BIRLA INSTITUTE OF TECHNOLOGY

MESRA – 835215, RANCHI, INDIA

UG

Name: ………………………………………………………. Roll No.: ………………………………………..

Branch: ………………………………………………………. Signature of Invigilator: ……………………

Semester: VIth Date: 02/05/2022 (MORNING)

Subject with Code: **ME387 ADVANCED HEAT TRANSFER**

Marks Obtained	Section A (30)	Section B (20)	Total Marks (50)

INSTRUCTION TO CANDIDATE

1. The booklet (question paper cum answer sheet) consists of two sections. First section consists of MCQs of 30 marks. Candidates may mark the correct answer in the space provided / may also write answers in the answer sheet provided. The Second section of question paper consists of subjective questions of 20 marks. The candidates may write the answers for these questions in the answer sheets provided with the question booklet.
2. The booklet will be distributed to the candidates before 05 minutes of the examination. **Candidates should write their roll no. in each page of the booklet.**
3. Place the Student ID card, Registration Slip and No Dues Clearance (if applicable) on your desk. All the entries on the cover page must be filled at the specified space.
4. Carrying or using of mobile phone / any electronic gadgets (except regular scientific calculator)/chits are strictly prohibited inside the examination hall as it comes under the category of unfair means.
5. No candidate should be allowed to enter the examination hall later than 10 minutes after the commencement of examination. Candidates are not allowed to go out of the examination hall/room during the first 30 minutes and last 10 minutes of the examination.
6. Write on both side of the leaf and use pens with same ink.
7. The medium of examination is English. Answer book written in language other than English is liable to be rejected.
8. All attached sheets such as graph papers, drawing sheets etc. should be properly folded to the size of the answer book and tagged with the answer book by the candidate at least 05 minutes before the end of examination.
9. The door of examination hall will be closed 10 minutes before the end of examination. Do not leave the examination hall until the invigilators instruct you to do so.
10. Always maintain the highest level of integrity. Remember you are a BITian.
11. Candidates need to **submit the question paper cum answer sheets before leaving the examination hall**.

BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(END SEMESTER EXAMINATION)

CLASS: BE — **SEMESTER : VI**
BRANCH: MECHANICAL — **SESSION : SP/22**

SUBJECT: ME387 ADVANCE HEAT TRANSFER

TIME: 2 HOURS — **FULL MARKS: 50**

INSTRUCTIONS:
1. **Question no.1 contains 15 objective type questions which are compulsory to answer.**
2. **Out of Question nos. 2 to 8, any 4 questions are to be solved.**
3. **The missing data, if any, may be assumed suitably.**
4. **Before attempting the question paper, be sure that you have got the correct question paper.**
5. **Use of “Heat Transfer Data Book” is allowed.**

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1. Choose the correct answer [2 x 15 = 30]

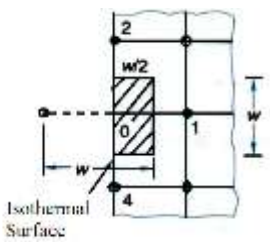
1. Two vectors $g_m(x_i)$ *and* $g_n(x_i)$ are said to be orthogonal to each other, if
   i. $g_m(x_i).\ g_n(x_i) \geq 0$
   ii. $g_m(x_i).\ g_n(x_i) = 0$
   iii. $\sum g_m(x_i)\ .\ g_n(x_i) = 0$
   iv. $\sum g_m(x_i)\ .\ g_n(x_i) \geq 0$

   (a) (i) is correct
   (b) (ii) is correct
   (c) (ii) & (iii) are correct
   (d) (i) & (iv) are correct

2. Method of separation of variable is applicable for
   (a) 1D transient problems
   (b) 2D steady state problems
   (c) linear and homogeneous governing differential equation
   (d) All the above are correct

