PHYSICS

BOOKS - HC VERMA PHYSICS (HINGLISH)

HEAT TRANSFER

Examples

1. One face of a copper cube of edge 10 cm is maintained at $100^\circ C$ and the opposite face is maintained at $0^\circ C$. All other surfaces are covered with an insulating material. Find the amount of heat flowing per second through the cube. Thermal conductivety of copper is $385 Wm^{-1}$ ^(@)C^(-1)`.

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2. Find the thermal resistance of an aluminium rod of length 20cm and area of cross section $1cm^2$. The heat current is along the length of the rod. Thermal conductivity of aluminium $= 200Wm^{-1}K^{-1}$.

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3. The light from th esun is found to have a maximum intensity near the wavelength of 470nm. Assuming that the surface o f the sun emits as a blackbody, calculate the temperture of the surface of the sun.

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4. A blackbody of sarface area $10cm^2 isheated \rightarrow$ 127^(@)C $and issuspended \in ar\infty mattemperature$27^(@)C` calculate the initial rate of loss of heat from the body to the room.

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5. A liquid cools from $70^\circ C \to 60^\circ C \in 5 \min utes. Calc\underline{a}tethetimetakenbytheliquid \to c\infty lom$

60^(@)C to 50^(@)C

$, If the temperature of the surround \in g is cons \tan tat$30^(@)C` .

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Worked Out Examples

1. The lower surface of a slab of stone of face-area 3600cm^(2) and thickness 10cm is exposed to steam at $100^\circ C$. A block of ice at 0^(@)C rests on the upper surface of the slab. 4.8g of ice melts in one hour. Calculate the thermal conductivity of the stone. Latent heat of fusion of ice `=3.36xx10^(5) J kg^(-1)

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2. An icebox made of 1.5cm thick stuyrofoam has dimensions $60cm \times 60cm \times 30cm. Itconta \in siceatwhichtheiceisme < \in g. Latenth$

=3.36xx10^(5)J kg^(-1). and $thermalconductivityofstyrofoam$

=0.04Wm^(-1) $\hat{} (\circ)C^{-1}$.

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3. A closed cubical box is made of perfectly insulating material and the only way for heat to enter or leave the box is through two solid cylindrical metal plugs, each of cross sectional area $12cm^2$ and length 8cm fixed in the opposite walls of the box. The outer surface of one plug is kept at a temperature of $100^\circ C$. while the outer surface of the plug is maintained at a temperature of $4(\circ)C$. The thermal conductivity of the material of the plug is $2.0Wm^{-1}$^(@)C^(-1)` . A source of energy generating 13W is enclosed inside the box. Find the equilibrium temperature of the inner surface of the box assuming that it is the same at all points on the inner surface.

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4. A bar of copper of length 75cm and a abr of steel of length 125cm are joined together end to end. Both are of circular cross section with diameter 2cm. The free ends of the copper and the steel bors are maintained at $100^{\circ} C$ and 0^(@)C

$respectively. The curved surface of the b$ or $s. are thermally \in sated. W\hat{i}s$

$? W\hat{i}s the amount of heat transmiedper unit time across the junction? Ther$

386Js^(-1)m^(-1) $\hat{}(\circ)C^{-1}$ and that of steel is 46Js^(-1)m^(-1)`(@)C^(-1)

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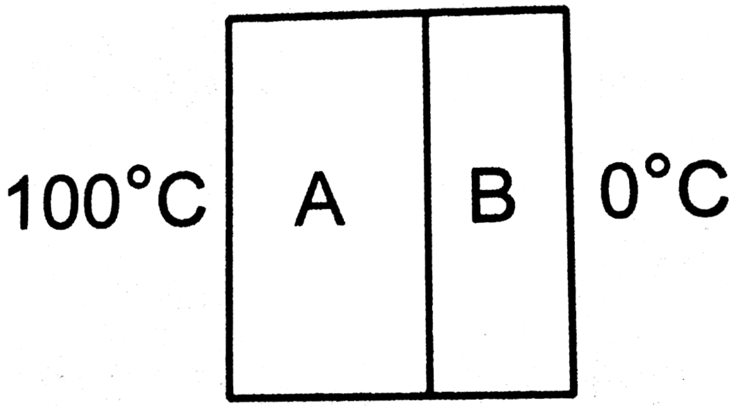
5. Two parallel plates A and B are joined together to form a compound plate . The thicknesses of the plate are $4.0 cm$ and $2.5 cm$ respectively and the area of cross section is $100 cm^2$ for each plate. The thermal conductivities are $K_A = 200 W m^{-1}$^(@)C^(-1)

f or $the pa < e B. The outer surface of the plate A is ma \int a \in \neq dat$

100^(@)C and $the outer surface of the plate A is ma \int a \in edat$100^(@)C`.

and the outer surface of the plate B is maintained at 0^(@)C. Find (a) the rate of heat flow through any cross section, (b) the temperature at the interface and (c) the equivalent thermal conductivity of the compound plate.



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6. A room has a $4m \times 4m \times 10cm$ concrete roof $(K = 1.26Wm^{-1}$ ^(@)C^(-1). $Atsome \in s\tan t, thetemperatureoutsideis$40(@)C and $t \widehat{\in} sideis32(\circ)C$. (a) Neglecting converction, calculate the amount of heat flowing per second into the room through the roof. (b) Bricks $(K = 0.65Wm^{-1}$^(@)C^(-1) of thickness $7.5cm$ are loid down on the roof. Calculate the new rate of heat flow under the some temperature conditions.

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7. An electric heatet is uesd in a room of total wall area $137m^2 \rightarrow ma \int a \in atemperatureof$20^(@)C inside it, when the outside temperature is $-10^\circ C$ .The wall have three different layers of matwerials. The innermost layer is of wood of thickness 2.5cm, the middle layer is of cement of thickness 1.0cm and the outermost layer is of brick of thickness 25.0cm. Find the power of the electric heater. Assume that there is no heat loss through the flooor and the celling. The thrermal conductivities of wood, cement and brick aree $0.125Wm^{-1}$^(@)C^(-1), $1.5Wm^{-1}$ ^(@)C^(-1). and $1.0Wm^{-1}$^(@)C^(-1)` respectively.

