PHYSICS

BOOKS - ARIHANT PHYSICS (HINGLISH)

CALORIMETRY

Level 1

1. You are on a picnic and you make tea for yourself and your friend. However, your friend has gone out to bring something for you. You observed that the fire (that you ignited for making tea) has heated two nearby blocks of stones – one of sand stone and other of granite – to $90^\circ C$. Both blocks have nearly same mass but granite has higher specific heat than marble. To keep the tea hot for your friend you decided to place the tea pot on one of the stones. Which stone will you choose – granite or marble?

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2. An electric kettle is filled with $1.3kg$ of water at $20^\circ C$. The power of the heating coil of the kettle is 2.0 KW. After switching it on the water begins to boil in $220s$. If the kettle was kept on for a further interval of Δt it was observed that only 200g water remained in the kettle and remaining water vaporized (the vapor is allowed to escape through a small vent). The specific latent heat of vaporization of water at $100^\circ C$ (boiling point) is $L = 2.26KJ/g$. Calculate the specific heat capacity of water and the interval Δt. Assume that heat supplied by the heater is completely absorbed by the water.

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3. A heavy machine rejects a liquid at $60^\circ C$ which is to be cooled to $30^\circ C$ before it is fed back to the machine. The liquid rejected by the machine is kept flowing through a long tube while it is cooled by 60 liter water surrounding the tube. The initial temperature of the cooling water is $10^\circ C$ and it is $20^\circ C$ when it is changed after 1 hour. Calculate the amount of liquid that passes through the tube in one hour. Specific heat capacity of the liquid and water are $0.5 cal g^{-1}.^\circ C^{-1}$ and $1.0 cal g^{-1}.^\circ C^{-1}$ respectively.

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4. A solid metal cube has side length L and density d. Its specific heat capacity and coefficient of linear expansion are s and α respectively. How much heat must be added to the cube to increase its volume by 2% ?

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5. A certain mass of a solid exists at its melting temperature of $20^\circ C$. When a heat Q is added $\frac{4}{5}$ of the material melts. When an additional Q amount of heat is added the material transforms to its liquid state at $50^\circ C$. Find the ratio of specific latent heat of fusion (in J/g) to the specific heat capacity of the liquid (in $Jg^{-1}.^\circ C^{-1}$) for the material.

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6. The temperature of samples of three liquids A, B and C are $12^\circ C$, $19^\circ C$ and $28^\circ C$ respectively. The temperature when A and B are mixed is $16^\circ C$ and when B and C are mixed it is $23^\circ C$.

(i) What should be the temperature when A and C are mixed?

(ii) What is final temperature if all the three liquids are mixed?

Assume no heat loss to the surrounding.

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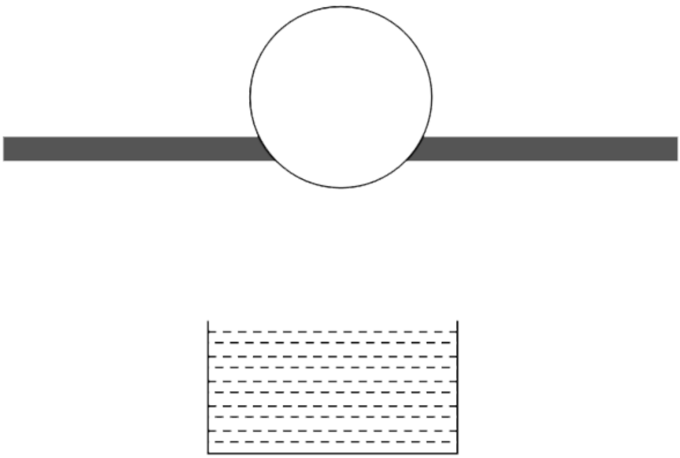
7. A table top is made of aluminium and has a hole of diameter 2 cm. An iron sphere of diameter 2.004 m is resting on this hole. Below the hole, an insulated container has 2 kg of water in it. Everything is at ambient temperature of $25^{\circ}C$. The table top along with the iron sphere is heated till the ball falls through the hole into the water. Find the equilibrium temperature of the ball and water system



Neglect any heat loss from ball–water system to the surrounding and assume the heat capacity of the container to be negligible.

Relevant data: Coefficient of linear expansion for aluminium and iron are $2.4 \times 10^{-5}.^{\circ}C^{-1}$ and $1.2 \times 10^{-5}.^{\circ}C^{-1}$ respectively. Specific heat capacity of water and iron are $4200J.^\circ C^{-1}g^{-1}$ and $450J.^\circ C^{-1}g^{-1}$ respectively. Density of iron at $25^\circ C$ is $8000kg/m^3$.

