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Bharatiya Vidya Bhavan's

# Sardar Patel College of Engineering

(A Government Aided Autonomous Institute)
Munshi Nagar, Andheri (West), Mumbai – 400058.
RE Exam
June 2016

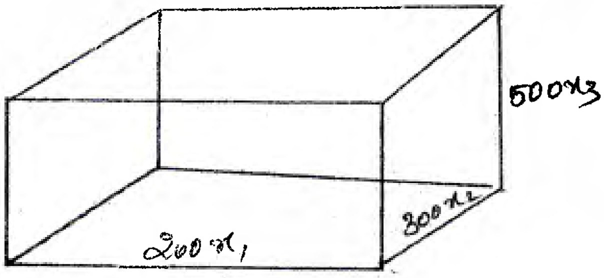
Max. Marks: 100
Class: M.Tech (M/c Design)          Semester: II
Name of the Course: Optimization Methods

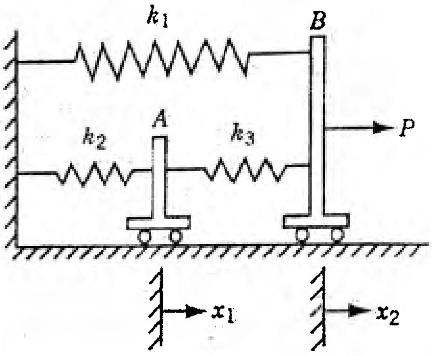
Duration: 4 hrs
Program: M.Tech (M/c Design)
Course Code : MTMD203
Master file.

**Instructions:**

1. Question No. 1 is compulsory
2. Attempt any four questions out remaining six
3. Assume suitable data if necessary

<table>
<tr><th>Question No</th><th></th><th>Maximum Marks</th><th>Course Outcome Number</th><th>Module No.</th></tr>
<tr><td>Q1</td><td>Attempt any Four of the Following:</td><td></td><td></td><td></td></tr>
<tr><td></td><td>(a) Formulation of Optimization Problem</td><td>05</td><td>01</td><td>01</td></tr>
<tr><td></td><td>(b) Random Search Algorithm</td><td>05</td><td>02</td><td>02</td></tr>
<tr><td></td><td>(c) Characteristics of Mechanical Systems</td><td>05</td><td>01</td><td>03</td></tr>
<tr><td></td><td>(d) Role computer software in solving optimization problem</td><td>05</td><td>01</td><td>06</td></tr>
<tr><td></td><td>(e) Redundant & Incompatible Specification</td><td>05</td><td>01</td><td>03</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Q2 (a)</td><td>Explain the Quadratic Interpolation Method of Optimization.</td><td>10</td><td>01</td><td>01</td></tr>
<tr><td>(b)</td><td>An electrical equipment is engaged in the production of high power and low power transformers using three operations: Making, Coil Assembly, Final Assembly.<br>A high power transformer (HPT) is sold at Rs. 8,000 and low power transformer (LPT) is old at Rs. 3,000. The cost of HPT and LPT are Rs. 3,000 and Rs. 2000 respectively. The time required for hours for each operation and their weekly availability are given below:
<table>
<tr><th rowspan="2">Operations</th><th colspan="2">Transformers</th><th>Weekly</th></tr>
<tr><th>HPT (Hrs.)</th><th>LPT (Hrs.)</th><th>Hours</th></tr>
<tr><td>Mould Making</td><td>3</td><td>1</td><td>50</td></tr>
<tr><td>Coil Assembly</td><td>8</td><td>3</td><td>150</td></tr>
<tr><td>Final Assembly</td><td>6</td><td>5</td><td>100</td></tr>
</table>
Formulate the problem and solve for maximizing the profit.</td><td>10</td><td>03</td><td>01</td></tr>
<tr><td>Q.3.(a)</td><td>Explain the Genetic Programming?<br>Give Genetic Algorithm</td><td>10</td><td>02</td><td>02</td></tr>
</table>

