg^{-1}, g = 10 m/s^2)

A-3. A copper cube of mass 200g slides down on a rough inclined plane of inclination 37º at a constant speed. Assume that any loss in mechanical energy goes into the copper block as thermal energy. Find the increase in the temperature of the block as it slides down 60 cm. Specific heat capacity of copper = 420 J/kg-K.

A-4. A paddle wheel is connected with a block of mass 10 kg as shown in figure. The wheel is completely immersed in liquid of heat capacity 4000 J/K. The container is adiabatic. For the time interval in which block goes down 1 m slowly calculate



(a) Work done on the liquid
(b) Heat supplied to the liquid
(c) Rise in the temperature of the liquid
Neglect the heat capacity of the container and the paddle. (g =10 m/s^2)

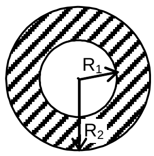
A-5 300 g of water at 25ºC is added to 100 g of ice at 0ºC. Find the final temperature of the mixture. **[1989; 2M]**

Section (B) : Thermal Expansion

B-1. The temperature of a metal ball is raised. Arrange the percentage change in volume, surface area and radius in ascending order.

B-2. A brass disc fits in a hole in a steel plate. Would you heat or cool the system to loosen the disc from the hole? Assume that $\alpha_s < \alpha_b$.

B-3. Temperature of plate is increased by $\Delta\theta$ then find new



(a) inner radius
(b) outer radius
(c) the difference in outer and inner radius and show that it is positive
(d) area of plate material (assume coefficient of expansion is α)

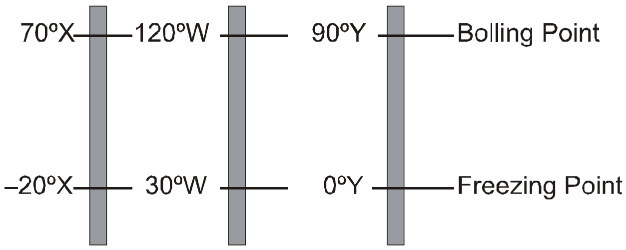
B-4. We have a hollow sphere and a solid sphere of equal radii and of the same material. They are heated to raise their temperature by equal amounts. How will the change in their volumes, due to volume expansions, be related? Consider two cases (i) hollow sphere is filled with air, (ii) there is vacuum inside the hollow sphere.

B-5 What should be the sum of lengths of an aluminium and steel rod at 0ºC is, so that at all temperatures their difference in length is 0.25m. (Take coefficient of linear expansion for aluminium and steel at 0°C as 22×10^{-6} /ºC and 11×10^{-6} /ºC respectively.)

B-6 A steel tape is correctly calibrated at 20 ºC and is used to measure the length of a table at 30°C. Find the percentage error in the measurement of length. [$\alpha_{steel} = 11 \times 10^{-6}$/ ºC]

Section (C) : Temperature

C-1. The figure shows three temperature scales with the freezing and boiling points of water indicated.



(a) Rank the size of a degree on these scales, greatest first.

(b) Rank the following temperatures, highest first : 50ºX, 50ºW and 50ºY.

C-2 . What is the temperature at which we get the same reading on both the centigrade and Fahrenheit scales?

PART - II : SINGLE CHOICE OBJECTIVE QUESTIONS

Section (A) : Calorimetry

A-1. A small quantity, mass m, of water at a temperature θ (inºC) is poured on to a large mass M of ice which is at its melting point. If c is the specific heat capacity of water and L the latent heat of fusion of ice, then the mass of ice melted is given by :

(A) $\frac{ML}{mc\theta}$ (B) $\frac{mc\theta}{ML}$ (C) $\frac{Mc\theta}{L}$ (D) $\frac{mc\theta}{L}$

A-2. A thermally isolated vessel contains 100 g of water at 0ºC. When air above the water is pumped out, some of the water freezes and some evaporates at 0ºC itself. Then the mass of the ice formed if no water is left in the vessel. Latent heat of vaporization of water at 0ºC = 2.10×10^6 J/kg and latent heat of fusion of ice = 3.36×10^5 J/kg.

(A) 86.2 g (B) 13.8 g (C) 76.2 g (D) 65.6 g

A-3. 20 gm ice at –10 ºC is mixed with m gm steam at 100 ºC. Minimum value of m so that finally all ice and steam converts into water. (Use s_{ice} = 0.5 cal/gmºC, s_{water} =1 cal/gmºC, L(melting)=80 cal/gm and L (vaporization) = 540 cal/gm)

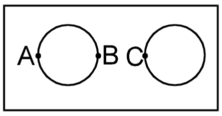
(A) $\frac{85}{32}$ gm (B) $\frac{85}{64}$ gm (C) $\frac{32}{85}$ gm (D) $\frac{64}{85}$ gm

A-4. 2 kg ice at – 20 ºC is mixed with 5 kg water at 20 ºC. Then final amount of water in the mixture will be : [Specific heat of ice = 0.5 cal/gm ºC, Specific heat of water = 1 cal/gm ºC, Latent heat of fusion of ice = 80 cal/gm] **[JEE-2003 (Scr.), 3/84,–1]**

(A) 6 kg (B) 7 kg (C) 3.5 kg (D) 5 kg

Section (B) : Thermal Expansion

B-1. Two large holes are cut in a metal sheet. If this is heated, distances AB and BC, (as shown)



(A) both will increase
(B) both will decrease
(C) AB increases, BC decreases
(D) AB decreases, BC increases

B-2. A steel scale is to be prepared such that the millimeter intervals are to be accurate within 6×10^{-5} mm. The maximum temperature variation from the temperature of calibration during the reading of the millimeter marks is ($\alpha = 12 \times 10^{-6}$ /ºC)

(A) 4.0°C
(B) 4.5°C
(C) 5.0°C
(D) 5.5°C

B-3. Expansion during heating
(A) occurs only in a solid
(B) increases the density of the material
(C) decreases the density of the material
(D) occurs at the same rate for all liquids and solids.

