VSB College of Engineering Technical Campus
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DEPARTMENT OF MECHANICAL ENGINEERING

ME8691 COMPUTER AIDED DESIGN AND MANUFACTURING

QUESTION BANK

UNIT – I INTRODUCTION

Part A

1. Define CAD.
2. Define Automated drafting.
3. Define model coordinate system.
4. What is a geometric model? Mention its types.
5. Write the various design tasks performed by CAD system.
6. What is the graphic configuration of a graphic system?
7. What are functions of a graphic package?
8. List the types of output devices used in conjunction with computer Aided design system.
9. What are the modules of ICG?
10. Write the display devices used in computer graphics application.
11. Define Recognition of need.
12. Write the analysis step of design process.
13. Define CAD. Mention areas of application of CAD.
14. What is meant by concurrent engineering?
15. What are the advantages of Concurrent engineering?
16. What are the benefits of CAD?
17. What are the characteristics of concurrent engineering?
18. Name any 3 reasons for implementing CAD in design?
19. Define computer graphics.
20. What are the functions of IGC?
21. What are the various display control facilities in graphics?
22. What is the need of homogeneous coordinates?
23. What is viewing transformation and windowing transformation?
24. What is meant by Clipping?
25. State the use of reflection transformation.

26. What are the main types of 2D transformations?
27. Write a note on engineering design?
28. Define wireframe model.
29. Define Rotation

Part-B

1. Elaborate on the basic requirements that CAD software has to satisfy.
2. Distinguish between modes of the design process and models of designs.
3. Describe the various database models which are generally used.
4. What are the differences between the sequential approach to the product development process and the concurrent engineering approach? Why should the latter be adopted?
5. A scaling factor of 2 is applied in the Y direction while no scaling is applied in the X direction to the line whose two end points are at coordinates (1, 3) and (3, 6). The line is to be rotated subsequently through 300, in the counter clockwise direction. Determine the necessary transformation matrix for the operation and the new coordinates of the end points**.**
6. What are the reasons for implementing a computer aided design system.
7. The vertices of a triangle are situated at points (15, 30), (25, 35) and (5, 45). Find the coordinates of the vertices if the triangle is first rotated 100' counter clockwise direction about the origin and then scaled to twice its size**.**
8.. Describe the basic types of coordinate transformation in CAD, and then show how these may all be calculated using matrix operations through the homogeneous coordinate with an example of matrix .How the general rotation transformation be expressed in terms of a combination of other transformation.
9. What is meant by Interactive Computer Graphics? Explain its various elements.
10. Briefly explain the Clipping and Line drawing with an example.
11. Compare and Contrast Sequential and Concurrent Engineering with suitable examples.
12. Explain with block diagram, the CAD process with suitable examples..
13. A rectangle with co-ordinate A(2,3), B(2, 5), C(6, 5) and D(6, 3) is reflected along line whose equation is y = 2x + 4, and sheared by 2 units in x direction and 2 units in y direction. Find the new co-ordinates of the object.

14. A triangle has coordinates with A(5, 2), B(3, 5), and C(7, 5).

First rotate the triangles by about the origin and then translate the triangle 2 units in x direction and 2 unit

UNIT – II GEO METRIC MODELING

Part A

1. Define geometric modelling?
2. Classify geometric modelling.
3. Define sculptured surface.
4. What is meant by lofted surface?
5. List the common entities of a typical surface modeler?
6. Name the two basic approaches followed in solid modeling.
7. Give any two characteristics of Bezier curves.
8. Distinguish between Bezier curves and Cubic Spline curve.
9. Define B-Spline curve?
10. What is a spline?
11. What are the different ways of specifying spline curve?
12. Define surface model.
13. Define solid model.
14. Define rational curve.
15. What are the various representation schemes used in three dimensional objects?
16. What is surface patch?
17. Write short notes on rendering bi-cubic surface patches of constant u and v method?
18. What are the important properties of Bezier Curve?
19. Describe the ‘Surface patch’.
20. List out properties of B-Spline.
21. Write down two important solid modeling techniques.

Part B

1. Write a note on:
   1. NURBS
   2. B-splines.
2. Discuss the modelling guidelines to be followed by the user while constructing a surface model as a CAD/CAM system.
3. Differentiate between Bezier and B- spline surface with reference to number of

control points, order of continuity and surface normal.

4. Explain how a Bezier curve is defined.

5. What are the advantages of Bezier curves over cubic spline?

6. Explain how the curves are represented in Generic form

7. Explain how the curves are represented in parametric form.

8. Describe the effect of characteristic polyhedron over the resulting Bezier surface.

9. What do you mean by blending function? Explain rep of a surface.

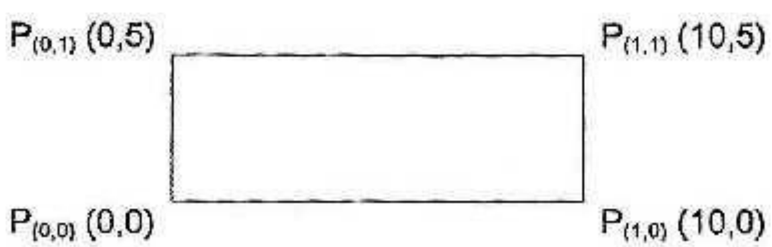
10. Briefly explain CSG and B–Rep of solid modelling techniques.

11. Explain the different schemes used to generate a solid model

12. Write short notes on approximated synthetic curves.

13. Derive the equation for Bezier Curve. Find the equation of a Bezier curve which is defined by the four points as P0 (2, 2, 0), P1(2, 3, 0), P2(3, 3, 0) and also find the points on the curve for u = 0, ¼, ½, ¾, 1.

14Find the equation of the Bezier surface with four corner points as shown in figure and also find midpoint of surface.



15. Derive the equation for Hermite Cubic spline curve.

16. Draw a Bezier spline for the following control points: (0, 0), (4, 3), (8, 4) & (12, 0)

UNIT – III CAD STANDARDS

Part A

1. Define Graphical Kernel System.
2. What is OpenGL?
3. What is IGES?
4. Define Data Exchange Standards.
5. What is Standards?
6. Write the functions of GKS.
7. List out the international organizations involved to develop the graphics standards.
8. List out the various standards in graphics programming
9. Define Graphics Kernel System (GKS)
10. Enumerate Open Graphics Library.
11. Narrate IRIS GL.
12. Define NAPLPS.
13. Define IGES
14. Define DXF
15. Define STEP
16. Define GKS
17. Define, PHIGS
18. List the various file sections in IGES.
19. List down the requirement s of data exchange.
20. State the methods of data exchange.

Part B

1. Explain the following polyhedral object using b-rep elements and verify the Euler equation for the same
   1 Simple polyhedral.
   2 Polyhedral object a face may have loops.
   3 Objects with holes that do not go through the entire object.
   4 Objects have holes that go through entire objects.

2. Sketch the following feature operations using CSG.

1. Extruded 2.revolved feature

3. Chamber 4.loft feature
5. Pocket 6.shell
7. Fillet 8.draft
9. Rib 10.Dimpe.

3. Explain briefly with sketches any six tests used for hidden line identification.
4. Describe the IGES methodology.
5. Describe the PDES methodology.
6. Compare various testing methods of IGES processors.
7. Explain about Graphics Kernel System (GKS).
8. Write short notes on drawing exchange format (DXF) standard.
9. Briefly explain any one of the known graphic standards.
10. Discuss the functions of Software Graphic package.
11. Create a CAD model and obtain the export files in different formats and make a comparative study.

UNIT – IV

FUNDAMENTAL OF CNC AND PART PROGRAMING

Part A

1. How does NC differ from CNC?
2. When do you go for incremental system? Why?
3. List the main elements of NC machine tool.
4. List out the demerits of NC machine.
5. Define continuous path control. .
6. How will you classify the CNC machines based on axis?
7. What are the advantages of CNC machines?
8. How does NC differ from conventional machines?
9. List out the merits of NC machines.
10. What is the use of drawing tool path diagram while using manual part programming?
11. How can one identify a CNC machine?
12. Define subroutine.
13. List the nature of jobs, which are suitable for NC manufacturing.
14. How does CNC increase the precision of a machine tool?
15. Define interpolation.
16. Why do we use stepper motor for axis drive?
17. What is the role of optical grating in CNC drive?
18. Why do we go in for pneumatic chuck in a CNC lathe?
19. Difference between NC lathe and Turning center.
20. What are the parts of a CNC program?
21. What are the disadvantages of manual part programming?
22. What do you meant by “Canned Cycle”?

Part – B

1. Describe the different data input devices of NC machine tool.
2. Explain the working of NC machine tool with the help of the diagram.

3. Describe the constructional details of CNC machine tools.
4. Describe the classifications of CNC based on feedback control system.
5. Describe the various type of CNC machine based on tool motion.
6. Explain the classification of interpolation.
7. Briefly explain the different types of control systems in NC.
8. Describe the features of a machining centre. Why machining centers are particularly advantage for the use of NC.
9. Briefly explain the Canned cycle in manual part programming.
10. With the aid of block diagram explain the steps involved in computer assisted part programming.
11. Briefly explain the process of CALS System.
12. Write a short note on communication standards.
13. Discuss about software used for mechanism simulations.
14. Explain CAD interference checking capabilities.
15. What are the roles of a PLC in a CNC machine?

UNIT – V

CELLULAR MANUFACTURING AND FLEXIBLE MANUFACTURING SYSTEM (FMS)

Part – A

1. What led to the development of Group Technology?
2. Define part family and machine cell.
3. What is cellular manufacturing?
4. What are the objectives of Group Technology?
5. What is Design part family?
6. What is manufacturing part family?
7. Define Hybrid code.
8. Define MICLASS.
9. Write a short note on DCLASS.
10. What is meant by Production Flow Analysis?
11. Define Composite Part concept.
12. Define FMS.
13. What are the different types of flexibility in FMS?
14. List out the various components of FMS.
15. Mention the commonly used layout for machine cell systems.
16. What are the applications of FMS?
17. List the parameters that must be met for a facility of FMS standards.
18. List the types of quantitative analysis of FMS.

Part – B

1. Enumerate the role of GT in CAD/CAM integration.
2. Briefly discuss the various benefits of implementing a GT in a firm; also bring out the advantages and limitations of using GT.
3. Define part classification and coding. How is it useful in forming group technology layout?
4. Discuss with examples the following:

(a)Monocode (b)Polycode (c)Mixed code.

5. List the factors to be considered in selecting a suitable classification and coding system.

6. Discuss DC CLASS and MI CLASS coding systems.
7. Discuss DC CLASS and OPITZ coding system with suitable examples.
8. Explain OPITZ parts classification and coding system with examples.
9. Briefly explain the techniques used in Automatic Identification systems for computer process monitoring.
10. Explain the different flexibilities in FMS.
11. Discuss tool management in relation to the operation of a FMS.
12. What is a FMC? How does FMC ensure flexibility in manufacturing?
13. Describe the additional subsystems that make a machining centre a flexible machining system.
14. Compare FMS with transfer lines and CNC on the basis of volume and variety of parts produced..

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VSB ENGINEERING COLLEGE
DEPARTMENT OF MECHANICAL ENGINEERING
ME8692 FINITE ELEMENT ANALYSIS
TWO MARKS QUESTIONS

Unit-I : INTRODUCTION

Historical Background – Mathematical Modeling of field problems in Engineering – Governing Equations – Discrete and continuous models – Boundary, Initial and Eigen Value problems– Weighted Residual Methods – Variational Formulation of Boundary Value Problems – Ritz Technique – Basic concepts of the Finite Element Method.

Introduction & Basic concepts of the Finite Element Method

1. What is meant by node? (Nov/Dec 2016 R08/10) (Nov/Dec 2015 R08/10)
2. What is discretization? (Nov/Dec 2015 R08/10)
3. What are the locations at which nodes can be positioned during discretization?
4. What are the methods generally associated with the finite element analysis? (May/June 2016)
5. State the three phases of finite element method.
6. What is meant by Pre Processing?
7. What is meant by Post Processing? (Nov/Dec 2016)
8. Classify elements, based on their dimensions. (Nov/Dec 2018) **(or)**
   How are finite elements classified?
9. Differentiate between primary and secondary variables with suitable examples. (April/May 2018)
10. Distinguish between essential and natural boundary conditions with suitable examples. (Nov/Dec 2019) (April/May 2019)
11. What are h and p versions of finite element method? (Nov/Dec 2018)
12. List the advantages of finite element method.
13. What are the applications of finite element method?
14. Name a few FEA packages. (Nov/Dec 2014 R08/10)
15. What do you mean by constitutive law? (April/May 2017)
16. Why polynomial type interpolation functions are mostly used in FEM? (April/May 2017)
17. Why are polynomial type of interpolation functions preferred over trigonometric functions? (April/May 2017 R08/10)
18. If a displacement field in x direction is given by $u = 2x^2 + 4y^2 + 6xy$. Determine the strain in x direction. (May/June 2016)

Mathematical Modeling

19. How will you mathematically model a long thin bar of varying cross section fixed at the upper end and subjected to its own self weight and a point load at the lower free end? (Nov/Dec 2019)

Boundary, Initial and Eigen Value problems

20. List the various methods of solving boundary value problems. (Nov/Dec 2016)
21. What are the differences between boundary value problem and initial value problem? (April/May 2017)

Weighted Residual Methods

22. Write about weighted residual method. (May/June 2016 R08/10) (Nov/Dec 2014 R08/10)
23. List the various weighted residual methods. (Nov/Dec 2017)
24. The general Weighted Residual Technique is expressed as , i = 1 ,2 , . . , n. Identify the weighting function associated with each of WRMs. (April/May 2019)

Variational Formulation – Ritz Technique

25. What is meant by weak formulation? (April/May 2017 R08/10)
26. Why is variational formulation referred as weak formulation? (Nov/Dec 2018)
27. Name the variational methods.
28. What are the advantages of weak formulation? (April/May 2015 R08/10)
29. What is Rayleigh-Ritz method? (Nov/Dec 2016 R08/10) (Nov/Dec 2015 R08/10)
30. Compare the Ritz technique with the nodal approximation method. (Nov/Dec 2014 R08/10) **(or)** Compare the Ritz technique with the nodal approximation technique. (Nov/Dec 2018)
31. Distinguish between Error in solution and Residual. (April/May 2015 R08/10)
32. What is the stationary property of total potential energy? (May/June 2016)
33. State the principle of minimum potential energy theorem. (May/June 2016 R08/10)

Unit-II : ONE DIMENSIONAL PROBLEMS

One Dimensional Second Order Equations – Discretization – Element types - Linear and Higher order Elements – Derivation of Shape functions and Stiffness matrices and force vectors - Assembly of Matrices - Solution of problems from solid mechanics and heat transfer. Longitudinal vibration frequencies and mode shapes. Fourth Order Beam Equation –Transverse deflections and Natural frequencies of beams.

Element types

1. What are the differences between a beam and a bar element. (April/May 2019)
2. What are higher order elements? Where are they preferred?

Shape functions

3. Define shape functions.
4. Give the properties of shape function. (Nov/Dec 2014 R08/10)
5. Polynomials are generally used as shape function, why? (Nov/Dec 2018) **(or)** Why polynomials are generally used as shape function? (Nov/Dec 2016)
6. Derive the shape functions for a 1D three noded element. (April/May 2019)
7. Derive the shape functions for a 1D quadratic bar element. (April/May 2015 R08/10)

Stiffness matrices

8. What are the properties of stiffness matrix? (April/May 2018) (April/May 2015 R08/10)
9. Write the stiffness matrix for a 1D two noded linear element. (Nov/Dec 2014 R08/10) (Nov/Dec 2017)
10. Write the expression of stiffness matrix for a truss element. (Nov/Dec 2015 R08/10)

Bar element

11. List all the differences between two noded Linear and three noded Quadratic bar element. (Nov/Dec 2019)

Beam element

12. Give the primary and secondary variables associated with the one dimensional beam element and their values at the boundary for a fixed-fixed beam and a simply supported beam. (Nov/Dec 2019)
13. Differentiate between longitudinal vibration and transverse vibration. (Nov/Dec 2018)
14. Give the Governing equation and the primary and secondary variables associated with the one dimensional beam element. (Nov/Dec 2017)

Dynamic Analysis

15. What is dynamic analysis? (Nov/Dec 2016) (Nov/Dec 2015 R08/10)
16. What is meant by transverse vibration? (April/May 2017 R08/10) (Nov/Dec 2015 R08/10)

17. Write the expression of governing equation for free axial vibration of rod and transverse vibration of beam. (May/June 2016)
18. Write the Governing equation for 1D longitudinal vibration of bar fixed at one end and give the boundary conditions. (April/May 2015 R08/10)
19. Write the expression of longitudinal vibration of bar element. (April/May 2017)
20. Write the natural frequency of bar of length 'L', Young's modulus 'E' and cross section 'A' fixed at one end and carrying lumped mass 'M' at the other end. (Nov/Dec 2017)
21. Specify the consistent mass matrix for a beam element. (Nov/Dec 2016 R08/10)
22. Consistent mass matrix gives accurate results than lumped mass matrix in dynamic analysis of bar element – Justify. (May/June 2016 R08/10)
23. Derive the mass matrix for a 1D linear bar element. (April/May 2015 R08/10) **(or)**
    Derive the mass matrix for a 2 noded element

Heat Transfer

24. Write the alalogies between structural and heat transfer problems. (Nov/Dec 2014 R08/10)
25. Write the Governing equation for one dimensional Heat transfer problem and give the boundary conditions.
26. Write the conduction, convection and thermal load matrices for 1D heat transfer through a fin. (April/May 2018)
27. Derive the convection heat transfer matrix for a 1D linear bar element. (Nov/Dec 2016 R08/10) (April/May 2015 R08/10)

Unit-III : TWO DIMENSIONAL SCALAR VARIABLE PROBLEMS

Second Order 2D Equations involving Scalar Variable Functions – Variational formulation –Finite Element formulation – Triangular elements – Shape functions and element matrices and vectors. Application to Field Problems - Thermal problems – Torsion of Non circular shafts – Quadrilateral elements – Higher Order Elements.

Scalar & Vector variable problems- Basics

1. What is meant by two-dimensional scalar variable problems?
2. Distinguish between scalar and vector variable problem in 2D. (April/May 2018)

Triangular elements – Shape functions

3. Write down the shape functions associated with the three noded linear triangular element and plot the variation of the same. (April/May 2017 R08/10) (April/May 2015 R08/10)

Thermal problems

4. What is steady state heat transfer and write its governing equation. (Nov/Dec 2018)
5. What are the boundary conditions in FEA heat transfer problems? (April/May 2017 R08/10) (May/June 2016 R08/10)
6. Write the conduction heat transfer matrix for a three noded linear triangular element. (Nov/Dec 2016 R08/10) (April/May 2015 R08/10)
7. Mention two natural boundary conditions as applied to thermal problems. (Nov/Dec 2015 R08/10)
8. Write the shape functions for two dimensional heat transfer.
9. Write the stiffness matrix for convection heat transfer of a three noded linear triangular element.

Torsion of Non circular shafts

10. Write the governing equation for the torsion of non-circular sections and give the associated boundary conditions. (Nov/Dec 2017)
11. State the assumptions in the theory of pure torsion. (Nov/Dec 2016)
12. Write the stiffness matrix used for the torsion problem of a square shaft assuming three noded triangular elements of area A. (April/May 2019)
13. Write the finite element equation for torsional triangular element.

Quadrilateral elements

14. A four noded quadrilateral element gives a better approximation than a three noded triangular element. Explain why. (Nov/Dec 2019)
15. Write the shape functions for a 4 noded quadrilateral element. (April/May 2018)
16. Write the shape functions for a four noded bi-linear rectangular element. (Nov/Dec 2017)

Higher Order Elements

17. What do you mean by Higher order element? Give examples.

Fluid Mechanics

18. Define path line and stream line. (May/June 2016)
19. Define stream line. (Nov/Dec 2015 R08/10)

Unit-IV : TWO DIMENSIONAL VECTOR VARIABLE PROBLEMS

Equations of elasticity – Plane stress, plane strain and axisymmetric problems – Body forces and temperature effects – Stress calculations - Plate and shell elements.

Plane Stress and Plane Strain Analysis

1. What are the ways by which a 3D problem can be reduced to a 2D problem? (Nov/Dec 2017) (Nov/Dec 2014 R08/10) **(or)**
What are the ways which a three dimensional problems can be reduced to a two dimensional approach? (April/May 2017)

2. What is meant by plane stress analysis? (Nov/Dec 2016) **(or)**
Define plane stress problem with a suitable example. (Nov/Dec 2016 R08/10)

3. Define plane strain analysis. (Nov/Dec 2015 R08/10)

4. Give one practical example each for Plane stress analysis and Plane strain analysis indicating the primary variables.(Nov/Dec 2019) **(or)**
Give atleast one example each for plane stress and planr strain analysis. (April/May 2017 R08/10) (April/May 2015 R08/10) **(or)**
Give the application of plane stress and plane strain problems. (May/June 2016 R08/10)

Axisymmetric Analysis

5. Brief the type of element that is best suited for analyzing a thin dome shaped structure subjected to out of plane load. (April/May 2019)

6. Give four applications where axisymmetric elements can be used. (Nov/Dec 2018) **(or)**
List the applications of axisymmetric elements. (May/June 2016 R08/10)

Element Matrices

(Strain-Displacement Matrix (or) Gradient Matrix [B], Stress-strain relationship matrix (or) Constitutive matrix [D] & Stiffness matrix [K])

7. What is meant by Constitutive Matrix? Write the same for plane stress analysis. (April/May 2019)

8. Write the Strain Displacement matrix for a 3 noded triangular element. (April/May 2018)
9. Write the stress stress-strain relationship matrix for plane strain condition. (April/May 2017)
10. Write the strain-displacement matrix for a CST element. (Nov/Dec 2016)
11. Write the constitutive matrix for axisymmetric analysis. (Nov/Dec 2019)
12. Write the stress-strain relationship matrix for an axisymmetric triangular element. (May/June 2016)

CST, QST and LST element

13. Differentiate CST and LST elements. (Nov/Dec 2018) **(or)**
    Distinguish between CST and LST elements. (April/May 2019)
14. Write the shape functions for a linear strain triangular (LST) element used for a scalar variable problem. (Nov/Dec 2019)
15. Why CST element so called? (Nov/Dec 2017) (Nov/Dec 2014 R08/10)
16. What is QST Element? (April/May 2017)
17. What is an LST element? (Nov/Dec 2016)
18. Write a displacement function equation for CST element. (May/June 2016)

Plate and Shell elements

19. Distinguish between plate and shell elements. (April/May 2018)
20. What are the assumptions used in thin plate and thick plate elements? (April/May 2017)
21. What are the types of shell element? (May/June 2016)

Unit-V : ISOPARAMETRIC FORMULATION

Natural co-ordinate systems – Isoparametric elements – Shape functions for isoparametric elements – One and two dimensions – Serendipity elements – Numerical integration and application to plane stress problems - Matrix solution techniques – Solutions Techniques to Dynamic problems – Introduction to Analysis Software

Natural co-ordinate systems

1. What are the advantages of Natural coordinates? (Nov/Dec 2019) (Nov/Dec 2014 R08/10) (April/May 2018) (Nov/Dec 2017)
2. What is the difference between natural coordinates and local coordinates? (May/June 2016)

Isoparametric, Subparametric and Super parametric elements

3. What is meant by 'Isoparametric element'? (Nov/Dec 2018)
4. Define Superparametric and subparametric element.
5. What is the purpose of isoparametric elements? (Nov/Dec 2016) (May/June 2016)
6. Write down the stiffness matrix equation for four noded isoparametric element. (April/May 2017)
7. Write the element force vector for the four noded quadrilateral element.

Shape functions

8. Write the shape functions for a 1D quadratic isoparametric element. (Nov/Dec 2014 R08/10)
9. Give the shape functions in terms of area coordinates for a three noded triangular element.

Serendipity elements

10. What are serendipity elements? Sketch a few such 2D and 3D elements. (Nov/Dec 2019)
11. With example, define Serendipity elements? (Nov/Dec 2018)
12. Sketch and write the advantages of serendipity elements. (April/May 2019)

Gaussian Quadrature

13. What is significance of Jacobian of transformation? (April/May 2019)
14. Derive the Jacobian of transformation for a 1D quadratic element. (April/May 2018)
15. Write the Jacobian for the one dimensional 2 noded linear element. (Nov/Dec 2017)
16. What are the advantages of Gauss quadrature numerical integration for isoparametric elements? (Nov/Dec 2016)
17. Write the Gaussian quadrature expression for numerical integration.

Dynamic Analysis

18. What type of analysis preferred in FEA when the structural member subjected to transient vibrations. (May/June 2016 R08/10)
19. State the principle of superposition.
20. Define dynamic analysis.

Introduction to Analysis Software

21. What are essential and natural boundary conditions? Give some examples. (April/May 2017)
22. Differentiate primary and secondary variables.

ME 8651 - DESIGN OF TRANSMISSION SYSTEMS

Question bank

UNIT I DESIGN OF FLEXIBLE ELEMENTS

Part-A (2 mark Questions)

1. How are the ends of flat-belt joined?
2. What are the five parts of roller chain?
3. Sketch the cross section of a v-belt and label its important parts.
4. Why is the face of a pulley crowned?
5. How is a wire rope specified?
6. Give the condition for maximum power transmission in terms of centrifugal tension in case of belt drive.
7. Give the relationship of ratio of tension in a v- belt drive.
8. Define maximum tension in a belt.
9. In what way the timing belt is superior to ordinary belt?
10. Derive and expression for tension ratio in a belt drive.
11. Sketch and name the different type of compound wire ropes.
12. What is meant by chordal action in chain drives?
13. Why tight-side of the belt should be at the bottom side of the pulley?
14. Explain the term "Crowning of Pulley".
15. In what way silent chain is better than ordinary driving chain?
16. What are the various losses in the power transmission by belts?
17. Name some materials used for belt drive.
18. What is done to accommodate initial sag in chain drive?