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8. A 50 g ice at $0^\circ C$ is added to 200 g water at $70^\circ C$ taken in a flask. When the ice has melted completely, the temperature of the flask and the contents is reduced to $40^\circ C$. Now to bring down the temperature of the contents to $20^\circ C$, find a further amount of ice that is to be added.

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9. The latent heat of vaporization of water at its boiling point is L_V. But water can evaporate at temperatures below the boiling point – for example it evaporates at body temperature when you perspire. Will the energy needed to evaporate unit mass of water at body temperature be more than or less than L_V?

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10. A vessel contains a small amount of water at $0^\circ C$. If the air in the vessel is rapidly pumped out, it causes freezing of the water. Why? What percentage of the water in the container can be frozen by this method? Latent heat of vaporization and fusion are $L_V = 540 cal g^{-1}$ and $L_f = 80 cal g^{-1}$ respectively.

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11. A vessel containing 100 g ice at $0^\circ C$ is suspended in a room where temperature is $35^\circ C$

. It was found that the entire ice melted in 10 hour. Now the same vessel containing 100 g of water at $0^{\circ} C$ is suspended in the same room. How much time will it take for the temperature of water to rise to $0.5^{\circ} C$. Neglect the heat capacity of the vessel. Specific heat of water and specific latent heat of fusion of ice are $1 cal g^{-1} . ^{\circ} C^{-1}$ and $80 cal g^{-1}$ respectively.

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12. A calorimeter of negligible heat capacity contains ice at $0^{\circ} C$. 50 g metal at $100^{\circ} C$ is dropped in the calorimeter. When thermal equilibrium is attained the volume of the content of the calorimeter was found to reduce by $0.5 \times 10^{-6} m^3$. Calculate the specific heat capacity of the metal. Neglect the change in volume of the metal. Specific latent heat of fusion of ice is $L = 300 \times 10^3 Jkg^{-1}$ and its relative density is 0.9.

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13. A refrigerator converts 1.3 kg of water at $20^\circ C$ into ice at $-15^\circ C$ in 1 hour. Calculate the effective power of the refrigerator. Specific latent heat of fusion of ice $= 3.4 \times 10^5 Jkg^{-1}$ Specific heat capacity of water $= 4.2 \times 10^3 Jkg^{-1}K^{-1}$ Specific heat capacity of ice $= 2.1 \times 10^3 Jkg^{-1}K^{-1}$

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14. A calorimeter of water equivalent 10 g contains a liquid of mass 50 g at $40.^\circ C$. When m gram of ice at $-10^\circ C$ is put into the calorimeter and the mixture is allowed to attain equilibrium, the final temperature was found to be $20^\circ C$. It is known that specific heat capacity of the liquid changes with temperature as $S = \left(1 + \frac{\theta}{500}\right) calg^{-1} . ^{\circ} C^{-1}$ where θ is temperature in $. ^{\circ} C$. The specific heat capacity of ice, water and the calorimeter remains constant and values are $S_{\text{ice}} = 0.5 calg^{-1} . ^{\circ} C^{-1}, S_{\text{water}} = 1.0 calg^{-1} . ^{\circ} C^{-1}$ and latent heat of fusion of ice is $L_f = 80 calg^{-1}$. Assume no heat loss to the surrounding and calculate the value of m.

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15. A well insulated container has a mixture of ice and water, at $0^\circ C$. The mixture is supplied heat at a constant rate of 420 watt by switching on an electric heater at time t = 0. The temperature of the mixture was recorded at time t = 150s, 273s and 378s and the readings were $0^\circ C, 10^\circ C$ and $20^\circ C$ respectively. Calculate the mass of water and ice in the mixture. Specific heat of water $= 4.2 J g^{-1} .^\circ C^{-1}$, Specific latent heat of fusion of ice $= 336 J g^{-1}$. Assume that the mixture is stirred slowly to maintain a uniform temperature of its content.