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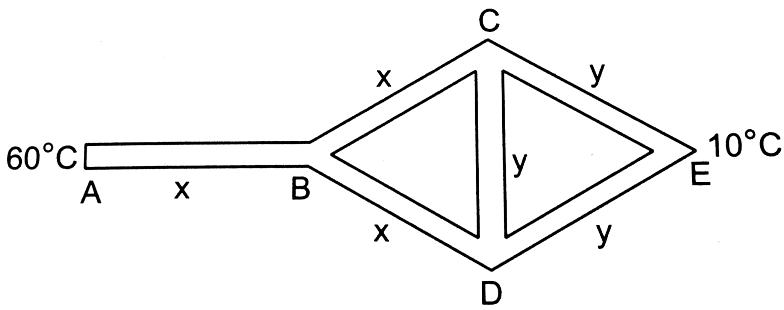
8. Three rods of material x and three of material y are connected as shown in figure. All the rods are identical in length and cross sectional area. If the end A is maintained at $60^\circ C$ and the junction E at $10^\circ C$, calculate the temperature of the junction B. The thermal conductivity of x is $800Wm^{-1}$^(@)C^(-1) and $t\hat{o}fyis$400Wm^(-1) ^ (∘)C^{-1}.



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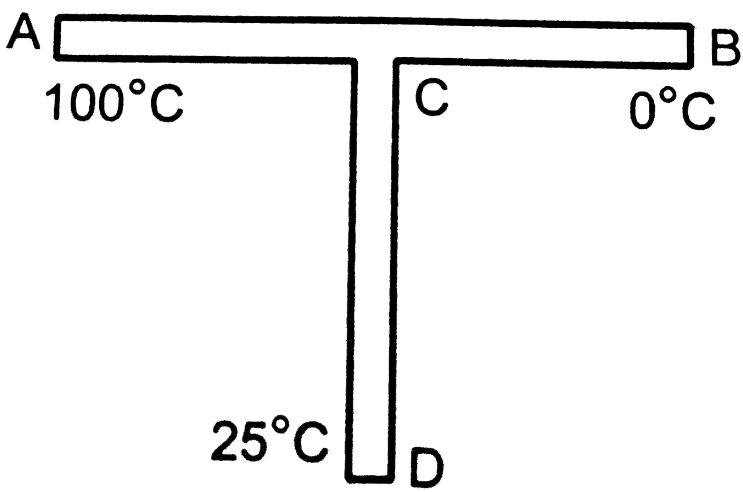
9. A rod CD of thermal resistance

$5.0KW_{-1}isjo \in edatthemidd \leq ofanidenticalrodABasshown \in figure$

100^(@)C, 0(@)C and 25(@)C respectively. Find the heat current in CD.



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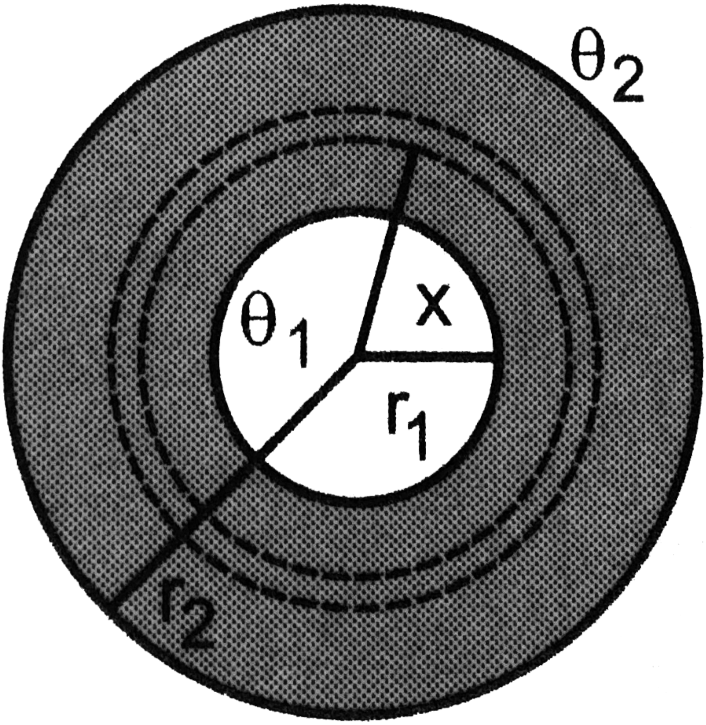
10. Two thin metallic spherical shells of radii r_1 and $r_2 (r_1 < r_2)$ are placed with their centres coinciding. A material of thermal conductivity K is filled in the space between the shells. The inner shells. Is maintained at temperature θ_1 .and the outer shell at temperature $\theta_2 (\theta_1 < \theta_2)$. Calculate the rate at which heat flows radially through the material.



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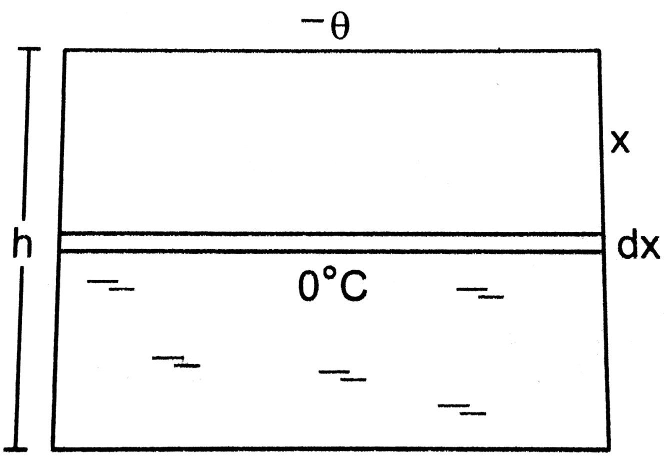
11. On a cold winter day, the atmospheric temperature is $-\theta$ (on Celsius scale) which is below $0^{\circ} C$. A cylindrical drum of height h made of a bad conductor is completely filled with water at $0^{\circ} C$ and is kept outside without any lid. Calculate the time taken for the whole mass of water to freeze. Thermal conductivity of ice is K and its latent heat of fusion is L. Neglect expansion of water on freezing.



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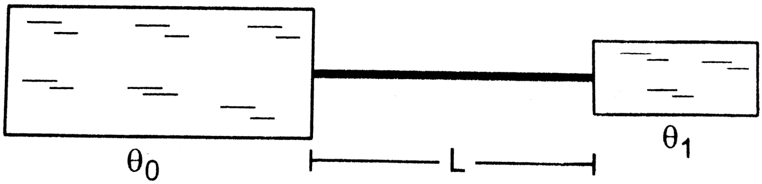
12. Figure shows a large tank of water at a constant temperature θ_0 . and a small vessel containinng a mass m of water at an initial temperature

$\theta(< \theta_0. Am\eta lrodof \leq n > hL, areaofcross\sec tionA$ and $thermalcond$
$\in thesmal \leq rvessel \rightarrow become$

theta_(2)(theta_(1)lttheta_(2)lttheta_(0))` . Specific heat capacity of water is s and all other heat capacities are negligible.