PART-B & C

1. Design a flat belt drive to transmit 6 kW at 900 rpm of the driver pulley. Speed reduction is to be 2:5:1Assume that the service is 16 hours a day.
2. Design a chain drive to transmit 6 KW at 900 rpm of a sprocket pinion. Speed reduction is 2:5:1. Driving motor is mounted on an adjustable base. Assume that load is steady, drive is horizontal and service is 16 hours/day.
3. Design a flat belt drive to transmit 25 kW at 720 rpm to an aluminium rolling machine with a speed reduction of 3.0. The distance between the shafts is 3 m. diameter of rolling machine

pulley is 1.2 m.

4. A chain driver to activate a compressor from a 15 kW electric motor at 960rpm.The compressor speed is 300rpm.the chain tension may be adjusted by shifting the motor on rails. The compressor is to work 8 hours /day.

5. Design a flat belt drive to transmit 110 kW for a system consisting of two pulleys of diameters 0.9 m and 1.2 m respectively, for a centre distance of 3.6 m, belt speed of 20 m/s and coefficient of friction =0.3.There is a slip of 1.2% at each pulley and 5% friction loss at each shaft with 20% over load.

6. A compressor is to be actuated from a 10 KW electric motor. The speed of the motor shaft is 1000 rpm and the compressor speed being 350 rpm .the minimum centre distance is 500 mm. the compressor operates 16 hours per day. Design a suitable chain drive.

7. Design a chain drive to actuate a compressor from 15KW electric motor running at 1000r.p.m, the compressor speed being 350 rpm. The minimum centre distance is 500 mm. The compressor operates 15 hours per day. The chain tension may be adjusted by shifting the motor.

8. Design a v- belt drive and calculate the actual belt tension and average stress for the following data. Driven pulley diameter, D = 500 mm, driver pulley diameter, d=150 mm, center distance C= 925 mm, speed N_1 =1000 r.p.m, N_2 =300 r.pm and power, P=7.5 KW.

9. A leather belt 9mm*250mm is use to drive a cast iron pulley 900 mm in diameter at 336 r.p.m. If the active are on the smaller pulley is 120^o and stress in tight side is 2 MPa, find the power capacity of the belt. The density of the leather may be taken as 980 kg/m^3 and coefficient of friction of leather on cast iron is 0.35.

10. Designs a chain drive to actuate a compressor from a 12 kW electric motor at 900 r.p.m , the compressor begin 250 r.p.m. Minimum centre distance should be 500 mm, the chain tension maybe adjusted by shifting the motor on rails. The compressor is to work 8 hour/day.

UNIT II SPUR GEARS AND PARALLEL AXIS HELICAL GEARS

Part-A (2 mark Questions)

1. Why is tangential component of gear tooth force called useful component?
2. Compare the contact between mating teeth of spur and helical gears?
3. When do we employ crossed helical gear?
4. What condition must be satisfied in order that a pair of spur gears may have a constant velocity ratio?
5. What is a herringbone gear? Where is it used?
6. Mention a few gear materials.
7. State an advantage and a disadvantage of helical gear.
8. What is backlash in gears?
9. What is the advantage of helical gear over spur gear?
10. State the law of gearing.
11. Specify the conditions based on which gear cutters are selected.
12. Why is dedendum value more than addendum value?
13. What is working depth of a gear-tooth?
14. What factors influence backlash in gear drives?
15. Where do we use skew helical gears?
16. What is interference in Involute profile?
17. How number of teeth affects the design of gears?
18. What are the advantages of the helical gear over spur gear?
19. State the law of Gearing.
20. What is pressure angle? What is the effect of increase in pressure angle?

PART-B & C

1. The pitch circles of a train of spur gears are shown in fig 3.gear A receives 3.5 kW power at 700 r.p.m through its shaft and rotates in clock wise direction .Gear B is the idler gear while gear C is the driven gear. The number of teeth on gears A, B and C are 30, 60 and 40 respectively, while the module is 5 mm. calculate the torque on each gear shaft; and the components of gear tooth forces.
2. A pair of helical gears is to transmit 14 KW. The teeth are 20 stubs and helix angle is 45.

Pinion runs at 10000 rpm and has 80 mm PCD. Wheel has 320 mm PCD. Both gears are made of cast steel. Design the gear pair and obtain the basic dimensions assuming a life of 1000 hours.

3. In a spur gear drive for a rock crusher, the gears are made of case hardened alloy steel. The pinion is transmitting 18 kW at 1200 r.p.m with a gear ratio of 3.5.The gear is to work 8hours/day for 3 years. Design the drives major dimensions, check for compressive and bending stresses and sketch the arrangement.

4. A pair of, helical gears subjected to heavy shock loading is to transmit 37.5 kW at 1750 rpm of the pinion. The speed reduction ratio is 4 and helix angle is 15^o .The service is continuous and the teeth are 20^o full depth in the normal plane. Select suitable material and design the gears. Check for working stresses and sketch the drive.

5. A motor shaft rotating at 1440 rpm has to transmit 15 kW to a low speed shaft rotating at 500rpm .The teeth are 20^o involute with 25 teeth on the pinion. Both the pinion and gear are made of cast iron with a maximum safe stress of 56 MPa .A safe stress of 35 Mpa may be taken for the shaft on which the gear is mounted. Design and sketch the spur gear drive to suit above conditions. The starting torque may be assumed as 1.25 times the running torque.

6. helical gear speed reducer is to be designed. The rated power of the speed reducer is 75 kW at a pinion speed of 1200 rpm .The speed ratio is 3 to 1. For medium shock conditions and 24 hours operation; determine the module, face width, number of teeth in each gear. The teeth are 20^o full depth in the normal plane. Assume suitable material.

7.A straight spur gear drive to transmit 8 kW. The pinion speed is 720 rpm and the speed ratio is 2. Both the gears are made of the same surface hardened carbon steel with 55 RC and core hardness less than 350 BHN. Ultimate strength is $720 N/mm^2$.

8.A helical gear with 30^o helix angle has to transmit 35kW at 1500 rpm. With a speed reduction ratio 2.5. If the pinion has 24 teeth, determine the necessary module, pitch diameter and face width for 20° full depths the teeth. Assume 15Ni 2Cr 1 Mo 15 material for both pinion and heel.

9. Two shafts 300 mm apart transmitting 7.46 kW are to be connected a steel pinion meshing with a cast iron gear. The velocity ratio of the drive is 3:1 and the pinion runs at 600 r.p.m. Assuming 20^o in volute tooth profile design the design.

10. A motor shaft rotating at 1500 rpm has to transmit 15 kW to a low speed shaft with a speed reduction of 3:1. Assume starting torque to be 25% higher than the running torque. The teeth are 20° involutes with 25 teeth on the pinion. Both the pinion and gear are made of C45 steel. Design a spur gear drive to suit the above conditions and check for compressive and bending stresses and plastic deformations. Also sketch the spur gear drive.

UNIT III BEVEL, WORM AND CROSS HELICAL GEARS

Part-A (2 mark Questions)

1. What are the various forces acting on a bevel gear?
2. Usually worm is made of hard material and worm gear is made of softer material- justify?
3. When is bevel gear preferred?
4. State the use of bevel gears.
5. Define zerol bevel gear.
6. Name the different application of worm gear.
7. Name the different applications of worm gear.
8. When is helical angle of worm?
9. What are commonly used materials for worm and wheel?
10. What is Herringbone gear? State its application.
11. State true or false and justify. "Mitre gears are used for connecting non-intersecting shafts".
12. State the advantages of Herringbone gear.
13. Why is multistate worm more efficient than the single start one?
14. Define the following terms: (a) Cone distance, (b) Face angle.
15. In which gear-drive, self-locking is available?
16. Where do we use skew gears?
17. What is the specific feature of a miter gear?
18. Why is the efficiency of worm gear drive comparatively low?
19. When the number start of a worm is increased in worm gear drive, how it affects the other parameters and action of the drive?
20. Define virtual(or)formative number of teeth in bevel gear.

PART-B & C

1. Design a pair of cast iron bevel gears for a special purpose machine tool to transmit 3.5 KW from a shaft at 500 rpm to another at 800 rpm.
2. Design a worm gear drive with a standard centre distance to transmit 7.5 KW from a worm rotating at 1440 rpm to a worm wheel at 20 rpm.
3. Design a bevel gear drive to transmit 10 kW at 1440 rpm. Gear ratio is 3, material for the

pinion and gear is C 45 steel. Minimum number of is to be 20.

4. A hardened steel worm rotates at 1440 rpm and transmits 11kw to a phosphor bronze gear ratio of 15. Design the worm gear drive and determine the power loss by heat generation.
5. A pair of cast iron bevel gears connect two shafts at right angles. The pitch diameters of the pinion and gear are 80 mm and 100 mm respectively. The tooth profiles of the gears are 141/2 ^{o} composite form. The allowable static stress for both the gears is 55 MPa. If the pinion transmits 2.75 kW at 1100 rpm, find the module and number of teeth on each gear and check the design. Take surface endurance limit as 630 MPa. and modulus of elasticity for cast iron as 84 kN/mm^2.
6. Design worm and gear speed reducer to transmit 22kW at a speed of 1440 rpm. The desired velocity ratio is 24:1. An efficiency of at least 85% is desired. Assume that the worm is made of hardened steel and gear of phosphor bronze. Take the centre distance as 100 mm.
7. Design a pair of bevel gears for two shafts whose axes are at right angles. The power transmitted is 25 KW. The speed of the pinion is 300 rpm and the gear is 120 rpm.
8. Design a worm gear drive to transmit 22.5 KW at a worm speed of 1440 rpm. Velocity ratio is 24:1. An efficiency of at least 85% is desired. The temperature rise should be restricted to 40^{o}C. Determine the required cooling area.
9. A 90^o degree straight bevel gear set is needed to give a 3:1 reduction. Determine the pitch cone angle, pitch circle diameter 4, and the transmitted power is 8HP at 550 pinion rpm.
10. A 2 kW power is applied to a worm shaft at 720 rpm. The worm is of quadruple start with 50mm as pitch circle diameter. The worm is of quadruple start type with 50mm as pitch circle diameter. The worm gear has 40 teeth with 5mm module. The pressure angle in the diametral plane is 20^o.Determine (i) the lead angle of the worm, (ii) velocity ratio, and (ii) centre distance. Also, calculate Efficiency of the worm gear drive, and power lost in friction.

UNIT IV GEAR BOXES

Part-A (2 mark Questions)

1. List the ways by which the number of intermediate steps may be arranged in a gear box.
2. What are the points to be considered while designing a sliding-mesh type of multi-speed gear box?
3. Which type of gear is used in constant mesh gear box? Justify.
4. Compare sliding mesh and synchromesh gear box.
5. Where is multi-speed gear boxes employed?

6. Name the series in which speeds are arranged in multi-speed gear boxes.
7. List six standard speeds starting from 18 r.p.m with a step ratio 1.4.

8. Sketch the kinematic layout of gear for 3 speeds between two shafts.
9. Draw the ray diagram for a six speed gear box.
10. What is the function of spacers in a gear-box?
11. What are the methods of lubrication in speed reducers?
12. What is the function of spacers in a gear-box?
13. What is step ratio? Name the series in which speeds of multi-speed gear box are arranged.
14. Give some applications of constant mesh gear box.

PART-B & C

1. An all geared speed gear box is to be designed for a radial drilling machine with the following specifications:Maximum size of the drill to be used=50mm, Minimum size of the drill to be used =10mm Maximum cutting speed (drilling) =40m/min, Minimum cutting speed (reaming, taping and boring) =6m/min. Number of speeds =12. Choose a 3x2x2 arrangement. Sketch the layout of the gearbox and the speed diagram. Calculate the percentage deviation of the obtainable speeds from the calculated ones.
2. Sketch three possible ray diagrams for a 6-speed gear box with 2x3 arrangements. Choose the best possible ray diagram. Give suitable explanation for the same.
3. Design a nine speed gear box for a minimum speed of 35 rpm and a maximum speed of 560 rpm. Draw the speed diagram and kinematic arrangement showing number of teeth in all gears. Check whether all the speeds obtained through the selected gears are within 3.
4. Design a 12 speed gear box for an all geared headstock of a lathe by drawing speed diagram. Show the details in a kinematic layout. The maximum and minimum speeds are to be 1400 rpm and 112 rpm respectively. Take the input drive speed to be the 1400 rpm.
5. The maximum and minimum speeds of nine speed gear box are to be 600 rpm and 100 rpm respectively. The drive is from an electric motor giving 3kW at 1440 r.p.m. Design the gear box. Construct the speed diagram and sketch the arrangement of gear box.
6. Design a 12 speed gear box for a headstock of a lathe. The maximum and minimum speeds are 600 rpm and 25 rpm respectively. The drive is from an electric motor giving 2.25 kW at 1440 r.p.m. Construct the speed diagram and sketch the arrangement of the gearbox.
7. Design a nine- speed gear box for machine to provide speeds ranging from 100 to 1500 rpm. The input is from a motor of 5 KW at 1440 r.p.m. Assume any alloy steel for the gear.

8. In a milling machine, 18 different speeds in the range of 35 rpm and 650 rpm are required. Design a three stage gear box with a standard step ratio. Sketch the layout of the gear box, indicating the number of teeth n each gear. The gear box receives 3.6 kW from an electric motor running at 1,440 rpm. Sketch also the speed diagram.
9. A gearbox is to be designed to provide 12 output speeds ranging from 160 to 200 rpm. The input speed of motor is 1600 rpm. Choosing a standard speed ratio construct the speed diagram and the kinematic arrangement calculate the no of teeth of all gears
10. A gearbox is to give 18 speeds for a spindle of a milling machine. The drive is from an electric motor of 3.75KW at 1440rpm. Maximum and minimum speeds of the spindle are to be around 650rpm and 35rpm respectively. Find the speed ratios which will give the desired speeds and draw the structural diagram and kinematic arrangement of the drive.

UNIT V CAMS, CLUTCHES AND BRAKES

Part-A (2 mark Questions)

1. What is the disadvantage of block brake with one short shoe? What is the remedy?
2. When do we use multiple disk clutches?
3. Differentiate between self-energizing and self-locking brakes.
4. Why is it necessary to dissipate the heat generated during clutch operation?
5. Name four profiles normally used in cams.
6. State the advantage of cam mechanisms.
7. How the' uniform rate of wear' assumption is valid for clutches?
8. Sketch a cone clutch.
9. What is the function of the clutch?
10. Give the reason for left and right shoes of the internal expansion brakes having, different actuating forces.
11. If a multidisc clutch has 8 discs in driving shaft and 9 discs in driven shaft, then how many number of contact surfaces it will have?
12. What is meant by self-energizing brake?.
13. Why should the temperature rise be kept within the permissible range in brakes?
14. Name four materials used for lining of friction surface in clutches.
15. Classify clutches based on the coupling methods.

16. What is fade?

17. Explain the desirable properties of friction material used for the lining of brake shoes.
18. Why in automobiles, braking action when travelling in reverse is not as effective as when moving forward?
19. What is the difference between a coupling and a clutch?

PART-B & C

1. The displacement specifications of follower are given below: Stroke of the follower 25 mm. Outstroke takes place with SHM during 90^o of cam rotation. Return stroke takes place with SHM during 75^o of cam rotation. Cam rotates with a uniform speed of 800 rpm.
Determine the induced contact stress, assuming follower mass as 0.25 kg and spring stiffness as 100 N/mm, when the cam rotation is 15^o. Take the thickness of the plate cam as 10mm. The base circle radius and the follower roller radius are 25 mm and 10 mm respectively. Material used is steel.
2. A block brake with a short shoe is shown in Fig. It is to be designed so that the product 'PV' is limited to 2, where 'P' is the normal pressure between Friction lining and the brake drum (N/mm^2) and 'v' is the peripheral velocity of brake drum (m/s).
3. A single plate clutch is used for an engine that develops a maximum torque of 120 N-m. Assume a factor of safety of 1.5 to account for slippage at full engine torque. The permissible intensity of pressure is 350 k pa and the coefficient of friction is 0.35.Calculate the inner and outer diameters of the friction lining and the axial force to be exerted by the engage the clutch.
4. A 360 mm radius brake drum contacts a single shoe as shown in resists a torque of 225 N-m at 500 rpm .The coefficient of friction is 0.3. Determine (i) the normal reaction on the shoe,(ii) the force to be applied at the lever end for counter clockwise rotation of the drum if e=0 (iii) the force to be applied at the lever end for clockwise rotation of the drum if e= 40mm.(iv) the force to be applied at the lever end for clockwise rotation of the drum if e = 40mm
5. A friction clutch is required to transmit 25 kW at 2000 rpm. It is to be single plate disc type with both sides. The pressure is exerted by means of springs and limited to 70 kN/m^2. If the maximum possible outer diameter of the clutch plate is 300 mm, find the required inner diameter of the clutch plate and the total force exerted by the spring's .assume the wear to be uniform and coefficient of friction 0.3.
6. An internal expanding shoe brake has the following dimensions:

Diameter of the drum = 300 mm, fulcrum centers = 80 mm, Distance of fulcrum centers and that of cam axis, both from the drum centre=100 mm, distance of the line of action of braking force from the cam axis=90 mm, distance between the points where the cam acts on the two brake shoes =30 mm. Each shoe subtends an angle of 90° at the drum cenre.If the breaking force is 750 N and the coefficient of friction is 0.3, find the braking torque on the drum. Assume the reactions between the brake shoes and the drum passes through the points bisects the contact angle. Also assume that forces exerted by the cam ends on the two shoes are equal.

7. Find the torque that a two surface, dry disk clutch can transmit if the outside and inside lining diameters are 120 mm and 70 mm, respectively, and the applied axial force is 10 KW. Assume uniform wear and =0.4. Is the pressure on the lining acceptable? What lining materiel would be suitable?

8. In a single block brake, the diameter of the drum is 250 mm and the angle of contact is 90°. The operating force of 700 N is applied at the end of lever which is at 250 mm from the center of the brake block. The coefficient of friction between the drum and the lining is 0.35. Determine the torque that may be transmitted. Fulcrum is at 200 mm from the centre of brake with an offset of 50 mm from the surface of contact.

9. In a band and block brake, the band is lined with 14 blocks, each of which subtends an angle of 20degrees at the drum centre. One end of band is attached to the function of the brake lever and the other to a pin 150mm from the fulcrum. Find the force required at the end of the lever 1 m long from the fulcrum to give a torque of 4kN-m. The diameter of the brake drum is 1m and the co-efficient of friction between the blocks and the drum is 0.25.

10. A multi – disk clutch has 3 disks on the driving shaft and two on the driven shaft. The inner and outer diameters of friction disks are 120mm and 240mm respectively. The coefficients of friction is 0.3 and find the max axial intensity of pressure between the discs for transmitting 25 kW at 1575 rpm .Assuming the uniform wear theory.

UNIT –I

PART -A

QUE STION AND ANSWERS

1 . Define Heat transfer?
Heat transfer can b e de fined as the transmission o f energy from one region to another region to temperature difference.
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2 . What are the mode s of heat transfer?
Conduction Convection Radiation.

3 . What is conduction?
Heat conduction n is a mechanism o f heat transfer from a region of high temperature to a region of low temperature with in a medium (Solid, liquid or Gases) or different medium in dire ct physic al contact. In conduction , energy exchange take s place b y the kinematics motion or direct impact o f mo le cu le s .Pure conduction is found only in solids.

4 . State Fourier's la w of conduction.
The rate of heat conduction is proportional to the area measured normal to the direction of heat flow and to the temperature gradient in that direction.

5 . Define Thermal conductivity
Thermal conductivity is define d as the ability of a sub stance to con duct heat.

6 . List down the three types of boundary conditions
Prescribe d temperature Prescribe d heat flux Boundary conditions.

7 . Define convection.
Convection is a process of heat transfer that will occur between solid surface and a flu id medium when they are at different temperatures. Convection is possible only in the presence of fluid medium.

8 . Define Radiation
The h ea t transfer from one body to another without any transmitting medium is known a s radiation .It is an electromagnetic wave phenomenon.

9 . State Newton's law o f cooling o r convection law.

Where A- Area exposed to heat transfer in m2 h - Heat transfer coefficient o f the surface in KT s-Temperature o f the surface in K- Temperature of the flu id in K

10. Define over all heat transfer co-efficient.

The overall heat transfer b y combined mode s is usually expressed in terms of an overall conductance o r overall heat transfer co-efficient' Heat transfer, Q

11. Define fins o r extended surfaces.

It is possible to increase the heat transfer rate by increasing the surface of heat transfer. The surfaces used for increasing heat transfer are called extended surface s some times known a s fin s.

12. State the application of fins.

1. Coo ling o f electronic components.
2. Cooling of motor cycle engines.
3. Cooling o f small capacity compressors
4. Cooling o f transformers.

13. Define fin efficiency.

The efficiency of a fin is defined a s the ratio of actual heat transferred to the maximum possible to heat transferred by the fin .

$\eta = Q_{fin} / Q_{max}$

14. Define F in effectiveness.

F in effectiveness is the ratio of heat transfer with fin to that without fin

F in effectiveness = Q with fin /Q without fin .

15. What is meant by steady state heat conduction?

If the temperature of a body does not vary with time , it is said to b e in a steady state and that type of conduction is known a s steady state heat conduction.

16. What is meant by transient heat conduction or unsteady state conduction ?

If the temperature of a body varies with time, it is said to be in a transient state and that type of conduction is known a s transient heat conduction or unsteady state conduction .

17. What is Periodic heat flow?

In Periodic heat flow, the temperature varies on a regular basis Example;

1. Cylinder o f an IC engine.
2. Surface of earth during a period of 24 hours.

18. What is non Periodic heat flow?
In non Periodic heat flow , the temperature at any point within the system varies n on linearly with time. Example :
1. Heating of an ingot in furnace .
2. Cooling of bars.

19. What is meant by Newtonian heating or cooling process?
The process in which the internal resistance is assumed as negligible in comparison with its surface resistance is known a s Newtonian heating or cooling process.

20. What is meant by Lumped he at analysis?
In a Newtonian heating or cooling process the temperature throughout the so lid is considered to be uniform a t a give n time. Such an analysis is called Lumped h ea t capacity analysis.

21. What is meant by semi-in finite solid s?
In semi-infinite solids, at any instant of time , there is always a point where the effect of heating or cooling at one of its boundaries is not felt a t all .At this point the temperature remains unchanged .In semi infinite solid s, the bio t number value s is

22. What is meant by infinite solid?
A so lid which extends itself infinitely in all directions o f space is known a s infinite solid. In infinite solids, the biot number value is in between0.1 and 100. 0.1 < Bi< 1 00

23. Define Biot number.
It is defined as the ratio of internal conductive resistance to the surface conductive resistance. Internal conductive resistance Bi= ----------------------------------- surface conductive resistance.

24. What is the significance o f Biot number?
Biot number is u se d to find Lumped he at analysis, Semi infinite solid s an d in finite solid s If Bi< 0.1 Lumped heat analysis. Bi= 0.1 < Bi< 10 025.

25. What are the factors affecting the thermal conductivity?
1. Moisture
2. Density o f material
3 . Pressure
4. Temperature
5. Structural of material.

26. Explain the significance o f thermal diffusivity.
The physic al significance of thermal diffusivity is that it tells us how fast heat is propagated or it diffuses through a material during change s of temperature with time .

27. What are Heislers charts?
In Heislers chart, the solution s for temperature distribution s and heat flows in plane walls, long cylinders and sphere s with finite in thermal and surface resistance are presented. Heislers charts are nothing but a analytic al solutions in the form of graphs

UNIT –II
PART -A
QUE STION AND ANSWER

28. What is dimensional analysis?
Dimensional analysis is a mathematic al method which makes use of the study o f the dimensions for solving several engineering problems. This method can be applied to all types o f fluid resistance, heat flow problems in flu id mechanics and thermodynamics.

29. State Buckingham’s theorem. Buckingham’s theorem state s as follow s:
“If there are n variables in a dimensionally homogeneous equation and if these contain M dimensions, then the variable s are arranged in to (n-m) dimension less terms. These dimensional terms are called Buckingham’s theorem.

30. What are all the advantages of dimensional analysis?
1. It expresses the functional relationship between the variables in dimensional terms.
2. It enables getting u p a theoretic al solution in a simplified dimensional form.
3. The results of one series o f test can be applied to a large number of other similar problems with the help of dimension an analysis.

31. What are all the limitations of dimensional analysis?
1. The complete information is no t provided by dimensional analysis .It only indicates that there is some relationship between the parameters.
2. No information is given about the internal mechanism o f physical phenomenon
3. Dimensional analysis doe s not give any clue regarding the selection of variables.

32. Define Reynolds number (Re)
It is de fined a s the ratio of inertia force to viscous force. Inertia force R e= ------------ --- Viscous force.

33. Define Prandtl number (P r)
It is the ratio of the momentum diffusivity to the thermal diffusivity. P r=Momentum diffusivity / thermal diffusivity

34. Define Nusselts Number (Nu).
It is defined as the ratio of the heat flow by convection process under an u nit temperature gradient to the heat flow rate b y conduction under an unit temperature gradient through a stationary thickness (L) of meter.

35. Define Grashof number (Gr).
It is de fined as the ratio o f product o f inertia force and buoyancy force to the square of viscous force

36. Define Stanton number (St)
It is the ratio of Mussels number to the product o f Reynolds number and Prandtl number.

37. What is meant by Newtonian and non- Newtonian flu ids?
The fluid s which obey the Newton 's la w of viscosity are called Newtonian s flu ids and those which do not obey a re called non Newtonian flu ids.