3. Conduction shape factor is
   (M= No. of temperature increments ‘ΔT’ along a heat flow tube; N = No. of heat flow tubes; Δx = thickness of temperature increment ; Δy = thickness of heat flow tube; k=material thermal conductivity)
   (a) kΔy(ΔT/Δx)
   (b) N/M
   (c) (M Δx) /(NΔy)
   (d) K(M/N) ΔT

4. During a numerical solution by Relaxation method, which is correct equation for the isothermal surface shown in the figure
   (a) $T_1 - T_0 + \frac{hw}{k}(T_\infty - T_0) = 0$
   (b) $\frac{1}{2}(T_2 - T_4) + (T_1 - 2T_0) = 0$
   (c) $\frac{1}{2}(T_2 - T_4) + (T_1 - 2T_0) + \frac{hw}{k}(T_\infty - T_0) = 0$
   (d) $\frac{1}{2}(T_1 - T_4 - T_0) = 0$



5. Which equation will provide solution to periodic heat transfer problems?
   (a) $\Theta(x, y) = X(x) + Y(y)$
   (b) $\Theta = X\,(e)^{i\omega t}$
   (c) $\Theta(x, t) = X(x) + \tau\,(t)$
   (d) All the above are correct

6. Which is correct equation for a triangular fin of base thickness‘t’, width ‘w’ and length ‘L’ at base temperature ‘T_0’?

(I_o , K_o= modified zeroth order Bessel function of first and second kind respectively, $B^2 = \frac{2Lh}{kt}$, k =thermal conductivity of fin material, h = convective coefficient)

(a) $\frac{\theta}{\theta_o} = \frac{I_o(2B\sqrt{x})}{I_o(2B\sqrt{L})}$

(b) $\frac{\theta}{\theta_o} = \frac{K_o(2B\sqrt{x})}{I_o(2B\sqrt{L})}$

(c) $\frac{\theta}{\theta_o} = \frac{I_o(2B\sqrt{x})}{K_o(2B\sqrt{L})}$

(d) $\frac{\theta}{\theta_o} = \frac{K_o(2B\sqrt{x})}{K_o(2B\sqrt{L})}$

7. The ratio of heat transfer rate from a surface with fin to that which would be obtained with the fin is

(a) Efficiency of fin
(b) COP of fin
(c) Effectiveness of fin
(d) Performance ratio of the fin

8. The dimensionless quantity $\left(\frac{hL_c}{k}\right)$ in a conduction heat transfer is called as

(h = convective coefficient; k = thermal conductivity of material; L_c = characteristic dimension)

(a) Nusselt number
(b) Biot number
(c) Both the above are correct
(d) Fourier’s number