| | | | | |
|---|---|---|---|---|
| Q.3. (b) | Given is the function:<br>$f(x_1,x_2) = (x_1 - 3)^2 + (x_2 -2)^2$<br>Minimize $f(x_1,x_2)$ by genetic Algorithm. Solve for atleast three generations | 10 | 03 | 02 |
| | | | | |
| Q.4 (a) | A steel framework as shown in Figure 1 is to be constructed at a minimum cost. The cost in dollars of all the horizontal members in one orientation is $200x_1$ and in other horizontal orientation is $300x_2$. The cost in dollars of all vertical members is $500x_3$. The frame must enclose a total volume of 900 $m^3$.<br>(a) Set up the objective function for total cost and the constraint(s) in terms of $x_1$, $x_2$ and $x_3$.<br>(b) Using the method of Lagrange multipliers for constrained optimization; determine the optimal values of the dimensions and the minimum cost.<br> | 10 | 03 | 01 |
| (b) | Show the effect of minute displacement error on curvature and on rigid body accelerations or theoretical stresses. | 10 | 01 | 04 |
| | | | | |
| Q.5 (a) | Explain the formulation of primary, subsidiary design equation and limit equation | 10 | 01 | 05 |
| (b) | A cylindrical torsion bar is to be designed for minimum weight to transmit a twisting moment Mt, = 9000 in-lb and to have a torque gradient of k= 900 in-lb/deg. Assuming a factor of safety $N_y = 1.5$. Available materials are AISI 4130, Titanium Alloy, and Aluminum Alloy. | 10 | 03 | 07 |
| | | | | |
| Q.6 (a) | Explain the case of normal and redundant specifications. | 10 | 01 | 05 |
| (b) | Four identical helical springs are to be used for supporting a milling machine weighing 5000 lb. Formulate the problem for finding wire diameter d, coil diameter D and number of turns N of each spring for minimum weight by limiting deflection to 0.1 in. and the shear stress to 10,000 psi in the spring. In addition, the natural frequency of vibration of the spring. In addition, natural frequency of the vibration of the spring is to be greater than 100 Hz. The stiffness of the spring (k), the shear stress in the spring ($\tau$), and the natural | 10 | 03 | 07 |

|  |  |  |  |  |
|---|---|---|---|---|
| • | frequency of vibration of the spring ($f_n$) are given by |  |  |  |
|  |  |  |  |  |
| Q.7(a) | Write the syntax for Matlab programme for the following linear equation:<br>Maximize $f(x_1,x_2,x_3) = -3x_1 - x_2 + 10x_3$<br>subject to,<br>$x_1 - x_2 + x_3 \le 8$<br>$x_1 - 2x_2 \ge -18$<br>$2x_1 + x_2 - 2x_3 \le 4$ | 10 | 02 | 06 |
| (b) | Figure shows two frictionless rigid bodies (carts) A and B connected by three linear elastic springs having spring constants $k_1$, $k_2$, $k_3$. The springs are at their natural positions when the applied force P is zero. Find the displacements $x_1$ and $x_2$ under the force P by using the principle of minimum potential energy.<br>Given: P = 40kN, $k_1$= 4 kN/m, $k_2$= 3 kN/m, $k_3$= 2 kN/m.<br> | 10 | 03 | 07 |

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# Sardar Patel College of Engineering

(A Government Aided Autonomous Institute)

Munshi Nagar, Andheri (West), Mumbai – 400058.

## Re- Exam--June 2016

| | | |
|---|---|---|
| Q. P. Code: | Max. Marks: **100** | Duration: **4 hrs** |
| Class: **MTech (M/c Dsg.)** | Semester: **II** | Program: **Mechanical Engineering** |
| Name of the Course: ***FRACTURE MECHANICS*** | | Course Code : ***MTMD 201*** |

**Instructions:**

- **Question No 1 is compulsory**
- **Attempt any four questions out of remaining six.**
- Assume suitable data if required and state it clearly.
- Answers to all sub-questions should be grouped together.

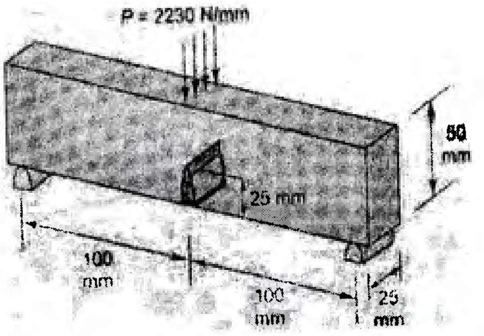
Master file.