38. What is meant by laminar flow and turbulent flow?
Laminar flow :
Laminar flow is sometimes called streams line flow .In this type o f flow , the fluid move s in la ye r and each fluid particle follows a smooth continuous path . The flu id particles in each layer remain in an orderly sequence with out mixing with each other.
Turbulent flow:
In addition to the lamina r type of flow, a distinct irregular flow is frequently observed in nature. This type of flow is called turbulent flow .T he path of any individual particle is zigzag an d irregular.

39. What is hydro dynamics boundary layer?
In hydrodynamics boundary layer, velocity o f the fluid is less than 99% of free stream velocity.

40. What is thermal boundary layer?
In thermal boundary layer, temperature o f the fluid is less than 99 % of free stream temperature.

41. Define convection.
Convection is a process o f heat transfer that will occur between a solid su rfac e and a fl id medium w hen they are at different temperatures.

42. What is meant by free or natural convection?
If the fluid motion is produced due to change in density resulting from temperature Gradients, the mode of heat transfer is said to be free or natural convection.

43. What is forced convection?
If the flu id motion is artificially created by means o f an external force like a blower of fan ,that eat transfer is known as forced convection.

44. What is the form of equation used to calculate transfer for flow through cylindrical pipe s?
Nu = 0 .023 (R e) 0 .8 (P r) n n = 0.4 for heating of fluids=0.3 for cooling of flu ids

45. What are the dimensional parameters used in forced convection?
1. Reynolds number (Re)
2. Nusselt Number (Nu)
3. Prandtl number (P r)

46. Define boundary la ye r thickness.
The thickness of the boundary layer has been defined a s the distance from the surface at which the local velocity or temperature reaches 99% of the external velocity or temperature.

47. Indicate the concept of significance of boundary layer.
In the boundary layer concept the flow field over a body is divided in to two regions: A thin region near the body called the boundary layer where the velocity and the temperature gradients are large. The region outside the boundary layer where the velocity and the temperature gradients are very nearly equal to their free stream values.

48. Define displacement thickness.
The displacement thickness is the distance , measured perpendicular to the boundary , by which the free stream is displaced on account of formation of boundary layer.

49. Define momentum thickness.
The momentum thickness is defined as the distance through which the total loss o f Momentum per second be equal to if it were passing a stationary plate.

50. Define energy thickness.
The energy thickness can be defined as the distance, measured perpendicular to the o f the solid body ,by which the boundary should be displaced to compensate for the reduction in kinetic energy of the flowing fluid on account o f boundary layer formation

UNIT –III
PART -A
QUE STION AND ANSWERS

51. Define boiling.
The change o f phase from liquid to vapour state is known as boiling

52. What is meant by condensation?
The change of phase from vapour to liquid state is known as condensation.

53. Give the application of boiling and condensation.
Boiling and condensation process finds wide application as mentioned be lo w.
1. Thermal and nuclear power point
2. Refrigeration systems.
3. Process of heating and cooling.
4. Air conditioning system .

54. What is meant pool boiling?
If heat is added to a liquid from a submerge d solid surface , the boiling process is referred to as pool boiling. In this case the liquid above the hot surface is essentially stagnant and it motion near the surface e is due to free convection and mixing induced by bubble growth and detachment.

55. What are the modes of condensation ?
There are two modes of condensation
1. Film wise condensation.
2. Drop wise condensation

56. What is Film wise condensation?
The liquid condensate wets the so lid surface , spread out and form s a continuo us film over the en tire surface is known as film wise condensation .

57. What is Drop wise condensation?

The vapour condenses into small liquid drop lets of various sizes which fall down the surface in a random fashion.

58. What is heat exchange?
The heat exchange is defined a s equipment which transfers the heat from a hot fluid to a co ld fluid.

59. What are the types of heat exchanger?
The type s o f heat exchangers are as follow s.
1. Direct con tact heat exchangers.
2. In direct contact heat exchangers
3. Surface heat exchangers
4. Parallel flow heat exchanger

60. What is meant by indirect contact heat exchangers?
In this type of heat exchangers, the transfer o f heat between two fluids could be Carried out by transmission through a wall which separates the two fluids

61. What is meant by Regenerators?
In this type o f heat exchangers, hot and co ld fluids flow alternately through the same. Example s: IC engines, Gas turbine.

62. What is meant by Recuperators or surface heat exchangers?
This is the most common type of heat exchangers in which the hot and cold flu id do no t come into direct contact with each other but are separated by a tube wall o r a surface Examples: Auto mobile radiators, Air pre heaters, economizers

63. What is meant by parallel flow heat exchangers?
In this type o f heat exchangers, hot and cold fluids move in the same direction.

64. What is meant by Counter flow heat exchangers?
In this type of heat exchangers, ho t an d cold flu ids move in parallel but opposite direction

65. What is meant by cross flow heat exchangers?
In this type o f heat exchangers, hot and cold fluids move at right angles to each other.

66. What is meant by Shell and tube heat exchangers?
In this type of heat exchangers, one of the fluids move s through a bund le o f tube s enclosed by a she ll. The other fluid is forced through the shell an d it moves over the outside surface of the tubes.

67. What is meant by Compact heat exchangers?
There are many special purpose heat exchangers called compact heat exchangers. They are generally employed when convection heat transfer co-efficient associated with one of the fluid s is much smaller than that associated with the other fluid .

68. What is meant by LMT D?
We know that the temperature difference between the ho t an d co ld fluids in the heat exchangers varies from point to point. In addition various modes o f heat exchanger are involved. Therefore based on concept of appropriate mean temperature difference, also called logarithmic mean temperature difference

69. What is meant Fouling factor?
We know, the surface s of heat exchangers do not remain clean after it has been in use for some time .The surface become fouled with scaling or deposits .The effect of these deposits affecting the value o f overall heat transfer coefficient. This effect is taken ca re of by introducing an additional thermal resistance called fouling resistance.

70. What is meant by Effectiveness?
The heat exchanger effectiveness is defined a s the ratio of actual heat transfer to the maximum possible heat transfer. £=actual heat transfer/maximum possible heat transfer

UNIT –IV
PART A
QUE STION AND UNIT ANSWERS

71. Define Radiation?
The h ea t transfer from on e body to another without any transmitting medium is known a s radiation .It is a n electromagnetic wave phenomenon.

72. Define emissive power?
The emissive power is defined as the total amount of radiation emitted by a body per unit time and unit area .It is expressed in W/m2.

73. Define monochromatic emissive power.
The energy emitted by the surface at a given length per unit time area in all direction is known as monochromatic emissive power.

74. What is meant by absorptive?
Absorptive is define d as the ratio between radiation absorbed and incident radiation

75. What is meant by reflectivity?
Reflectivity is defined a s the ratio of radiation reflected to the incident radiation

76. What is meant by transmissivity?
Transmissivity is de fine d as the ratio of radiation transmitted to the incident radiation

77. What is black body?
Black body is an ideal surface having the following prop erties.1. A black body absorbs all incident radiation, regardless o f wave length a d direction.2. For a prescribed temperature and wave length, n o surface can emit more energy than black body.

78. State Wien's displacement law.
The Wien's displacement law gives the relationship between temperature and wave length corresponding to the maximum spectral emissive power of the black body a t that temperature. T ma x= C3C3= 2.9 * 10-3 T ma x= 2.9 * 10-3mk

79. State the Stefan –Boltzmann law.
The emissive power of a black body is proportion al to the fourth power of absolute temperature. Eb = Emissive p owe r W/m2
Stefan –Boltzmann constant = 5.67 * 10-8W/m2 K4

80. Define Emissivity.
It is de fined as the ability of the surface of a body to radiate heat .It is also defined as the ratio of emissive power of anybody to the emissive power of a black body of equal temperature

81. What is meant by gray body?
If a body absorbs a definite percentage o f incident radiation irrespective of their wave length, the body is known as gray body. The emissive power of a gray body is always less than that of the black body.

82. State Kirchhoff's law of radiation.
This law states that the ratio o f total emissive power to the absorptive is constant for all surfaces which are in thermal equilibrium with the surrounding. It also states that the emissivity o f the body is always equal to its absorptivity when the body remains in thermal equilibrium with its surroundings.

83. Define intensity of radiation (Ib).
It is defined as the rate o f energy leaving a space in a given direction per un it so lid angle per unit area of the emitting surface normal to the mean direction in space.

85. What is the purpose of radiation shield ?
Radiation shield constructed from lo w emissivity (high reflective) materials. It is used to reduce the ne t radiation transfer between two surfaces.

86. Define Irradiation (G)?
It is defined as the total radiation incident upon a surface per unit time per un it area . It is expressed in W/m2

87. What is radiosity (J)
It is used to indicate the total radiation leaving a surface per unit time per un it area. It is expressed in W/m2.

88. What are the assumptions made to calculate radiation exchange between the surfaces?
1. All surfaces are considered to be either black of gray.
2. Radiation and reflection process are assumed to b e diffuse .
3. The absorptivity o f a surface is taken equal to the emissivity and independent o f temperature o f the source of the incident radiation.

89. What is meant by shape factor and mention its physic al significance .
The shape facto r is de fined a s
"The fraction o f the radioactive energy that is diffused from one surface element and strikes the other surface directly with no intervening reflection " it is represented by Fij.Other names for radiation shape factor are view factor, angle factor and configuration factor .The shape facto r is u se d in the analysis of radioactive heat exchange between two surface s

90. Discuss the radiation characteristics of carbon dioxide and water vapour.
T h e C O 2 andH2 O both absorb and emit radiation over certain wave length region s called absorption bands. The radiation in these gases is a volume phenomenon. The

emissivity of CO2and the emissivity of H2O at a particular temperature increases with partial pressure and mean beam length.

UNIT –V

PART-A

91. Define Schmidt Number?
It is defined as the ratio of the molecular diffusivity o f momentum to the molecular diffusivity of mass
.
92. Define Scherwood number.
It is de fined a s the ratio of concentration gradient at the boundary.

93. Define Mass Concentration .
Mass of a component per unit volume of the mixture .It is expressed in k g/m3.

94. Define Mass Concentration .
Mass of a component per unit volume of the mixture .It is expressed in k g/m3

95. Define mass fraction.
The mass fraction is de fine d as the ratio o f mass concentration of species to the total density of the mixture

96. Define mole fractions.
The mole fraction is de fine d as the ratio o f mole concentration of species to the total molar concentration.
It state s that the total emissive power Eb from a radiating plane surface in any direction proportional to the cosine o f the angle of emission

ME 2251 Heat and Mass Transfer

Unit-1 Conduction

Part -B

1. A wall is constructed of several layers. The first layer consists of masonry brick 20 cm. thick of thermal conductivity 0.66 W/mK, the second layer consists of 3 cm thick mortar of thermal conductivity 0.6 W/mK, the third layer consists of 8 cm thick lime stone of thermal conductivity 0.58 W/mK and the outer layer consists of 1.2 cm thick plaster of thermal conductivity 0.6 W/mK. The heat transfer coefficient on the interior and exterior of the wall are 5.6 W/m^{2}K and 11 W/m^{2}K respectively. Interior room temperature is 22°C and outside air temperature is -5°C.

Calculate

a) **Overall heat transfer coefficient**
b) **Overall thermal resistance**
c) **The rate of heat transfer**
d) **The temperature at the junction between the mortar and the limestone.**

Given Data

Thickness of masonry L_1 = 20cm = 0.20 m

Thermal conductivity K_1 = 0.66 W/mK

Thickness of mortar L_2 = 3cm = 0.03 m

Thermal conductivity of mortar K_2 = 0.6 W/mK

Thickness of limestone L_3 = 8 cm = 0.08 m

Thermal conductivity K_3 = 0.58 W/mK

Thickness of Plaster L_4 = 1.2 cm = 0.012 m

Thermal conductivity K_4 = 0.6 W/mK

Interior heat transfer coefficient h_a = 5.6 W/m^{2}K

Exterior heat transfer co-efficient h_b = 11 W/m^{2}K

Interior room temperature T_a = 22°C + 273 = 295 K

Outside air temperature T_b = -5°C + 273 = 268 K.

Solution:

Heat flow through composite wall is given by

$Q = \frac{\Delta T_{overall}}{R}$ [From equation (13)] (or) [HMT Data book page No. 34]

Where, $\Delta T = T_a - T_b$

$$R = \frac{1}{h_a A} + \frac{L_1}{K_1 A} + \frac{L_2}{K_2 A} + \frac{L_3}{K_3 A} + \frac{L_4}{K_4 A} + \frac{1}{h_b A}$$

$$\Rightarrow Q = \frac{T_a - T_b}{\frac{1}{h_a A} + \frac{L_1}{K_1 A} + \frac{L_2}{K_2 A} + \frac{L_3}{K_3 A} + \frac{L_4}{K_4 A} + \frac{1}{h_b A}}$$

$$\Rightarrow Q/A = \frac{295 - 268}{\frac{1}{5.6} + \frac{0.20}{0.66} + \frac{0.03}{0.6} + \frac{0.08}{0.58} + \frac{0.012}{0.6} + \frac{1}{11}}$$

Heat transfer per unit area $Q/A = 34.56\ W/m^2$

We know, Heat transfer $Q = UA (T_a - T_b)$ [From equation (14)]

Where U – overall heat transfer co-efficient

$$\Rightarrow U = \frac{Q}{A \times (T_a - T_b)}$$

$$\Rightarrow U = \frac{34.56}{295 - 268}$$

Overall heat transfer co-efficient $U = 1.28\ W/m^2K$

We know

Overall Thermal resistance (R)

$$R = \frac{1}{h_a A} + \frac{L_1}{K_1 A} + \frac{L_2}{K_2 A} + \frac{L_3}{K_3 A} + \frac{L_4}{K_4 A} + \frac{1}{h_b A}$$

For unit Area

$$R = \frac{1}{h_a} + \frac{L_1}{K_1} + \frac{L_2}{K_2} + \frac{L_3}{K_3} + \frac{L_4}{K_4} + \frac{1}{h_b}$$

$$= \frac{1}{56} + \frac{0.20}{0.66} + \frac{0.03}{0.6} + \frac{0.08}{0.58} + \frac{0.012}{0.6} + \frac{1}{11}$$

$R = 0.78\ K/W$

Interface temperature between mortar and the limestone T_3

Interface temperatures relation

$$\Rightarrow Q = \frac{T_a - T_1}{R_a} = \frac{T_1 - T_2}{R_1} = \frac{T_2 - T_3}{R_2} = \frac{T_3 - T_4}{R_3} = \frac{T_4 - T_5}{R_4} = \frac{T_5 - T_b}{R_b}$$

$$\Rightarrow Q = \frac{T_a - T_1}{R_a}$$

$$Q = \frac{295 - T_1}{1/h_a A} \qquad \left[\because R_a = \frac{1}{h_a A}\right]$$

$$\Rightarrow Q/A = \frac{295 - T_1}{1/h_a}$$

$$\Rightarrow 34.56 = \frac{295 - T_1}{1/5.6}$$

$$\Rightarrow \boxed{T_1 = 288.8\ K}$$

$$\Rightarrow Q = \frac{T_1 - T_2}{R_1}$$

$$Q = \frac{288.8 - T_2}{\frac{L_1}{K_1 A}} \qquad \left[\because R_1 = \frac{L_1}{k_1 A}\right]$$

$$\Rightarrow Q/A = \frac{288.8 - T_2}{\frac{L_1}{K_1}}$$

$$\Rightarrow 34.56 = \frac{288.8 - T_2}{\frac{0.20}{0.66}}$$

$$\Rightarrow \boxed{T_2 = 278.3\ K}$$

$$\Rightarrow Q = \frac{T_2 - T_3}{R_2}$$

$$Q = \frac{278.3 - T_3}{\frac{L_2}{K_2 A}} \qquad \left[\because R_2 = \frac{L_2}{K_2 A}\right]$$

$$\Rightarrow Q/A = \frac{278.3 - T_3}{\frac{L_2}{K_2}}$$

$$\Rightarrow 34.56 = \frac{278.3 - T_3}{\frac{0.03}{0.6}}$$

$$\Rightarrow \boxed{T_3 = 276.5\ K}$$

Temperature between Mortar and limestone (T_3 is 276.5 K)

2. A furnace wall made up of 7.5 cm of fire plate and 0.65 cm of mild steel plate. Inside surface exposed to hot gas at 650°C and outside air temperature 27°C. The convective heat transfer co-efficient for inner side is 60 W/m^{2}K. The convective heat transfer co-efficient for outer side is 8W/m^{2}K. Calculate the heat lost per square meter area of the

furnace wall and also find outside surface temperature.

Given Data

Thickness of fire plate L_1 = 7.5 cm = 0.075 m

Thickness of mild steel L_2 = 0.65 cm = 0.0065 m

Inside hot gas temperature T_a = 650°C + 273 = 923 K

Outside air temperature T_b = 27°C + 273 = 300°K

Convective heat transfer co-efficient for

Inner side $h_a = 60 W/m^2K$

Convective heat transfer co-efficient for

Outer side $h_b = 8 W/m^2K$.

Solution:

(i) Heat lost per square meter area (Q/A)

Thermal conductivity for fire plate

$K_1 = 1035 \times 10^{-3}$ W/mK [From HMT data book page No.11]

Thermal conductivity for mild steel plate

K_2 = 53.6W/mK [From HMT data book page No.1]

Heat flow $Q = \frac{\Delta T_{overall}}{R}$, Where

$\Delta T = T_a - T_b$

$$R = \frac{1}{h_a A} + \frac{L_1}{K_1 A} + \frac{L_2}{K_2 A} + \frac{L_3}{K_3 A} + \frac{1}{h_b A}$$

$$\Rightarrow Q = \frac{T_a - T_b}{\frac{1}{h_a A} + \frac{L_1}{K_1 A} + \frac{L_2}{K_2 A} + \frac{L_3}{K_3 A} + \frac{1}{h_b A}}$$

[The term L_3 is not given so neglect that term]

$$\Rightarrow Q = \frac{T_a - T_b}{\frac{1}{h_a A} + \frac{L_1}{K_1 A} + \frac{L_2}{K_2 A} + \frac{L_3}{K_3 A} + \frac{1}{h_b A}}$$

The term L_3 is not given so neglect that term]

$$\Rightarrow Q = \frac{T_a - T_b}{\frac{1}{h_a A} + \frac{L_1}{K_1 A} + \frac{L_2}{K_2 A} + \frac{1}{h_b A}}$$

$$Q / A = \frac{923 - 300}{\frac{1}{60} + \frac{0.075}{1.035} + \frac{0.0065}{53.6} + \frac{1}{8}}$$

$$\boxed{Q / A = 2907.79\ W / m^2}$$

(ii) Outside surface temperature T_3

We know that, Interface temperatures relation

$$Q = \frac{T_a - T_b}{R} = \frac{T_a - T_1}{R_a} = \frac{T_1 - T_2}{R_1} = \frac{T_2 - T_3}{R_2} = \frac{T_3 - T_b}{R_b} \ldots\ldots\ldots (A)$$

$$(A) \Rightarrow Q = \frac{T_3 - T_b}{R_b}$$

where

$$R_b = \frac{1}{h_b A}$$

$$\Rightarrow Q = \frac{T_3 - T_b}{\frac{1}{h_b A}}$$

$$\Rightarrow Q/A = \frac{T_3 - T_b}{\frac{1}{h_b}}$$

$$\Rightarrow 2907.79 = \frac{T_3 - 300}{\frac{1}{8}}$$

$$\boxed{T_3 = 663.473\ K}$$

3. A steel tube (K = 43.26 W/mK) of 5.08 cm inner diameter and 7.62 cm outer diameter is covered with 2.5 cm layer of insulation (K = 0.208 W/mK) the inside surface of the tube receivers heat from a hot gas at the temperature of 316°C with heat transfer co-efficient of 28 W/m^{2}K. While the outer surface exposed to the ambient air at 30°C with heat transfer co-efficient of 17 W/m^{2}K. Calculate heat loss for 3 m length of the tube.

Given

Steel tube thermal conductivity K_1 = 43.26 W/mK

Inner diameter of steel d_1 = 5.08 cm = 0.0508 m
Inner radius r_1 = 0.0254 m
Outer diameter of steel d_2 = 7.62 cm = 0.0762 m
Outer radius r_2 = 0.0381 m
Radius $r_3 = r_2$ + thickness of insulation
Radius r_3 = 0.0381 + 0.025 m r_3 = 0.0631 m
Thermal conductivity of insulation K_2 = 0.208 W/mK
Hot gas temperature T_a = 316°C + 273 = 589 K
Ambient air temperature T_b = 30°C + 273 = 303 K
Heat transfer co-efficient at inner side h_a = 28 W/m²K
Heat transfer co-efficient at outer side h_b = 17 W/m²K
Length L = 3 m

Solution :

Heat flow $Q = \frac{\Delta T_{overall}}{R}$ [From equation No.(19) or HMT data book Page No.35]

Where $\Delta T = T_a - T_b$

$$R = \frac{1}{2\pi L}\left[\frac{1}{h_a r_1} + \frac{1}{K_1} In\left[\frac{r_2}{r_1}\right] + \frac{1}{K_2} In\left[\frac{r_3}{r_2}\right] + \frac{1}{K_3} In\left[\frac{r_4}{r_3}\right] + \frac{1}{h_b r_4}\right]$$

$$\Rightarrow Q = \frac{T_a - T_b}{\frac{1}{2\pi L}\left[\frac{1}{h_a r_1} + \frac{1}{K_1} In\left[\frac{r_2}{r_1}\right] + \frac{1}{K_2} In\left[\frac{r_3}{r_2}\right] + \frac{1}{K_3} In\left[\frac{r_4}{r_3}\right] + \frac{1}{h_b r_4}\right]}$$

[The terms K_3 and r_4 are not given, so neglect that terms]

$$\Rightarrow Q = \frac{T_a - T_b}{\frac{1}{2\pi L}\left[\frac{1}{h_a r_1} + \frac{1}{K_1} In\left[\frac{r_2}{r_1}\right] + \frac{1}{K_2} In\left[\frac{r_3}{r_2}\right] + \frac{1}{h_b r_3}\right]}$$

$$\Rightarrow Q = \frac{589 - 303}{\frac{1}{2\pi \times 3}\left[\frac{1}{28 \times 0.0254} + \frac{1}{43.26} In\left[\frac{0.0381}{0.0254}\right] + \frac{1}{0.208} In\left[\frac{0.0631}{0.0381}\right] + \frac{1}{17 \times 0.0631}\right]}$$

$$\boxed{Q = 1129.42 \text{ W}}$$

Heat loss Q = 1129.42 W.

4. Derive an expression of Critical Radius of Insulation For A Cylinder.

Consider a cylinder having thermal conductivity K. Let r_1 and r_0 inner and outer radii of insulation.

Heat transfer $Q = \dfrac{T_i - T_\infty}{\dfrac{In\left[\dfrac{r_0}{r_1}\right]}{2\pi KL}}$ [From equation No.(3)]

Considering h be the outside heat transfer co-efficient.

$$\therefore Q = \frac{T_i - T_\infty}{\dfrac{In\left[\dfrac{r_0}{r_1}\right]}{2\pi KL} + \dfrac{1}{A_0 h}}$$

Here $A_0 = 2\pi r_0 L$

$$\Rightarrow Q = \frac{T_i - T_\infty}{\dfrac{In\left[\dfrac{r_0}{r_1}\right]}{2\pi KL} + \dfrac{1}{2\pi r_0 Lh}}$$

To find the critical radius of insulation, differentiate Q with respect to r_0 and equate it to zero.

$$\Rightarrow \frac{dQ}{dr_0} = \frac{0 - (T_i - T_\infty)\left[\dfrac{1}{2\pi KLr_0} - \dfrac{1}{2\pi hLr_0^2}\right]}{\left(\dfrac{1}{2\pi KL} In\left[\dfrac{r_0}{r_1}\right] + \dfrac{1}{2\pi hLr_0}\right)^2}$$

since $(T_i - T_\infty) \neq 0$

$$\Rightarrow \frac{1}{2\pi KLr_0} - \frac{1}{2\pi hLr_0^2} = 0$$

$$\Rightarrow \boxed{r_0 = \frac{K}{h} = r_c}$$

5. A wire of 6 mm diameter with 2 mm thick insulation (K = 0.11 W/mK). If the convective heat transfer co-efficient between the insulating surface and air is 25 W/m²L, find the critical thickness of insulation. And also find the percentage of change in the heat transfer rate if the critical radius is used.

Given Data

d_1= 6 mm
r_1 = 3 mm = 0.003 m
$r_2 = r_1 + 2 = 3 + 2 = 5$ mm = 0.005 m
K = 0.11 W/mK

h_b = 25 W/m^{2}K

Solution :

1. Critical radius $r_c = \frac{K}{h}$ [From equation No.(21)]

$$r_c = \frac{0.11}{25} = 4.4 \times 10^{-3} m$$

$$\boxed{r_c = 4.4 \times 10^{-3} m}$$

Critical thickness = $r_c - r_1$

$$= 4.4 \times 10^{-3} - 0.003$$

$$= 1.4 \times 10^{-3} \text{ m}$$

$$\boxed{\text{Critical thickness } t_c = 1.4 \times 10^{-3} \text{ (or) } 1.4 \text{ mm}}$$

2. Heat transfer through an insulated wire is given by

$$Q_1 = \frac{T_a - T_b}{\frac{1}{2\pi L}\left[\frac{\ln\left[\frac{r_2}{r_1}\right]}{K_1} + \frac{1}{h_b r_2}\right]}$$

[From HMT data book Page No.35]

$$= \frac{2\pi L\,(T_a - T_b)}{\left[\frac{\ln\left[\frac{0.005}{0.003}\right]}{0.11} + \frac{1}{25 \times 0.005}\right]}$$

$$Q1 = \frac{2\pi L\,(T_a - T_b)}{12.64}$$

Heat flow through an insulated wire when critical radius is used is given by

$$Q_2 = \frac{T_a - T_b}{\frac{1}{2\pi L}\left[\frac{\ln\left[\frac{r_c}{r_1}\right]}{K_1} + \frac{1}{h_b r_c}\right]} \qquad [r_2 \rightarrow r_c]$$

$$= \frac{2\pi L\,(T_a - T_b)}{\dfrac{\ln\left[\dfrac{4.4\times10^{-3}}{0.003}\right]}{0.11} + \dfrac{1}{25\times4.4\times10^{-3}}}$$

$$Q_2 = \frac{2\pi L\,(T_a - T_b)}{12.572}$$

$\therefore$ Percentage of increase in heat flow by using

$$\text{Critical radius} = \frac{Q_2 - Q_1}{Q_1}\times100$$

$$= \frac{\dfrac{1}{12.57} - \dfrac{1}{12.64}\times100}{\dfrac{1}{12.64}}$$

$= 0.55\%$

6. **An aluminium alloy fin of 7 mm thick and 50 mm long protrudes from a wall, which is maintained at 120°C. The ambient air temperature is 22°C. The heat transfer coefficient and conductivity of the fin material are 140 W/m^{2}K and 55 W/mK respectively. Determine**

1. Temperature at the end of the fin.
2. Temperature at the middle of the fin.
3. Total heat dissipated by the fin.

Given

Thickness t = 7mm = 0.007 m
Length L= 50 mm = 0.050 m
Base temperature T_b = 120°C + 273 = 393 K
Ambient temperature T_∞ = 22° + 273 = 295 K
Heat transfer co-efficient h = 140 W/m^{2}K
Thermal conductivity K = 55 W/mK.