B-4. If a bimetallic strip is heated, it will
(A) bend towards the metal with lower thermal expansion coefficient.
(B) bend towards the metal with higher thermal expansion coefficient.
(C) twist itself into helix.
(D) have no bending

B-5. 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 $\ell_1 + \ell_2$. The coefficients of linear expansion for aluminium and steel are α_a and α_s respectively. If the length of each rod increases by the same amount when their temperature are raised by tºC, then find the ratio $\frac{\ell_1}{(\ell_1 + \ell_2)}$. **[JEE-2003 (Scr.), 3/84,–1]**

(A) $\frac{\alpha_s}{\alpha_a}$
(B) $\frac{\alpha_a}{\alpha_s}$
(C) $\frac{\alpha_s}{(\alpha_a + \alpha_s)}$
(D) $\frac{\alpha_a}{(\alpha_a + \alpha_s)}$

B-6. A liquid with coefficient of volume expansion γ is filled in a container of a material having the coefficient of linear expansion α .If the liquid overflows on heating, then –

(A) $\gamma > 3\alpha$
(B) $\gamma < 3\alpha$
(C) $\gamma = 3\alpha$
(D) none of these

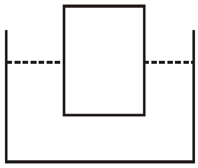
Section (C) : Temperature

C-1. A difference of temperature of 25º C is equivalent to a difference of :

(A) 45º F
(B) 72º F
(C) 32º F
(D) 25º F

PART - III : MATCH THE COLUMN

1.✍ A cylindrical isotropic solid of coefficient of linear expansion α and density ρ floats in a liquid of coefficient of volume expansion γ and density d as shown in the diagram



Column I	**Column II**
(A) volume of cylinder inside the liquid remains constant	(p) $\gamma = 0$
(B) volume of cylinder outside the liquid remains constant	(q) $\gamma = 2\alpha$
(C) Height of cylinder outside the liquid remains constant	(r) $\gamma = 3\alpha\ \frac{d}{\rho}$
(D) Height of cylinder inside the liquid remain constant	(s) $\gamma = (2\alpha + \alpha\frac{d}{\rho})$

2.✍ In the following question column-I represents some physical quantities & column-II represents their units, match them

Column I	**Column II**
(A) Coefficient of linear expansion	(p) Cal/°C
(B) Water equivalent	(q) gm
(C) heat capacity	(r) $(°C)^{-1}$
(D) Specific heat	(s) Cal/g°C

Exercise-2

✍ **Marked Questions can be used as Revision Questions.**

PART - I : ONLY ONE OPTION CORRECT TYPE

1.✍ A metal ball of specific gravity 4.5 and specific heat 0.1 cal/gm-°C is placed on a large slab of ice at 0°C. When ball's temperature become 0°C then half of the ball sinks in the ice. The initial temperature of the ball is : (Latent heat capacity of ice = 80 cal/g, specific gravity of ice = 0.9)

(A) 100 °C (B) 90 °C (C) 80 °C (D) 70 °C

2. In a steel factory it is found that to maintain M kg of iron in the molten state at its melting point an input power P watt is required. When the power source is turned off, the sample completely solidifies in time t second. The latent heat of fusion of iron is

(A) 2 Pt / M (B) Pt / 2M (C) Pt / M (D) PM / t

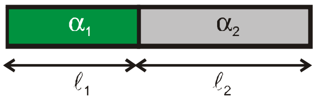
3. Steam at 100ºC is passed into 1.1 kg of water contained in a calorimeter of water equivalent 0.02 kg at 15ºC till the temperature of the calorimeter and its contents rises to 80ºC. The mass of the steam condensed in kilogram is : **[JEE 1986, 2]**

(A) 0.130 (B) 0.065 (C) 0.260 (D) 0.135

4.✍ If I is the moment of inertia of a solid body having α -coefficient of linear expansion then the change in I corresponding to a small change in temperature ΔT is

(A) $\alpha I \Delta T$ (B) $\frac{1}{2}\alpha I \Delta T$ (C) $2\alpha I \Delta T$ (D) $3\alpha I \Delta T$

5. Two rods having length □$_1$ and □$_2$, made of materials with the linear coefficient of expansion α_1 and α_2, were welded together. The equivalent coefficients of linear expansion for the obtained rod :



(A $\frac{\ell_1\alpha_2+\ell_2\alpha_1}{\ell_1+\ell_2}$) (B) $\frac{\ell_1\alpha_1+\ell_2\alpha_2}{\alpha_1+\alpha_2}$ (C) $\frac{\ell_1\alpha_1+\ell_2\alpha_2}{\ell_1+\ell_2}$ (D) $\frac{\ell_2\alpha_1+\ell_1\alpha_2}{\alpha_1+\alpha_2}$

6. The volume thermal expansion coefficient of an ideal gas at constant pressure is

(A) T (B) T^2 (C) $\frac{1}{T}$ (D) $\frac{1}{T^2}$

(Here T = absolute temperature of gas)

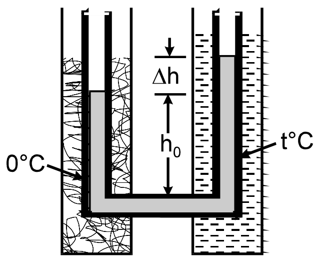
7. A metal ball immersed in water weighs w_1 at 5ºC and w_2 at 50ºC. The coefficient of cubical expansion of metal is less than that of water. Then