| **Q. No.** | | | **Max Mark** | **Module** | **COs** |
|---|---|---|---|---|---|
| 1. | | Answer the following: | | | |
| | a) | List the Fracture Mechanics approaches to design. Explain in detail any one of them. | 20 | M3 | CO1 |
| | b) | In general what happens with an advancing crack in component? List typical fractured surface characteristic of ductile fracture. | | M1 | CO1, |
| | c) | What are the constraint on specimen geometry for $K_{IC}$ testing? What is the justification for each constraint? | | M5 | CO2<br>CO3 |
| | d) | What is Griffith energy criterion? Explain. | | M6 | CO2 |
| 2. | a) | Determine the energy release rate, using elementary beam theory for the configuration given in fig.no.2. | 14 | M2 | CO1,<br>CO2 |
| | b) | A large plate of 30 mm thickness with an edge crack a=25mm length is pulled very slowly under displacement control loading. At the displacement of 7.2 mm, when the recorded load is 2750 N, the crack starts growing. At a= 41.7 mm, the crack is arrested and the load decreases to 1560 N. Determine the critical energy release rate. | 3 | M2 | CO1 |
| | c) | Determine the critical energy release rate of a DCB specimen loaded in a tensile testing machine. The thickness of the DCB specimen is 30mm, depth of each cantilever 12mm and crack length 50mm. The crack is about to propagate at 15405 N pulling load. (E = 207 GPa) | 3 | M2 | CO1 |
| 3. | a) | Write down the expression of J-integral for a plane problem and explain the term involved in it. State two important features of J-integral. | 8 | M4 | CO1 |
| | b) | Consider three point bend specimen with center load as shown in fig.1. The material properties are given below: Determine: i)$K_I$ ii) Plastic zone size, iii) $G_I$ based on LEFM, iv) $J_p$ | 12 | M3,<br>M7 | CO1,<br>CO2 |

$\sigma_{ys} = \sigma_0 = 700$ MPa, $\varepsilon_0 = \sigma_0/E$
$E = 207$ GPa, $\alpha = 8.2$, $n = 6$

| | | | | | |
|---|---|---|---|---|---|
| 4. | a) | What is the fatigue fracture? How the cyclic stresses are characterized? | 5 | M6 | CO1 |
| | b) | What are the phases of fatigue life? What are the factors that affect the fatigue life? | 5 | M6 | CO2 |
| | c) | An edge crack detected in large plate, is of length 5mm under a constant amplitude cyclic load having stress range of 150 MPa and maximum stress of 322 MPa. If the plate is made of steel having $K_{IC}$ = 155 MPa $m^{0.5}$, determine—1) propagation life up to failure 2) propagation life considering the change in correction factor(for every 5mm increment of crack) if crack length is not to exceed 15mm. Take width as 200mm, C = 6.8 X $10^{-12}$ , m = 3.0 | 10 | M6,<br>M7 | CO1,<br>CO2 |
| 5 | a) | Define CTOD. Write down the expression for CTOD in terms of SIF and also in terms of rate of energy release (G). (*Use the expression of COD of mode I.*) | 10 | M4 | CO1 |
| | b) | Derive the expression for plastic zone shape in plane strain case using Tresca and Misces criterion. | 10 | M3 | CO1,<br>CO2 |
| 6 | a) | Show that, stress function chosen for mode-II crack problem (Westergaards Approach) satisfies the bi-harmonic equation. Determine the stress and displacement component in terms of $Z_{II}$. | 12 | M3 | CO1 |
| | b) | Derive the relation between SIF and energy release rate. | 4 | M2,<br>M3 | CO1 |
| | c) | What is the Griffith theory of fracture? Explain the Irwin-Orowan modifications of Griffith theory. | 4 | M2 | CO1 |
| 7 | a) | List the different types of specimens used for fracture toughness test. Sketch any one of it showing proper dimensions. | 5 | M5 | CO3 |
| | b) | Show that J-integral is path independent. | 5 | M4 | CO1 |
| | c) | Discuss variable amplitude fatigue loading analysis for life calculation. | 4 | M1 | CO1 |
| | d) | Discuss major factors influencing environment assisted fracture. | 6 | M1 | CO1 |