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13. One mode of an ideal monatomic gas is kept in a rigid vessel. The vessel is kept inside a steam chamber whose temperature is $97^\circ C$. Initially, the temperature of the gas is $5.0^\circ C$. The walls of the vessel have an inner surface of area $800 cm^2$ and thickness $1.0 cm$ If the temperature of the gas increases to $9.0^\circ C$ in 0.5 second, find the thermal conductivity of the material of the walls.

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14. monatomic ideal gas is contained in a rigid container of volume V with walls of totsl inner surface area A, thickness x and thermal condctivity K. The gas is at an initial temperature t_0 and pressure P_0 . Find tjr pressure of the gas as a function of time if the temperature of the surrounding air is T_s . All temperature are in absolute scale.

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15. Conside a cubical vessel of edge a having a small hole in one of its walls is r. At time $t = 0$, it contains air at atmospheric pressure p_a and $temperature$T_(0)$. The temperature of the surroud \in gairis$

T_(a)(gtT_(0)

$. F \in dtheamountofthegas(\in mo \leq s) \in thevesselattimet. Take$

C_(v)$ofair \rightarrow be5R/2.$

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16. A blackbody of surface area $1cm^2$ is placed inside an enclosure. The enclosure has a constant temperature $27(\circ)C$ and the blackbody is maintained at $327(\circ)C$ by heating it electrically. What electric power is needed to maintain the temperature? $\sigma = 6.0 \times 10^{-s} Wm^{-2} K(-2)$.

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17. An electric heater emits 100W of thermal radiation. The coil has a surface area of $0.02m^2$. Assuming that the coil radiates like a blackbody, Find its temperature. Sigma=6.00xx10^(-s)Wm^(-2)K(-4)`.

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18. The earth receives solor radiation at a rate of $8.2 Jcm^{-2} \min^{-1}$. Assuming that the sun radiates like a blackbody, calculate the surface of the sun. The angle subtended by the sun on the earth is $0.55(\circ)C$ and the stefan constant $\sigma = 5.67 \times 10^{-s} Wm^{-2} K^{-4}$.

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19. The temperature of a body falls from $40^\circ C$ to $36(\circ)C$ in 5 minutes when placed in a surrouning of constant temperature $16(\circ)C$ Find the time taken for the temperature of the body to become $32(\circ)C$.

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20. A hot fbody placed in air is cooled down according to Newton's law of cooling, the rate of decrease of temperature being k times the temperature difference from the surrounding. Starting from $t=0$, find the time in which the body will loss half the maximum heat it can lose.

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Short Answer

1. The heat current is written as $\frac{\Delta Q}{\Delta t}$. Why don't we write $\frac{dQ}{dt}$?

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2. Does a body at $20^\circ C$ radiate in a room, where the room temperature is $30^\circ C$? If yes, why does its temperature not fall further?

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3. Why does blowing over a spoonful of hot tea cools it ? Does evaporation play a role ? Does radiation play a role ?

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4. On a hot summer day we want to cool our room by opening the refrigerator door annd closing all the windows and doors. Will the process work ?

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5. On a cold winter nigth you are asked to sit on a chair. Would you like to choose a metal chair or a wooden chair ? Both are kept in the same lawn and are at the same temperature.

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6. Two identical metal balls one at $T_1 = 300K$ and the other $T_2 = 600K$ are kept at a distance of 1m in vacuum. Will the temperatures equalise by radiation? Will the rate of heat gained bby th ecolder sphere be proportional to `T_(2)^(4)-T_(1)^(4) as may be expected from the Stefan's law ?

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7. An ordinary electric fan does not cool the air, still it gives comfort in summer. Explain.

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8. The temperature of the atmosphere at a high alititude is around `500^(@)C. Yet an animal there would freeze to death and not boil. Explain.

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9. Standing in the sun is more pleasant on a cold winter day than standing in shade. Is the temperature of air in shade?

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10. Cloudy nights are warmer then the nights with clean sky. Explain.

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11. Why is a white dress more comfortable than a dark dress in summer?

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Objective 1

1. The thermal conductivity of a rod depends on

A. length

B. mass

C. area of cross section

D. material of the rod.

Answer: D

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2. In a room containing air,, heat can go from one place to anther

A. by conduction only

B. by convection only

C. by radiation only

D. by all the three modes.

Answer: D

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3. A solid at temperature T_1 is kept in an evacuated chamber at temperature $T_2 > T_1$. The rate of increase of temperature of the body is proportional to

A. $T_2 - T_1$

B. $T_2^2 - T_1^2$

C. $T_2^3 - T_1^3$

D. $T_2^2 - T_1^4$.

Answer: D

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4. The thermal radiation emited bby a body is propertional to T^n where T is its absolute temperature. The value of n is exanctly 4 for

A. a blackbody

B. all bodies

C. bodies painted black only

D. polished bodies only.

Answer: B

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5. Two bodies A and B having equal surface areas are maintained at temperatures $10^\circ C$. And $20^\circ C$. The thermal radiation emitted in a given time by A and B are in the ratio

A. $1 : 1.15$

B. $1:02$

C. $1:04$

D. $1:16$.

Answer: A

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6. One end of a metal rod is kept in a furnce. In steady state, the temperature of the rod

A. increases

B. decreases

C. remains constant

D. is non uniform.

Answer: D

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7. Newton's law of cooling is a spcial case of

A. Wien's displacement law

B. Krichhoff's law

C. Stefan's law

D. planck's law.

Answer: C

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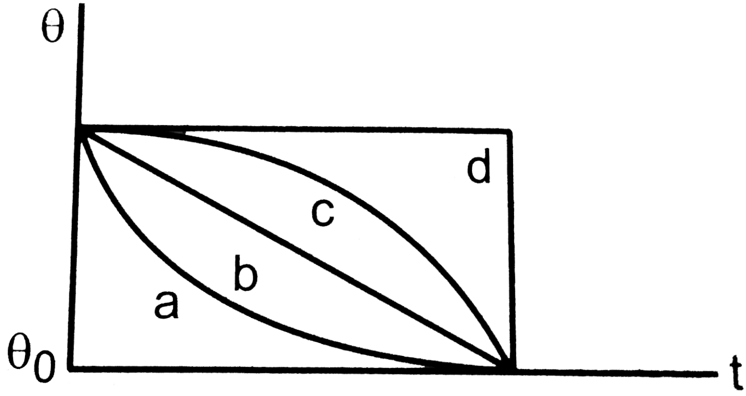
8. A hot liquid is kept in a big room. Its temperature is plotted as a function of time. Which of the following curves may represent the plot?