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16. An insulated container has 60 g of ice at $-10^\circ C$. 10 g steam at $100^\circ C$, sourced from a boiler, is mixed to the ice inside the container. When thermal equilibrium was attained, the entire content of the container was liquid water at $0^\circ C$. Calculate the percentage of steam (in terms of mass) that was condensed before it was fed to the container of ice. Specific heat and latent heat values are

$S_{\text{ice}} = 0.5 cal g^{-1} . ^\circ C^{-1}$,

$S_{\text{water}} = 1.0 cal g^{-1} . ^{\circ} C^{-1}$

$L_{\text{fusion}} = 80 cal g^{-1}, L_{\text{vaporization}} = 540 cal g^{-1}$

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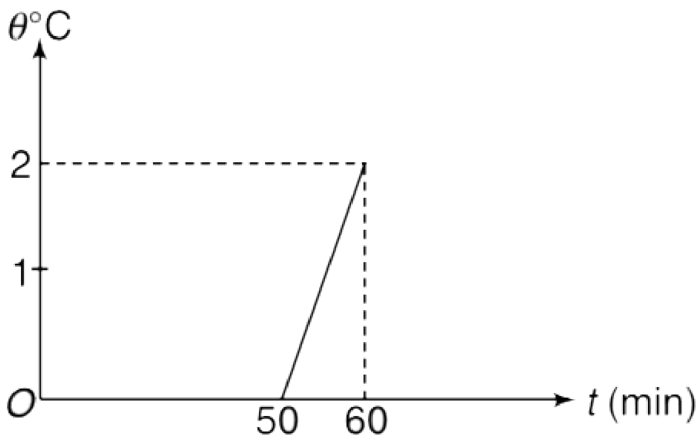
17. A container contains 5 kg of water at $0^{\circ} C$ mixed to an unknown mass of ice in thermal equilibrium. The water equivalent of the container is 100 g. At time t = 0, a heater is switched on which supplies heat at a constant rate to the container. The temperature of the mixture is measured at various times and the result has been plotted in the given figure.

Neglect any heat loss from the mixture – container system to the surrounding and calculate the initial mass of the ice.

Given: S_p. latent heat of fusion of ice is

$L_f = 80 cal g^{-1}$

S_p. heat capacity of water $= 1 cal g^{-1} . ^\circ C^{-1}$



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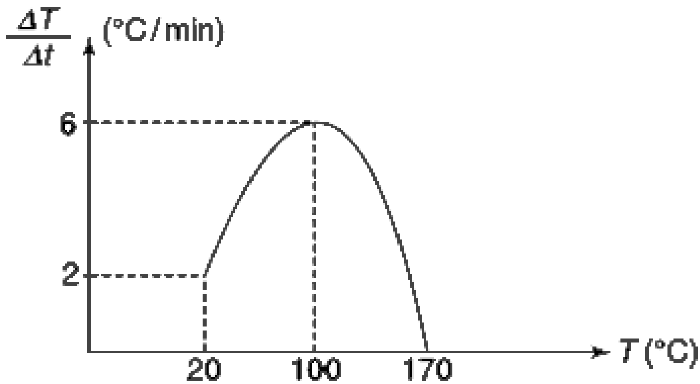
18. A liquid kept in a beaker is supplied heat. The rate of change of temperature of the liquid is plotted versus its temperature. Which intrinsic property of the liquid can be inferred from the graph? What is its value?



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19. A meteorite has mass of 500 kg and is composed of a metal. The temperature of the meteor is $-20^\circ C$ and its speed is 10 km/hr when it is at large distance from a planet. The meteorite crashes into the planet and its entire kinetic energy gets converted into heat. This heat is equally shared between the planet and the meteorite. Assume that the heating of meteorite is uniform and the average specific heat capacity of the metal, for its solid, liquid and vapour phase, is $1200 Jkg^{-1}.^\circ C^{-1}$. The latent heat of fusion and vaporization of the metal are $L_f = 4 \times 10^5 Jkg^{-1}$ and $L_v = 1.1 \times 10^7 Jkg^{-1}$

respectively. The melting point and boiling points are $380.^\circ C$ and $2380.^\circ C$ respectively. Find the temperature of the meteorite material immediately after the impact.

Take: $G = 6.6 \times 10^{11} Nm^2 kg^{-2}$, mass of planet $M = 6 \times 10^{24} kg$, radius of planet R = 6600 km

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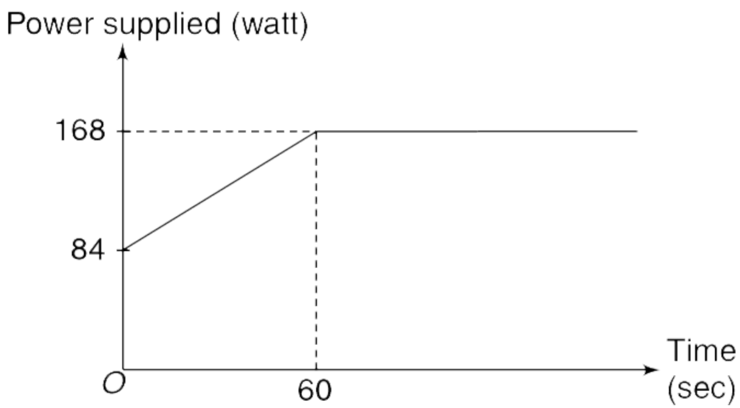
20. 100 g of ice at $-40^\circ C$ is supplied heat using a heater. The heater is switched on at time t = 0 and its power increases linearly for first 60 second and thereafter it becomes constant as shown in the graph. Heater is kept on for 5 minutes. The specific heat capacity for ice and water are known to be $2.1\frac{J}{g^\circ C}$ and $4.2\frac{J}{g^\circ C}$ respectively. The specific latent heat for fusion of ice is $336J/g$.