9. Which is correct from the following **at node ‘1’** with respect to the given Figure?

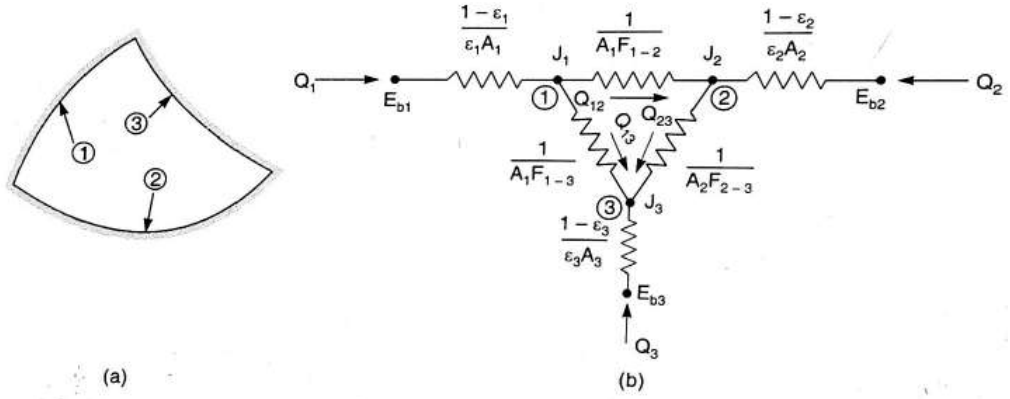


Figure: Three surface enclosure and equivalent radiation network

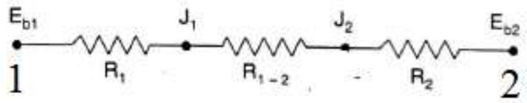
(a) $\frac{E_{b1} - J_1}{\frac{1-\varepsilon_1}{\varepsilon_1 A}} + \frac{J_2 - J_1}{\frac{1}{A_1F_{1-2}}} + \frac{J_3 - J_1}{\frac{1}{A_1F_{1-3}}} = 0$

(b) $\frac{J_1 - J_2}{\frac{1}{A_1F_{1-2}}} + \frac{J_3 - J_2}{\frac{1}{A_2F_{2-3}}} + \frac{E_{b2} - J_2}{\frac{1-\varepsilon_2}{\varepsilon_2 A_2}} = 0$

(c) $\frac{J_1 - J_3}{\frac{1}{A_1F_{1-3}}} + \frac{J_2 - J_3}{\frac{1}{A_2F_{2-3}}} + \frac{E_{b3} - J_3}{\frac{1-\varepsilon_3}{\varepsilon_3 A_3}} = 0$

(d) $\frac{E_{b1} - J_1}{\frac{1-\varepsilon_1}{\varepsilon_1 A}} + \frac{J_2 - J_3}{\frac{1}{A_2F_{2-3}}} + \frac{E_{b2} - J_3}{\frac{1-\varepsilon_3}{\varepsilon_3 A_3}} = 0$

10. Which is correct referring the network approach in radiation heat transfer shown in the figure? (F-Shape factor; ϵ = emissivity; A = surface area of radiating surface)



(a) $R_1 = \frac{1-\epsilon_1}{A_1F_{1-1}}$; $R_{1-2} = \frac{1}{A_1F_{1-2}}$; $R_2 = \frac{1-\epsilon_2}{A_2F_{2-2}}$

(b) $R_1 = \frac{1-\epsilon_1}{A_1F_{1-2}}$; $R_{1-2} = \frac{1}{A_1F_{1-2}}$; $R_2 = \frac{1-\epsilon_2}{A_2F_{1-2}}$

(c) $R_1 = \frac{1-F_{1-1}}{A_1F_{1-1}}$; $R_{1-2} = \frac{1}{A_1F_{1-2}}$; $R_2 = \frac{1-F_{2-2}}{A_2F_{2-2}}$

(d) $R_1 = \frac{1-\epsilon_1}{A_1\epsilon_1}$; $R_{1-2} = \frac{1}{A_1F_{1-2}}$; $R_2 = \frac{1-\epsilon_2}{A_2\epsilon_2}$

11. Energy equation is given by:
$\rho\frac{De}{Dt} = \rho\dot{q} + \nabla(k\nabla T) - p\Delta\vec{V} + \mu\phi$
where the symbols have their usual meaning.
For 2D steady incompressible flows neglecting high speed flow of isotropic fluid with negligible volumetric heating and considering $e = C_pT$, the above energy equation reduces to

(a) $\rho\frac{\partial e}{\partial t} + C_p\left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z}\right) = \alpha\nabla^2T$, here $\alpha = \frac{k}{\rho C_p}$