Solution :

Length of the fin is 50 mm. So, this is short fin type problem. Assume end is insulated.

We know

Temperature distribution [Short fin, end insulated]

$\dfrac{T - T_\infty}{}$ $\quad T_b - T_\infty$

$= \frac{\cos h\ m[L - x]}{\cos h\ (mL)}$ .... (A)

[From HMT data book Page No.41]

(i) Temperature at the end of the fin, Put x = L

(A) $\Rightarrow \quad \frac{T - T_\infty}{T_b - T_\infty} = \frac{\cos h\ m\,[L\text{-}L]}{\cos h\,(mL)}$

$\Rightarrow \quad \frac{T - T_\infty}{T_b - T_\infty} = \frac{1}{\cos h\,(mL)}$ ...(1)

where

$m = \sqrt{\frac{hP}{KA}}$

P = Perimeter = 2 ×L (Approx)

= 2 × 0.050

$\boxed{P = 0.1\text{ m}}$

A – Area = Length × thickness = 0.050 × 0.007

$\boxed{A = 3.5 \times 10^{-4} m^2}$

$\Rightarrow m = \sqrt{\frac{hP}{KA}}$

$= \sqrt{\frac{140 \times 0.1}{55 \times 3.5 \times 10^{-4}}}$

$\boxed{m = 26.96}$

(1) $\Rightarrow \quad \frac{T - T_\infty}{T_b - T_\infty} = \frac{1}{\cos\ h\,(26.9 \times 0.050)}$

$\Rightarrow \quad \frac{T - T_\infty}{T_b - T_\infty} = \frac{1}{2.05}$

$\Rightarrow \quad \frac{T - 295}{393 - 295} = \frac{1}{2.05}$

$\Rightarrow T - 295 = 47.8$

$\Rightarrow \quad \boxed{T = 342.8\text{ K}}$

$\boxed{\text{Temperature at the end of the fin } T_{x=L} = 342.8\text{ K}}$

(ii) Temperature of the middle of the fin,

Put x = L/2 in Equation (A)

(A) $\Rightarrow \dfrac{T - T_\infty}{T_b - T_\infty} = \dfrac{\cos h\, m\,[L - L/2]}{\cos h\,(mL)}$

$$\Rightarrow \frac{T - T_\infty}{T_b - T_\infty} = \frac{\cos h\, 26.9\left[0.050 - \dfrac{0.050}{2}\right]}{\cos h\,[26.9 \times (0.050)]}$$

$$\Rightarrow \frac{T - 295}{393 - 295} = \frac{1.234}{2.049}$$

$$\Rightarrow \frac{T - 295}{393 - 295} = 0.6025$$

$$\boxed{T = 354.04\ K}$$

Temperature at the middle of the fin

$$\boxed{T_{x = L/2} = 354.04\ K}$$

(iii) Total heat dissipated

[From HMT data book Page No.41]

$\Rightarrow Q = (hPKA)^{1/2}(T_b - T_\infty)\tan h\,(mL)$

$\Rightarrow [140 \times 0.1 \times 55 \times 3.5 \times 10^{-4}]^{1/2} \times (393 - 295)$

$\times \tan h\,(26.9 \times 0.050)$

$\boxed{Q = 44.4\ W}$

7. **A copper plate 2 mm thick is heated up to 400°C and quenched into water at 30°C. Find the time required for the plate to reach the temperature of 50°C. Heat transfer co-efficient is 100 W/m^{2}K. Density of copper is 8800 kg/m^3. Specific heat of copper = 0.36 kJ/kg K.**
Plate dimensions = 30 × 30 cm.
[Oct. 97 M.U. April '97 Bharathiyar University]

Given

Thickness of plate L = 2 mm = 0.002 m
Initial temperature T_0 = 400°C + 273 = 673 K
Final temperature T = 30°C + 273 = 303 K
Intermediate temperature T = 50°C + 273 = 323 K
Heat transfer co-efficient h = 100 W/m^{2}K
Density ρ = 8800 kg/m^3
Specific heat C_ρ= 360 J/kg k
Plate dimensions = 30 × 30 cm

To find

Time required for the plate to reach 50°C.

[From HMT data book Page No.2]

Solution:

Thermal conductivity of the copper K = 386 W/mK
For slab,

Characteristic length $L_c = \frac{L}{2}$

$= \frac{0.002}{2}$

$\boxed{L_c = 0.001 \text{ m}}$

We know,

Biot number $B_i = \frac{hL_c}{K}$

$= \frac{100 \times 0.001}{386}$

$B_i = 2.59 \times 10^{-4} < 0.1$

Biot number value is less than 0.1. So this is lumped heat analysis type problem.

For lumped parameter system,

$$\frac{T - T_\infty}{T_0 - T_\infty} = e^{\left[\frac{-hA}{C_\rho \times V \times \rho} \times t\right]} \text{..........(1)}$$

[From HMT data book Page No.48]

We know,

Characteristics length $L_c = \frac{V}{A}$

$$(1) \Rightarrow \frac{T - T_\infty}{T_0 - T_\infty} = e^{\left[\frac{-h}{C_\rho \times L_c \times \rho} \times t\right]}$$

$$\Rightarrow \frac{323 - 303}{673 - 303} = e^{\left[\frac{-100}{360 \times 0.001 \times 8800} \times t\right]}$$

$$\Rightarrow \boxed{t = 92.43 \text{ s}}$$

Time required for the plate to reach 50°C is 92.43 s.

8.

. A steel ball (specific heat = 0.46 kJ/kgK. and thermal conductivity = 35 W/mK) having 5 cm diameter and initially at a uniform temperature of 450°C is suddenly placed in a control environment in which the temperature is maintained at 100°C. Calculate the time required for the balls to attained a temperature of 150°C. Take h = 10W/m^{2}K.

[M.U. April-2000, 2001, 2002, Bharathiyar Uni. April 98] Bharathiyar Uni. April 98]

Given

Specific heat C_ρ = 0.46 kJ/kg K = 460 J/kg K
Thermal conductivity K = 35 W/mK
Diameter of the sphere D = 5 cm = 0.05 m
Radius of the sphere R = 0.025 m
Initial temperature T_0 = 450°C + 273 = 723 K
Final temperature T_∞ = 100°C + 273 = 373 K
Intermediate temperature T = 150°C + 273 = 423 K
Heat transfer co-efficient h = 10 W/m^2K

To find

Time required for the ball to reach 150°C
[From HMT data book Page No.1]

Solution

Density of steel is 7833 kg/m^3

$$\boxed{\rho = 7833\ kg/m^3}$$

For sphere,

Characteristic Length $L_c = \frac{R}{3}$

$$= \frac{0.025}{3}$$

$$\boxed{L_c = 8.33 \times 10^{-3}\ m}$$

We know,

Biot number $B_i = \frac{hL_c}{K}$

$$= \frac{10 \times 8.3 \times 10^{-3}}{35}$$

$B_i = 2.38 \times 10^{-3} < 0.1$

Biot number value is less than 0.1. So this is lumped heat analysis type problem.

For lumped parameter system,

$$\frac{T - T_\infty}{T_0 - T_\infty} = e^{\left[\frac{-hA}{C_\rho \times V \times \rho} \times t\right]} \ldots\ldots\ldots(1)$$

[From HMT data book Page No.48]

We know,

Characteristics length $L_c = \frac{V}{A}$

$$(1) \Rightarrow \frac{T - T_\infty}{T_0 - T_\infty} = e^{\left[\frac{-h}{C_\rho \times L_c \times \rho} \times t\right]}$$

$$\Rightarrow \frac{423 - 373}{723 - 373} = e^{\left[\frac{-10}{460 \times 8.33 \times 10^{-3} \times 7833} \times t\right]}$$

$$\Rightarrow \ln \frac{423 - 373}{723 - 373} = \frac{-10}{460 \times 8.33 \times 10^{-3} \times 7833} \times t$$

$$\Rightarrow \boxed{t = 5840.54 \text{ s}}$$

Time required for the ball to reach 150°C is 5840.54 s.

9. Alloy steel ball of 2 mm diameter heated to 800°C is quenched in a bath at 100°C. The material properties of the ball are K = 205 kJ/m hr K, ρ = 7860 kg/m^3, C_ρ = 0.45 kJ/kg K, h = 150 KJ/ hr m^2 K. Determine (i) Temperature of ball after 10 second and (ii) Time for ball to cool to 400°C.

Given

Diameter of the ball D = 12 mm = 0.012 m
Radius of the ball R = 0.006m
Initial temperature T_0 = 800°C + 273 = 1073 K
Final temperature T_∞ = 100°C + 273 = 373 K
Thermal conductivity K = 205 kJ/m hr K

$$= \frac{205 \times 1000 J}{3600 \text{ s mK}}$$

$$= 56.94 \text{ W/mK} \qquad [\because \text{J/s} = \text{W}]$$

Density ρ = 7860 kg/m^3
Specific heat C_ρ = 0.45 kJ/kg K
= 450 J/kg K

Heat transfer co-efficient h = 150 kJ/hr m^2 K

$$= \frac{150 \times 1000 J}{3600 \text{ s m}^2\text{K}}$$

$$= 41.66 \text{ W / m}^2\text{K}$$

Solution

Case (i) Temperature of ball after 10 sec.

For sphere,

Characteristic Length $L_c = \frac{R}{3}$

$$= \frac{0.006}{3}$$

$$\boxed{L_c = 0.002 \text{ m}}$$

We know,

Biot number $B_i = \frac{hL_c}{K}$

$$= \frac{41.667 \times 0.002}{56.94}$$

$B_i = 1.46 \times 10^{-3} < 0.1$

Biot number value is less than 0.1. So this is lumped heat analysis type problem.

For lumped parameter system,

$$\frac{T - T_\infty}{T_0 - T_\infty} = e^{\left[\frac{-hA}{C_\rho \times V \times \rho} \times t\right]} \text{..........(1)}$$

[From HMT data book Page No.48]

We know,

Characteristics length $L_c = \frac{V}{A}$

$$(1) \Rightarrow \frac{T - T_\infty}{T_0 - T_\infty} = e^{\left[\frac{-h}{C_\rho \times L_c \times \rho} \times t\right]} \text{..........(2)}$$

$$\Rightarrow \frac{T - 373}{1073 - 373} = e^{\left[\frac{-41.667}{450 \times 0.002 \times 7860} \times 10\right]}$$

$$\Rightarrow \boxed{T = 1032.95 \text{ K}}$$

Case (ii) Time for ball to cool to 400°C

$\therefore T = 400°C + 273 = 673$ K

$$(2) \Rightarrow \frac{T - T_\infty}{T_0 - T_\infty} = e^{\left[\frac{-h}{C_\rho \times L_c \times \rho} \times t\right]} \text{.......(2)}$$

$$\Rightarrow \frac{673 - 373}{1073 - 373} = e^{\left[\frac{-41.667}{450 \times 0.002 \times 7860} \times t\right]}$$

$$\Rightarrow \ln\left[\frac{673 - 373}{1073 - 373}\right] = \frac{-41.667}{450 \times 0.002 \times 7860} \times t$$

$$\Rightarrow \boxed{t = 143.849 \text{ s}}$$

10. A large steel plate 5 cm thick is initially at a uniform temperature of 400°C. It is suddenly exposed on both sides to a surrounding at 60°C with convective heat transfer co-efficient of 285 W/m^{2}K. Calculate the centre line temperature and the

temperature inside the plate 1.25 cm from themed plane after 3 minutes.

Take K for steel = 42.5 W/mK, α for steel = 0.043 m^2/hr.

Given

Thickness L = 5 cm = 0.05 m
Initial temperature T_i = 400°C + 273 = 673 K
Final temperature T_∞ = 60°C + 273 = 333 K
Distance x = 1.25 mm = 0.0125 m
Time t = 3 minutes = 180 s
Heat transfer co-efficient h = 285 W/m^2K
Thermal diffusivity α = 0.043 m^2/hr = 1.19×10^{-5} m^2/s.
Thermal conductivity K = 42.5 W/mK.

Solution

For Plate :

Characteristic Length $L_c = \frac{L}{2}$

$$= \frac{0.05}{2}$$

$$\boxed{L_c = 0.025 \text{ m}}$$

We know,

Biot number $B_i = \frac{hL_c}{K}$

$$= \frac{285 \times 0.025}{42.5}$$

$$\Rightarrow \boxed{B_i = 0.1675}$$

0.1 < B_i < 100, So this is infinite solid type problem.

Infinite Solids

Case (i)

[To calculate centre line temperature (or) Mid plane temperature for infinite plate, refer HMT data book Page No.59 Heisler chart].

X axis $\rightarrow$ Fourier number = $\frac{\alpha t}{L_c^2}$

$$= \frac{1.19 \times 10^{-5} \times 180}{(0.025)^2}$$

$$\boxed{\text{X axis} \rightarrow \text{Fourier number} = 3.42}$$

Curve $= \frac{hL_c}{K}$

$$= \frac{285 \times 0.025}{42.5} = 0.167$$

$$\boxed{\text{Curve} = \frac{hL_c}{K} = 0.167}$$

X axis value is 3.42, curve value is 0.167, corresponding Y axis value is 0.64

$$\text{Y axis} = \frac{T_0 - T_\infty}{T_i - T_\infty} = 0.64$$

$$\frac{T_0 - T_\infty}{T_i - T_\infty} = 0.64$$

$$\Rightarrow \quad \frac{T_0 - T_\infty}{T_i - T_\infty} = 0.64$$

$$\Rightarrow \quad \frac{T_0 - 333}{673 - 333} = 0.64$$

$$\Rightarrow \quad \boxed{T_0 = 550.6 \text{ K}}$$

$$\boxed{\text{Center line temperature } T_0 = 550.6 \text{ K}}$$

Case (ii) Temperature (T_x) at a distance of 0.0125 m from mid plane

[Refer HMT data book Page No.60, Heisler chart]

$$\text{X axis} \rightarrow \text{Biot number } B_i = \frac{hL_c}{K} = 0.167$$

$$\text{Curve} \rightarrow \frac{x}{L_c} = \frac{0.0125}{0.025} = 0.5$$

X axis value is 0.167, curve value is 0.5, corresponding Y axis value is 0.97.

$$\frac{T_x - T_\infty}{T_0 - T_\infty} = 0.97$$

$$\text{Y axis} = \frac{T_x - T_\infty}{T_0 - T_\infty} = 0.97$$

$$\Rightarrow \quad \frac{T_x - T_\infty}{T_0 - T_\infty} = 0.97$$

$$\Rightarrow \quad \frac{T_x - 333}{550.6 - 333} = 0.97$$

$$\Rightarrow \quad \boxed{T_x = 544 \text{ K}}$$

Temperature inside the plate 1.25 cm from the mid plane is 544 K.

Unit-2 Convection

Part-B

1. **Air at 20°C, at a pressure of 1 bar is flowing over a flat plate at a velocity of 3 m/s. if the plate maintained at 60°C, calculate the heat transfer per unit width of the plate. Assuming the length of the plate along the flow of air is 2m.**

Given : Fluid temperature T_∞ = 20°C, Pressure p = 1 bar,

Velocity U = 3 m/s, Plate surface temperature T_w = 60°C,

Width W = 1 m, Length L = 2m.

Solution : We know,

Film temperature $T_f = \frac{T_w + T_\infty}{2}$

$= \frac{60 + 20}{2}$

$T_f = 40°C$

Properties of air at 40°C:

Density ρ = 1.129 Kg/m^3 Thermal conductivity K = 26.56×10^{-3} W/mK,

Kinematic viscosity $v = 16.96 \times 10^{-6} m^2/s$ Prandtl number Pr = 0.699

We know, Reynolds number Re = $\frac{UL}{v} = \frac{3 \times 2}{16.96 \times 10^{-6}}$

$= 35.377 \times 10^4$

$Re = 35.377 \times 10^4 < 5 \times 10^5$

Reynolds number value is less than 5×10^5, so this is laminar flow.

For flat plate, Laminar flow,

Local Nusselt Number $Nu_x = 0.332 (Re)^{0.5} (Pr)^{0.333}$

$Nu_x = 0.332\ (35.377 \times 10^4)^{0.5} \times (0.699)^{0.333}$

$Nu_x = 175.27$

We know that,

Local Nusselt Number $Nu_x = \frac{h_s \times L}{}$

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K

$$\Rightarrow 175.27 = \frac{h_s \times 2}{26.56 \times 10^{-3}}$$

Local heat transfer coefficient h_x = 2.327 W/m^{2}K   We know,

Average heat transfer coefficient $h = 2 \times h_x$ $h = 2 \times 2.327$

h = 4.65 W/m^{2}K

Heat transfer $Q = h\,A\,(T_w - T_\infty)$

$= 4.65 \times 2\ (60 - 20)$

$[\therefore \text{Area} = \text{width} \times \text{length} = 1 \times 2 = 2]$

$Q = 372$ Watts.

2. Air at 20°C at atmospheric pressure flows over a flat plate at a velocity of 3 m/s. if the plate is 1 m wide and 80°C, calculate the following at x = 300 mm.

1. Hydrodynamic boundary layer thickness,
2. Thermal boundary layer thickness,
3. Local friction coefficient,
4. Average friction coefficient,
5. Local heat transfer coefficient
6. Average heat transfer coefficient,
7. Heat transfer.

Given: Fluid temperature T_∞ = 20°C   Velocity U = 3 m/s

Wide   W = 1 m   Surface temperature Tw = 80°C

Distance x = 300 mm = 0.3 m

Solution: We know, Film temperature $T_f = \frac{T_w + T_\infty}{2}$

$$= \frac{80 + 20}{2}$$

$T_f = 50°C$

Properties of air at 50°C

Density ρ = 1.093 kg/m^3

Kinematic viscosity v = 17.95 $\times 10^{-6}$ m^2 / s

Pr andtl number Pr =0.698

Thermal conductivity $K = 28.26 \times 10^{-3} W / mK$

We know,

Reynolds number $Re = \frac{UL}{v}$

$$= \frac{3 \times 0.3}{17.95 \times 10^{-6}}$$

$$Re = 5.01 \times 10^4 < 5 \times 10^5$$

Since $Re < 5 \times 10^5$, flow is laminar

For Flat plate, laminar flow,

1. Hydrodynamic boundary layer thickness:

$$\delta_{hx} = 5 \times x \times (Re)^{-0.5}$$

$$= 5 \times 0.3 \times (5.01 \times 10^4)^{-0.5}$$

$$\delta_{hx} = 6.7 \times 10^{-3} m$$

2. Thermal boundary layer thickness:

$$\delta_{TX} = \delta_{hx} (Pr)^{-0.333}$$

$$\Rightarrow \delta_{TX} = \left(6.7 \times 10^{-3}\right)(0.698)^{-0.333}$$

$$\delta_{TX} = 7.5 \times 10^{-3} m$$

3. Local Friction coefficient:

$$C_{fx} = 0.664 (Re)^{-0.5}$$

$$= 0.664 (5.01 \times 10^4)^{-0.5}$$

$$C_{fx} = 2.96 \times 10^{-3}$$

4. Average friction coefficient:

$$\overline{C_{fL}} = 1.328 (Re)^{-0.5}$$

$$= 1.328 (5.01 \times 10^4)^{-0.5}$$

$$= 5.9 \times 10^{-3}$$

$$\overline{C_{fL}} = 5.9 \times 10^{-3}$$

5. Local heat transfer coefficient (h_x):

Local Nusselt Number $Nu_x = 0.332 (Re)^{0.5} (Pr)^{0.333}$

$= 0.332\ (5.01 \times 10^4)\ (0.698)^{0.333}$

$Nu_x = 65.9$

We know

Local Nusselt Number

$$Nu_x = \frac{h_x \times L}{K}$$

$$65.9 = \frac{h_x \times 0.3}{23.26 \times 10^{-3}} \quad [\because x = L = 0.3m]$$

$\Rightarrow h_x = 6.20\ W/m^2K$

Local heat transfer coefficient $h_x = 6.20\ W/m^2K$

6. Average heat transfer coefficient (h):

$$h = 2 \times h_x$$
$$= 2 \times 6.20$$
$$h = 12.41\ W/m^2K$$

7. Heat transfer:

We know that,
$$Q = h\,A(T_w - T_\infty)$$
$$= 12.41 \times (1 \times 0.3)\ (80-20)$$
$$Q = 23.38\ \text{Watts}$$

3. Air at 30°C flows over a flat plate at a velocity of 2 m/s. The plate is 2 m long and 1.5 m wide. Calculate the following:

1. **Boundary layer thickness at the trailing edge of the plate,**
2. **Total drag force,**
3. **Total mass flow rate through the boundary layer between x = 40 cm and x = 85 cm.**

Given: Fluid temperature $T_\infty = 30°C$

Velocity	$U = 2\ m/s$
Length	$L = 2\ m$
Wide W	$W = 1.5\ m$

To find:

1. **Boundary layer thickness**

2. **Total drag force.**
3. **Total mass flow rate through the boundary layer between x = 40 cm and x = 85 cm.**

Solution: Properties of air at 30°C

$\rho = 1.165$ kg/m^3

$v = 16 \times 10^{-6}$ m^2 / s

$Pr = 0.701$

$K = 26.75 \times 10 - 3$ W / mK

We know,

Reynolds number $Re = \frac{UL}{v}$

$= \frac{2 \times 2}{16 \times 10^{-6}}$

$Re = 2.5 \times 10^5 < 5 \times 10^5$

Since Re<5 $\times 10^5$,flow is laminar

For flat plate, laminar flow, [from HMT data book, Page No.99]

Hydrodynamic boundary layer thickness

$\delta_{hx} = 5 \times x \times (Re)^{-0.5}$

$= 5 \times 2 \times (2.5 \times 10^5)^{-0.5}$

$\delta_{hx} = 0.02$ m

Thermal boundary layer thickness,

$\delta_{tx} \delta_{hx} \times (Pr)^{-0.333}$

$= 0.02 \times (0.701)^{-0.333}$

$\delta_{TX} = 0.0225$ m

We know,

Average friction coefficient,

$$\overline{C_{fL}} = 1.328\ (Re)^{-0.5}$$
$$= 1.328 \times (2.5 \times 10^5)^{-0.5}$$
$$\overline{C_{fL}} = 2.65 \times 10^{-3}$$

We know

$$\overline{C_{fL}} = \frac{t}{\frac{\rho U^2}{2}}$$

$$\Rightarrow 2.65 \times 10^{-3} = \frac{t}{\frac{1.165 \times (2)^2}{2}}$$

$\Rightarrow$ Average shear stress $t = 6.1 \times 10^{-3} N/m^2$

Drag force = Area $\times$ Average shear stress

$= 2 \times 1.5 \times 6.1 \times 10^{-3}$

Drag force = 0.018 N

Drag force on two sides of the plate

$= 0.018 \times 2$

$= 0.036$ N

Total mass flow rate between x = 40 cm and x= 85 cm.

$$\Delta m = \frac{5}{8} \rho U \left[\delta_{hx} = 85 - \delta_{hx} = 40\right]$$

Hydrodynamic boundary layer thickness

$$\delta_{hx=0.5} = 5 \times x \times (Re)^{-0.5}$$
$$= 5 \times 0.85 \times \left[\frac{U \times x}{v}\right]^{-0.5}$$

$$= 5 \times 0.85 \times \left[\frac{2 \times 0.85}{16 \times 10^{6}}\right]^{-0.5}$$

$$\delta_{HX=0.85} = 0.0130 \text{ m}$$

$$\delta_{hx=0.40} = 5 \times x \times (Re)^{-0.5}$$

$$= 5 \times 0.40 \times \left(\frac{U \times x}{v}\right)^{-0.5}$$

$$= 5 \times 0.40 \times \left(\frac{2 \times 0.40}{16 \times 10^{-6}}\right)^{-0.5}$$

$$\delta_{HX=0.40} = 8.9 \times 10^{-3} \text{ m}$$

(1) $\Rightarrow \Delta m = \frac{5}{8} \times 1.165 \times 2 \left[0.0130 - 8.9 \times 10^{-3}\right]$

$\Delta m = 5.97 \times 10^{-3}$ Kg/s,

4. **Air at 290°C flows over a flat plate at a velocity of 6 m/s. The plate is 1m long and 0.5 m wide. The pressure of the air is 6 kN/^{2}. If the plate is maintained at a temperature of 70°C, estimate the rate of heat removed form the plate.**

Given : Fluid temperature T_∞ = 290°C Velocity U = 6 m/s. Length L = 1 m

Wide W = 0.5 m Pressure of air P = 6 kN/m^2 $= 6 \times 10^3 N/m^2$

Plate surface temperature T_w = 70°C

To find: Heat removed from the plate

Solution: We know, Film temperature $T_f = \frac{T_w + T_\infty}{2}$

$$= \frac{70 + 290}{2}$$

$$T_f = 180°C$$

Properties of air at 180°C (At atmospheric pressure)

$\rho = 0.799$ Kg/m^3

$\nu = 32.49 \times 10^{-6}$ m^2 / s

$Pr = 0.681$

$K = 37.80 \times 10^{-3}$ W/mK

Note: Pressure other than atmospheric pressure is given, so kinematic viscosity will vary with pressure. Pr, K, C_p are same for all pressures.