The temperature of the ice sample kept on increasing till time t_1 and then remained constant in the interval $t_1 < t < t_2$.

(i) Find t_1 and t_2

(ii) Find final temperature of the sample when the heater is switched off.

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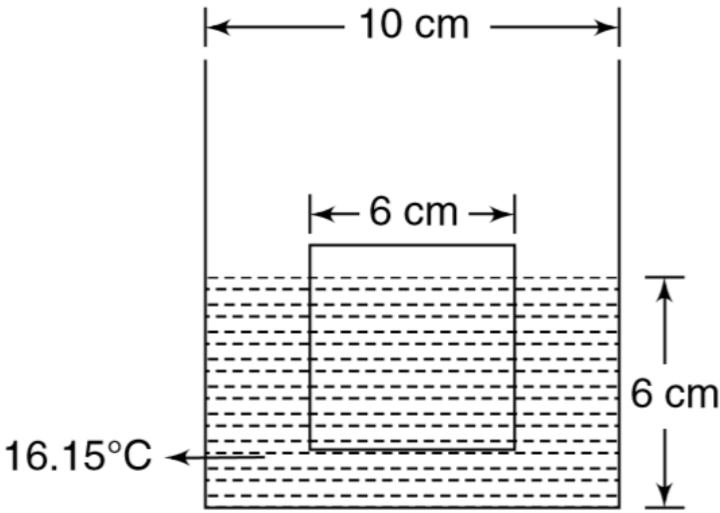
Level 2

1. A container has a square cross-section of $10cm \times 10cm$. A cubical ice block of side length 6 cm is floating in water in the container. Water level in the container is 6 cm high. The ice block is at a temperature of $0^{\circ}C$ and the water is at $16.15^{\circ}C$. Assume that heat exchange take place between the ice block and water only. What length of ice block will remain submerged in water when the system reaches thermal equilibrium? Assume that the ice block maintains its cubical shape as it melts. Take - density of ice $= 0.9 g / cc$, density of water = $1.0 g / cc$

Specific heat capacity of water $= 1 cal g^{-1} . ^{\circ} C^{-1}$, Specific latent heat of fusion of ice $= 80 cal g^{-1}$



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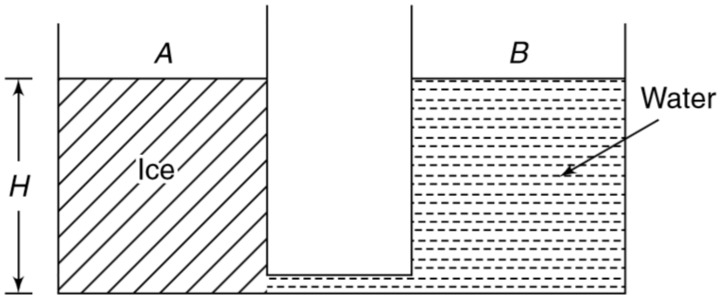
2. Two identical cylindrical containers A and B are interconnected by a tube of negligible dimensions. Container A is filled with an ice block up to height H = 1.8 m and container B is filled up

to same height with water. Ice is at $0^\circ C$ and water is at $40^\circ C$. Due to heat exchange between water and ice, the ice block begins to melt. Assume that the ice block melt in horizontal layers starting from the bottom. The thickness of ice block reduces uniformly over the entire cross section of the container. The ice block moves without friction inside the container and no water enters between the vertical wall of the container and the ice block. Heat is exchanged only between the ice block and the water and there is no heat exchange with containers or atmosphere. Calculate the height of water in container B when thermal equilibrium is attained. Relative density and specific latent heat of fusion of ice are 0.9 and $80 cal g^{-1}$ respectively. Specific heat capacity of water is $1 cal g^{-1} .^{\circ} C^{-1}$.