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9. A hot liquid is kept in a big room. The logarithm of the numerical value of the temperature difference between the liquied and the room is plot will be very nearly

A. a straight line

B. a circular arc

C. a parabola

D. an ellipse.

Answer: A

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10. A body cools down from $65^\circ C$ to $60^\circ C$ in 5minutes. It will cool down from $60^\circ C$ to $55^\circ C$ in

A. 5 minutes

B. less than 5 minutes

C. more than 5 minutes

D. less than or more than 5 minutes depending on whether its mass is more than or less than $1kg$

Answer: C

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Objective 2

1. One end of a metal rod is dipped in boiling water and the other is dipped in melting ice.

A. all parts of the rod are in thermal equilibrium with each other

B. we can assign a temperature to the rod

C. we can assign temperature to the rod after steady state is reached.

D. the state of the rod does not change after steady state is reached

Answer: D

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2. A blackbody does not

A. emit radiation

B. absorb raddiation

C. reflect radiation

D. refract radiationo.

Answer: C::D

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3. In summer, a mild wind is often found on the shore of a clam river. This is caused due to

A. difference in thermal conductivity of water and soil

B. convection currents

C. conduction between air and the soil

D. radiation from the soil

Answer: B

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4. A piece of charcol and a piece of shining steel of the same surface area are kept for a long time in an open lawn in bright sun.

A. The steel will absorb more heat than the charcoal.

B. The temperature of the steel will be higher htan that of the charcoal.

C. If both are oicked up by bare hands, the steel will be felt hotter than the chacoal.

D. If the two are picked up ferom the lawn and kept in a cold chamber, the charcoal will lose heat at a faster rate than the steel.

Answer: C::D

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5. A hearter body emits radiation which has maximum intensity near the frequency v_0 The emissivity of the material is $\odot 5$. If the absolute temperature of the body is doubled,

A. the maximum intensity of radiation will be near the frequency $2v_0$

B. the maximum intensity of radiation will be near the frequency $\frac{v_0}{2}$

C. the total energy emitted will increases by a factor of 16

D. the total energy emitted will increases by a factor of 8.

Answer: A::C

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6. A solid sphere and a hollow sphere of the same material and of equal radii are heated to the same temperature.

A. Both will emit equal amount of radiation per unit time in the beginning.

B. Both will absorb equal amount of radiation from the surrounding in the beginning.

C. The initial rate of cooling $\left(d\frac{T}{dt}\right)$ will be the same for the two spheres.

D. The two spheres will have equal temperature at any instant.

Answer: A::B

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Exercises

1. A uniform slab of dimension $10cm \times 10cm \times 1cm$ is kept between two heat reservoire at temperatures $10^{\circ} C$ and 90^(@)C $Thelar \geq rsurfaceareas \rightarrow uchthereservoirs. Thethermalcondutivityo$ 0.80Wm^(-1) $\hat{} (\circ)C^{-1}$. Find the amount of heat flowing through the slab per minute.

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2. A liquid-nitrogen container is made of a $1 - cm$ thick styrofoam sheet having thermal conductivity $0.025Js^{-1}m^{-1}$^(@)C^(1) $. Liquidnitro \geq nat80Kiskept \in it. A \rightarrow talareaof$0.80m^(-2) $is \in contcetwiththeliquidnitro \geq n. Theatmospherictemperatureis$

300K` . Calculate the rate of heat flow from the atmosphere to the liquid nitrogen.

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3. The normal body-temperature of a person is $97(\circ)F$. Calculate the rate at which heat is flowing out of this body through the clothes asssuming the following values. Room temperature $= 47^{\circ} F$, surface of the body under clothes $= 1.6m^{-2}$, condutivity of the cloth $= 0.04Js^{-1}m^{-1}$^(@)C^(-1), $thick \ne ssofthecloth$=0.5cm.

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4. Water is boiled in a container having a bottom of surface area $25cm^{2}$, thickness $1.0mm$ and $thermalconductivity$50Wm^(-1) $\hat{} (\circ)C^{-1}$, 100g of water is converted into steam per minute in the steady state after the boiling starts.Assuming that no heat is lost to the atmosphere, calculate the temperature of the lower surface of the bottom. Latent heat of vaporrization of water $= 2.26 \times 10^{6} Jkg^{-1}$.

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5. One end of a steel rod $\left(K = 46Js^{-1}m^{-1}\right.$^(@)C^(-1)$of \leq n > h$1.0m is kept in ice at $0^{\circ}C$ and the other end is kept in boiling water at 100^(@)C. $Theareaofcross$ sec $tionoftherodis$0.04cm^(2) $. As \sum \in gnoheatloss \rightarrow theatmosphere, f \in dthemassoftheiceme <$ =3.36xx10^(5)Jkg^(-1)\`.

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6. An icebox almost comletely filled with ice at $0^{\circ}C$ is dipped into a large volume of watert at $20^{\circ}C$. The box has walls of surface area $2400cm^2$ thickness $2.0mm$ and thermal conductivity 0.06Wm^(-1) $\hat{} (\circ)C^{-1}$. Calculate the rate at which the ice melts in the box. Letent heat of fusion of ice $= 3.4 \times 10^5 Jkg^{-1}$.

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7. A pitcher with $1 - mm$ thick porous walls contain 10kg of water. ,Water comes to its outer surface and evaporates at the rate of $0.1gs^{-1}$. The surface area of the pitcher (one side) $= 200cm^2$. The room temperature $= 42^{\circ}C$, latent heat of vaporization $= 2.27 \times 10^6 Jkg^{-1}$, and the thermal conductivity of the porous walls $= 0.80js^{-1}m^{-1}$^(@)C^(-1)` . Calculate the temperature of water in the pitcher when it attains a constant value.

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8. A steel farme $(K = 45Wm^{-1}$^(@)C^(-1)$of \rightarrow tal \leq n > h$60cm and $cross\sec tionarea$0.02cm^(2) , F or $msthreesideofa\square . The \text{e}eendsarema \int a \in edat$20^(@)C and 40^(@)C` . Find the rate of heat flow through a cross section of the frame.