Kinematic viscosity $\nu = \nu_{atm} \times \frac{P_{atm}}{P_{given}}$

$$\Rightarrow \nu = 32.49 \times 10^{-6} \frac{1 \text{ bar}}{6 \times 10^3 N/m^2}$$

[∵ Atmospheric pressure = 1 bar]

$$= 32.49 \times 10^{-6} \times \frac{10^5 N/m^2}{6 \times 10^3 N/m^3}$$

[∵ 1 bar = $1 \times 10^5 N/m^2$]

Kinematic viscosity v = $5.145 \times 10^{-4} m^2/s$.

We know, Reynolds number $Re = \frac{UL}{v}$

$$= \frac{6 \times 1}{5.145 \times 10^{-4}}$$

$Re = 1.10 \times 10^4 - 5 \times 10^5$

Since Re< 5×10^5, flow is laminar

For plate, laminar flow,

Local nusselt number

$$NU_x = 0.332 (Re)^{0.5} (Pr)^{0.333}$$

$$= 0.332 (1.10 \times 10^4)^{0.5} (0.681)^{0.333}$$

$NU_x = 30.63$

We know $NU_x = \frac{h_x L}{K}$

$$30.63 = \frac{h_x \times 1}{37.80 \times 10^{-3}} \quad [∵ L = 1 \text{ m}]$$

Local heat transfer coefficient $h_x = 1.15 W/m^2K$

We know

Average heat transfer coefficient $h = 2 \times h_x$

$$h = 2 \times 1.15$$

$$h = 2.31 \text{ W/m}^2\text{K}$$

We know

Heat transferred $Q = h\,A\,(T_\infty - T_w)$

$= 2.31 \times (1 \times 0.5) \times (563 - 343)$

$Q = 254.1\,W$

Heat transfer from both side of the plate = 2×254.1

= 508.2 W.

5. Air at 40°C flows over a flat plate, 0.8 m long at a velocity of 50 m/s. The plate surface is maintained at 300°C. Determine the heat transferred from the entire plate length to air taking into consideration both laminar and turbulent portion of the boundary layer. Also calculate the percentage error if the boundary layer is assumed to be turbulent nature from the very leading edge of the plate.

Given : Fluid temperature T_∞ = 40°C, Length L = 0.8 m, Velocity U = 50 m/s , Plate surface temperature T_w = 300°C

To find :

1. Heat transferred for:
   i. Entire plate is considered as combination of both laminar and turbulent flow.
   ii. Entire plate is considered as turbulent flow.
2. Percentage error.

Solution: We know Film temperature $T_f = \frac{T_w - T_\infty}{2} T$

$= \frac{300 + 40}{2} = 443\ K$

$T_f = 170°C$

Pr operties of air at 170°C:

$\rho = 0.790\ Kg/m^3$

$\nu = 31.10 \times 10^{-6}\ m^2/s$

$Pr = 0.6815$

$K = 37 \times 10^{-3}\ W/mK$

We know

Reynolds number $Re = \frac{UL}{v}$

$= \frac{50 \times 0.8}{31.10 \times 10^{-6}} = 1.26 \times 10^6$

$Re = 1.26 \times 10^6 > 5 \times 10^5$

$Re > 5 \times 10^5$,so this is turbulent flow

Case (i): Laminar – turbulent combined. [It means, flow is laminar upto Reynolds number value is 5×10^5, after that flow is turbulent]

Average nusselt number = $Nu = (Pr)^{0.333} (Re)^{0.8} - 871$

$Nu = (0.6815)^{0.333} [0.037 (1.26 \times 10^6)^{0.8} - 871$

Average nusselt number Nu = 1705.3

We know $Nu = \frac{hL}{K}$

$$1705.3 = \frac{h \times 0.8}{37 \times 10^{-3}}$$

$h = 78.8 \text{ W/m}^2\text{K}$

Average heat transfer coefficient

$h = 78.8 \text{ W/m}^2\text{K}$

Head transfer $Q_1 = h \times A \times (T_w + T_\infty)$

$= h \times L \times W \times (T_w + T_\infty)$

$= 78.8 \times 0.8 \times 1 \times (300 - 40)$

$Q_1 = 16390.4 \text{ W}$

Case (ii) : Entire plate is turbulent flow:

Local nusselt number} $Nux = 0.0296 \times (Re)^{0.8} \times (Pr)^{0.333}$

$NU_x = 0.0296 \times (1.26 \times 10^6)^{0.8} \times (0.6815)^{0.333}$

$NU_x = 1977.57$

We know $NU_x = \frac{h_x \times L}{K}$

$$1977.57 = \frac{h_x \times 0.8}{37 \times 10^{-3}}$$

$h_x = 91.46 \text{ W/m}^2\text{K}$

Local heat transfer coefficient $h_x = 91.46 \text{ W/m}^2\text{K}$

Average heat transfer coefficient (for turbulent flow)

$h = 1.24 \times h_x$

$= 1.24 \times 91.46$

Average heat transfer coefficient} h = 113.41 W/m^2K

We know Heat transfer $Q_2 = h \times A \times (T_w + T_\infty)$

$= h \times L \times W \times (T_w + T_\infty)$

$= 113.41 \times 0.8 \times 1\ (300 - 40)$

$Q_2 = 23589.2$ W

2. Percentage error = $\frac{Q_2 - Q_1}{Q_1}$

$= \frac{23589.2 - 16390.4}{16390.4} \times 100$

= 43.9%

6. **250 Kg/hr of air are cooled from 100°C to 30°C by flowing through a 3.5 cm inner diameter pipe coil bent in to a helix of 0.6 m diameter. Calculate the value of air side heat transfer coefficient if the properties of air at 65°C are**

K = 0.0298 W/mK

μ = 0.003 Kg/hr – m

Pr = 0.7

ρ = 1.044 Kg/m^3

Given : Mass flow rate in = 205 kg/hr

$= \frac{205}{3600}$ Kg/ s in = 0.056 Kg/s

Inlet temperature of air T_{mi} = 100°C

Outlet temperature of air T_{mo} = 30°C

Diameter D = 3.5 cm = 0.035 m

Mean temperature $T_m = \frac{T_{mi} + T_{mo}}{2} = 65°C$

To find: Heat transfer coefficient (h)

Solution:

Reynolds Number Re = $\frac{UD}{\nu}$

Kinematic viscosity $\nu = \frac{\mu}{\rho}$

$$\frac{\frac{0.003}{3600}\ \text{Kg/ s} - \text{m}}{1.044\ \text{Kg/m}^3}$$

$\text{v} = 7.98 \times 10^{-7}\ \text{m}^2/\text{s}$

Mass flow rate in = ρ A U

$$0.056 = 1.044 \times \frac{\pi}{4} \times D^2 \times U$$

$$0.056 = 1.044 \times \frac{\pi}{4} \times (0.035)^2 \times U$$

$\Rightarrow$ U = 55.7 m/s

(1) Re = $\frac{UD}{\nu}$

$= \frac{55.7 \times 0.035}{7.98 \times 10^{-7}}$

Re = 2.44×10^6

Since Re > 2300, flow is turbulent

For turbulent flow, general equation is (Re > 10000)

$$Nu = 0.023 \times (Re)^{0.8} (Pr)^{0.3}$$

This is cooling process, so n = 0.3

$\Rightarrow$ Nu = $0.023 \times (2.44 \times 10^6)^{0.8} (0.7)^{0.3}$

$Nu = 2661.7$

We know that, $Nu = \frac{hD}{K}$

$$2661.7 = \frac{h \times 0.035}{0.0298}$$

Heat transfer coefficient h = 2266.2 W/m^{2}K

7. **In a long annulus (3.125 cm ID and 5 cm OD) the air is heated by maintaining the temperature of the outer surface of inner tube at 50°C. The air enters at 16°C and leaves at 32°C. Its flow rate is 30 m/s. Estimate the heat transfer coefficient between air and the inner tube.**

Given : Inner diameter D_i = 3.125 cm = 0.03125 m

Outer diameter D_o = 5 cm = 0.05 m

Tube wall temperature T_w = 50°C

Inner temperature of air T_{mi} = 16°C

Outer temperature of air t_{mo} = 32°C

Flow rate U = 30 m/s

To find: Heat transfer coefficient (h)

Solution:

Mean temperature $T_m = \frac{T_{mi} + T_{mo}}{2}$

$= \frac{16 + 32}{2}$

$T_m = 24°C$

Properties of air at 24°C:

$\rho = 1.614$ Kg/m^3

$\nu = 15.9 \times 10^{-6}$ m^2 / s

Pr = 0.707

K = 26.3×10^{-3}W / mK

We know,

Hydraulic or equivalent diameter

$$D_h = \frac{4A}{P} = \frac{4 \times \frac{\pi}{4}\left[D^2 - D_i^2\right]}{\pi\left[Do + D_i\right]}$$

$$= \frac{(D_o + -D_i)(D_o - D_i)}{(D_o + D_i)}$$

$$= D_o - D_i$$

= 0.05 – 0.03125

D_h = 0.01875 m

Reynolds number Re = $\frac{UD_h}{\nu}$

$$= \frac{30 \times 0.01875}{15.9 \times 10^6}$$

Re = 35.3×10^{-6}

Since Re > 2300, flow is turbulent

For turbulent flow, general equation is (Re > 10000)

Nu = 0.023 (Re)$^{0.8}$ (Pr)^n

This is heating process. So n = 0.4

$\Rightarrow$ Nu = $0.023 \times (35.3 \times 10^3)^{0.8}(0.707)^{0.4}$

Nu = 87.19

We know Nu = $\frac{hD_h}{K}$

$\Rightarrow 87.19 = \frac{h \times 0.01875}{26.3 \times 10_{-3}}$

$\Rightarrow$ h = 122.3 W/m^{2}K

8. **Engine oil flows through a 50 mm diameter tube at an average temperature of 147°C. The flow velocity is 80 cm/s. Calculate the average heat transfer coefficient if the tube wall is maintained at a temperature of 200°C and it is 2 m long.**

Given : Diameter D = 50 mm = 0.050 m

Average temperature T_m = 147°C

Velocity U = 80 cm/s = 0.80 m/s

Tube wall temperature T_w = 200°C

Length L = 2m

To find: Average heat transfer coefficient (h)

Solution : Properties of engine oil at 147°C

ρ = 816 Kg/m^3

$\nu = 7 \times 10^{-6}$ m^2 / s

Pr = 116

K = 133.8×10^{-3} W/mK

We know

Reynolds number Re = $\frac{UD}{\nu}$

$= \frac{0.8 \times 0.05}{7 \times 10^{-6}}$

Re = 5714.2

Since Re < 2300 flow is turbulent

$$\frac{L}{D} = \frac{2}{0.050} = 40$$

$$10 < \frac{L}{D} < 400$$

For turbulent flow, (Re < 10000)

$$\text{Nusselt number } Nu = 0.036\,(Re)^{0.8}(Pr)^{0.33}\left(\frac{D}{L}\right)^{0.055}$$

$$Nu = 0.036\,(5714.2)^{0.8}(1.16)^{0.33} \times \left(\frac{0.050}{2}\right)^{0.055}$$

$$Nu = 142.8$$

$$\text{We know } Nu = \frac{hD}{K}$$

$$\Rightarrow 142.8 = \frac{h \times 0.050}{133.8 \times 10^{-3}}$$

$$\Rightarrow h = 382.3\ W/m^2K$$

9. A large vertical plate 4 m height is maintained at 606°C and exposed to atmospheric air at 106°C. Calculate the heat transfer is the plate is 10 m wide.

Given :

Vertical plate length (or) Height L = 4 m

Wall temperature T_w = 606°C

Air temperature T_∞ = 106°C

Wide W = 10 m

To find: Heat transfer (Q)

Solution:

Film temperature $T_f = \dfrac{T_w + T_\infty}{2}$

$= \dfrac{606 + 106}{2}$

$T_f = 356°C$

Properties of air at 356°C = 350°C

$\rho = 0.566 \text{ Kg/m}^3$

$\nu = 55.46 \times 10^{-6} \text{ m}^2 / \text{s}$

Pr = 0.676

$K = 49.08 \times 10^{-3}$ W/mK

Coefficient of thermal expansion} $\beta = \dfrac{1}{T_f \text{ in K}}$

$= \dfrac{1}{356 + 273} = \dfrac{1}{629}$

$\beta = 1.58 \times 10^{-3} K^{-1}$

Grashof number $Gr = \dfrac{g \times \beta \times L^3 \times \Delta T}{v^2}$

$\Rightarrow \; Gr = \dfrac{9.81 \times 2.4 \times 10^{-3} \times (4)^3 \times (606 - 106)}{(55.46 \times 10^{-6})^2}$

$Gr = 1.61 \times 10^{11}$

$Gr\,Pr = 1.61 \times 10^{11} \times 0.676$

$Gr\,Pr = 1.08 \times 10^{11}$

Since $Gr\,Pr > 10^9$, flow is turbulent

For turbulent flow,

Nusselt number $Nu = 0.10\,[Gr\,Pr]^{0.333}$

$\Rightarrow Nu = 0.10\,[1.08 \times 10^{11}]^{0.333}$

Nu = 471.20

We know that,

Nusselt number $Nu = \dfrac{hL}{K}$

$$\Rightarrow 472.20 = \frac{h \times 4}{49.08 \times 10^{-3}}$$

Heat transfer coefficient h = 5.78 W/m^2K

Heat transfer Q = h A ΔT

$$= h \times W \times L \times (T_w - T_\infty)$$
$$= 5.78 \times 10 \times 4 \times (606 - 106)$$
$$Q = 115600 \text{ W}$$
$$Q = 115.6 \times 10^3 \text{ W}$$

10. A thin 100 cm long and 10 cm wide horizontal plate is maintained at a uniform temperature of 150°C in a large tank full of water at 75°C. Estimate the rate of heat to be supplied to the plate to maintain constant plate temperature as heat is dissipated from either side of plate.

Given :

Length of horizontal plate L = 100 cm = 1m

Wide W = 10 cm = 0.10 m

Plate temperature T_w = 150°C

Fluid temperature T_∞ = 75°C

To find: Heat loss (Q) from either side of plate

Solution:

Film temperature $T_f = \frac{T_w - T_\infty}{2}$

$= \frac{150 + 75}{2}$

$T_f = 112.5°C$

Properties of water at 112.5°C

$\rho = 951$ Kg/m^3

$\nu = 0.264 \times 10^{-6}$ m^2 / s

Pr = 1.55

K = 683×10^{-3} W/mK

Coefficient of thermal expansion} $\beta = \frac{1}{T_f \text{ in K}} = \frac{1}{112.5 + 273}$

$\beta = 2.59 \times 10^{-3} K^{-1}$

Grashof Number Gr = $\frac{g \times \beta \times L^3 \times \Delta T}{v^2}$

For horizontal plate,

Characteristic length $L_c = \frac{W}{2} = \frac{0.10}{2}$

$L_c = 0.05$ m

(1) $\Rightarrow$ Gr = $\frac{9.81 \times 2.59 \times 10^{-3} \times (0.05)^3 \times (150 - 75)}{(0.264 \times 10^{-6})^2}$

Gr = 3.41×10^9

Gr Pr = $3.41 \times 10^9 \times 1.55$

Gr Pr = 5.29×10^9

Gr Pr value is in between 8×10^6 and 10^{11}

i.e., $8 \times 10^6 <$ Gr Pr $< 10^{11}$

For horizontal plate, upper surface heated:

Nusselt number Nu = 0.15 (Gr Pr)$^{0.333}$

$\Rightarrow$ Nu = 0.15 $[5.29 \times 10^9]^{0.333+}$

$\Rightarrow$ Nu = 259.41

We know that,

$$\text{Nusselt number Nu} = \frac{h_u L_c}{K}$$

$$259.41 = \frac{h_u \times 0.05}{683 \times 10^{-3}}$$

h_u = 3543.6 W/m^{2}K

Upper surface heated, heat transfer coefficient h_u = 3543.6 W/m^{2}K

For horizontal plate, lower surface heated:

Nusselt number Nu = 0.27 $[\text{Gr Pr}]^{0.25}$

$\Rightarrow$ Nu = 0.27 $[5.29 \times 10^9]^{0.25}$

Nu = 72.8

We know that,

$$\text{Nusselt number Nu} = \frac{h_1 L_c}{K}$$

$$72.8 = \frac{h_1 L_c}{K}$$

$$72.8 = \frac{h_1 \times 0.05}{683 \times 10^{-3}}$$

h_1 = 994.6 W/m^{2}K

Lower surface heated, heat transfer coefficient h_1 = 994.6 W/m^{2}K

Total heat transfer Q = $(h_u + h_1) \times A \times \Delta T$

$= (h_u + h_1) \times W \times L \times (T_w - T_\infty)$

$= (3543.6 + 994.6) \times 0.10 \times (150 - 75)$

Q = 34036.5 W

Unit-3

Part-B

1. **Water is boiled at the rate of 24 kg/h in a polished copper pan, 300 mm in diameter, at atmospheric pressure. Assuming nucleate boiling conditions calculate the temperature of the bottom surface of the pan.**

Given :

m = 24 kg / h

$$= \frac{24 \text{ kg}}{3600 \text{ s}}$$

$$\boxed{m = 6.6 \times 10^{-3} \text{kg/s}}$$

d = 300 mm = .3m

Solution:

We know saturation temperature of water is 100°C

i.e. T_{sat} = 100°C

Properties of water at 100°C

From HMT data book Page No.13

Density ρl = 961 kg/m^3

Kinematic viscosity v = 0.293×10^{-6} m^2 / s

Pr andtl number P_r– 1.740

Specific heat Cpl = 4.216 kj/kg K = 4216 j/kg K

Dynamic viscosity $\mu l = \rho l \times v$

$= 961 \times 0.293 \times 10^{-6}$

$$\boxed{\mu L = 281.57 \times 10^{-6} \text{ Ns/m}^2}$$

From steam table (R.S. Khumi Steam table Page No.4)

At 100°C

Enthalpy of evaporation hfg = 2256.9 kj/kg

$$\boxed{hfg = 2256.9 \times 10^3 \text{ j/kg}}$$

Specific volume of vapour

$Vg = 1.673 \text{ m}^3/\text{kg}$

Density of vapour

$$\rho v = \frac{1}{vg}$$

$$\frac{1}{1.673}$$

$$\boxed{\rho v = 0.597 \text{ kg/m}^3}$$

For nucleate boiling

$$\text{Heat flux } \frac{Q}{A} = \mu l \times hfg \left| \frac{g \times ()\rho_l - \rho_v}{\sigma} \right| \times \left| \frac{Cpl \times \Delta T}{Csf \times hfg P_r^{1.7}} \right|^3$$

We know transferred Q = m ×hfg

Heat transferred Q = m × hfg.

$$\frac{Q}{A} = \frac{mhg}{A}$$

$$\frac{Q}{A} = \frac{6.6 \times 10^{-3} \times 2256.9 \times 10^3}{\frac{\pi}{4} d^2}$$

$$= \frac{6.6 \times 10^{-3} \times 2256.9 \times 10^3}{\frac{\pi}{4} (.3)^2}$$

$$\boxed{\frac{Q}{A} = 210 \times 10^3 \text{ w/m}^2}$$

$\sigma =$ surface tension for liquid vapour interface

At 100°C (From HMT data book Page No.147)

$\boxed{\sigma = 58.8 \times 10^{-3} N/m}$

For water – copper – Csf = Surface fluid constant = 013

$\boxed{C_{sf} = .013}$ (From HMT data book Page No.145)

Substitute, μl, h_{fg}, ρl, ρv, σ, Cpl, hfg, $\frac{Q}{A}$ and P_r values in Equation (1)

$$(1) \Rightarrow \quad 210 \times 10^3 = 281.57 \times 10^{-6} \times 2256.9 \times 10^3$$
$$\left|\frac{9.81 \times 961 - 597}{58.8 \times 10^{-3}}\right|^{0.5}$$
$$\left|\frac{4216 \times \Delta T}{.013 \times 2256.9 \times 10^3 \times (1.74)^{1.7}}\right|^3$$

$$\Rightarrow \left|\frac{4216 \times \Delta T}{75229.7}\right| = 0.825$$

$\Rightarrow \Delta T(.56)^3.8{=}25$

$\Rightarrow \Delta T \times .056 = 0.937$

ΔT - 16.7

We know that

Excess temperature $\Delta T = T_w - T_{sat}$

$16.7 = T_w - 100°C.$

$\boxed{T_w = 116.7°C}$

2. A nickel wire carrying electric current of 1.5 mm diameter and 50 cm long, is submerged in a water bath which is open to atmospheric pressure. Calculate the voltage at the burn out point, if at this point the wire carries a current of 200A.

Given :

D = 1.5mm = 1.5×10^{-3} m; L = 50 cm = 0.50m; Current I = 200A

Solution

We know saturation temperature of water is 100°C

i.e. T_{sat} = 100°C

Properties of water at 100°C

(From HMT data book Page No.11)

ρl = 961 kg/m^3
$v = 0.293 \times 10^{-6}$ m^2 / s
P_r - 1.740
Cpl = 4.216 kj/kg K = 4216 j/kg K

$\mu l = \rho l \times v = 961 \times 0.293 \times 10^{-6}$
$\mu l = 281.57 \times 10^{-6}$ Ns/m^2
From steam Table at 100°C

R.S. Khurmi Steam table Page No.4

hfg – 2256.9 kj/kg
hfg = 2256.9×10^3 j/kg
v_g = 1.673m^3/ kg

$$\rho v = \frac{1}{v_g} = \frac{1}{1.673} = 0.597 \text{ kg/m}^3$$

σ = Surface tension for liquid – vapour interface

At 100°C

$\sigma = 58.8 \times 10^{-3}$ N/m (From HMT data book Page No.147)

For nucleate pool boiling critical heat flux (AT burn out)

$$\frac{Q}{A} = 0.18 \times h_{fg} \times \rho v \left[\frac{\sigma \times g \times (\rho l - \rho v)}{\rho v^2} \right]^{0.25} ----1$$

(From HMT data book Page No.142)

Substitute h_{fg}, ρl, ρv, σ values in Equation (1)

$$(1) \Rightarrow \frac{Q}{A} = 0.18 \times 2256.9 \times 10^3 \times 0.597 \left[\frac{58.8 \times 10^{-3} \times 9.81\,(961 - .597)}{.597^2} \right]^{0.25}$$

$$\boxed{\frac{Q}{A} = 1.52 \times 10^6 \text{ W/m}^2}$$

We know

Heat transferred Q = V × I

$$\frac{Q}{A} = \frac{V \times I}{A}$$

$$1.52 \times 10^6 = \frac{V \times 200}{\pi dL} \qquad \because A = \pi dL$$

$$1.52 \times 10^6 = \frac{V \times 200}{\pi \times 1.5 \times 10^{-3} \times .50}$$

$$\boxed{V = 17.9 \text{ volts}}$$

3. Water is boiling on a horizontal tube whose wall temperature is maintained ct 15°C above the saturation temperature of water. Calculate the nucleate boiling heat transfer coefficient. Assume the water to be at a pressure of 20 atm. And also find the change in value of heat transfer coefficient when

1. **The temperature difference is increased to 30°C at a pressure of 10 atm.**
2. **The pressure is raised to 20 atm at Δ T = 15°C**

Given :

Wall temperature is maintained at 15°C above the saturation temperature.

$T_w = 115°C.$ $T_{sat} = 100°C$ $T_w = 100 + 15 = 115°C$

= p = 10 atm = 10 bar

case (i)

$\Delta T = 30°C$; $p = 10$ atm = 10 bar

case (ii)

p = 20 atm = 20 bar; ΔT - 15°C

Solution:

We know that for horizontal surface, heat transfer coefficient

$h = 5.56\ (\Delta T)^3$ From HMT data book Page No.128

$h = 5.56\ (T_w - T_{sat})^3$

$= 5.56\ (115 - 100)^3$

$h = 18765\ w/m^2K$

Heat transfer coefficient other than atmospheric pressure

$h_p = hp^{0.4}$ From HMT data book Page No.144

$= 18765 \times 10^{0.4}$

Heat transfer coefficient $h_p = 47.13 \times 10^3\ W / m^2 K$

Case (i)

P = 100 bar ΔT = 30°C From HMT data book Page No.144

Heat transfer coefficient

$$h = 5.56\,(\Delta T)^3 = 5.56(30)^3$$

$$\boxed{h = 150 \times 10^3\ W/m^2K}$$

Heat transfer coefficient other than atmospheric pressure

$h_p = hp^{0.4}$

$$= 150 \times 10^3 (10)^{0.4}$$

$$\boxed{h_p = 377 \times 10^3\ W/m^2K}$$

Case (ii)

P = 20 bar; ΔT = 15°C

Heat transfer coefficient $h = 5.56\,(\Delta T)^3 = 5.56\,(15)^3$

$$\boxed{h = 18765\ W/m^2K}$$

Heat transfer coefficient other than atmospheric pressure

$h_p = hp^{0.4}$

$= 18765\,(20)^{0.4}$

$$\boxed{h_p = 62.19 \times 10^3\ W/m^2K}$$

4. A vertical flat plate in the form of fin is 500m in height and is exposed to steam at atmospheric pressure. If surface of the plate is maintained at 60°C. calculate the following.