(b) $u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \alpha\nabla^2T$

(c) $\rho\frac{De}{Dt} = k\nabla^2T$

(d) $u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = k\nabla^2T$

12. Colburn's analogy is represented by

(a) $St.(Pr)^{2/3} = \frac{C_{fx}}{2}$, is valid for $Pr \approx 1$

(b) $\frac{Nu}{Re.Pr} = St = \frac{C_{fx}}{2}$, is valid for $0.5 \le Pr \le 60$

(c) $St.(Pr)^{2/3} = \frac{C_{fx}}{2}$, is valid for $0.5 \le Pr \le 60$

(d) $St = \frac{C_{fx}}{2}$, is valid for $Pr \approx 1$

13. The thermal entry length for laminar and turbulent flow through pipe is given by, respectively,

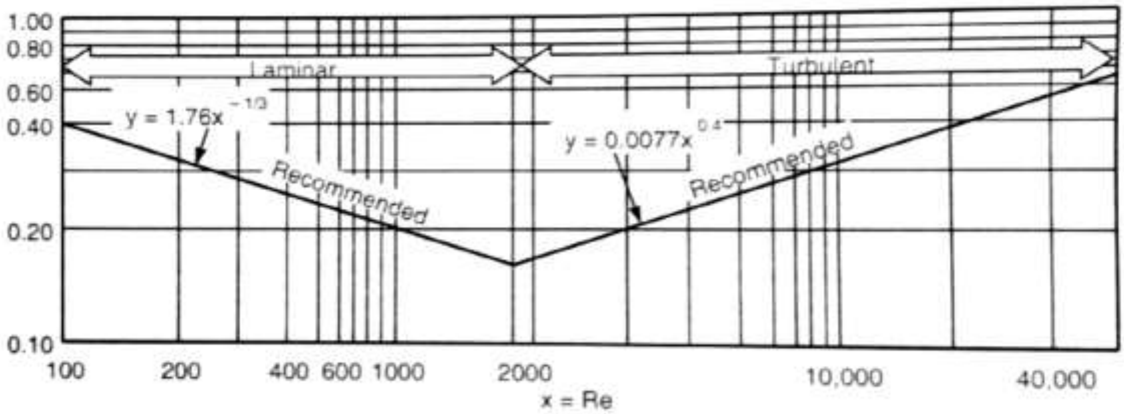
(a) $x_{eth} = 10D$; $x_{eth} = 0.5D\,Re_D\,Pr$

(b) $x_{eth} = 0.5D\,Re_D$ Pr ; $x_{eth} = 10D$

(c) $x_{eth} = 0.5D\,Re_D$; $x_{eth} = 0.5D\,Pr$

(d) $x_{eth} = 0.5D\,Re_D$; $x_{eth} = 10D$

14. In the following figure for the phenomenon of condensation, the parameter that exists along ordinate is



(a) $h\left(\frac{\mu^2}{\rho^2gk_f^2}\right)^{1/3}$

(b) $h\left(\frac{\rho^2}{\mu^2gk_f^2}\right)^{1/3}$

(c) $h\left(\frac{k_f^2}{\rho^2 g \mu^2}\right)^{1/3}$

(d) $k_f^2\left(\frac{\mu^2}{\rho^2 g h}\right)^{1/3}$

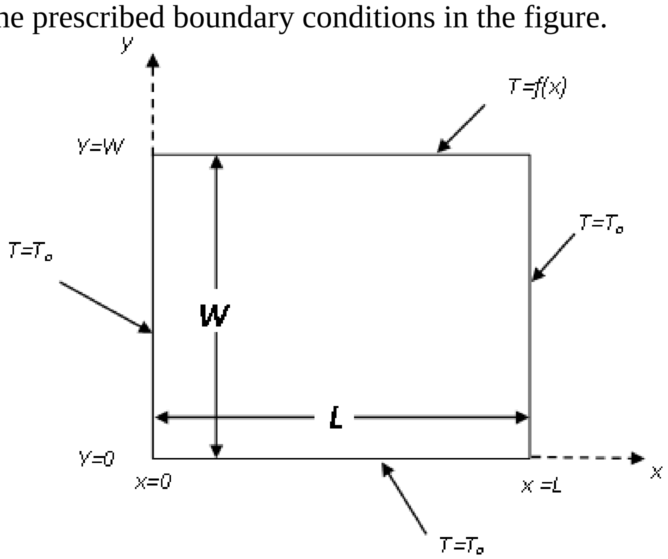
15. ___ is in transit as result of a species concentration difference in a mixture.
(a) Heat flux
(b) Density
(c) Velocity
(d) Mass