(A) $w_1 > w_2$ (B) $w_1 < w_2$ (C) $w_1 = w_2$ (D) data is insufficient

8. A piece of metal floats on mercury. The coefficient of volume expansion of the metal and mercury are γ_1 & γ_2 respectively. If the temperatures of both mercury and the metal are increased by an amount ΔT, the fraction of the volume of the metal submerged in mercury changes by the factor of (Ratio of final fraction to the initial fraction) **[JEE 1991, 2]**

(A) $\frac{1+\gamma_2\Delta T}{1+\gamma_1\Delta T}$ (B) $\frac{1+\gamma_1\Delta T}{1+\gamma_2\Delta T}$ (C) $1 + (\gamma_1 + \gamma_2)\Delta T$ (D) None of these

9. Two vertical glass tubes filled with a liquid are connected at their lower ends by a horizontal capillary tube. One tube is surrounded by a bath containing ice and water at 0°C and the other by hot water at t°C. The difference in the height of the liquid in the two columns is Δh, and the height of the column at 0°C is h_0. Coefficient of volume expansion of the liquid is.



(A) $\frac{\Delta h}{h_0 t}$ (B) $\frac{2\Delta h}{h_0 t}$ (C) $\frac{2h_0}{\Delta h t}$ (D) $\frac{h_0}{\Delta h t}$

10. A small pond of depth 0.5 m deep is exposed to a cold winter with outside temperature of 263 K. Thermal conductivity of ice is $K = 2.2$ W m^{-1} K^{-1}, latent heat $L = 3.4 \times 10^5$ Jkg^{-1} and density $\rho = 0.9 \times 10^3$ kgm^{-3}. Take the temperature of the pond to be 273 K. The time taken for the whole pond to freeze is about. **[Olympiad (Stage-1) 2017]**

(A) 20 days (B) 25 days (C) 30 days (D) 35 days

11. Two rods identical in geometry but of different materials having co-efficient of thermal expansion α_1 and α_2 and Young's modulii Y_1 and Y_2 respectively are fixed between two rigid massive walls. The rods are heated such that they undergo the same increase in temperature. There is no bending of the rods. If $\alpha_1 : \alpha_2 = 2 : 6$ the thermal stresses developed in the two rods are equal provided $Y_1 : Y_2$ is equal to :
(A) 2 : 3 (B) 1 : 1 (C) 3 : 1 (D) 4 : 9

12. Two identical thin metal strips, one of aluminum and the other of iron are riveted together to form a bimetallic strip. The temperature is raised by 50º C. If the central planes of the two strips are separated by 2mm and the coefficients of thermal expansion of aluminum and iron are respectively $30 \times 10^{-6}/^0$ C and $10 \times 10^{-6}/^0$ C the average radius of curvature of the bimetallic strip is about. **[Olympiad 2014 (stage-1)]**

(A) 50 cm (B) 100 cm (C) 150 cm (D) 200 cm

13. Two thin rods of length l_1 and l_2 at a certain temperature are joined to each other end to end. The composite rod is then heated through a temperature θ.The coefficients of linear expansion of the two rods are α_1 and α_2 respectively. Then, the effective coefficient of linear expansion of the composite rod is: **[Olympiad 2015 (stage-1)]**

(A) $\frac{\alpha_1+\alpha_2}{2}$ (B) $\sqrt{\alpha_1.\alpha_2}$ (C) $\frac{l_1\alpha_2+l_2\alpha_1}{l_1+l_2}$ (D) $\frac{l_1\alpha_1+l_2\alpha_2}{l_1+l_2}$

PART - II : SINGLE AND DOUBLE VALUE INTEGER TYPE

1. A pitcher contains 20 kg of water. 0.5 gm of water comes out on the surface of the pitcher every second through the pores and gets evaporated taking energy from the remaining water. Calculate the approximate time (in min) in which temperature of the water decreases by 5ºC. Neglect backward heat transfer from the atmosphere to the water. (Write the answer to the nearest integer)
Specific heat capacity of water = 4200J/KgºC
Latent heat of vaporization of water 2.27×10^6 J/Kg

2. How long does a 59 kw water heater take to raise the temperature of 150 L of water from 21°C to 38ºC (in min)

3. The specifc heat of a substance varies with temperature according to $c = 0.2 + 0.16\ T + 0.024\ T^2$ with T in °c and c is cal/gk. Find the energy (in cal) requied to raise the temp of 2g substance from 0° to 5°C.

4. 50g of Ice at 0°C is mixed with 200g of water at 0°C. 6 kcal heat is given to system [Ice + water]. Find the temperature (in °C) of the system.

5. Earth receives 1400 W/m^2 of solar power. If all the solar energy falling on a lens of area 0.2 m^2 is focused on to a block of ice of mass 280 grams, the time taken to melt the ice will be X × 10 sec. Find the value of x. (Latent heat of fusion of ice = 3.3×10^5 J/kg) **[JEE 1997, 2]**

6. A 50 gm lead bullet, specific heat 0.02 cal/gm is initially at 30ºC. It is fired vertically upwards with a speed of 840 m/sec & on returning to the starting level strikes a cake of ice at 0º C. How much ice is melted. Assume that all energy is spent in melting only. [Latent heat of ice = 80 cal/gm]. Write the answer (in gms) to nearest integer. **[REE 1988, 5]**

7. The temperature of 100 gm of water is to be raised from 24º C to 90º C by adding steam to it. Calculate the mass of the steam (in gms) required for this purpose. **[JEE 1996, 2]**

8. An electrical heating coil was placed in a calorimeter containing 360 gm of water at 10º C. The coil consumes energy at the rate of 90 watt. The water equivalent of the calorimeter and the coil is 40 gm.

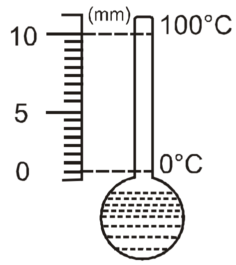
Calculate what will be the temperature (in °C) of water after 10 minutes. Write the answer to nearest integer. J = 4.2 Joules/cal. **[REE 1985, 7]**

9.