1. The film thickness at the trailing edge

2. Overall heat transfer coefficient

3. Heat transfer rate

4. The condensate mass flow rate.

Assume laminar flow conditions and unit width of the plate.

Given :

Height ore length L = 500 mm = 5m

Surface temperature T^w = 60°C

Solution

We know saturation temperature of water is 100°C

i.e. T_{sat} = 100°C

(From R.S. Khurmi steam table Page No.4

h_{fg} = 2256.9kj/kg

$h_{fg} = 2256.9 \times 10^3$ j/kg

We know

Film temperature $T_f = \frac{T_w + T_{sat}}{2}$

$= \frac{60 + 100}{2}$

$\boxed{T_f = 80°C}$

Properties of saturated water at 80°C

(From HMT data book Page No.13)

ρ - 974 kg/m^3

$v = 0.364 \times 10^{-6}\ m^2/s$

k = 668.7 $\times 10^{-3}$W/mk

$\mu = p \times v = 974 \times 0.364 \times 10^{-6}$

$$\boxed{\mu = 354.53 \times 10^{-6} Ns/m^2}$$

1. Film thickness δ_x

We know for vertical plate

Film thickness

$$\delta x = \left(\frac{4 \mu K \times x \times (T_{sat} - T_w)}{g \times h_{fg} \times \rho^2} \right)^{0.25}$$

Where

X = L = 0.5 m

$$\delta_x = \frac{4 \times 354.53 \times 10^{-6} \times 668.7 \times 10^{-3} \times 0.5 \times 100 - 60}{9.81 \times 2256.9 \times 10^3 \times 974^2}$$

$$\delta_x = 1.73 \times 10^{-4} m$$

2. Average heat transfer coefficient (h)

For vertical surface Laminar flow

$$h = 0.943 \left[\frac{k_3 \times \rho^2 \times g \times h_{fg}}{\mu \times L \times T_{sat} - T_w} \right]^{0.25}$$

The factor 0.943 may be replace by 1.13 for more accurate result as suggested by Mc Adams

$$1.13\left(\frac{(668.7\times10^{-3})^3(974)^2 9.81\times 2256.9\times 10^3}{354.53\times10^{-6}\times1.5\times100-60}\right)^{0.25}$$

$h = 6164.3$ W/m^{2}k.

3. Heat transfer rate Q

We know

$$Q = hA(T_{sat} - T_w)$$
$$= h \times L \times W \times (T_{sat} - T_w)$$
$$= 6164.3 \times 0.5 \times 1 \times 100\text{-}60$$

$$\boxed{Q = 123286\ W}$$

4. Condensate mass flow rate m

We know

$$Q = m \times h_{fg}$$
$$m = \frac{Q}{h_{fg}}$$
$$m = \frac{1.23.286}{2256.9 \times 10^3}$$

$$\boxed{m = 0.054\ kg/s}$$

10. Steam at 0.080 bar is arranged to condense over a 50 cm square vertical plate. The surface temperature is maintained at 20°C. Calculate the following.

a. **Film thickness at a distance of 25 cm from the top of the plate.**
b. **Local heat transfer coefficient at a distance of 25 cm from the top of the plate.**
c. **Average heat transfer coefficient.**

d. Total heat transfer
e. Total steam condensation rate.

f. What would be the heat transfer coefficient if the plate is inclined at 30°C with horizontal plane.

Given :

Pressure P = 0.080 bar

Area A = 50 cm × 50 cm = 50 × 050 = 0.25 m^2

Surface temperature T_w = 20°C

Distance x = 25 cm = .25 m

Solution

Properties of steam at 0.080 bar

(From R.S. Khurmi steam table Page no.7)

$T_{satj / kg} = 41.53°C$

$h_{fg} =$ 2403.2kj/kg = 2403.2 ×10^3j / kg

We know

Film temperature $T_f = \frac{T_w + T_{sat}}{2}$

$= \frac{20+41.53}{2}$

$\boxed{T_f = 30.76°C}$

Properties of saturated water at 30.76°C = 30°C

From HMT data book Page No.13

$\rho - 997 \text{ kg/m}^3$

$\nu = 0.83 \times 10^{-6} \text{ m}^2/\text{s}$

$k = 612 \times 10^{-3} \text{W / mK}$

$\mu = p \times v = 997 \times 0.83 \times 10^{-6}$

$\mu = 827.51 \times 10^{-6} \text{Ns /m}^2$

a. Film thickness

We know for vertical surfaces

$$\delta x = \left(\frac{4\mu K \times x \times (T_{sat} - T_w)}{g \times h_{fg} \times \rho^2} \right)^{0.25}$$

(From HMT data book Page No.150)

$$\delta_x = \frac{4 \times 827.51 \times 10^{-6} \times 612 \times 10^{-3} \times .25 \times (41.53 - 20)100}{9.81 \times 2403.2 \times 10^3 \times 997^2}$$

$$\delta_x = 1.40 \times 10^4 \text{m}$$

b. Local heat transfer coefficient h_x Assuming Laminar flow

$$h_x = \frac{k}{\delta x}$$

$$h_x = \frac{612 \times 10^{-3}}{1.46 \times 10^{-4}}$$

$$\boxed{hx = 4{,}191 \text{ W/m}^2\text{K}}$$

c. Average heat transfer coefficient h

(Assuming laminar flow)

$$h = 0.943 \left[\frac{k^3 \times \rho^2 \times g \times h_{fg}}{\mu \times L \times T_{sat} - T_w} \right]^{0.25}$$

The factor 0.943 may be replaced by 1.13 for more accurate result as suggested by Mc adams

$$h = 0.943\left[\frac{k^3 \rho^2 g\, h_{fg}}{\mu \times L \times T_{sat} - T_w}\right]^{0.25}$$

Where L = 50 cm = .5 m

$$h = 1.13\left|\frac{(612 \times 10^{-3})^3 (997)9.81^2 \times 2403.2 \times 10^3}{827.51 \times 10^{-6} \times .5 \times 41.53 - 20}\right|^{0.25}$$

$$h = 5599.6\ W/m^2k$$

d. Heat transfer (Q)

We know

$Q = hA(T_{sat} - T_w)$

$$h \times A \times (T_{sat} - T_w)$$
$$= 5599.6 \times 0.25 \times (41.53 - 20$$
$$Q = 30.139.8\ W$$

e. Total steam condensation rate (m)

We know

Heat transfer

$$Q = m \times h_{fg}$$
$$m = \frac{Q}{h_{fg}}$$

$$m = \frac{30.139.8}{2403.2 \times 103}$$
$$m = 0.0125\ kg/s$$

f. If the plate is inclined at θ with horizontal

$h_{inclined} = h_{vertical} \times \sin\theta^{1/4}$

$h_{inclined} = h_{vertical} \times (\sin 30)^{1/4}$

$h_{inclined} = 5599.6 \times \left(\frac{1}{2}\right)^{1/4}$

$h_{inclined} = 4.708.6 \text{ W/m}^2\text{k}$

Let us check the assumption of laminar film condensation

We know

$\text{Reynolds Number } R_e = \frac{4m}{w\mu}$

where

W = width of the plate = 50cm = .50m

$R_e = \frac{4 \times .0125}{0.50 \times 827.51 \times 10^{-6}}$

$R_e = 120.8 < 1800$

So our assumption laminar flow is correct.

5. A condenser is to designed to condense 600 kg/h of dry saturated steam at a pressure of 0.12 bar. A square array of 400 tubes, each of 8 mm diameter is to be used. The tube surface is maintained at 30°C. Calculate the heat transfer coefficient and the length of each tube.

Given :

$m = 600 \text{ kg/h} = \frac{600}{3600} \text{kg/ s} = 0.166 \text{ kg/s}$

m = 0.166 kg/s

Pressure P – 0.12 bar   No. of tubes = 400

Diameter D = 8mm = 8 $\times 10^{-3}$m

Surface temperature $T_w = 30°C$

Solution

Properties of steam at 0.12 bar   From R.S. Khurmi steam table Page No.7

$T_{sat} = 49.45°C$

$h_{fg} = 2384.3$ kj/kg

$h_{fg} = 2384.9 \times 10^3$ j/kg

We know

Film temperature $T_f = \frac{T_w + T_{sat}}{2}$

$= \frac{30 + 49.45}{2}$

$T_f = 39.72°C = 40°C$

Properties of saturated water at 40°C

From HMT data book Page No.13

ρ - 995 kg/m^3

$\nu = .657 \times 10^{-6}$ m^2 / s

$k = 628.7 \times 10^{-3}$ W/mk

$\mu = \rho \times \nu = 995 \times 0.657 \times 10^{-6}$

$\boxed{\mu = 653.7 \times 10^{-6} \text{ Ns/m}^2}$

with 400 tubes a 20 × 20 tube of square array could be formed

i.e. $N = \sqrt{400} = 20$

$\boxed{N = 20}$

For horizontal bank of tubes heat transfer coefficient.

$$h = 0.728 \left[\frac{K^3 \rho^2 g\, h_{fg}}{\mu D (T_{sat} - T_w)} \right]^{0.25}$$

From HMT data book Page No.150

$$h = 0.728 \left[\frac{(628 \times 10^{-3})^3 (995)^2\, 9.81 \times 2384.3 \times 10^3}{653.7 \times 10^{-6} \times 20 \times 8 \times 10^{-3} \times (49.45 - 30)} \right]^{0.25}$$

$\boxed{h = 5304.75 \text{ W/m}^2\text{K}}$

We know

Heat transfer

$Q = hA(T_{sat} - T_w)$

No. of tubes = 400

$Q = 400 \times h \times \pi \times D \times L \times (T_{sat} - T_w)$

$Q = 400 \times 5304.75 \times \pi \times 8 \times 10^{-3} \times 1\ (49.45\text{-}30)$

$\boxed{Q = 1.05 \times 10^{6} \times L \ldots\ldots 1}$

We know

$Q = m \times h_{fg}$

$= 0.166 \times 2384.3 \times 103$

$Q = 0.3957 \times 10^{6}$ W

$= 0.3957 \times 10^{6} = 1.05 \times 10^{6} L$

$\boxed{L = 0.37 \text{ m}}$

Problems on Parallel flow and Counter flow heat exchangers

From HMT data book Page No.135

Formulae used

1. Heat transfer $Q = UA\,(\Delta T)_m$

Where

U – Overall heat transfer coefficient, W/m^2K

A – Area, m^2

$(\Delta T)_m$ – Logarithmic Mean Temperature Difference. LMTD

For parallel flow

$$(\Delta T)_m = \frac{(T_1 - t_1) - (T_2 - t_2)}{\ln\left[\dfrac{T_1 - t_1}{T_2 - t_2}\right]}$$

In Counter flow

$$(\Delta T)_m = \frac{(T_1 - t_1) - (T_2 - t_2)}{\ln\left[\dfrac{T_1 - t_1}{T_2 - t_2}\right]}$$

Where

T_1 – Entry temperature of hot fluid °C $\qquad$ T_2 – Exit temperature of hot fluid °C

T_1 – Entry temperature of cold fluid °C T_2 – Exit temperature of cold fluid °C

2. Heat lost by hot fluid = Heat gained by cold fluid

$$Q_h = Q_c$$

$$m_h C_{ph} (T_1 - T_2) = m_c C_{pc} (t_2 - t_1)$$

M_h – Mass flow rate of hot fluid, kg/s

M_c – Mass flow rate of cold fluid kg/s

C_{ph} – Specific heat of hot fluid J/kg K

C_{pc} – Specific heat of cold fluid J/kg L

3. Surface area of tube

$A = \pi D_1 L$

Where D_1 Inner din

4. $Q = m \times h_{fg}$

Where h_{fg} – Enthalpy of evaporation j/kg K

5. Mass flow rate

$m = \rho AC$

Unit-4 Radiation

Part-B

1. A black body at 3000 K emits radiation. Calculate the following:

- **i) Monochromatic emissive power at 7 μm wave length.**
- **ii) Wave length at which emission is maximum.**
- **iii) Maximum emissive power.**
- **iv) Total emissive power,**
- **v) Calculate the total emissive of the furnace if it is assumed as a real surface having emissivity equal to 0.85.**

Given: Surface temperature T = 3000K

Solution: 1. Monochromatic Emissive Power :

From Planck's distribution law, we know

$$E_{b\lambda} = \frac{C_1 \lambda^{-5}}{\;}$$

$$e^{\left(\frac{C_2}{\lambda T}\right)} - 1$$

[From HMT data book, Page No.71]

Where

$c_1 = 0.374 \times 10^{-15}$ W m^2
$c_2 = 14.4 \times 10^{-3}$ mK
$\lambda = 1 \times 10^{-6}$ m [Given]

$$\Rightarrow \quad E_{b\lambda} = \frac{0.374 \times 10^{-15} [1 \times 10^{-6}]^{-5}}{\left[\dfrac{144 \times 10^{-3}}{1 \times 10^{-6} \times 3000} \right]_{-1}}$$

$$E_{b\lambda} = 3.10 \times 10^{12} \text{ W/m}^2$$

2. Maximum wave length (λ_{max})

From Wien's law, we know

$$\lambda_{max} T = 2.9 \times 10^{-3} \text{ mK}$$

$$\Rightarrow \quad \lambda_{max} = \frac{2.9 \times 10^{-3}}{3000}$$

$$\lambda_{max} = 0.966 \times 10^{-6} \text{m}$$

3. Maximum emissive power ($E_{b\lambda}$) max:

Maximum emissive power

$(E_{b\lambda})_{max} = 1.307 \times 10^{-5}\, T^5$
$= 1.307 \times 10^{-5} \times (3000)^5$
$(E_{b\lambda})_{max} = 3.17 \times 10^{12}$ W/m^2

4. Total emissive power (E_b):

From Stefan – Boltzmann law, we know that

$E_b = \sigma T^4$
[From HMT data book Page No.71]

Where σ = Stefan – Boltzmann constant
$= 5.67 \times 10^{-8}$ W/m^{2}K^4
$\Rightarrow$ $E_b = (5.67 \times 10^{-8})\,(3000)^4$
$E_b = 4.59 \times 10^{6}$ W/m^2

5. Total emissive power of a real surface:

$(E_b)_{real} = \varepsilon\, \sigma\, T^4$
Where ε = Emissivity = 0.85

$(E_b)_{real} = 0.85 \times 5.67 \times 10^{-8} \times (3000)^4$

$(E_b)_{real} = 3.90 \times 10^6 \ W/m^2$

2. **Assuming sun to be black body emitting radiation at 6000 K at a mean distance of 12×10^{10} m from the earth. The diameter of the sun is 1.5×10^9 m and that of the earth is $\times 10^6$ m. Calculation the following.**

1. Total energy emitted by the sun.
2. The emission received per m^2 just outside the earth's atmosphere.
3. The total energy received by the earth if no radiation is blocked by the earth's atmosphere.
4. The energy received by a 2×2 m solar collector whose normal is inclined at 45° to the sun. The energy loss through the atmosphere is 50% and the diffuse radiation is 20% of direct radiation.

Given: Surface temperature T = 6000 K

Distance between earth and sun $R = 12 \times 10^{10}$ m

Diameter on the sun $D_1 = 1.5 \times 10^9$ m

Diameter of the earth $D_2 = 13.2 \times 10^6$ m

Solution:1. Energy emitted by sun $E_b = \sigma T^4$

$\Rightarrow \quad E_b = 5.67 \times 10^{-8} \times (6000)^4$

[$\because$ σ = Stefan - Boltzmann constant

$= 5.67 \times 10^{-8} \ W/m^2 K^4$]

$E_b = 73.4 \times 10^6 \ W/m^2$

Area of sun $A_1 = 4\pi R_1^2$

$$= 4\pi \times \left(\frac{1.5 \times 10^9}{2}\right)^2$$

$$\boxed{A_1 = 7 \times 10^{18} \ m^2}$$

$\Rightarrow$ Energy emitted by the sun

$E_b = 73.4 \times 10^6 \times 7 \times 10^{18}$

$$\boxed{E_b = 5.14 \times 10^{26} \ W}$$

2. The emission received per m^2 just outside the earth's atmosphere:

The distance between earth and sun $\quad R = 12 \times 10^{10}$ m

Area, $A = 4\pi R^2$

$= 4 \times \pi \times (12 \times 10^{10})^2$

$\boxed{A = 1.80 \times 10^{23}\ m^2}$

$\Rightarrow$ The radiation received outside the earth atmosphere per m^2

$= \frac{E_b}{A}$

$= \frac{5.14 \times 10^{26}}{1.80 \times 10^{23}}$

$= 2855.5\ W/m^2$

3. Energy received by the earth:

Earth area $= \frac{\pi}{4}(D_2)^2$

$= \frac{\pi}{4} \times [13.2 \times 10^6]^2$

$\boxed{\text{Earth area} = 1.36 \times 10^4 m^2}$

Energy received by the earth

$= 2855.5 \times 1.36 \times 10^4$

$= 3.88 \times 10^{17}\ W$

4. The energy received by a 2 $\times$ 2 m solar collector;

Energy loss through the atmosphere is 50%. So energy reaching the earth.

$= 100 - 50 = 50\%$

$= 0.50$

Energy received by the earth

$= 0.50 \times 2855.5$

$= 1427.7\ W/m^2$ ......(1)

Diffuse radiation is 20%

$\Rightarrow 0.20 \times 1427.7 = 285.5\ W/m^2$

$\boxed{\text{Diffuse radiation} = 285.5\ W/m^2}$ ....(2)

Total radiation reaching the collection

$= 142.7 + 285.5$

$= 1713.2 \text{ W/m}^2$

Plate area $= A \times \cos\theta$

$= 2 \times 2 \times \cos 45°$

$= 2.82 \text{ m}^2$

Energy received by the collector

$= 2.82 \times 1713.2$

$= 4831.2 \text{ W}$

3. Two black square plates of size 2 by 2 m are placed parallel to each other at a distance of 0.5 m. One plate is maintained at a temperature of 1000°C and the other at 500°C. Find the heat exchange between the plates.

Given: Area $A = 2 \times 2 = 4 \text{ m}^2$

$T_1 = 1000°C + 273$

$= 1273 \text{ K}$

$T_2 = 500°C + 273$

$= 773 \text{ K}$

Distance = 0.5 m

To find : Heat transfer (Q)

Solution : We know Heat transfer general equation is

where $Q_{12} = \dfrac{\sigma\left[T_1^4 - T_2^4\right]}{\dfrac{1-\varepsilon_1}{A_1\varepsilon_1} + \dfrac{1}{A_1F_{12}} + \dfrac{1-\varepsilon_2}{A_1\varepsilon_2}}$ [From equation No.(6)]

For black body $\varepsilon_1 = \varepsilon_2 = 1$

$\Rightarrow Q_{12} = \sigma[T_1^4 - T_2^4] \times A_1 F_{12}$

$= 5.67 \times 10^{-8}\left[(1273)^4 - (773)^4\right] \times 4 \times F_{12}$

$\boxed{Q_{12} = 5.14 \times 10^5 F_{12}}$ ......(1)

Where F_{12} – Shape factor for square plates

In order to find shape factor F_{12}, refer HMT data book, Page No.76.

$$X \text{ axis} = \frac{\text{Smaller side}}{\text{Distance between planes}}$$

$$= \frac{2}{0.5}$$

$$\boxed{X \text{ axis} = 4}$$

Curve → 2 [Since given is square plates]

X axis value is 4, curve is 2. So corresponding Y axis value is 0.62.

i.e., $\boxed{F_{12} = 0.62}$

$(1) \Rightarrow Q_{12} = 5.14 \times 10_5 \times 0.62$

$$\boxed{Q_{12} = 3.18 \times 10^5 W}$$

4. Two parallel plates of size 3 m × 2 m are placed parallel to each other at a distance of 1 m. One plate is maintained at a temperature of 550°C and the other at 250°C and the emissivities are 0.35 and 0.55 respectively. The plates are located in a large room whose walls are at 35°C. If the plates located exchange heat with each other and with the room, calculate.

1. Heat lost by the plates.

2. Heat received by the room.

Given: Size of the plates = 3 m × 2 m

Distance between plates = 1 m

First plate temperature $T_1 = 550°C + 273 = 823$ K

Second plate temperature $T_2 = 250°C + 273 = 523$ K

Emissivity of first plate $\varepsilon_1 = 0.35$

Emissivity of second plate $\varepsilon_2 = 0.55$

Room temperature $T_3 = 35°C + 273 = 308$ K

To find: 1. Heat lost by the plates

2. Heat received by the room.

Solution: In this problem, heat exchange takes place between two plates and the room. So this is three surface problems and the corresponding radiation network is given below. Area

$A_1 = 3 \times 2 = 6\ m^2$

$$\boxed{A_1 = A_2 = 6m^2}$$

Since the room is large $\boxed{A_3 = \infty}$

From electrical network diagram.

$$\frac{1-\varepsilon_1}{\varepsilon_1 A_1} = \frac{1-0.35}{0.35 \times 6} = 0.309$$

$$\frac{1-\varepsilon_2}{\varepsilon_2 A_2} = \frac{1-0.55}{0.55 \times 6} = 0.136$$

$$\frac{1-\varepsilon_3}{\varepsilon_3 A_3} = 0 \qquad [\because A_3 = \infty]$$

Apply $\frac{1-\varepsilon_3}{\varepsilon_3 A_3} = 0$, $\frac{1-\varepsilon_1}{\varepsilon_1 A_1} = 0.309$, $\frac{1-\varepsilon_2}{\varepsilon_2 A_2} = 0.136$ values in electrical network diagram.

To find shape factor F_{12} refer HMT data book, Page No.78.

$$X = \frac{b}{c} = \frac{3}{1} = 3$$

$$Y = \frac{a}{c} = \frac{2}{1} = 2$$

X value is 3, Y value is 2, corresponding shape factor [From table]

$F_{12} = 0.47$

$$\boxed{F_{12} = 0.47}$$

We know that,

$F_{11} + F_{12} + F_{13} = 1$ But, $F_{11} = 0$

$\Rightarrow \quad F_{13} = 1 - F_{12}$

$\Rightarrow \quad F_{13} = 1 - 0.47$

$$\boxed{F_{13} = 0.53}$$

Similarly, $F_{21} + F_{22} + F_{23} = 1$ We know $F_{22} = 0$

$\Rightarrow \quad F_{23} = 1 - F_{21}$

$\Rightarrow \quad F_{23} = 1 - F_{12}$

$F_{13} = 1 - 0.47$

$\boxed{F_{23} = 0.53}$

From electrical network diagram,

$$\frac{1}{A_1F_{13}} = \frac{1}{6 \times 0.53} = 0.314 \qquad ....(1)$$

$$\frac{1}{A_2F_{23}} = \frac{1}{6 \times 0.53} = 0.314 \qquad ....(2)$$

$$\frac{1}{A_1F_{12}} = \frac{1}{6 \times 0.47} = 0.354 \qquad ....(3)$$

From Stefan – Boltzmann law, we know

$$E_b = \sigma T^4$$

$$E_{b1} = \sigma T_1^4$$

$$= 5.67 \times 10^{-8} [823]^4$$

$$\boxed{E_{b1} = 26.01 \times 10^3 W / m^2} \qquad .....(4)$$

$$E_{b2} = \sigma T_2^4$$

$$= 5.67 \times 10^{-8} [823]^4$$

$$\boxed{E_{b2} = 4.24 \times 10^3 W / m^2} \qquad .....(5)$$

$$E_{b3} = \sigma T_3^4$$

$$= 5.67 \times 10^{-8} [308]^4$$

$$\boxed{E_{b3} = J_3 = 510.25 \ W / m^2} \qquad .....(6)$$

[From diagram]

The radiosities, J_1 and J_2 can be calculated by using Kirchoff's law.

$\Rightarrow$ The sum of current entering the node J_1 is zero.

At Node J_1:

$$\frac{E_{b1}-J_1}{0.309}+\frac{J_2-J_1}{\frac{1}{A_1F_{12}}}+\frac{E_{b3}-J_1}{\frac{1}{A_1F_{13}}}=0$$

[From diagram]

$$\Rightarrow \frac{26.01\times10^3-J_1}{0.309}+\frac{J_2-J_1}{0.354}+\frac{510.25-J_1}{0.314}=0$$

$$\Rightarrow 84.17\times10^3-\frac{J_1}{0.309}+\frac{J_2}{0.354}+\frac{J_1}{0.354}+1625-\frac{J_1}{0.354}=0$$

$$\Rightarrow \quad -9.24J_1+2.82J_2=-85.79\times10^3 \quad .....(7)$$

At node j_2

$$\frac{J_1-J_2}{\frac{1}{A_1F_{12}}}+\frac{E_{b3}-J_2}{\frac{1}{A_2F_{23}}}+\frac{E_{b2}-J_2}{0.136}=0$$ **-+***

$$\frac{J_1-J_2}{0.354}+\frac{510.25-J_2}{0.314}+\frac{4.24\times10^3-J_2}{0.136}=0$$

$$\frac{J_1}{0.354}-\frac{J_2}{0.354}+\frac{510.25}{0.314}-\frac{J_2}{0.314}+\frac{4.24\times10^3}{0.136}-\frac{J_2}{0.136}=0$$

$$\Rightarrow \quad 2.82J_1-13.3J_2=-32.8\times10^3 \quad ....(8)$$

Solving equation (7) and (8),

$$\Rightarrow \quad -9.24J_1+2.82J_2=-85.79\times10^3 \quad .....(7)$$

$$\Rightarrow \quad 2.82J_1-13.3J_2=-32.8\times10^3 \quad .....(8)$$

$$\boxed{\begin{aligned} J_2 &= 4.73\times10^3\ W/m^2 \\ J_1 &= 10.73\times10^3\ W/m^2 \end{aligned}}$$

Heat lost by plate (1) is given by

$$Q_1=\frac{E_{b1}-J_1}{\left(\frac{1-\varepsilon_1}{\varepsilon_1A_1}\right)}$$

$$Q_1 = \frac{26.01\times10^3 - 10.73\times10^3}{\frac{1-0.35}{0.35\times6}}$$

$$\boxed{Q_1 = 49.36\times10^3 \text{ W}}$$

Heat lost by plate 2 is given by

$$Q_2 = \frac{E_{b2} - J_2}{\left(\frac{1-\varepsilon_2}{\varepsilon_2 A_2}\right)}$$

$$Q_2 = \frac{4.24\times10^3 - 4.73\times10^3}{\frac{1-0.55}{6\times0.55}}$$

$$\boxed{Q_2 = -3.59\times10^3 \text{ W}}$$

Total heat lost by the plates

$$Q = Q_1 + Q_2$$

$$= 49.36\times10^3 - 3.59\times10^3$$

$$\boxed{Q = 45.76\times10^3 \text{ W}} \qquad ......(9)$$

Heat received by the room

$$Q = \frac{J_1 - J_3}{\frac{1}{A_1F_{13}}} + \frac{J_2 - J_3}{\frac{1}{A_1F_{12}}}$$

$$= \frac{10.73\times10^3 - 510.25}{0.314} = \frac{4.24\times10^3 - 510.25}{0.314}$$

$$[\because E_{b1} = J_1 = 512.9]$$

$$\boxed{Q = 45.9\times10^3 \text{ W}} \qquad .....(10)$$

From equation (9), (10), we came to know heat lost by the plates is equal to heat received by the room.