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9. Water at $506(\circ)C$ is filled in a closed cylindercal vessel of height $10cm$ and cross sectional area $10cm^2$ The walls of the vessel are adiabatic but the flat parts are made of $1-mm$ thick aluminium $\left(K=200Js^{-2}m^{-1}\right.$ ^(@)C^(-1). $As\sum et\hat{t}heoutsidetemperatureis$20^(@)C . $Thedensityofwateris$1000kgm^(-3) and $thespec$ if $yheat\cap acityofwater$=4200Jkg^(-1) $\hat{}(\circ)C^{-1}$ .Estimate the time taken for the temperature to fall by $1.0^{\circ}C$. Make any simplifying assumotion you need but speify them.

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10. The lleft end of a copper rod $(\leq n>h=20cm.\ Areaofcross\sec tion=0.02cm^2$ is maintained at $20^{\circ}C$ and the right end is maintained at $80^{\circ}C$. Neglecting any lkkoss of heat through radiation, find (a) the temperature at a point 11cm from the left end and (b) the heat current through the rod. thermal conductivity of copper $=385Wm=^{-1}$ ^(@)C^(-1)` .

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11. The ends of a metre stick are maintain at $100^{\circ} C$ and $0^{\circ} C$. One end of a rod is mainntained $25^{\circ} C$. Where should its other end be touched on the metre stick so that there is no heat current in the rod in steady state?

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12. A cubical box of volume $216 cm^3$ is made up of $0.1 cm thick w\infty d, The \in side is heatede \leq ctrically by 100 W heater. It is fo$

5^(@)C` . In steady state . Assuming that the entire electrically energy spent appears as heat, find the thermal conductivity of the material of the box.

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13. Figure shows water in a container having $2.0 - mm$ thick walls made of a material of thermal conductivity $0.50 W m^{-1}$^(@)C^(-1)

$. Theconta \in eriskept \in ame < \in g - icebathat$0^(@)C

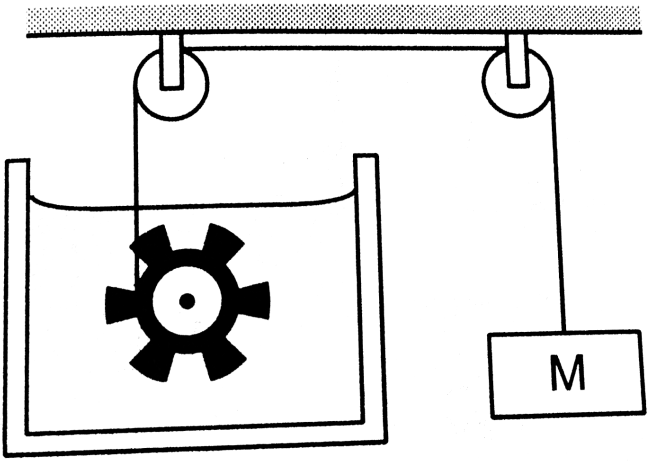
$. The \rightarrow talsurfacearea \in contactwithwateris$0.05m^(2)

$. Awheelisclamped \in sidethewater$ and $iscoup \leq \rightarrow ablockofmassMa$
$\pm etimeasteadystateisreached \in whichtheblockgoesdonwwithacon\tan t$
10cm^(-1) and $thetemperatureofthewaaterrema \in scon\tan tat$

1.0^(@)C

$. F \in dthemassMoftheblock. As\sum et\hat{t}heheatflowoutofthewateronlyth$

g=10ms^(-2)` .



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14. On a winter day when the atmospheric temperature drops to $-10^{\circ}C$, ice forms on the surface of a lajke. (a) Calculate the rate of increases of thickness of the ice when 10cm of ice is already formed. (b) Calculate the total time taken in forming 10cm of ice. Assume that the temperature of the entire water reaches $0^{\circ} C$ before the ice starts forming. Density of water $= 1000 kgm^{-3}$, latent heat of fusion of ice $= 3.36 \times 10^{5} Jkg^{-1}$ and thermal conductivity of ice $= 1.7 Wm^{-1}$^(@)C^(-1)` . Neglect the expension of water on freezing.

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15. Consider the situation of the previous problem. Assume that the temperature of the water at the botton of the lake remains contant at $4^{\circ} C$ as the ice forms on the surface (the heat required to maintain the temperature of the bottom layer may come from the bed of the lake). The depth of the lake is $1.0m. Showt\hat{t} hethick \ne ssoftheicef$ or $medaa \in sasteadystatemami\mu r$

=0.50Wm ^(-1) $\hat{}$ $(\circ) C^{-1}$. Take other relevent data form the previous problelm.

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16. Three rods of lengths 20cm eac h and area of cross section $1cm^2$ are joined to from a triangle ABC. The conductivites of the rods are $k_{AB} = 50Js^{-1}m^{-1}$(@)C^(-1), k_(BC)=200Js^(-1)m^(-1)($\circ$)C^{-1} , and $k_{AC} = 400Js^{-1}m^{-1}$(@)C^(-1)

$. The junction A, B$ and $Carema \int a \in edat$40^(@)C, 80^(@)C and 80^(@)C` respectivelt. Find the rate of heat flowing through the rods AB, AC and BC .

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17. A semicircular rods is joined at its end to a straight rod of the same material and the same cross-sectional area. The straight rod formss a diameter of the other rod. The junction are maintaine dat different temperature. Find the ratio of the heat transffered through a cross section of the straigh rod in a given time.

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18. A metal rod of cross sectional area $1.0 cm^2$ is being heated at one end. At one time , the temperature gradient is $5.0^\circ C cm^{-1}$ at cross section A and is $2.5^\circ C cm^{-1}$ at cross section B. calculate the rate at which the temperature is increasing in the part AB of the rod. The heat capacity of the part AB $= 0.40 J^\circ C^{-1}$, thermal conductivity of the material of the rod. $K = 200 W m^{-1} C^{-1}$. Neglect any loss of heat to the atmosphere.

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19. Steam at 120^(@)$Ciscont \in uouslypassedthrougha$50-cm $longruertubeof \in \ne r$ and $outerratii$1.0cm and 1.2cm $. Ther\infty mtemperatureis$30^(@)C $. Calc\underline{a}tetherateofheatflowthroughthewallsofthetube. Thermalconduct$ = 0.15Js^(-1)m^(-1)($\circ$)C^{-1} .