As a result of temp rise of 32° C, a bar with a crack at its centre buckles upward. If the fixed distance ℓ_0 is 4 m, and coefficient of linear expansion of bar in 25 × 10^{-6} °c^{-1}.
Find the rise x (in cm) of the centre.

10. Level of a certain liquid at 0°C and 100° C are 0 and 10 mm on a given fixed scale (as shown in fig.) coefficient of volume expansion this liquid varies with temperature as $\gamma = \gamma_0\left(1+\frac{T}{100}\right)$ (where T in °C)

Find the level (in mm) of liquid at 48°C.



11. A simple seconds pendulum is constructed out of a very thin string of thermal coefficient of linear expansion α = 20 x 10^{-4} / °C and a heavy particle attached to one end. The free end of the string is suspended from the ceiling of an elevator at rest. The pendulum keeps correct time at 0°C. When the temperature rises to 50°C, the elevator operator of mass 60kg being a student of Physics accelerates the elevator vertically, to have the pendulum correct time. Find the apparent weight (kgwt) of the operator when the pendulum keeps correct time at 50 °C. (Take g = 10 m/s^2)

12. A steel rod 25 cm long has a cross-sectional area of 0.8 cm^2. The force required to stretch this rod by the same amount as the expansion produced by heating it through 10°C is 10 X. Find the value of X ? (Coefficient of linear expansion of steel is 10^{-5}/°C and Young's modulus of steel is – 2 × 10^{10} N/m^2.) **[JEE 1989, 3]**

13. A one liter flask contains some mercury. It is found that at different temperatures the volume of air inside the flask remains the same. The volume (in litre) of mercury in the flask is X/100. Find the value of X Coefficient of linear expansion of glass = 9 × 10^{-6} /° C. Coefficient of volume expansion of mercury = 1.8 × 10^{-4} /°C. **[JEE 1991, 3]**

PART - III : ONE OR MORE THAN ONE OPTIONS CORRECT TYPE

1. When two non reactive samples at different temperatures are mixed in an isolated container of negligible heat capacity the final temperature of the mixture can be :

(A) lesser than lower or greater than higher temperature

(B) equal to lower or higher temperature

(C) greater than lower but lesser than higher temperature

(D) average of lower and higher temperatures

2. When m gm of water at 10°C is mixed with m gm of ice at 0°C, which of the following statements are false?

(A) The temperature of the system will be given by the equation m × 80 + m × 1 × (T – 0) = m × 1 × (10 – T)

(B) Whole of ice will melt and temperature will be more than 0°C but lesser than 10°C

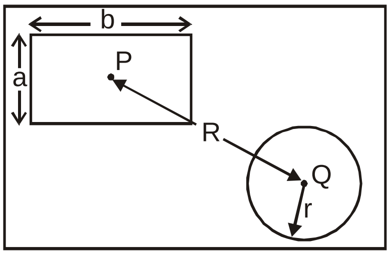
(C) Whole of ice will melt and temperature will be 0°C

(D) Whole of ice will not melt and temperature will be 0°C

3. Two identical beakers with negligible thermal expansion are filled with water to the same level at 4°C. If one says A is heated while the other says B is cooled, then :
(A) water level in A must rise
(B) water level in B must rise
(C) water level in A must fall
(D) water level in B must fall

4. A bimetallic strip is formed out of two identical strips, one of copper and the other of brass. The coefficients of linear expansion of the two metals are α_C and α_B. On heating, the temperature of the strips goes up by ΔT and the strip bends to form an arc of radius of curvature R. Then R is:
(A) Proportional to ΔT
(B) inversely proportional to ΔT
(C) proportional to $|\alpha_B - \alpha_C|$
(D) inversely proportional to $|\alpha_B - \alpha_C|$

5. There is a rectangular metal plate in which two cavities in the shape of rectangle and circle are made, as shown with dimensions. P and Q are the centres of these cavities. On heating the plate, which of the following quantities increase ?



(A) πr^2
(B) ab
(C) R
(D) b

6. A metallic wire of length ℓ is held between two supports under some tension. The wire is cooled through $\theta°$. Let Y be the Young's modulus, ρ the density and α the thermal coefficient of linear expansion of the material of the wire. Therefore, the frequency of oscillations of the wire varies as

[OLYMPIAD-2016_STAGE-1]

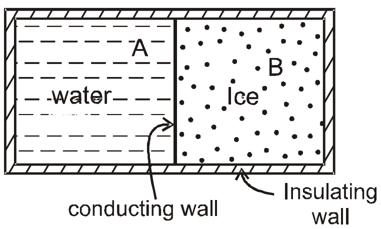
(A) $\sqrt{Y}$
(B) $\sqrt{\theta}$
(C) $\frac{1}{\ell}$
(D) $\sqrt{\frac{\alpha}{\rho}}$

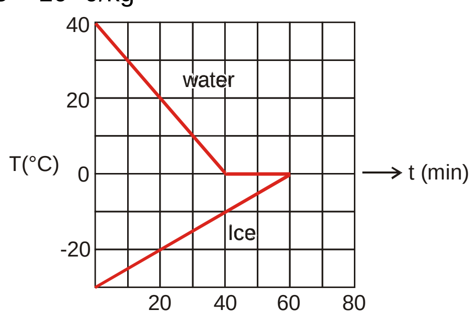
PART - IV : COMPREHENSION

Comprehension-1

A 0.60 kg sample of water and a sample of ice are placed in two compartments A and B that are separated by a conducting wall, in a thermally insulated container. The rate of heat transfer from the water to the ice though the conducting wall is constant P, until thermal equilibrium is reached. The temperature T of the liquid water and the ice are given in graph as functions of time t. Temperature of the compartments remain homogeneous during whole heat transfer process.