Solve any 4 questions from the following: [5 x 4 = 20]

2. The inside dimensions of a small cubical furnace constructed of fire clay bricks (k=1.05W/m°C) are 0.6m x 0.6m x 0.6m; the walls being 0.12m thick. The temperatures at the inside and outside surfaces are 600°C and 70°C respectively. Determine the heat lost through the walls. [5]

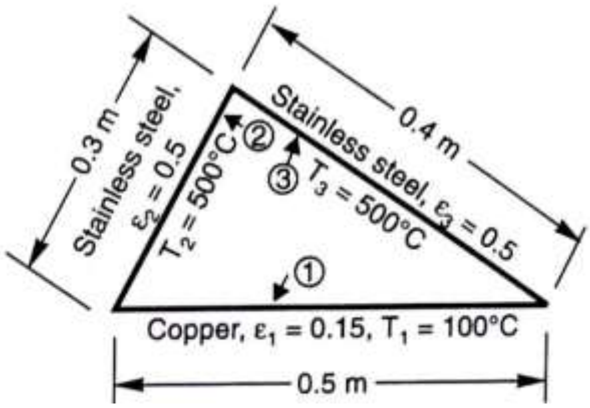
3. Refer figure below, a long solid bar of rectangular cross-section subject the boundary conditions as mentioned in the figure, is free of internal heat sources and has constant thermal conductivity. If there are no temperature gradients in z-direction because the end effects can be neglected as the bar is long, then under steady state conditions the temperature distribution T(x,y) in the bar is represented by the following Laplace equation. Analyse T(x,y) by solving the given Laplace equation, by separation of variables method, subject to the prescribed boundary conditions in the figure. [5]

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2}{\partial y^2} = 0$$

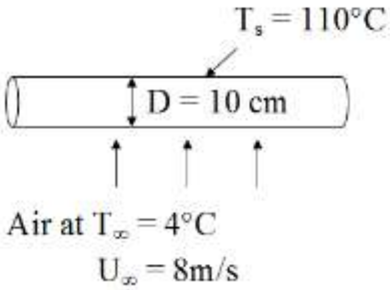


4. Triangular fins of 2.5cm thickness at base and 10cm long and made from stainless steel (k = 17.7 W/mK and ρ = 7850 kg/m^3) are to be fitted to an sir cooled cylinder wall. If the wall temperature is 600°C and the heat transfer coefficient between the solid surface and air (T_∞= 40°C) is 20 W/m^{2}K, estimate the rate of heat flow per unit mass of the fin. [5]

5. Two sides of a long triangular duct as shown in the figure are made of stainless steel (ε = 0.5) and are maintained at 500°C. The third side is of copper (ε = 0.15) and has a uniform temperature of 100°C. Calculate the rate of heat transfer to the copper base per meter length of the duct. [5]



6. A long 10 cm diameter steam pipe is exposed to atmospheric air at 4°C. The outer surface of the pipe is at 110°C and air is flowing across the pipe at the velocity of 8 m/s. Determine the rate of heat loss from the pipe per unit of its length. [5]



7. Explain pool boiling phenomenon with boiling curve mentioning various regimes. [5]

8. Explain Fick's law of diffusion in terms mass as well as molar concentration. [5]

The hydrogen gas diffuses through a steel wall of 2 mm thickness. The molar concentration of hydrogen at the interface is 1.5 kg-mol/m^3 and it is zero on the outer face. Calculate the diffusion rate of hydrogen, if its diffusivity coefficient is 0.3×10^{-12} m^2/s.

::::: 02/05/2022 :::::