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20. A hole of radius r_1 is made centrally in a uniform circular disc of thickness d and radius r_2 . The inner surface (a cylinder of length d and radius r_1 is maintained at a temperature θ_1 and the oouter surface (a cylinder of length d and radius r_2 . The is maintianed at a temperature $\theta_2(\theta_1 > \theta_2)$ .The thermal conductivity of the material of the dics is K. Calculate the heat flowing per unit time through the disc.

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21. A hollow tube has a length l, inner radius R_1 and outer radius R_2 . The material has a thermal conductivity K. Find the heat flowing through the walls of the tube if (a) the flat ends are maintained at temperature T_1 and T_2(T_(2)gtT_(1)$(b) the \in sideofthetubeisma\int a \in edattemperature$T_(1) and $theoutsideisma\int a \in edat$T_(2)\`.

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22. A composite slab is prepared by pasting two plates of thickness L_1 and L_2 and thermal conductivites K_1 and K_2 . The slab have equal cross-sectional area. Find the equivalent conductivity of the composite slab.

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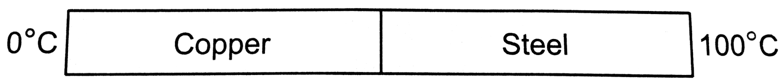
23. Figure shows a copper rod joined to a steel rod. The rods have equal length and and the equal cross sectional area. The free end of the copper rod is kept at $0^\circ C$ and that of the steel rod is kept at $100^\circ C$. Find the temperature at the junction of the rods. conductivity of copper $= 390 WM^{-1}$^(@)C^(-1) and $t\hat{o} f steel$=46Wm^(-1)($\circ$)C^{-1} .



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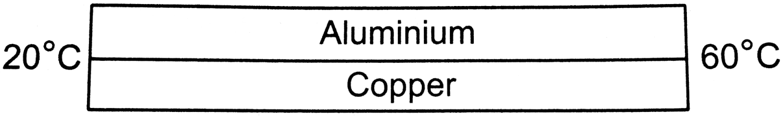
24. An aluminium rod and a copper rod of equal length $1.0 m$ and cross-sectional area. $1 cm^2$ are welded together as shown in figure. One end is kept at a temperature of $20^{\circ}C$ and the other at $60^{\circ}C$ Calculate the amount of heat taken out per second from the hot end. thermal conuctivity of aluminium $= 200Wm^{-1}$^(@)C^(-1) and $of copper$ =390Wm^(-1) $\hat{}(\circ)C^{-1}$.



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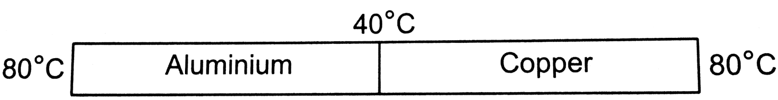
25. Figure shows an aluminium rod joined to a copper rod. Each of the rods has a length of 20cm and area of ccross section $0.20cm^2$. The junction is maintained at a constant temperature $40^{\circ}C$ and the two ends are maintained at 80^(@)C $. Calcatetheamountofheattakenoutomthecoldjunction \in o \ne \min utea$

K_(Al)=200Wm^(-1) $\hat{}(\circ)C^{-1}$. and $K_{Cu} = 400Wm^{-1}$^(@)C^(-1)`.



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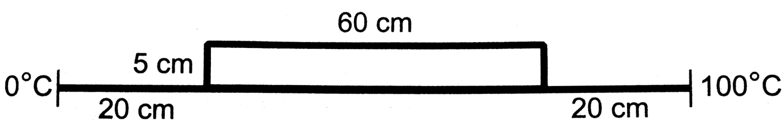
26. Conside the situation shown in figure. The frame is made of the same material and has a unifrom cross-section area everywhere. Calculate the amount of heat flowing per second through a cross section of the bent part if the total heat taken out per second from the end at $100^{\circ} C$ is $130 J$

.



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27. Suppose the bent part of the frame of the previous problem has a thermal conductivity of $780 s^{-1} m^{-1}$^(@)C^(-1)$whereasitis$ 390Js^(-1)m^(-1) $\hat{} (\circ) C^{-1}$ for the staight the bent part to the rate of heat flow through the staight part.

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28. A room has s window fitted with a single $0.1m \times 2.0m$ glass of thickness 2mm. (a) Calculate the rate of heat flow through the clossed window when the temperature inside the room is 32^(@)C and $t\hat{o}utsideis$40^(@)C

. $(b)Theglassisnowreplacedbytwoglasspance, eachhav \in gathick \neq ssof$

$< etherateofheatflowunderthesameconditionoftemperature. Therma$

=1.0Js^(-1)m^(-1) $\hat{}$ ($\circ$)C^{-1} and that of air $= 0.025Js^{-1}m^{-1}$^(@)C^(-1)`

.

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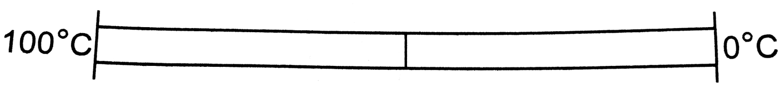
29. The two rods show in figure have identical geomerical dimension.. They are in contact with two heat baths at temperature $100^{\circ}C$. And $0^{\circ}C$. The temperature of the junction is 70^(@)C` . Find the temperature of the junction if the rods are interchanged.



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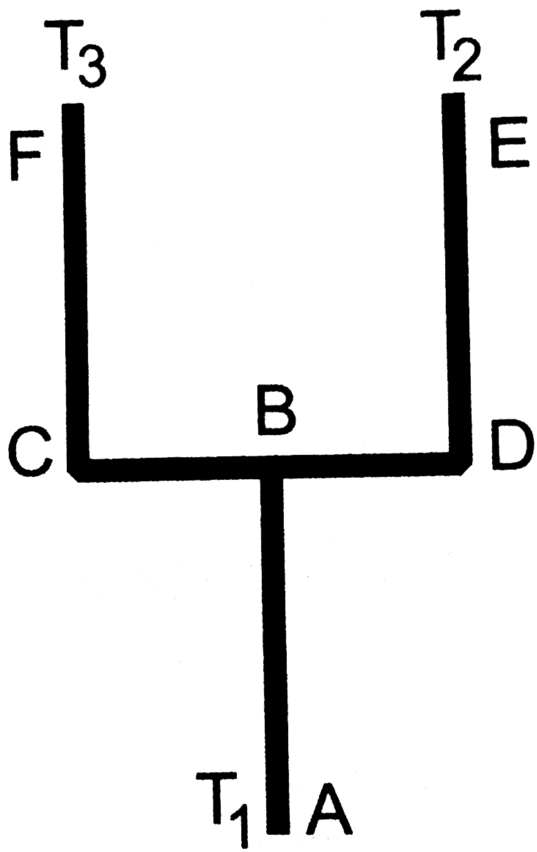
30. Four identical rods AB, CD, CF and DE are joined as shown in figure. The length, cross-sectional area and thermal conductivity of each rod are l, A and K respectively. The ends A, E and F are maintained at temperature T_1 , T_2 and T_3 respectively. Assuming no loss of heat to the atmospere, find the temperature at B.