Given specific heat of ice = 2100 J/kg-K
Given specific heat of water = 4200 J/kg-K
Latent heat of fusion of ice = 3.3×10^5 J/kg





1. The value of rate P is
(A) 42.0 W
(B) 36.0 W
(C) 21.0 W
(D) 18.0 W

2.✍ The initial mass of the ice in the container is equal to
(A) 0.36 kg (B) 1.2 kg (C) 2.4 kg (D) 3.6 kg

3.✍ The mass of the ice formed due to conversion from the water till thermal equilibrium is reached, is equal to
(A) 0.12 kg (B) 0.15 kg (C) 0.25 kg (D) 0.40 kg

Comprehension-2

In a container of negligible heat capacity, 200 gm ice at 0°C and 100 gm steam at 100°C are added to 200 gm of water that has temperature 55°C. Assume no heat is lost to the surroundings and the pressure in the container is constant 1.0 atm. (Latent heat of fusion of ice = 80 cal/gm, Latent heat of vaporization of water = 540 cal/gm, Specific heat capacity of ice = 0.5 cal/gm-K, Specific heat capacity of water = 1 cal/gm-K)

4. What is the final temperature of the system ?
(A) 48°C (B) 72°C (C) 94°C (D) 100°C

5. At the final temperature, mass of the total water present in the system, is
(A) 472.6 gm (B) 483.3 gm (C) 493.6 gm (D) 500 gm

6. Amount of the steam left in the system, is equal to
(A) 16.7 gm (B) 12.0 gm (C) 8.4 gm
(D) 0 gm, as there is no steam left.

Exercise-3

✍ Marked Questions can be used as Revision Questions.

*** Marked Questions may have more than one correct option.**

PART - I : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

1.✍ A cube of coefficient of linear expansion α_s is floating in a bath containing a liquid of coefficient of volume expansion γ_L. When the temperature is raised by ΔT, the depth upto which the cube is submerged in the liquid remains the same. Find the relation between α_s and γ_L showing all the steps.
[JEE-2004 (Mains), 2/60]

2. 2 liters water at 27°C is heated by a 1 kW heater in an open container. On an average heat is lost to surroundings at the rate 160 J/s. The time required for the temperature to reach 77°C is
[JEE-2005 (Scr.), 3/84, –1]
(A) 8 min 20 sec (B) 10 min (C) 7 min (D) 14 min

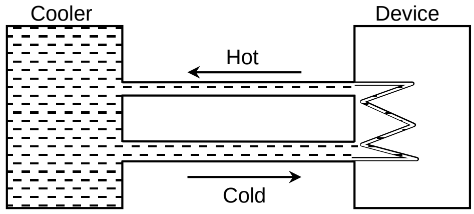
3. In an insulated vessel, 0.05 kg steam at 373 K and 0.45 kg of ice at 253 K are mixed. Find the final temperature of the mixture (in Kelvin). **[JEE-2006, 6/184, –1]**
Given, L_{fusion} = 80 cal/gm = 336 J/gm, $L_{vaporization}$ = 540 cal/gm = 2268 J/gm,
S_{ice} = 2100 J/kg K = 0.5 cal/gm K and S_{water} = 4200 J/kg K = 1 cal/gmK

4.✍ A piece of ice (heat capacity = 2100 J kg^{-1} ^{o}C^{-1} and latent heat = 3.36 × 10^{5} J kg^{-1}) of mass m grams is at –5 ^{o}C at atmospheric pressure. It is given 420 J of heat so that the ice starts melting. Finally when the ice-water mixture is in equilibrium, it is found that 1 gm of ice has melted. Assuming there is no other heat exchange in the process, the value of m is : **[JEE-2010, 3/163]**

5.✍ Steel wire of length 'L' at 40°C is suspended from the ceiling and then a mass 'm' is hung from its free end. The wire is cooled down from 40°C to 30°C to regain its original length 'L'. The coefficient of linear thermal expansion of the steel is 10^{-5} /°C, Young's modulus of steel is 10^{11} N/m^{2} and radius of the wire is 1 mm. Assume that L >> diameter of the wire. Then the value of 'm' in kg is nearly.

[JEE-2011, 4/160]

6. A water cooler of storage capacity 120 litres can cool water at a constant rate of P watts. In a closed circulation system (as shown schematically in the figure), the water from the cooler is used to cool an external device that generates constantly 3 kW of heat (thermal load). The temperature of water fed into the device cannot exceed 30°C and the entire stored 120 litres of water is initially cooled to 10°C. The entire system is thermally insulated. The minimum value of P (in watts) for which the device can be operated for 3 hours is : (Specific heat of water is 4.2 kJ kg^{-1} K^{-1} and the density of water is 1000 kg m^{-3}) **[JEE (Advanced) 2016; P-1, 3/62, –1]**



(A) 1600 (B) 2067 (C) 2533 (D) 3933

7. The ends Q and R of two thin wires, PQ and RS, are soldered (joined) together. Initially each of the wires has a length of 1m at 10 °C. Now the end P is maintained at 10 °C, while the end S is heated and maintained at 400°C. The system is thermally insulated from its surroundings. If the thermal conductivity of wire PQ is twice that of the wire RS and the coefficient of linear thermal expansion of PQ is 1.2×10^{-5} K^{-1}, the change in length of the wire PQ is. **[JEE (Advanced) 2016; P-2, 3/62, –1]**

(A) 0.78 mm (B) 0.90 mm (C) 1.56 mm (D) 2.34 mm

PART - II : JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

1. Time taken by a 836 W heater to heat one liter of water from 10ºC to 40ºC is : **[AIEEE 2004; 4/120, –1]**

(1) 50 s (2) 100 s (3) 150 s (4) 200 s

2. The specific heat capacity of a metal at low temperature (T) is given as : **[AIEEE 2011,11 May; 4/120, –1]**

$$C_p\ (kjK^{-1}\ kg^{-1}) = 32\left(\frac{T}{400}\right)^3$$

A 100 gram vessel of this metal is to be cooled from 20K to 4K by a special refrigerator operating at room temperature (27ºC). The amount of work required to cool the vessel is :