Fig.1


P = 2230 N/mm
50 mm
25 mm
100 mm
100 mm
25 mm

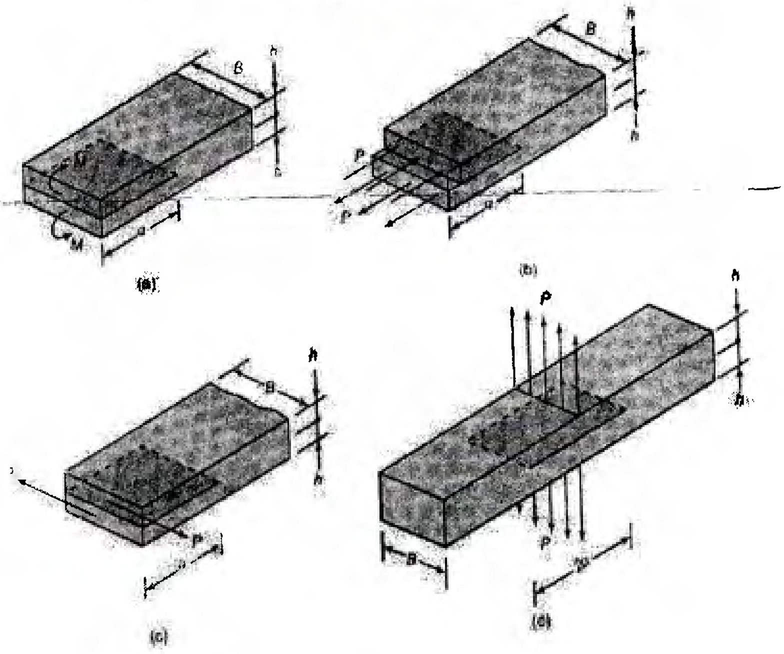

B
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Fig.2

# APPENDIX 6B

## The J-Integral of Some Common Cases through Engineering Approach

For the engineering approach (Sec. 6.6), $J_p$ is defined as $J_p = \alpha\sigma_0\varepsilon_0 b g_1 h_1 (P/P_0)^{n-1}$. In this appendix, the expressions for the geometric factor $g_1$ and collapse load $P_0$ are given, and the geometric factor $h_1$ is listed for plane stress $(p-\sigma)$ and plane strain $(p-\varepsilon)$ for some commonly encountered cases. Usually, $\sigma_0$ is chosen to be same as yield stress $(\sigma_{ys})$.

## 6B.1 THREE-POINT BEND SPECIMEN

The specimen is loaded with force $P$ per unit thickness, as shown in Fig. 6.12.

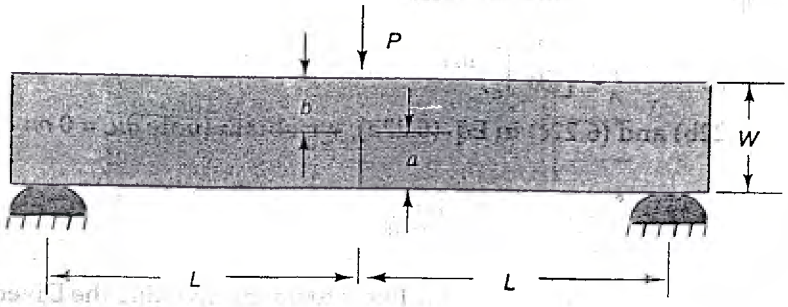

Fig. 6.12 Three-point bend specimen

$P_0 = 0.728\,\sigma_{ys}\,b^2/L$ for plane strain

$P_0 = 0.536\,\sigma_{ys}\,b^2/L$ for plane stress

$g_1 = 1$, and $h_1$ = listed in Table 6.1 for $L/W = 2$.

TABLE 6.1 $h_1$ for three-point bend specimen

| $a/W$ | Type | $n$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 5 | 7 | 10 | 13 | 16 | 20 |
| 1/8 | $p-\varepsilon$ | 0.937 | 0.869 | 0.805 | 0.687 | 0.580 | 0.437 | 0.329 | 0.245 | 0.165 |
| | $p-\sigma$ | 0.676 | 0.600 | 0.548 | 0.459 | 0.383 | 0.297 | 0.238 | 0.192 | 0.148 |
| 1/4 | $p-\varepsilon$ | 1.20 | 1.034 | 0.930 | 0.762 | 0.633 | 0.523 | 0.396 | 0.304 | 0.215 |
| | $p-\sigma$ | 0.869 | 0.731 | 0.629 | 0.479 | 0.370 | 0.246 | 0.174 | 0.117 | 0.0593 |
| 3/8 | $p-\varepsilon$ | 1.33 | 1.15 | 1.02 | 0.846 | 0.695 | 0.556 | 0.442 | 0.360 | 0.265 |
| | $p-\sigma$ | 0.963 | 0.797 | 0.680 | 0.527 | 0.418 | 0.307 | 0.232 | 0.174 | 0.105 |
| 1/2 | $p-\varepsilon$ | 1.41 | 1.09 | 0.922 | 0.675 | 0.495 | 0.331 | 0.211 | 0.135 | 0.0741 |
| | $p-\sigma$ | 1.02 | 0.767 | 0.621 | 0.453 | 0.324 | 0.202 | 0.128 | 0.0813 | 0.0298 |
| 5/8 | $p-\varepsilon$ | 1.46 | 1.07 | 0.896 | 0.631 | 0.436 | 0.255 | 0.142 | 0.084 | 0.411 |
| | $p-\sigma$ | 1.05 | 0.786 | 0.649 | 0.494 | 0.357 | 0.235 | 0.173 | 0.105 | 0.471 |
| 3/4 | $p-\varepsilon$ | 1.48 | 1.15 | 0.974 | 0.693 | 0.500 | 0.348 | 0.223 | 0.140 | 0.0745 |
| | $p-\sigma$ | 1.07 | 0.786 | 0.643 | 0.474 | 0.343 | 0.230 | 0.167 | 0.110 | 0.0442 |