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31. Seven rods A, B, C, D, E, F and G are joined as shown in figure. All the rods have equal cross-sectional area A and length l. The thermal conductivies of the rods are $K_A = K_C = K_0$, K_(B)=K_(D)=2K_(0), $K_E = 3K_0$, K_(F)=4K_(0) and K_(G)=5K_(0)

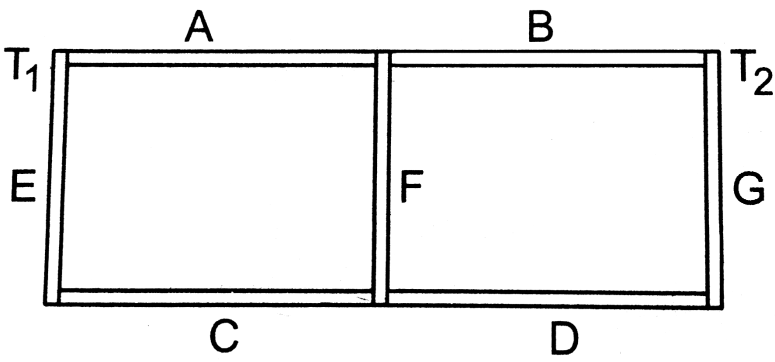
$. The rod E is kept at a cons \tan t temperature$T_(1)

and $the rod G is kept at a cons \tan t temperature$T_(2)(T_(2)gtT_(1))

$. (a) Show t\hat{t} he rod F has a un$ if or $m temperature$T=(T_(1)+2T_(2))//3

$. (b) F \in d the rate of heat flow \in g om the source which ma \int a \in s the tempe$

T_(2)` .



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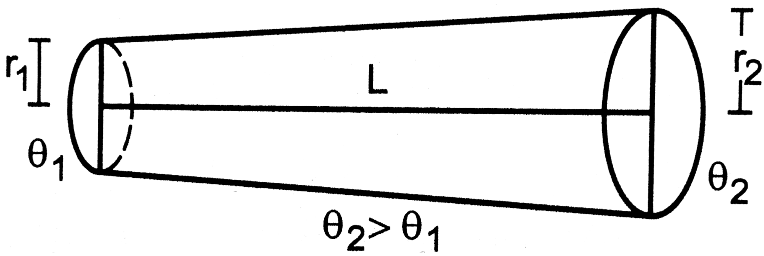
32. Find the rate of heat flow through a cross section of the rod shown in figure $(\theta_2 > \theta_1$. Thermal conductivity of the material of the rod is K.



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33. A rod of negligible heat capacity has length 20cm, area of cross section $1.0cm^2$ and thermal conductivity $200Wm^{-1}$^(@)C^(-1) $. Thetemperatureofo \ne endisma \int a \in edat$0^(@)C and $t\hat{o}ftheotherendisshowly$ and $l \in earlyvariedom$0^(@)C $\rightarrow$ 60^(@)C` in 10 minutes. Assuming no loss of heat through the sides, find the total heat transmitted through the rod in these 10 minutes.

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34. A hollow metallic sphere of radius 20cm surrounds a concentric metallic sphere of radius 5cm. The space between the two sphere is filled with a nonmetallic material. The inner and outer sphere are maintained at $50^\circ C$ and $10^\circ C$ respectively and it is found that 100J of heat passes from the inner sphere to the outer sphere per second. Find the thermal conductivity of the material between the sphere.

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35. Figure shown two adiabatic vessels, each containing a mass m of water at different temperature. The ends of a metal rod of length L, area of cross section. A and thermal conductivity K, are inserted in the water as shown in the figure. Find the time taken for the difference between the temperature in the vessels to become half of the original value. The specific heat capacity of water is s. Neglect the heat capacity of the rod and the container and any loss of heat top the atmosphere.

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36. Two bodies of masses m_1 and m_2 and specific heat capacities S_1 and S_2 are connected by a rod of length l, cross-ssection area A, thermal conductivity K and negligible heat capacity. The whole system is thermally insulated. At time $t=0$, the temperature of the fisrt body is T_1 and the temperature of the second body is $T_2(T_2 > T_1)$. Find the temperature difference between the two bodies at time t.

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37. An amount n (in moles) of a monatomic gas at initial temperature T_0 is enclosed in a cylinderical vessel fitted with a ligth piston. The surrounding air has a temperature $T_s(> T_0)$. And the atmospheric pressure is P_a . Heat may be conducted between the surrounding and the gas through the bottom of the cylinder. The bottom has a surface area A, thickness x and thermal conductivity K. Assuming all change to be slow, find the distance moved by the piston in time t.

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38. Assume that the total surface area of a human body is $1 - 6m^2$ and that it radiates like an ideal radiator. Calculate the amount of energy radiates per second by the body if the body temperature is $37^\circ C$. Stefan constant σ is $6.0 \times 10^{-s} Wm^{-2} K^{-4}$.

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39. Calculate the amount of heat radiated per second by a body of surface area $12 cm^2$ kept in thermal equilibrium in a room at temperature $20^\circ C$ The emissivity of the surface $= 0.80$ and $\sigma = 6.0 \times 10^{-s} Wm^{-2} K^{-4}$.

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40. A solid aluminium sphere and a solid copper sphere of twice the radius are heated to the same temperature and are allowed to cool under identical surrounding temperatures. Assume that the emissivity of both the spheres is the same. Find ratio of (a) the rate of heat loss from the aluminium sphere to the rate of all of temperature of the copper sphere. The specific heat capacity of aluminium $= 900 Jkg^{-1}$^(@)C^(-1) . and $t\hat{o} f copper =$ 390Jkg^(-1) $\hat{}\ (\circ) C^{-1}$. The density of copper =3.4 times the correct wattage.

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41. A 100W bulb has tungsten filament of total length $1.0 m$ and radius $4 \times 10^{-5} m$. The emissivity of the filament is 0.8 and $\sigma = 6.0 \times 10^{-8} W m^{-2} K^{-4}$. Calculate the temperature of the filament when the bulb is operating at correct wattage.