(1) greater than 0.148 kJ (2) between 0.148 kJ and 0.028 kJ
(3) less than 0.028 kJ (4) equal to 0.002 kJ

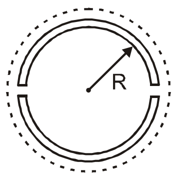
3. A metal rod of Young's modulus Y and coefficient of thermal expansion α is held at its two ends such that its length remains invariant. If its temperature is raised by tºC, the linear stress developed in its is : **[AIEEE 2011, 11 May; 4/120, –1]**

(1) $\frac{Y}{\alpha t}$ (2) $Y\alpha t$ (3) $\frac{1}{(Y\alpha t)}$ (4) $\frac{\alpha t}{Y}$

4. An aluminium sphere of 20 cm diameter is heated from 0ºC to 100ºC. Its volume changes by (given that coefficient of linear expansion for aluminium $\alpha_{Al} = 23 \times 10^{-6}$/ºC) **[AIEEE 2011, 11 May; 4/120, –1]**

(1) 2.89 cc (2) 9.28 cc (3) 49.8 cc (4) 28.9 cc

5. A wooden wheel of radius R is made of two semicircular parts (see figure). The two parts are held together by a ring made of a metal strip of cross sectional area S and length L. L is slightly less than $2\pi R$. To fit the ring on the wheel, it is heated so that its temperature rises by ΔT and it just steps over the wheel. As it cools down to surrounding temperature, it presses the semicircular parts together. If the coefficient of linear expansion of the metal is α, and its Young's modulus is Y, the force that one part of the wheel applies on the other part is : **[AIEEE 2012 ; 4/120, –1]**



(1) $2\pi SY\alpha\Delta T$ (2) $SY\alpha\Delta T$ (3) $\pi SY\alpha\Delta T$ (4) $2SY\alpha\Delta T$

6. A pendulum clock lose 12 s a day if the temperature is 40°C and gains 4 s a day if the temperature is 20°C. The temperature at which the clock will show correct time, and the co-efficient of linear expansion (α) of the metal of the pendulum shaft are respectively : **[JEE (Main) 2016, 4/120, –1]**

(1) 60°C ; $\alpha = 1.85 \times 10^{-4}$/°C (2) 30°C ; $\alpha = 1.85 \times 10^{-3}$/°C
(3) 55°C ; $\alpha = 1.85 \times 10^{-2}$/°C (4) 25°C ; $\alpha = 1.85 \times 10^{-5}$/°C

7. A copper ball of mass 100 gm is at a temperature T. It is dropped in a copper calorimeter of mass 100 gm, filled with 170 gm of water at room temperature. Subsequently, the temperature of the system is found to be 75º C. T is given by : (Given : room temperature = 30ºC, specific heat of copper = 0.1 cal/gmºC) **[JEE (Main) 2017, 4/120, –1]**

(1) 825º C (2) 800ºC (3) 885ºC (4) 1250ºC

8. An external pressure P is applied on a cube at 0°C so that it is equally compressed from all sides. K is the bulk modulus of the material of the cube and α is its coefficient of linear expansion. Suppose we want to bring the cube to its original size by heating. The temperature should be raised by : **[JEE (Main) 2017, 4/120, –1]**

(1) $3PK\alpha$ (2) $\frac{P}{3\alpha K}$ (3) $\frac{P}{\alpha K}$ (4) $\frac{3\alpha}{PK}$

Answers

EXERCISE-1

PART-I

Section (A)

A-1. H = 590 kcal **A-2.** 136 km

A-3. $\frac{3}{350} = 8.6 \times 10^{-3}$ ºC

A-4. (a) 100 J (b) 0 (c) 1/40 ºC

A-5 0ºC

Section (B)

B-1. %R < %A < %V

B-2. We will cool the system.

B-3. (a) $R_1' = R_1 (1 + \alpha\Delta\theta)$ (b) $R_2' = R_2 (1 + \alpha\Delta\theta)$

(c) $R_2' - R_1' = (R_2 - R_1)(1 + \alpha\Delta\theta)$

(d) $A' = (\pi R_2^2 - \pi R_1'^2)(1 + 2\alpha\Delta\theta) = A(1 + 2\alpha\Delta\theta)$

B-4. (i) hollow sphere > solid sphere
(ii) hollow sphere = solid sphere

B-5. 0.75m **B-6.** 1.1×10^{-2}

Section (C)

C-1. (a) All tie (b) 50ºX, 50ºY, 50ºW.

C-2 . – 40ºC or – 40ºF

PART-II

Section (A)

A-1.	(D)	**A-2.**	(A)	**A-3.**	(A)
A-4.	(A)				

Section (B)

B-1.	(A)	**B-2.**	(C)	**B-3.**	(C)
B-4.	(A)	**B-5.**	(C)	**B-6.**	(A)

Section (C)

C-1. (A)

PART-III

1. (A) – (p) ; (B) – (r) ; (C) – (s) ; (D) – (q)

2. (A) – (r) ; (B) – (q) ; (C) – (p) ; (D) – (s)

EXERCISE-2

PART-I

1.	(C)	**2.**	(C)	**3.**	(A)
4.	(C)	**5.**	(C)	**6.**	(C)
7.	(B)	**8.**	(A)	**9.**	(A)
10.	(A)	**11.**	(C)	**12.**	(D)
13.	(D)				

PART-II

1.	6	**2.**	3	**3.**	8
4.	8	**5.**	33	**6.**	53
7.	12	**8.**	42	**9.**	8
10.	4	**11.**	66	**12.**	16
13.	15				