5. A gas mixture contains 20% CO_2 and 10% H_2o by volume. The total pressure is 2 atm.

The temperature of the gas is 927°C. The mean beam length is 0.3 m. Calculate the emissivity of the mixture.

Given : Partial pressure of CO_2, P_{CO_2} = 20% = 0.20 atm

Partial pressure of H_2o, $P_{H_2 0}$ = 10% = 0.10 atm.

Total pressure P = 2 atm

Temperature T = 927°C + 273

= 1200 K

Mean beam length L_m = 0.3 m

To find: Emissivity of mixture (ε_{mix}).

Solution : To find emissivity of CO_2

$$P_{CO_2} \times L_m = 0.2 \times 0.3$$

$$\boxed{P_{CO_2} \times L_m = 0.06 \text{ m - atm}}$$

From HMT data book, Page No.90, we can find emissivity of CO_2.

From graph, Emissivity of CO_2 = 0.09

$$\boxed{\varepsilon_{CO_2} = 0.09}$$

To find correction factor for CO_2

Total pressure, P = 2 atm

$$P_{CO_2} L_m = 0.06 \text{ m - atm.}$$

From HMT data book, Page No.91, we can find correction factor for CO_2

From graph, correction factor for CO_2 is 1.25

$$\boxed{C_{CO_2} = 1.25}$$

$$\varepsilon_{CO_2} \times C_{CO_2} = 0.09 \times 1.25$$

$$\boxed{\varepsilon_{CO_2} \times C_{CO_2} = 0.1125}$$

To find emissivity of H_2o :

$$P_{H_2o} \times L_m = 0.1 \times 0.3$$

$$\boxed{P_{H_2o} L_m = 0.03 \text{ m - atm}}$$

From HMT data book, Page No.92, we can find emissivity of H_2o.

From graph Emissivity of H_2o = 0.048

$$\boxed{\varepsilon_{H_2o} = 0.048}$$

To find correction factor for H_2o :

$$\frac{P_{H_2o} + P}{2} = \frac{0.1 + 2}{2} = 1.05$$

$$\frac{P_{H_2o} + P}{2} = 1.05,$$

$$P_{H_2o} \; L_m = 0.03 \text{ m - atm}$$

From HMT data book, Page No.92 we can find emission of H_20

6. Two black square plates of size 2 by 2 m are placed parallel to each other at a distance of 0.5 m. One plate is maintained at a temperature of 1000°C and the other at 500°C. Find the heat exchange between the plates.

Given: Area A = 2 × 2 = 4 m^2

T_1 = 1000°C + 273 = 1273 K

T_2 = 500°C + 273 = 773 K

Distance = 0.5 m

To find : Heat transfer (Q)

Solution : We know Heat transfer general equation is

where $$Q_{12} = \frac{\sigma\left[T_1^4 - T_2^4\right]}{\frac{1-\varepsilon_1}{A_1\varepsilon_1} + \frac{1}{A_1F_{12}} + \frac{1-\varepsilon_2}{A_1\varepsilon_2}}$$

[From equation No.(6)]

For black body $\varepsilon_1 = \varepsilon_2 = 1$

$$\Rightarrow Q_{12} = \sigma[T_1^4 - T_2^4] \times A_1 F_{12}$$

$$= 5.67 \times 10^{-8} \left[(1273)^4 - (773)^4\right] \times 4 \times F_{12}$$

$$\boxed{Q_{12} = 5.14 \times 10^5 F_{12}} \quad ......(1)$$

Where F_{12} – Shape factor for square plates

In order to find shape factor F_{12}, refer HMT data book, Page No.76.

$$\text{X axis} = \frac{\text{Smaller side}}{\text{Distance between planes}}$$

$$= \frac{2}{0.5}$$

$$\boxed{\text{X axis} = 4}$$

Curve $\rightarrow$ 2 [Since given is square plates]

X axis value is 4, curve is 2. So corresponding Y axis value is 0.62.

i.e., $\boxed{F_{12} = 0.62}$

$$(1) \Rightarrow Q_{12} = 5.14 \times 10^5 \times 0.62$$

$$\boxed{Q_{12} = 3.18 \times 10^5 W}$$

From graph,

Correction factor for H_2o = 1.39

$$\boxed{C_{H_2O} = 1.39}$$

$$\varepsilon_{H_2O} \times C_{H_2O} = 0.048 \times 1.39$$

$$\boxed{\varepsilon_{H_2O} \times C_{H_2O} = 0.066}$$

Correction factor for mixture of CO_2 and H_2O:

$$\frac{P_{H_2o}}{P_{H_2o}+P_{CO_2}}=\frac{0.1}{0.1+0.2}=1.05$$

$$\boxed{\frac{P_{H_2o}}{P_{H_2o}+P_{CO_2}}=0.333}$$

$$P_{CO_2}\times L_m+P_{H_2O}\times L_m=0.06+0.03$$

$$\boxed{P_{CO_2}\times L_m+P_{H_2O}\times L_m=0.09}$$

From HMT data book, Page No.95, we can find correction factor for mixture of CO_2 and H_2o.

Unit-5 Mass Transfer

Part-B

1. Hydrogen gases at 3 bar and 1 bar are separated by a plastic membrane having thickness 0.25 mm. the binary diffusion coefficient of hydrogen in the plastic is 9.1 × 10^{-3} m^2/s. The solubility of hydrogen in the membrane is 2.1 × 10^{-3} $\frac{kg-mole}{m^3\ bar}$

An uniform temperature condition of 20° is assumed.

Calculate the following

1. Molar concentration of hydrogen on both sides
2. Molar flux of hydrogen
3. Mass flux of hydrogen

Given Data:

Inside pressure $P_1 = 3$ bar

Outside pressure $P_2 = 1$ bar

Thickness, $L = 0.25$ mm $= 0.25 \times 10^{-3}$ m

Diffusion coefficient $D_{ab} = 9.1\times10^{-8}\ m^2/s$

Solubility of hydrogen = $2.1\times10^{-3}\ \frac{kg-mole}{m^3-bar}$

Temperature T = 20°C

To find

1. Molar concentration on both sides C_{a1} and C_{a2}
2. Molar flux
3. Mass flux

Solution :

1. Molar concentration on inner side,

C_{a1} = Solubility × inner pressure

$C_{a2} = 2.1 \times 10^{-3} \times 3$

$C_{a1} = 6.3 \times 10^{-3} \dfrac{\text{kg - mole}}{m^3}$

Molar concentration on outer side

C_{a1} = solubility × Outer pressure

$C_{a2} = 2.1 \times 10^{-3} \times 1$

$C_{a2} = 2.1 \times 10^{-3} \dfrac{\text{kg - mole}}{m^3}$

2. We know $\dfrac{m_o}{A} = \dfrac{D_{ab}}{L}[C_{a1} - C_{a2}]$

$$\text{Molar flux,} = \frac{9.1}{} - \frac{(6.3\times10^{-3} - 2.1\times10^{-3})}{.25\times10^{-3}}[1.2 - 0]$$

$$\frac{m_a}{A} = 1.52 \times10^{-6} \frac{\text{kg-mole}}{\text{s-m}^2}$$

3. Mass flux = Molar flux × Molecular weight

$$= 1.52 \times10^{-6} \frac{\text{kg – mole}}{\text{s} - m^2} \times 2 \text{ mole}$$

[∵ Molecular weight of H_2 is 2]

$$\text{Mass flux} = 3.04 \times 10^{-6} \frac{\text{kg}}{\text{s} - m^2}.$$

2. Oxygen at 25°C and pressure of 2 bar is flowing through a rubber pipe of inside diameter 25 mm and wall thickness 2.5 mm. The diffusivity of O2 through rubber is 0.21 × 10^{-9} m^2/s and the solubility of O2 in rubber is 3.12 × 10^{-3} diffusion per metre length of pipe.

Given data:

Temperature, T = 25°C fig

Inside pressure P_1 = 2 bar

Inner diameter d_1 = 25 mm

Inner radius r_1 = 12.5 mm = 0.0125 m

kg – mole

m^3 – bar **. Find the loss of O_2 by** ________

Outer radius r_2 = inner radius + Thickness

= 0.0125 + 0.0025

r_2 = 0.015 m

Diffusion coefficient, $D_{ab} = 0.21 \times 10^{-9}\ m^2/s$

Solubility, = $3.12 \times 10^{-3} \frac{kg-mole}{m^3}$

Molar concentration on outer side,

C_{a2} = Solubility × Outer pressure

$C_{a2} = 3.12 \times 10^{-3} \times 0$

$C_{a2} = 0$

[Assuming the partial pressure of O_2 on the outer surface of the tube is zero]

We know,

$$\frac{m_a}{A} = \frac{D_{ab}[C_{a1} - C_{a2}]}{L}$$

For cylinders, $L = r_2 - r_1$; $A = \frac{2\pi L(r_2 - r_1)}{\ln\left[\frac{r_2}{r_1}\right]}$

Molar flux, (1) $\Rightarrow \frac{m_a}{2\pi L(r_2 - r_1)(r_2 - r_1)} = \frac{D_{ab}[C_{a1} - C_{a2}]}{}$

$$\Rightarrow m_a = \frac{2\pi L.D_{ab}[C_{a1} - C_{a2}]}{\ln\frac{r_2}{r_1}} \quad [\because \text{Length} = 1m)$$

$$m_a = 4.51 \times 10^{-11} \frac{kg-mole}{s}.$$

3. An open pan 210 mm in diameter and 75 mm deep contains water at 25°C and is exposed to dry atmospheric air. Calculate the diffusion coefficient of water in air. Take the rate of diffusion of water vapour is 8.52×10^{-4} kg/h.

Given :

Diameter d = 210 = .210 m

Deep $(x_2 - x_1)$ = 75 mm = .075 m

Temperature, T = 25°C + 273 = 298K

Diffusion rate (or) mass rate, = 8.52×10^{-4} kg/h

= 8.52×10^{-4} kg/3600s = 2.36×10^{-7} kg/s

Mass rate of water vapour = 2.36×10^{-7} kg/s

To find

Diffusion coefficient (D_{ab})

Solution

Dry atmospheric air

We know that, molar rate of water vapour.

$$\frac{m_a}{A} = \frac{D_{ab}}{GT} \frac{P}{(x_2 - x_1)} \times in\left[\frac{P - P_{w2}}{P - P_{w1}}\right]$$

$$m_a = \frac{D_{ab} \times A}{GT} \frac{P}{(x_2 - x_1)} \times in\left[\frac{P - P_{w2}}{P - P_{w1}}\right]$$

We know that,

Mass rate of water vapour = Molar rate of water vapour × Molecular weight of steam

$$2.36 \times 10^{-7} = \frac{D_{ab} \times A}{GT} \times \frac{P}{(x_2 - x_1)} \times in\left[\frac{P - P_{w2}}{P - P_{w1}}\right] \times 18 \ldots (1)$$

where,

A – Area = $\frac{\pi}{4} d^2 = \frac{\pi}{4} \times (0.210)^2 = 0.0346\ m^2$

G – Universal gas constant = $8314 \frac{1}{\text{kg-mole-k}}$

P – total pressure = 1 bar = 1×10^5 N/ m^2

P_{w1} – Partial pressure at the bottom of the test tube corresponding to saturation temperature 25°C

At 25°C

$P_{w1} = 0.03166$ bar

$P_{w1} = 0.03166 \times 10^5$ N/m^2

P_{w2} = Partial pressure at the top of the pan, that is zero

$P_{w2} = 0$

(1) $\Rightarrow 2.36 \times 10^{-7}$

$$= \frac{D_{ab} \times .0346}{8314 \times 298} \times \frac{1 \times 10^5}{0.075} \times \ln\left[\frac{1 \times 10^5 - 0}{1 \times 10^5 - 0.03166 \times 10^5}\right] \times 18$$

$D_{ab} = 2.18 \times 10^{-5}\ m^2 / s.$

4. An open pan of 150 mm diameter and 75 mm deep contains water at 25°C and is exposed to atmospheric air at 25°C and 50% R.H. Calculate the evaporation rate of water in grams per hour.

Given :

Diameter, d = 150mm = .150m

Deep $(x_2 - x_1)$ = 75 mm = .075m

Temperature, T = 25 + 273 = 298 K

Relative humidity = 50%

To find

Evaporation rate of water in grams per hour

Solution:

Diffusion coefficient (D_{ab}) [water + air] at 25°C

$= 93 \times 10^{-3}\ m^2 /h$

$$\Rightarrow D_{ab} = \frac{93 \times 10^{-3}}{3600} m^2 / s$$

$\boxed{D_{ab} = 2.58 \times 10^{-5}\ m^2 / s.}$

Atmospheric air 50% RH (2)

We know that, for isothermal evaporation,

Molar flux,

$$\frac{m_a}{A} = \frac{D_{ab}}{GT} \frac{P}{(x_2 - x_1)} \ln\left[\frac{P - P_{w2}}{P - P_{w1}}\right] \quad (1)$$

where,

A - Area $= \frac{\pi}{4} d^2 = \frac{\pi}{4} \times (.150)^2$

$$\left[\text{Area} = 0.0176 \ m^2\right]$$

G – Universal gas constant = 8314 $\frac{J}{\text{kg-mole-K}}$

P – Total pressure = 1 bar = 1×10^5 N/m^2

P_{w1} – Partial pressure at the bottom of the test tube corresponding to saturation temperature 25°C

At 25°C

P_{w1} = 0.03166 bar

P_{w1} = 0.03166 × 10^5 N/m^2

P_{w2} = Partial pressure at the top of the test pan corresponding to 25°C and 50% relative humidity.

At 25°C

$P_{w2} = 0.03166$ bar $= 0.03166 \times 10^5 \times 0.50$

$P_{w2} = 0.03166 \times 10^5 \times 0.50$

$$\boxed{P_{w2} = 1583 \ N/m^2}$$

$(1) \Rightarrow \frac{a}{0.0176}$

$$= \left[\frac{2.58 \times 10^{-5} \times 1 \times 10^5 \times \ln\left[\frac{1 \times 10^5 - 1583}{\quad}\right]}{\quad}\right]$$

Molar rate of water vapour, $m_a = 3.96 \times 10^{-9} \frac{\text{kg – mole}}{\text{s}}$

Mass rate of water vapour = Molar rate of water vapour × Molecular weight of steam

$= 3.96 \times 10^{-9} \times 18$

Mass rate of water vapour = 7.13×10^{-8} kg/s.

$= 7.13 \times 10^{-8} \times \frac{1000g}{1/3600^h}$

Mass rate of water vapour = 0.256 g/h

If Re < 5 $\times 10^5$, flow is laminar

If Re > 5 $\times 10^5$, flow is turbulent

For laminar flow :

Sherwood Number (Sh) = 0.664 $(Re)^{0.5}$ $(Sc)^{0.333}$

[From HMT data book, Page No.179]

where, Sc – Schmidt Number = $\frac{\nu}{D_{ab}}$

D_{ab} – Diffusion coefficient

Sherwood Number, Sh = $\frac{h_m x}{D_{ab}}$

Where, h_m – Mass transfer coefficient – m/s

For Turbulent flow :

Shedwood Number (Sh) = [.037 $(Re)^{0.8}$ – 871] $Sc^{0.333}$

$Sh = \frac{h_m x}{D_{ab}}$ [From HMT data book, Page No.180]

Solved Problems on Flat Plate.

5. Air at 10°C with a velocity of 3 m/s flows over a flat plate. The plate is 0.3 m long. Calculate the mass transfer coefficient.

Given :

Fluid temperature, $T_\infty = 10°C$

Velocity, $U = 3$ m/s

Length, $x = 0.3$ m

To find: Mass transfer coefficient (h_m)

Solution: Properties of air at 10°C [From HMT data book, Page No.22]

Kinematic viscosity. $V = 14.16 \times 10^{-6}$ m²/s

We know that,

$$\text{Reynolds Number, Re} = \frac{Ux}{\nu}$$

$$= \frac{3 \times 0.3}{14.16 \times 10^{-6}}$$

$$Re = 0.63 \times 10^5 < 5 \times 10^5$$

Since, $Re < 5 \times 10^5$, flow is laminar

For Laminar flow, flat plate,

Sherwood Number (Sh) = $0.664\,(Re)^{0.5}\,(Sc)^{0.333}$ ….(1)

[From HMT data book, Page No.179]

Where, Sc – Schmidt Number = $\frac{\nu}{D_{ab}}$......(2)

D_{ab} – Diffusion coefficient (water+Air) at 10°C = 8°C

$$= 74.1 \times 10^{-3} \frac{m^2}{3600 s}$$

$$\boxed{D_{ab} = 2.50 \times 10^{-5}\ m^2/s.}$$

$$(2) Sc = \frac{14.16 \times 10^{-6}}{2.05 \times 10^{-5}}$$

$$\boxed{Sc = 0.637}$$

Substitute Sc, Re values in equation (1)

(1) $\Rightarrow Sh = 0.664\,(0.63 \times 10^{5})^{0.5}(0.687)^{0.333}$

$\boxed{Sh = 147}$

We know that,

Sherwood Number, $Sh = \dfrac{h_m x}{D_{ab}}$

$$\Rightarrow 147 = \frac{h_m \times 0.3}{2.05 \times 10^{-5}}$$

$\boxed{\text{Mass transfer coefficient, } h_m = .01\ m/s.}$

VSB ENGINEERING COLLEGE KARUR
DEPARTMENT OF MECHANICAL ENGINEERING

PR8592 WELDING TECHNOLOGY

TWO MARKS QUESTIONS & ANSWERS

UNIT I GAS AND ARC WELDING PROCESSES

1. What is the principle of Oxy-Acetylene welding process?

In Oxy-acetylene welding process, acetylene is mixed in correct proportions in the welding torch and ignited, the flame resulting at the tip of the torch is sufficiently hot to melt and join the parent metal.

2. Mention the significance of three types of flames in the welding process.

Neutral flame is produced when approximately equal volumes of oxygen and acetylene are mixed in the welding torch and burnt at the torch tip. The temperature of neutral flame is 3260°C. It effects no chemical change in the molten metal and therefore will not oxidize or carburize the metal.

In Oxidizing flame, the proportion of oxygen and hydrogen is (O_2:C_2H_2=1.5:1). The temperature of reducing flame is around 3480°C. Excess oxygen in the flame at high temperatures tend to combine with many metals to form hard, brittle, low strength oxides.

In reducing flame, volume of oxygen supplied to the neutral flame is reduced. The temperature of Oxidizing flame is around 3030°C. This flame does not consume available carbon, therefore its burning temperature is lower and the left over carbon is forced into molten metal. This produces very hard, brittle substance known as iron carbide.

3. What is a flux? (or) Why is flux needed in welding?

In high-temperature metal joining processes the primary purpose of flux is to prevent oxidation of the base and filler materials. The role of a flux in joining processes is dissolving of the oxides on the metal surface, which facilitates wetting by molten metal and acting as an oxygen barrier by coating the hot surface, preventing its oxidation.

4. List the advantages and disadvantages of gas welding process.

Advantages:

1. Applied to wide variety of manufacturing process.
2. Welder has considerable control over the temperature.
3. Rate of heating and cooling is relatively slow.
4. Cost of maintenance is low.

Disadvantages:

1. Heavy sections cannot be joined.
2. Flame temperature is less than the temperature of the arc.

3. Fluxes used in certain welding and brazing operations produce fumes
4. Gas flames take long time to heat up.
5. Prolonged heating of the joint in gas welding results in a larger heat affected area.

5. State the applications of Oxy acetylene welding process.

1. For joining thin materials
2. Automobile and aircraft applications
3. In sheet metal fabrication plants.
4. Joining ferrous and non-ferrous metals. E.g. Carbon steels.

6. Write the principle of Carbon arc welding process.

Arc is maintained between the job and the carbon electrode. DC straight polarity is preferred to restrict electrode disintegration and the amount of carbon going into weld metal. The arc is struck by touching the electrode with the job momentarily and then taking away the electrode a definite distance. Filler metal and flux may or may not be used, depending upon the type of joint and the material to be welded.

7. What are the different types of joint design?

The different types of joint design are 1) Plain butt 2) Beveled butt 3) Lap 4) Corner 5) Flange 6) TEE

8. Mention the advantages and disadvantages of carbon arc welding process.

Advantages:

1. Heat input to the workpiece can be easily controlled.
2. Easy mechanization.
3. Welding cost is less compared other welding process.
4. More suitable for butt welding of thinner work pieces.

Disadvantages:

1. Carbon transfers from the electrode to weld metal, causing harder weld deposit in case of ferrous materials.
2. Absence of proper electrode geometry and in confined spaces arc blow results gives poorwelds.
3. Separate filler metal is needed, which slows down the welding speed.

9. What is twin carbon-electrode Arc welding process?

The arc is produced between two carbon electrodes held in a special holder. Two electrodes touch momentarily, part away and thus an arc establishes. Current is switched on and by operating the mechanism of arc length adjustment. The size of the arc depends upon the distance between the electrode tips, electrode diameters and the welding current.

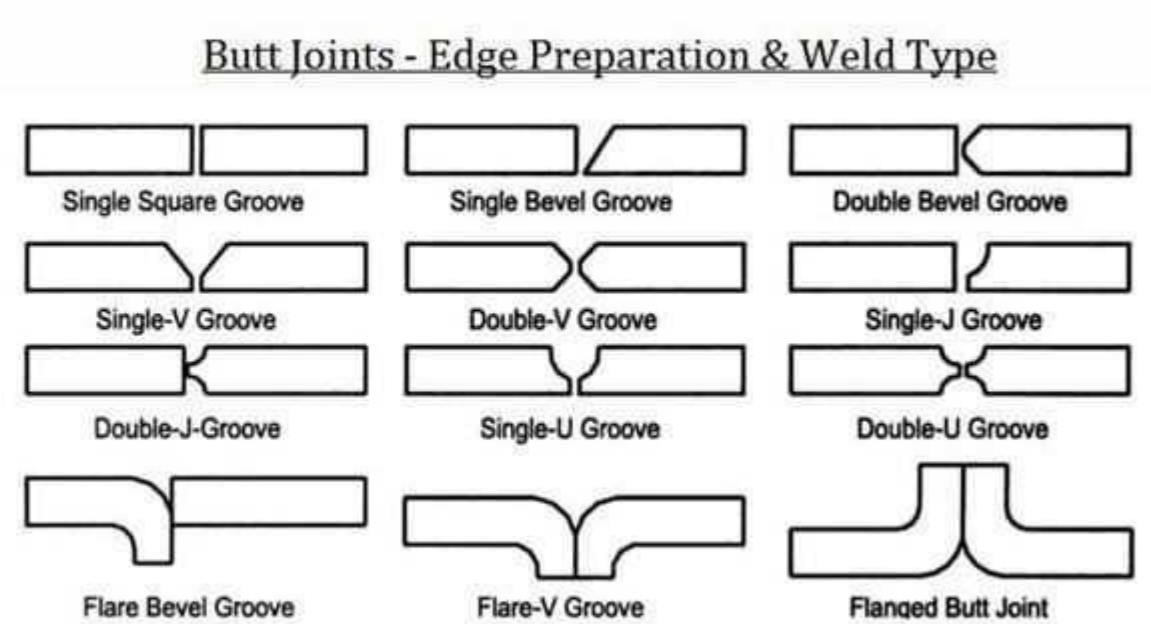
10. State the principle of flux shielded metal arc welding process.

To strike the electric arc, the electrode is brought into contact with the work piece by a very light touch with the electrode to the base metal then is pulled back slightly. This initiates the arc and thus the melting of the work piece and the consumable electrode, and causes droplets of the electrode to be passed from the electrode to the weld pool. As the electrode melts, the flux covering disintegrates, giving off shielding gases that protect the weld area from oxygen and other atmospheric gases. In addition, the flux provides molten slag which covers the filler metal as it travels from the electrode to the weld pool.

11. Define weaving in welding process.

Weaving implies giving side to side motion to the welding arc during transferring material to the joint to be welded. Weaving gives better fusion on the sides of the weld and enables the metal to built up or reinforced along any desired line.

12. List the different types of edge preparation.



13. Mention the factors affecting edge preparation.

Surface and edge of the plates to be welded are cleaned to remove the dirt, dust, paint, oil, grease etc. present on the surface either by mechanical or chemical methods. Use of chemical approach for cleaning the surface using hydrogen containing acid (sulphuric acid, hydrochloric acid etc.) sometimes introduce hydrogen in base metal which in long run can diffuse in weld and HAZ and facilitate crack nucleation & propagation (by HIC) besides making weldment brittle. Improper cleaning sometimes leaves impurities on faying surface, which, if are melted or evaporated during the welding then these impurities can induce inclusions in weld metal. Presence of inclusions in weld metal acts as stress raiser for nucleation and growth of cracks and so weakens the joint and lowers fatigue performance.