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# Sardar Patel College of Engineering

(A Government Aided Autonomous Institute)
Munshi Nagar, Andheri (West), Mumbai – 400058.
**Re-Examination**
**June 2016**

Max. Marks: **100**
Class: **M. Tech. (Thermal Engg)** **Semester: II**
Name of the Course: **Design of Heat Exchanger**

Duration: **4 hrs**
Program: **Mech Engg**
Course Code: **MTTH 201**

Master file.

**Instructions:**

- Use of HMT Data Book and HEAT EXCHANGER DESIGN DATA BOOK are allowed.
- **Question No. 1 is compulsory.**
- Attempt **any Four questions** out of remaining six questions.
- Answers to all sub questions should be grouped together.
- All questions carry equal marks.
- Make suitable assumptions with proper explanations.

| **Q. No.** | | **Marks** | CO No. | M N |
|---|---|---|---|---|
| **Q. 1** | **Answer the following questions (any five)** | **20** | 1 - 3 | 1- 6 |
| **a)** | State and explain different types of flow arrangements of Gasketed plate heat exchangers? | | | |
| **b)** | What are the basic requirements heat exchangers? | | | |
| **c)** | What are the different factors to be considered for surface selection of compact heat exchanger and shell and tube heat exchanger? | | | |
| **d)** | What are the different inputs to be considered for sizing and rating of shell and tube heat exchanger? | | | |
| **e)** | State and explain the applications of Disk and Doughnut baffles with neat sketches. | | | |
| **f)** | Explain the thermo-hydraulic and mechanical design aspects of heat exchangers. | | | |
| **Q. 2 (A)** | The steam condenser of a thermal power plant operates at a pressure of 7 kPa. Cooling water is circulated with a mass flow rate of 500 kg/s through 1000 tubes of 25 mm ID and 29 mm OD made of brass (K = 110 W/m.K). The steam side heat transfer coefficient is 11500 W/m$^2$K.<br>Assuming average properties of water:<br>K = 0.6 W/m.K, $\mu = 9.6 \times 10^{-4}$ kg/ms, Pr = 6.6<br>Calculate the overall heat transfer coefficient based on the outer diameter of the tubes.<br>If the inside surfaces of the tubes are fouled due to scale formation over a period of time, and the heat transfer coefficient is estimated to be 1968 W/m$^2$K, determine the corresponding fouling factor.<br>Compute the exit temperature of water if the steam flow rate is 13 kg/s and the cooling water inlet temperature is 20°C. | **15** | 3 | 2 & 3 |