PART-III

1.	(BCD)	**2.**	(ABC)	**3.**	(AB)
4.	(BD)	**5.**	(ABCD)	**6.**	(ABCD)

PART-IV

1.	(A)	**2.**	(C)	**3.**	(B)
4.	(D)	**5.**	(B)	**6.**	(A)

EXERCISE-3

PART-I

1.	$\gamma_L = 2\alpha_s$	**2.**	(A)	**3.**	273 K
4.	8 gm	**5.**	3	**6.**	(B)
7.	(A)				

PART-II

1.	(3)	**2.**	(2)	**3.**	(2)
4.	(4)	**5.**	(4)	**6.**	(4)
7.	(3)	**8.**	(2)		

VAdvance Level Problems (ALP):-

SUBJECTIVE QUESTIONS

1. A thermally insulated, closed copper vessel contains water at 15ºC. When the vessel is shaken vigorously for 15 minutes, the temperature rises to 17ºC. The mass of the vessel is 100g and that of the water is 200g. The specific heat capacities of copper and water are 420 J/kg-K and 4200 J/kg-K respectively. Neglect any thermal expansion. (a) How much heat is transferred to the liquid-vessel system? (b) How much work has been done on this system? (c) How much is the increase in internal energy of the system?

2. The time represented by the clock hands of a pendulum clock depends on the number of oscillations performed by pendulum. Every time it reaches to its extreme position the second hand of the clock advances by one second that means second hand moves by two second when one oscillation is completed.

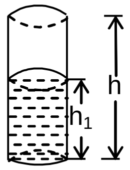
(a) How many number of oscillations completed by pendulum of clock in 15 minutes at calibrated temperature 20ºC

(b) How many number of oscillations are completed by a pendulum of clock in 15 minutes at temperature of 40ºC if $\alpha = 2 \times 10^{-5}$ /ºC

(c) What time is represented by the pendulum clock at 40ºC after 15 minutes if the initial time shown by the clock is 12 : 00 pm ?

(d) If the clock gains two seconds in 15 minutes in correct clock then find –
(i) Number of extra oscillations (ii) New time period (iii) change in temperature.

3. Consider a cylindrical container of cross section area 'A', length 'h' having coefficient of linear expansion α_C. The container is filled by liquid of volume expansion coefficient γ_L up to height h_1. When temperature of the system is increased by $\Delta\theta$ then



(a) Find out new height, area and volume of cylindrical container and new volume of liquid.

(b) Find the height of liquid level when expansion of container is neglected.

(c) Find the relation between γ_L and α_c for which volume of container above the liquid level.
(i) increases (ii) decreases (iii) remains constant.

(d) If $\gamma_{\square} > 3\alpha_c$ and $h = h_1$ then calculate, the volume of liquid overflow.

(e) If the surface of a cylindrical container is marked with numbers for the measurement of liquid level of liquid filled inside it. Assuming correct marking at initial temperature if we increase the temperature of the system by $\Delta\theta$ then

(i) Find height of liquid level as shown by the scale on the vessel. Neglect expansion of liquid

(ii) Find height of liquid level as shown by the scale on the vessel. Neglect expansion of container.

(iii) Find relation between γ_L and α_C so that height of liquid level with respect to ground
(1) increases (2) decreases (3) remains constant.

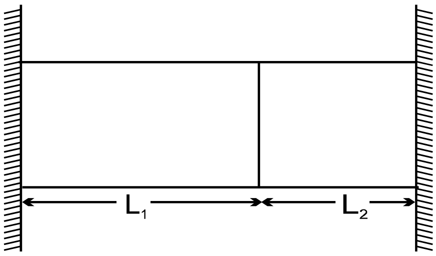
4. One gram of water (volume = 1 cm^3) becomes 1671 cm^3 of steam when boiled at a pressure of one atmosphere. Latent heat of vaporization at this pressure is 539 cal/gm. Compute the work done.
[1 atm = 1.013×10^5 Nm^{-2}] **[REE 1986, 3]**

5. A metal piece weighing 15g is heated to 100ºC and then immersed in a mixture of ice and water at the thermal equilibrium. The volume of the mixture is found to be reduced by 0.15 cm^3 with the temperature of mixture remaining constant. Find the specific heat of the metal. Given specific gravity of ice = 0.92, latent heat of fusion of ice = 80 cal/gm.

6. The brass scale of a barometer gives correct reading at 0º C. Coefficient of thermal expansion of brass is 0.00002/º C. The barometer reads 75 cm at 27º C. What is the correct atmospheric pressure at 27ºC? **[JEE 1989, 2]**

7. A clock with an iron pendulum keeps correct time at 20º C. How much will it lose or gain in a day if the temperature changes to 40º C? (Coefficient of cubical expansion of iron = 0.000036/º C) **[JEE1990, 3]**

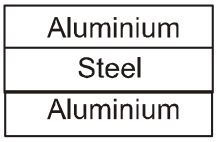
8. Two rods of different metals having same area of cross section A are placed end to end between two massive platforms, as shown in the figure. The first rod has a length L_1, coefficient of linear expansion α_1 and Young's modulus Y_1. The corresponding quantities for the second rod are L_2, α_2, and Y_2. The temperature of both the rods is now increased by T° C. Find the force with which the rods act on each other (at the higher temperature) in terms of given quantities. Also find the lengths of the rods at the higher temperature. Assume that there is no change in the cross sectional area of the rods and that the rods do not bend. There is no deformation of the walls. **[JEE 1990, 5]**