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42. A spherical ball of surface area $20cm^{\circ}$ absorbs any radiation that falls on it. It is suspended in a closed box maintained at $57^{\circ}C$. (a) Find the amount of radiation falling on the ball per second. (b0 Find the net rate of heat flow to or from the ball at an instant when its temperature is $200^{\circ}C$. Stefan constant $= 6.0 \times 10^{-s} Wm^{-2}K^{-4}$.

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43. A spherical tungsten pices of radius $1.0cm$ is suspended in an evacuated chamber maintained at $300K. The\pi cesisma \int a \in edat1000Kbyheat \in gite \le ctrically. F \in dthe$ 0.30 and $theStefancons\tan t\sigma is$6.0xx10^(-s)Wm^(-2)K^(-4)`.

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44. A cubical block of mass $1.0kg$ and edge $5.0cm$ is heated to $227^{\circ}C$. It is kept in an evacuated chamber maintained at $27^{\circ}C$. Assuming that the block emits radiation like a blackbody, find the rate at which the temperature of the block will decreases. Specific heat capacity of the material of the block is $400 J kg^{-1} K^{-1}$.

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45. A copper sphere is suspended in an evacuated chamber maintained at 300K. The sphere is maintained at a constant temperature of 500K by heating it electrically. A total of 210W is electric power is needed to do it. When the surface of the copper sphere is completely blanked, 700W is needed to maintain the same temperature of the sphere. Calculate the emissivity of copper.

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46. A spherical ball A of surface area $20 cm^2$ is kept at the centre of a hollow spherical shell B of area $80 cm^2$. The surface of A and the inner surface of B emit as blackbodies. Both A and B are at 300K. (a) How much is the radiation energy emitted per second by the ball A? (b) How much is the radiation energy emitted per second in the inner surface of B? (c)

How much of the energy emitted by the inner surface of B falls back on this surface itself?

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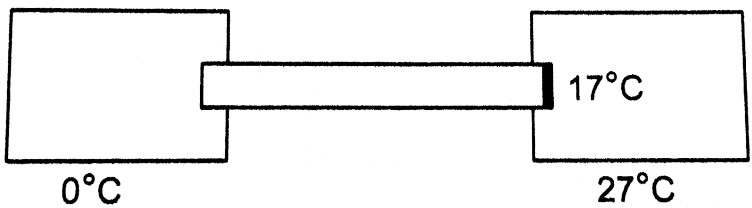
47. A cylinderical rod of length 50cm and cross sectional area $1cm^2$ is fitted between a large ice chamber at $0^\circ C$ and an evacuated chamber maintained at $27^\circ C$ as shown in figure. Only small protions of the rod are insid ethe chamber and the rest is thermally insulated from the surrounding. The cross section going inti the evacuted chamber is blackened so that it completely absorbe any radiation falling on it. The temperatuere of the blackened end is $17^\circ C$ when steady state is reachhed. Stefan constant $\sigma = 6 \times 10^{-s} Wm^{-2}K^{-4}$. Find the thermal conductivity of the material of the rod.



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48. One end of a rod length 20cm is inserted in a furnace at 800K. The sides of the rod are coved with an insulating material and the other end emits radiation like a blackbody. The temperature of this end is 750K in the steady state. The temperature of the surrounding air is 300K. Assuming radiation to be the only important mode of energy tranfer between the surrounding and the open end of the rod, find the thermal conductivity of the rod. Stefan constant $\sigma s = 6.0 \times 10^{-1} Wm^{-2}K^{-4}$.

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49. A calorimeter of negligible heat capacity contains 100cc of water at $40^\circ C$. The water cools to $35^\circ C$ in 5minutes. The water is now replaced by k-oil of equal volume at $40^\circ C$. Find the time taken for the temperature to become $35^\circ C$ under similar conditions. Specific heat cpacities of water and K-oil are $4200 Jkg^{-1}K^{-1}$ and $2100 Jkg^{-1}K^{-1}$ respectively. Density of K-oil $= 800 kgm^{-3}$.

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50. A body cools down from $50^\circ C$ to $45^\circ C$ in 5 minutes and to $40^\circ C$ in another 8 minutes. Find the temperature of the surrounding.

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51. A calorimeter containes 50g of water at $50^\circ C$. The temperature falls to $45^\circ C$ in 10 minutes. When the calorimeter contains 100g of water at $50^\circ C$ it takes 18 minutes for the temperature to become $45^\circ C$. Find the water equivalent of the calorimeter.

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52. A metal ball of mass 1kg is heated by means of a 20W heater in a room at $20^\circ C$. The temperature of the ball becomes steady at $50^\circ C$. (a) Find the area of loss of heat to the surrounding when the ball is at $-50^\circ C$. (b) Assuming Newton's law of cooling, calculate the rate of loss of heat to the surrounding when the ball is at $30^\circ C$. (c) Assume that the temperature of the ball rises uniformly from $20^\circ C$ to $30^\circ C$ in 5 minutes. Find the total loss of heat to the surrounding during this period. (d) Calculate the speific heat capicity of the metal.

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53. A metal block of heat capacity $90J/.^\circ C$ placed in a room at $25^\circ C$ is heated electrically. The heater is switched off when the temperature reaches $35^\circ C$. The temperature of the block rises at the rate of $2^\circ C/s$ just after the heater is switched on and falls at the rate of $0.2^\circ C/s$ just after the heater is switched off. Assume Newton's law of cooling to hold (a) Find the power of the heater. (b) Find the power radiated by the block just after the heater is switched off. (c) Find the power radiated by the block when the temperature of the block is $30^\circ C$. (d) Assuming that the power radiated at $30^\circ C$ respresents the average value in the heating process, find the time for which the heater was kept on.

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54. A hot body placed in a surrounding of temperature θ_0 obeys Newton's law of cooling $\frac{d\theta}{dt} = -k(\theta - \theta_0)$. Its temperature at $t = 0$ is θ_1 the specific heat capacity of the body is s and its mass is m. Find (a) the maximum heat that the body can lose and (b) the time starting from $t = 0$ in which it will lose 90% of this maximum heat.

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Exerciese

1. The three rods shown in figure have identical geometrical dimensions. Heat flows from the hot end at a rate of 40W in the arrangement (a). Find the rates of heat flow when the rods are joined as in arrangement (b) and in (c). Thermal conductivities of aluminium and copper are $200Wm^{-1}$ ^(@)C^(-1) and 00Wm^(-1) $\hat{}\ (\circ)C^{-1}$ respectively.

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