|  |  |  |  |  |
|---|---|---|---|---|
|  | State assumptions considered if any. Take $h_{fg}$ at 7 kPa = 2409.1 kJ/kg<br>Use Dittus-Bilter co-relations Nu = $\frac{h_i d_i}{K}$ = 0.023 $(Re)^{0.8}$ $(Pr)^{0.4}$ |  |  |  |
| **(B)** | Explain the following types of heat exchangers as per TEMA standards:<br>AES, BGU, CKT, AFM, NEN | **05** | 1 | 4 |
| **Q. 3 A)** | Explain the optimization methods of determination of optimum baffle spacing in design process. | **05** | 2 | 2 |
| **B)** | Prove that heat transfer coefficient is a function of Reynolds number, Prandtl number, tube diameter and mass velocity. | **05** | 2 | 2 |
| **C)** | Explain the different types of plate heat exchanger. State the different geometrical properties and operating conditions which are required for design of plate heat exchanger | **10** | 2 | 6 |
| **Q. 4 (A)** | State and explain four main types of heat exchanger failures in detail. | **10** | 3 | 1-7 |
| **(B)** | What is cooling towers? Explain different types of cooling towers. State the factors which are responsible for performance of cooling towers. | **10** | 2 | 7 |
| **Q.5 A)** | A counter flow double-pipe heat exchanger is used to cool the engine oil for a large engine. The oil at a floe rate of 1.8 kg/s is required to be cooled from 95°C to 90°C using water at a flow rate of 1.2 kg/s and 25°C. Seven meter long carbon-steel hairpin is to be used. The inner and outer pipes are 1¼ and 2 nominal schedule 40, respectively (Use ID = 35 mm and OD = 42 mm). The engine oil flows through the inner tube. How many hairpins will be required? When the heat exchanger is initially in service (no fouling) with the hairpins, determine the outlet temperatures, the heat transfer rate, and the pressure drops for heat exchanger. Assume water outlet temperature as 30°C. Use $\varepsilon$ -NTU method. Use thermal conductivity of material = 56.7 W/mK.<br>Use properties of oil at Tb:<br>$\rho$ = 848 kg/m$^3$, Cp = 2161 J/kgK, K = 0.137 W/mK, $\mu = 2.52 \times 10^{-2}$ Ns/m$^2$, Pr = 395<br>Find properties of water at Tb from property table.<br>Use friction factor f (for turbulent flow): $f = [1.58 \ln(Re) - 3.28]^{-2}$<br>and for laminar flow: $f = \frac{16}{Re}$<br>for laminar flow: Nu = 1.86 $(\frac{D_h\, Re\, Pr}{L})^{0.33}$<br>for turbulent flow:<br>$Nu_b = \frac{\left(\frac{f}{2}\right)(Re - 1000)Pr}{1 + 12.7\left(\frac{f}{2}\right)^{\frac{1}{2}}\left(Pr^{\frac{2}{3}} - 1\right)}$ | **20** | 2 & 3 | 5 |
| **Q. 6 A)** | Radiator is used to cool the engine at 50 km/h on a 7% grade road. Design engineer is to make sure that the coolant (50% water and 50% glycol) at the radiator inlet (top tank) does not exceed 120°C temperature at 100 kPa gauge radiator cap pressure.<br>Determine the radiator top tank temperature for the following conditions:<br>Engine heat rejection rate = 35 kW, Air flow rate = 0.75 kg/s, Air inlet temperature = 53°C, water glycol flow rate = 1.4 kg/s | **15** | 2 & 3 | 5 |

| | | | | |
|---|---|---|---|---|
| | Take: UA = 1180 W/k, Cp for air 1009 J/kgK, Cp for coolant = 3664 J/kgK<br>What will be the outlet temperature of coolant? Consider the radiator with both fluids unmixed. | | | |
| **B)** | Determine the type of heat exchanger to use for each of the following applications:<br>1) Heating oil with steam, 2) Cooling I C engines liquid coolant,<br>3) evaporating a hot liquid | **5** | 1 | 1-6 |
| Q. 7 | **Answer the following questions. (any Four)** | **20** | 1-6 | |
| A) | Explain the effects of fouling on heat transfer, pressure drop of heat exchanger. | | | 3 |
| **B)** | What are the different surface cleaning techniques used to control fouling? | | | 3 |
| **C)** | Explain heat exchanger design methodology with flow diagram. | | | 2 |
| **D)** | Explain the variable overall heat transfer coefficient. How it is different from constant overall heat transfer coefficient? | | | 2 |
| **E)** | Explain the methods of design of plate-fin and tube-fin compact heat exchanger. | | | 5 |
| **F)** | Write short notes on Heat transfer in helical coils and spiral heat exchanger. | | | 5 & 6 |

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# Sardar Patel College of Engineering

(A Government Aided Autonomous Institute)
Munshi Nagar, Andheri (West), Mumbai – 400058.

## RE-Examination, June 2016

**M.Tech. (Thermal), Sem-I** **M.Tech. in Mechanical Engineering**

## TRANSPORT PHENOMENA

**Max. Marks: 100** **Duration: 4 Hours**

Master file.