9. A composite rod is made by joining a copper rod end to end with a second rod of different material but of the same cross section. At 25° C the composite rod is 1 m in length of which the length of the copper rod is 30 cm. At 125° C the length of the composite rod increases by 1.91 mm. When the composite rod is not allowed to expand by holding it between two rigid walls it is found that the length of the two constituents do not change with the rise of temperature. Find the Young's modulus and the linear expansion of the second rod given that Young's modulus of for copper = 1.3×10^{11} N/m^2 and the coefficient of linear expansion of copper = 1.7×10^{-5} /° C. **[JEE 1990, 4]**

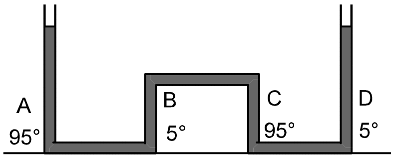
10. A piece of metal weighs 46 g in air. When it is immersed in a liquid of specific gravity 1.24 at 27° C it weighs 30 g. When the temperature of liquid is raised to 42° C the metal piece weighs 30.5 g. Specific gravity of liquid at 42° C is 1.20. Calculate the coefficient of linear expansion of the metal. **[JEE 1991, 3]**

11. Two Aluminium rods and a steel rod of equal cross-sectional area and equal length ℓ_0 are joined rigidly side by side as shown in figure. Initially the rods are at 0°C. Find the length of the rod at the temperature θ if young's modulus of elasticity of the aluminium and steel are Y_a and Y_s respectively and coefficient of linear expansion of aluminium and steel are α_a and α_s respectively.



12. Consider a metal scale of length 30 cm and an object. The scale is calibrated for temp 20°C.
(a) What is the actual length of division which is shown as 1 cm by scale at 40°C. Given $\alpha_s = 2\times10^{-5}$ /°C.
(b) What will be the reading of scale at 40°C if the actual length of object is 10 cm.
(c) What will be the actual length of object at 40 °C if its measured length is 10 cm.
(d) What is % error in measurement for part (b) and (c).
(e) If the linear expansion coefficient of object is $\alpha_0 = 4 \times 10^{-5}$ and neglecting the expansion of scale, then answers of (b) and (c) parts.
(f) If $\alpha_0 = 4 \times 10^{-5}$ and $\alpha_s = 2 \times 10^{-5}$ then find answers of (b) and (c) part.

13. The apparatus shown in the figure consists of four glass columns connected by horizontal sections. The height of two central columns B & C are 49 cm each. The two outer columns A & D are open to the atmosphere. A & C are maintained at a temperature of 95° C while the columns B & D are maintained at 5° C. The height of the liquid in A & D measured from the base line are 52.8 cm & 51 cm respectively. Determine the coefficient of thermal expansion of the liquid. **[JEE 1997, 5]**



Advance Level Problems (ALP) Answer:-

1. (a) zero (b) 1764 J (c) 1764 J

2. (a) 450 (b) 449 (c) 12:14:59 pm

(d) (i) 1 (ii) $\frac{900}{451}$ s (iii) $\frac{10^5}{450}$ ºC

3. (a) $h_f = h\{1 + \alpha_c \Delta\theta\}$
$A_f = A\{1 + 2\alpha_c \Delta\theta\}$
$v_f = Ah\{1 + 3\alpha_c \Delta\theta\}$
volume of liquid $V_W = Ah_1(1 + \gamma_L \Delta\theta)$

(b) $h_f = h_1\{1 + \gamma_L \Delta\theta\}$

(c) (i) $3h\,\alpha_c > h_1\,\gamma_{□}$ (ii) $3h\,\alpha_c < h_1\,\gamma_{□}$
(iii) $3h\,\alpha_c = h_1\,\gamma_{□}$

(d) $\Delta V = Ah(\gamma_L - 3\alpha_C)\Delta\theta$

(e) (i) $h_f = h_1(1 - 3\alpha_C \Delta\theta)$
(ii) $h_f = h_1(1 + \gamma_L \Delta\theta)$
(iii) (1) $\gamma_L > 2\alpha_c$ (2) $\gamma_L < 2\alpha_c$
(3) $\gamma_L = 2\alpha_c$

4. 169.171 J

5. 0.092 cal/gmºC

6. 75.0405 cm

7. 10.368 s

8. $F = \frac{AT(L_1\alpha_1 + L_2\alpha_2)Y_1Y_2}{L_1Y_2 + L_2Y_1}$, Length of the first rod $= L_1 + \frac{L_1L_2T(Y_1\alpha_1 - Y_2\alpha_2)}{L_1Y_2 + L_2Y_1}$,

Length of the second rod

$$= L_2 + \frac{L_1L_2T(Y_2\alpha_2 - Y_1\alpha_1)}{L_1Y_2 + L_2Y_1}$$

9. $Y_2 = 1.105 \times 10^{11}$ N/m^2, $\alpha_2 = 2 \times 10^{-5}$ /º C]

10. $\alpha = \frac{1}{43200}$ /º C = 2.31×10^{-5} /º C

11. $□_0\left[1 + \frac{2Y_a\alpha_a + Y_s\alpha_s}{2Y_a + Y_s}\theta\right]$

12. (a) $□ = 1\{1 + 2 \times 10^{-5} \times 20\}$

(b) $□ = 10\{1 - 4 \times 10^{-4}\}$

(c) $□ = 10\{1 + 4 \times 10^{-4}\}$

(d) $\%\ □_1 = -4 \times 10^{-2}\ \%$

$\%\ □_2 = \frac{-4 \times 10^{-2}}{1 + 4 \times 10^{-4}}\ \% \approx -4 \times 10^{-2}\ \%$

(e) $□_1 = 10\{1 + 20 \times 4 \times 10^{-5}\}$
$□_2 = 10\{1 - 20 \times 4 \times 10^{-5}\}$

(f) $□_1 = 10\{1 + 40 \times 10^{-5}\}$
$□_2 = 10\{1 - 40 \times 10^{-5}\}$

13. $\gamma = 2 \times 10^{-4}$ / °C