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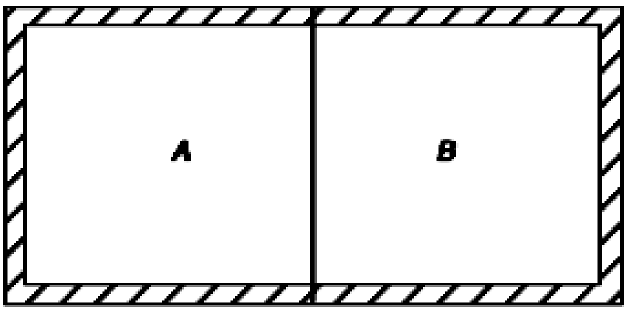
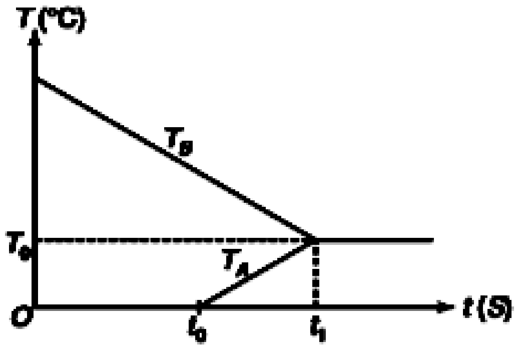
3. A well insulated box has two compartments A and B with a conducting wall between them. 100 g of ice at $0^{\circ} C$ is kept in compartment A and 100

g of water at $100^\circ C$ is kept in B at time t = 0. The temperature of the two parts A and B is monitored and a graph is plotted for temperatures T_A and T_B versus time (t) [Fig. (b)]. Assume that temperature inside each compartment remains uniform.



(a)



(b)

(a) Is it correct to assert that the conducting wall conducts heat at a uniform rate, irrespective of the temperature difference between A and B?

(b) Find the value of time t_1 and temperature T_0 shown in the graph, if it is known that $t_0 = 200s$.

Specific heat of ice $= 0.5 cal g^{-1} . ^{\circ} C^{-1}$

Specific heat of water $= 1.0 cal g^{-1} . ^{\circ} C^{-1}$

Latent heat of fusion of ice $= 80 cal g^{-1}$

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4. An ice ball has a metal piece embedded into it. The temperature of the ball is $-\theta^{\circ} C$ and it contains mass M of ice. When placed in a large tub containing water at $0^{\circ}C$, it sinks. Assume that the water in immediate contact with the ice ball freezes and thereby size of the ball grows. What is the maximum possible mass of the metal piece so that the ball can eventually begin to float. Densities of ice, water and metal are σ, ρ and d respectively. Specific heat capacity of ice is s and its specific latent heat is L. Neglect the heat capacity of the metal piece.

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5. Water from a reservoir maintained at a constant temperature of $80^\circ C$ is added at a slow and steady rate of m $= 3gs^{-1}$ to a calorimeter initially containing 1000 g of water at $20^\circ C$. The water in the calorimeter is stirred slowly to make the temperature uniform. Assume heat loss to the surrounding and work done in stirring is negligible and heat capacity of the calorimeter is negligible. Write the temperature of water in the calorimeter as a function of time.

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6. A cylindrical container has a cross sectional area of $A_0 = 1cm^2$ at $0^\circ C$. A scale has been marked on vertical surface of the container which shows correct reading at $0^\circ C$. A liquid is poured in the container. When the liquid and container is heated to $100^\circ C$, the scale shows the height of the liquid as 83.33 cm. The coefficient of volume expansion for the liquid is $\gamma = 0.001^\circ C^{-1}$ and the coefficient of linear expansion of the material of cylindrical container is $\alpha = 0.0005^\circ C^{-1}$. A beaker has $300cm^3$ of same liquid at $0^\circ C$. The two liquids are mixed. Find the final temperature of the mixture assuming that heat exchange takes place between the liquids only, and its specific heat capacity is independent of temperature

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Level 3

1. A copper calorimeter has mass of 180 g and contains 450 g of water and 50 g of ice, all at $0^{\circ}C$. Dry steam is passed into the calorimeter until a certain temperature (θ) is reached. The mass of the calorimeter and its contents at the end of the experiment increased by 25 g. Assume no heat loss to the surrounding and take specific heat capacities of water and copper to be $4200 J kg^{-1} K^{-1}$ and $390 J kg^{-1} K^{-1}$, respectively. Take specific latent heat of vaporization of water to be $3.36 \times 10^5 J kg^{-1}$ and $2.26 \times 10^6 J kg^{-1}$ respectively.

(a) Find the final temperature θ

(b) If steam enters into the system at a steady rate of $5 g \min^{-1}$, plot the variation of temperature of the system till final temperature θ is attained.

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