**Instructions:**

- Answer any **FIVE** from seven questions.
- Answers to all sub questions should be grouped together
- Make suitable assumption if needed with proper reasoning
- Figures on right in square bracket shows maximum marks for a particular sub-question.

**1.** A. Write boundary layer equation under the assumption proposed by Prandtl. What is Von Karmon's Momentum Integral equation? Derive a mathematical expression for it. **[10]**

B. Assuming second degree velocity distribution in the boundary layer, determine using the integral momentum equation, the thickness of boundary layer, friction coefficient, displacement and momentum thicknesses. **[10]**

**2.** A. What is meant by exergy? Derive the expression for exergy loss in a process executed by: **[10]**
(a) closed system,
(b) open system.

B. Differentiate between developed and developing region for laminar and turbulent flow, **[10]**

For a given flow field $\vec{V} = \left(y^2 + 2xz\right)\vec{i} + \left(-2yz + x^2yz\right)\vec{j} + \left(\frac{1}{2}x^2z^2 + x^3y^4\right)\vec{k}$ explain

(i) Is this flow possible?
(ii) Is this flow steady or unsteady?
(iii)Is it a possible incompressible flow?
(iv) Find an expression for shear stress $\tau_{xy}$ and $\tau_{yz}$.

**3.** A. Assume a steady incompressible laminar parallel flow between two parallel plates separated by a small gap 'b' and moving in opposite direction with equal velocity. Develop a governing equation for the problem using 2D-Navier Stokes equation and derive an expression for velocity profile. Estimate following quantities: **[10[**
Maximum and average velocity, (ii) Volume flow rate, and (iii) Pressure drop

B. Liquid water at 200 kPa and 20°C is heated in a chamber by mixing it with superheated steam at 200 kPa and 150°C. Liquid water enters the mixing chamber at a rate of 2.5 kg/s, and the chamber is estimated to lose heat to the surrounding air at 25°C at a rate of 1200 kJ/min. If the mixture leaves the mixing chamber at 200 kPa and 60°C, determine (*a*) the **[10[**

mass flow rate of the superheated steam and ($b$) the rate of entropy generation during this mixing process.

assuming minimum mesh size=12 cells and considering stability restriction imposed by explicit scheme, show time evolution of temperature for minimum 5 time steps in tabular form.

(Take thermal diffusivity $\alpha$ for the material as $10^{-5}$ $m^2/s$).

**[20]**

**4.** Answer any **four (04)** of the following with sufficient illustration:

(i) What is the need of thermodynamic laws for the analysis of thermal a system?

(ii) What do you understand by boundary condition? Write about common thermal and flow boundary conditions.

(iii) Discuss characteristic features of a turbulent flow.

(iv) Define boundary layer. Explain the concept of displacement and momentum thickness.

(v) What is flow separation? Why does it occur?

**[10]**

**5.** A. What is heat transfer coefficient? List down the important parameters influencing it. Show the variation of h in laminar, transition and turbulent regions and explain the reasons for such variation.

**[10]**

B. Write the differential form of common conservation law applied to a thermal system and explain the meaning of each terms involved there.

A liquid flows down an inclined plane surface in a steady, fully developed laminar film of thickness $h$. Simplify the continuity and Navier Stokes equations to model this flow field. Clearly state all the assumption made reasons.

**[10]**

**6.** A. Define and Explain the physical meaning of following non-dimensional numbers:

a. Reynolds number,
b. Nusselt number,
c. Prandtl number and
d. Grashof number

**[10]**

B. A pressure vessel has a volume of $2.83m^3$. It contains air at 7 MPa and 65°C. A valve is now opened and highly pressurized air at a rate of 0.455 kg/s and at temperature 144.4°C enters the vessel. Determine the gas pressure and temperature in the vessel after 1 minute of charging.

**[10]**

**7.** A. What is transient heat conduction? Explain it with suitable examples. Listing all assumption made in lumped parameter model analysis develop a governing equation and get a general solution. State the condition of its validity.

**[10]**

B. Write differential form of energy equation and explain the different terms involved. Simplify the equation for the following cases:

a. Two dimension transient heat conduction
b. One dimension transient heat conduction with heat generation.

The temperature distribution across a copper plate 0.65 m thick heated from one side is given by $T = 70 - 80x + 24x^2$ where T is in K and x is in meters. Calculate the heat flux at x = 0, x = 0.25 m and x = 0.65 m. Thermal conductivity of the material is 386 W/mK.