14. What is the principle of submerged arc welding?

The flux starts depositing on the joint to be welded. Flux serves as a shield and protects the molten weld pool from atmospheric contamination. Since the flux when cold is non-conductor of electricity, the arc may be struck either by touching the copper coated electrode (bare) with the work piece or by placing steel wool between electrode and job before switching on the welding current or by using a high frequency unit. The electrode at a predetermined speed is continuously fed to the joint to be welded. In semi-automatic welding sets the welding head is moved manually along the joint. In automatic welding a separate drive moves either the welding head over the stationary job or the job moves/rotates under the stationary welding head.

15. List the different types of equipment in submerged arc welding process.

The different types of equipments are 1) Welding head 2) Flux hopper 3) Welding power source 4) Flux
5) Electrode.

16. Define the term "weld backing".

Submerged arc welding produces a large volume of highly fluid weld metal which needs to be supported (backed), until it solidifies when making butt welds in one pass where complete penetration is desired. Some of the methods are 1) Backing strips 2) Backing weld 3) Copper backing 4) Flux backing 5) Gas backing.

17. Differentiate TIG and MIG.

S.No.	TIG	MIG
1	Long non-consumable tungsten electrode welding rods and slowly feed them into the weld puddle. The welding process is slower.	MIG welding uses the filler metal wire itself to produce arc and in turn melts itself to add to weld pool. Wire or Electrode used is a Continuous feeding wire, which is a very aids for quicker putting down welds.
2	TIG welding on the other hand is more commonly used for your thinner gauge materials.	A range of material thicknesses can be welded from thin gauge sheet metal right up to heavier structural plates.
3	Power required is less.	Power required is more
4	Control over welding is better.	Control over arc and metal transfer in MIG welding is inferior to TIG welding.
5	Productivity is low and high quality welds are produced.	Productivity of MIG welding is significantly higher, but the quality is inferior to TIG

18. What is the principle of Plasma Arc welding process?

Plasma arc welding is an arc welding process wherein coalescences produced by the heat obtained from a constricted arc setup between a tungsten/alloy tungsten electrode and the water-cooled (constricting) nozzle (non-transferred arc) or between a tungsten/alloy tungsten electrode and the job (transferred arc). The process employs two inert gases, one forms the arc plasma and the second shields the arc plasma. Filler metal may or may not beaded.

19. State the principle of Electro slag welding process.

Electro slag welding (ESW) is a highly productive, single pass welding process for thick (greater than 25 mm up to about 300 mm) materials in a vertical or close to vertical position. (ESW) is similar to electro gas welding, but the main difference is the arc starts in a different location. An electric arc is initially struck by wire that is fed into the desired weld location and then flux is added. Additional flux is added until the molten slag, reaching the tip of the electrode, extinguishes the arc. The wire is then continually fed through a consumable guide tube (can oscillate if desired) into the surfaces of the metal work pieces and the filler metal are then melted using the electrical resistance of the molten slag to cause coalescence.

UNIT II RESISTANCE WELDING PROCESSES

1. Write basic principle of the resistance welding process.

Electric resistance welding (ERW) refers to a group of welding process such as spot and seam welding that produce coalescence of faying surfaces where heat to form the weld is generated by the electrical resistance of material combined with the time and the force used to hold the materials together during welding.

2. Mention the different types of Resistance welding process.

Different types of Resistance welding process are Spot welding, Seam welding, Projection welding, Resistance Butt welding, Flash Butt welding, Percussion welding and High frequency resistance welding processes

3. State the terminologies used in a resistance welding cycle.

The terminologies used in resistance welding cycle are : 1) off time 2) Squeeze time 3) Weld time 4) Forge time

4. List the resistance welding variables.

Different types of welding variables 1) Welding current 2) Weld Time 3) Pressure control

5. What are the resistance welding equipments?

Resistance welding equipments comprises of electrical circuit, Contactor, timers and mechanical system for the application of desired pressure.

6. Write short notes on the heat balance in the resistance welding process.

In resistance welding, the parts to be welded are supplied with electric current by means of direct contact between the parts and the welding electrodes. As the current flows through the parts, resistance to flow of electric current produces welding heat. Combination of welding force and heat produces a strong weld at the interface. The weld nuggets will develop closer to the electrode with smaller diameter due to the higher current density or electrode with high resistivity tip due to reduced thermal conductivity hence heat dissipation.

7. Mention the factors influencing the selection of joint design.

Factors influencing joint design are 1) Edge distance 2) overlap 3) Fit up 4) Accessibility 5) Electrode marking or indentation 6) Welding sections of unequal thickness 7) Weld strength

8. Define the term 'fit up' in the resistance welding process.

The overlapping parts for spot welding should fit well with very little or no visible gap between them at the interface, otherwise a part of the force exerted will be spent in closing the gap and thus may not be adequate to form a sound and strong weld.

9. Define the term 'Weld Nugget'.

In resistance spot welding, "the welding of overlapping pieces of metal at small points by application of pressure and electric current" creates a pool of molten metal that quickly cools and solidifies into a round joint known as a "**nugget**."

10. Mention the variants of Resistance spot welding process.

The variants of resistance welding process are :

1) series welding
2) Multiple spot welding
3) Pulsation welding

11. What are the different types of Resistance seam welding process?

Different types of seam welding process are:
(i) Roll spot and stitch welding (ii) Mash seam welding (iii) Foil-butt seam welding

12. Mention the applications of seam welding

Applications:

1) Leak proof joints in tanks bandboxes
2) Welding thin materials ranging from 2.2 mm – 5.0mm
3) Welding materials of low hardenability rating – hot rolled grades of low alloy steels
4) Making flange welds for watertight tanks

13. Define the projection welding process.

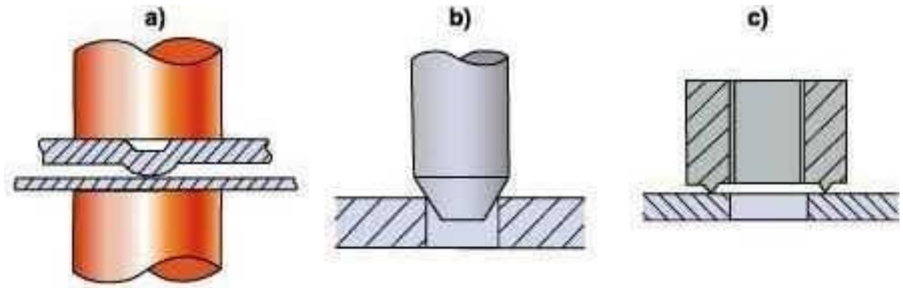
Projection welding is an electric resistance welding process that uses small projections, embossments, or intersections on one or both components of the weld to localize the heat and pressure. By doing so, weld current and force is focused into the small area of the projection, and heat is obtained from the resistance to the flow of the welding current. Due to this heat, the projections collapse and the parts are weld together.

14. List the different types of projection welding process.

(a) Embossed Projections

(b) Stud-to-Plate Projections

(c) Annular Projections



15. Define the term 'Metal fiber' welding process.

Metal fiber resistance welding process is a variant of projection welding process in which metal fibre is used instead of projection points. Metal fiber is generally a felt material which is produced from a small piece of filler material by pressing.

17. State the principle of operation in flash butt welding process.

Flash butt welding is a type of resistance welding without using any filler metal. It is used for joining two metal parts together using heat and force. Each of the two parts to be joined are clamped against an electrode, usually a copper alloy.

18. Mention the applications of Flash Butt Welding process.

1) Railway Lines (Flash butt welding machines are often transported to the work site on a road-rail vehicle)
2) Chains
3) Steel wheels
4) Sheets or rods of steel in rolling mills
5) Starter Rings
6) Bus bar

19. What is the principle of percussion welding process?

Percussion welding creates a high temperature arc that is formed from a short quick electrical discharge. Immediately following the electrical discharge, pressure is applied which forges the materials together. This type of joining brings the materials together in a percussive manner.

20. State the significance of high frequency welding process.

The predominant application of High-Frequency Resistance Welding is for continuous manufacturing of pipe and tubing. These are generally prepared for welding in a continuous roll forming strip mill where the flat strip is gradually shaped to a round form. In the weld area the open edges of the formed strip are brought together by pressure rolls, to form a vee with the apex at the weld point. Here a set of pressure forge rolls squeezes the edges, forge welding them together with expulsion of excessive metal and impurities. The main two versions differ in the way of application of High-Frequency welding current.

UNIT III SOLID STATE WELDING PROCESS

1) Mention the different types of solid state welding process.

The different types of solid state welding are 1) Friction stir welding 2) Explosion welding 3) Forge welding 4) Cold welding 5) Diffusion welding 6) Ultrasonic welding 7) Inertia welding

2) What are the major components in the friction welding machine?

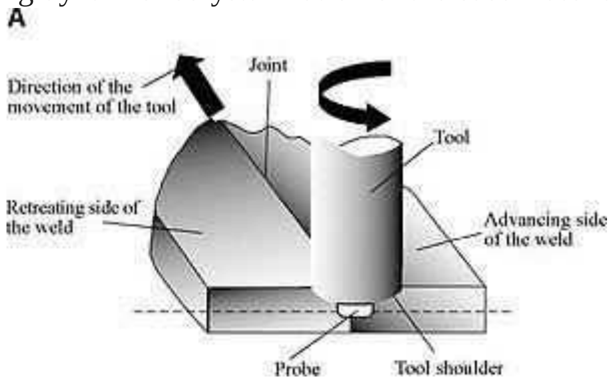
The major components of the friction stir welding are: 1) Driven head 2) Clamping arrangements 3) Rotating and upsetting mechanisms 4) Controls 5) Braking mechanisms

3) List the variants in the friction welding process.

The variants of friction welding are
1. Inertia welding 2. Friction welding Sub-variants of friction stir welding are:
a) Hybrid friction stir welding b) Friction stir spot welding c) Friction stir surfacing d) Miscellaneous welding

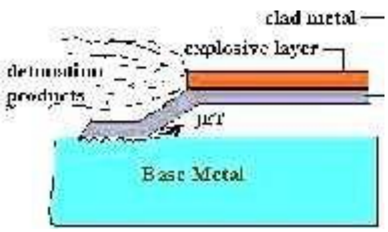
4) Briefly mention the principle of Friction stir welding (FSW) process.

A constantly rotated non-consumable cylindrical-shouldered tool with a profiled probe is transversely fed at a constant rate into a butt joint between two clamped pieces of butted material. The probe is slightly shorter than the weld depth required, with the tool shoulder riding atop the work surface.
Frictional heat is generated between the wear-resistant welding components and the work pieces. This heat, along with that generated by the mechanical mixing process and the adiabatic heat within the material, cause the stirred materials to soften without melting. As the pin is moved forward, a special profile on its leading face forces plasticized material to the rear where clamping force assists in a forged consolidation of the weld.
This process of the tool traversing along the weld line in a plasticized tubular shaft of metal results in severe solid state deformation involving dynamic recrystallization of the base material.



Schematic of FSW

5) Mention the principle of explosive welding.

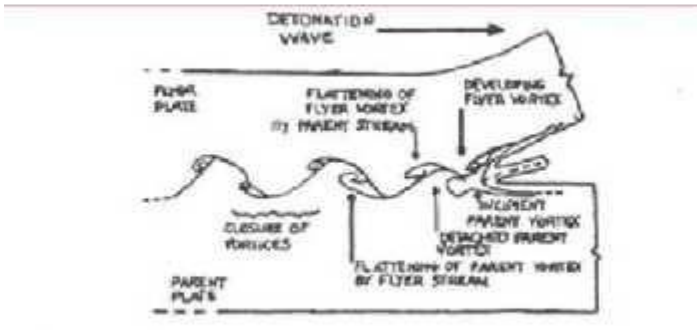


Schematic of explosive welding

Explosion welding (EXW) is a solid state (solid-phase) process where welding is accomplished by accelerating one of the components at extremely high velocity through the use of chemical explosives. This process is most commonly utilized to clad carbon steel plate with a thin layer of corrosion resistant material
(e.g., stainless steel, nickel alloy, titanium, or zirconium). Due to the nature of this process, producible geometries are very limited. They must be simple.
Typical geometries produced include plates, tubing and tube sheets.

6) What is phenomenon of 'surface jetting'?

Welds made with collision velocities above the critical value have a wavy interface as shown in figure. Welding such an interface has better mechanical properties than those with flat interface. In such welds, a phenomenon known as surface jetting is also observed so that a small jet of metal is formed from the two impacting components. Such a jet is freely expelled at the edge of the joint; however, if it is trapped it results in rippling effect.



Surface Jetting

7) List the basic components involved in Explosion welding process.

The basic components in this process are:

1. Target plate 2. Flyer plate 3. Buffer plate 4. Explosive or detonator

8) State the process variables in explosive welding process.

The process variables in explosive welding process are 1) Impact velocity 2) Stand-off distance 3) Angle of approach.

9) List the applications of explosive welding process.

- The explosive welding are used for making lap joints
- Aluminium and Copper can be welded to stainless steel, Aluminium to Nickel alloy, Stainless steel to Nickel.
- Cladding of plates and cylinders
- Can weld metals which are incompatible for fusion welding.
- Fabrication of heat exchangers

10) State the principle of diffusion welding.

Diffusion welding (DFW) is a solid state welding process by which two metals (which may be dissimilar) can be bonded together. Diffusion involves the migration of atoms across the joint, due to concentration gradients.

11) Write down the applications of diffusion welding.

DFW is usually used on sheet metal structures. Typical materials that are welded include titanium, beryllium, and zirconium. It is usually used on low volume work pieces mainly for aerospace, nuclear, and electronics industries. In many military aircraft diffusion bonding will help to allow for the conservation of expensive strategic materials and the reduction of manufacturing costs. Some aircraft have over 100 diffusion-bonded parts, including; fuselages, outboard and inboard actuator fittings, landing gear trunnions, and nacelle frames.

12) Define cold welding process.

Cold welding or contact welding is a solid-state welding process in which joining takes place without fusion/heating at the interface of the two parts to be welded. Unlike in the fusion-welding processes, no liquid or molten phase is present in the joint. It was then discovered that two clean, flat surfaces of similar metal would strongly adhere if brought into contact under vacuum. Newly discovered micro and nano-scale cold welding has already shown great potential in the latest nano fabrication processes.

13) Mention the applications of Cold welding process.

Perhaps the greatest use of cold pressure welding has been for joining of wire, foil to wire, wire to bi-metals, and sealing of heat sensitive containers such as those containing explosives (detonators for example).

Rod coils are butt welded to permit continuity in post-weld drawing to smaller diameters.

In the electronics industry, cold welding processes are used to seal tin plated steel crystal cans and copper packages for heat sensitive semiconductor devices. Glass packages are also sealed using an indium or tin alloy interlayer.

An interesting application of the process is underground wire servicing where joins need to be made in hostile environments, such as in the presence of explosive gases.

14) Define 'Forge welding' process.

Forge welding (FOW) is a solid-state welding process that joins two pieces of metal by heating them to a high temperature and then hammering them together. It may also consist of heating and forcing the metals together with presses or other means, creating enough pressure to cause plastic deformation at the weld surfaces. The process is one of the simplest methods of joining metals and has been used since ancient times. Forge welding is versatile, beingable to join a host of similar and dissimilar metals.

15) State the principle of 'Ultrasonic Welding' process.

Ultrasonic-welding is a solid state process. It achieves the joining of metals or plastics by locally applying vibratory energy to work pieces pressed together. The energy of vibration produces a local relative parallel displacement at the interface between two metal abutting surfaces. The motion breaks and disperses surface oxides and causes intimate metal to metal contact that results in a weld.

16) List the applications of Ultrasonic welding process.

- Wire terminations and splicing in electrical and electronics industry - Eliminates need for soldering
- Assembly of aluminum sheet metal panels
- Welding of tubes to sheets in solar panels
- Assembly of small parts in automotive industry

17) State the components in the Ultrasonic welding process.

An Ultrasonic-welding system includes:

- An electronic power supply that elevates the frequency of the electrical current [from that of the grid to that required by the process, typically from 15 to 40 kHz (kilo Hertz)].
- A piezoelectric transducer that transforms electrical into mechanical energy.
- An acoustic coupling device or booster that modifies the shape and magnitude of the vibrations, and
- A weld tool called horn or sonotrode that transmits the oscillations to the materials to be welded, clamped together by pressure unto the stationary anvil.

18) Mention the process parameters in the Ultrasonic welding process.

Some of the process parameters are : 1) Amplitude 2) Down speed 3) Alignment/leveling of horn 4) Welding/hold force 5) Trigger force 6) welding mode

20) List the materials that can be welded in the Ultrasonic Welding process.

Ultrasonics can also be used to weld metals, but are typically limited to small welds of thin, malleable metals, e.g. aluminum, copper, nickel.

21) What is 'Roll welding' process?

Roll-welding, also called Roll Bonding, is a process that joins together a stack of sheets or plates. The stack is fed through a cold rolling mill under sufficient pressure to produce significant deformation and solid state welding. Metals should be ductile, like copper, aluminum, low carbon steel, nickel.

UNIT IV OTHER WELDINGPROCESS

1) Write the principle of operation of thermit welding process.

Thermit welding is based on casting and foundry practice and consists essentially of providing, by means of chemical reaction, a volume of molten weld metal which is poured into the joint to be welded

2) Mention the different types of thermit mixtures.

The different types of thermit mixtures are

1. Plaint hermit
2. Mild steel thermit
3. cast iron thermit
4. Thermit for welding rails 5.Thermit for welding electric connections

3) State the advantages and limitations of thermit welding process. Advantages:

1) Heat required for welding is obtained from the chemical reaction of the hermit mixture. Hence, no costly power supply is required.

2) The process is best suitable, particularly in remote locations where sophisticated welding equipments and power supply cannot be arranged.

Limitations:

1).Thermit welding is applicable only to ferrous metal part of heavy actions

2). The process is not economical if used to weld cheap metals or light parts

4) List the uses and applications of thermit welding.

Thermit welding is mainly used in repair and welding of large forgings and castings, pipes, mill housings and heavy rail sections.

5) What is the principle of Atomic Hydrogen Welding?

Atomic hydrogen welding (AHW) is an arc welding process that uses an arc between two metal tungsten electrodes in a shielding atmosphere of hydrogen. The process was invented by Irving Langmuir in the course of his studies of atomic hydrogen.

6) State the different equipments in the atomic welding process.

The equipments are: 1) Welding torch with tungsten electrodes and cable 2) Hydrogen gas supply 3) AC power source

7) List the advantages and disadvantages of the Atomic Hydrogen Welding(AHW).

The advantages are :

1) High concentration of heat makes qui9ckweld
2) Work can be easily moved, without extinguishing, since 2 tungsten electrodes maintain thearc.
3) No flux is used
4) Uniform dense, dense, ductile welds can be produced The disadvantages are:

1) Less welding speed compared to MIG welding
2) Uneconomical
3) Process cannot be used for depositing large quantities of metals

8) Mention the radiant energy process used for welding.

The radiant energy welding process are 1) Electron Beam Welding (EBW) 2) Laser Beam Welding (LBW)

9) State the principle of electron welding process.

Work piece are joined together by the heat obtained from a high velocity electron beam impinging On the work piece.

10) Mention the sequence of Electron Beam Welding (EBW).

The sequence is as follows 1) Joint preparation 2) Workpiece cleaning 3) Fixturing of workpiecec 4)

Workpiece demagnetization 5) Settin up workpieces 6) Pump down 7) Pre-heating of workpiecec 8) Weld schedule 9) Welding

11) List the different types of environment in which EBW are carried out.

The different types of environment are: 1) Hard vacuum 2) Partial vacuum 3) Atmosphere

12) Compare vacuum and atmospheric welding systems in EBW.

S.No	Vaccum welding	Atmospheric welding
1	Vaccum welding assures degasification and decontamination	Inert gas shielding protects the molten weld
2.	Size of the weld depends on the size of the vacuum	Considerably wider welds are produced. Large workpiece can be welded
3.	Metal vapours obstruct the free passage of the beam.	Metal vapours do not spoil the beam gun
4.	Time taken for setting is more.	Time taken is comparatively less.

13) State the equipments in EBW equipment.

1) Electron beam gun
   *Tungsten filament *Cathode
   *Anode *Focusing coil
2) Vacuum pumping system
   *work chamber
   *vacuum pump

14) What are the safety precautions to be taken for electron beam welding?

Protection must be provide against
1) The electron beam itself
2) The high voltages involved in generating the electron beam
3) X-rays produced by impinging of the beam on the work piece

15) List the process variables in EBW.

Variables that control electron beam welding are
1) Accelerating voltage 2) Beam current
3) Distance from gun to work 4) Focusing current

16) Mention the advantages of Electron Beam Welding.

1) No filler metal is required
2) Clean weld is produced
3) The process yields high penetration
4) Penetration can be easily controlled by accelerating beam voltage, beam current &beam focus

17) State the principle of Laser Beam Welding (LBW).

Welding process wherein coalescence is produced by the heat obtained from the application of a concentrated coherent light beam impinging upon the surfaces to be joined.

18) List the different types of lasers used for LBW.

1) Ruby laser 2) Gas laser
3) Liquid laser 4) Semi-conductor laser

19) Mention the advantages and disadvantages of LBW. Advantages:

1) Weld can be made inside transparent glass or plastic housings
2) Areas not readily accessible can also be welded
3) It is possible to weld heat treatment alloys without affecting their heat treatment condition
4) Unlike electron beam it operates in air, no vacuum is required

Disadvantages:

1) The major drawback to laser beam welds is the slow welding speeds
2) Materials such as magnesium tends to vaporize and produce severe surface voids

20) What are the applications of Laser Beam Welding (LBW)?

1) Laser is high energy light beam that can both weld and cut metals
2) For connecting leads on small electronic components and in integrated circuitry in the electronic industry
3) To join hard high melting point metal alloys
4) In space and aircraft industry for welding light gauge materials
5)

22) List the different types of underwater welding process.

i. Dry welding
ii. Wet welding

23) What is 'hyperbaric' welding?

Hyperbaric welding is the process of welding at elevated pressures, normally underwater. Hyperbaric welding can either take place *wet*in the water itself or *dry* inside a specially constructed positive pressure enclosure and hence a dry environment. It is predominantly referred to as "hyperbaric welding" when used in a dry environment, and "underwater welding" when in a wet environment. The applications of hyperbaric welding are diverse—it is often used to repair ships, offshore oil platforms, and pipelines. Steel is the most common material welded.

24) State the principle of cavity welding.

- Cavity welding is another approach to weld in water free environment.
- Conventional arrangements for feeding wire and shielding gas
- Introducing cavity gas and the whole is surrounded by a trumpet shaped nozzle through which high velocity conical jet of water passes.
- It avoids the need for a habitat chamber and it lends itself to automatic and remote control.
- The process is very suitable for flat structures.

25) What are the characteristics of a good underwater welding process?

1) Inexpensive welding equipments and low welding cost
2) Decreased electrical hazards
3) Permit good visibility
4) Easy operation
5)Produce good quality welds
6) Permit welding in all positions

26) List the applications of underwater welding process.

The following are the applications

- Offshore construction for tapping sea resources.
- Temporary repair work caused by ship's collisions, or unexpected accidents.
- Salvaging vessels sunk in the sea.
- Construction of large ships beyond the capacity of existing docks.
- Maintenance of oilrigs.

27) What are the three basic functions of automation?

The basic functions are 1)Physical function
2) Programming function
3) Control function

27) Classify welding automation.

The four welding automations are

1) Welding mechanization
2) General Purpose welding automation
3) Welding programming automation
4) Welding or motion programming automation(Robotics)

28) What are the benefits of automation in welding?

The advantages are:

1) Consistent weld quality

2) Reduced variable welding cost
3) Predictable welding production rates
4) Increased arc time

UNIT V – DESIGN OF WELD JOINTS, WELDABILITY AND TESTING OF WELDMENTS

1. **What are the requirements of joint design?**
   The requirements of joint design are :
   1) Control distortion
   2) Minimize residual stresses
   3) Facilitate good workmanship
   4) Achieve proper weld strength
   5) Reduce welding cost
   6) Result in greater reliability
2. **Mention the considerations for joint design.**
   The important considerations are 1) Safety 2) Service 3) Quality 4) Cost or economy

3. **List the different types of welding joints.**
   Five types of welding joints 1) butt, 2) corner, 3) edge, 4) lap, and 5) Tee

4. **Mention the types of Butt joint.**
   The types are as follows:
   1) Square 2)Single Vee 3) Single bevel 4) Single J 5) Single U 6) Double Vee 7) Double bevel 8) Double J 9) Double U

5. **List the types of corner joint.**
   The types are 1) Full open corner joint 2) Half open corner joint 3) Closed corner joint

6. **Mention any four characteristics of lap joint.**
   The following are the characteristics of lap joint :
   1) Single fillet and double fillet joints are used on all thickness
   2) Double fillet joint is better as compared to single fillet when the joint is subjected severe loading
   3) Single fillet joints are not not recommended on plates under bending, fatigue or impact loading condition.
7. **What is a plug weld?**
   A plug weld is used to fasten two pieces of metal together using a welder. When joining the pieces, a hole is drilled into the top piece and it is laid over the bottom one. A weld is then made by running a bead inside of the drilled hole, thereby holding the two pieces together. When doing auto body repair, this type of weld is often used when replacing body panels. The finished result resembles a spot weld in that it is circular.
8. **Define the term fillet welds.**
   Fillet welding refers to the process of joining two pieces of metal together whether they be perpendicular or at an angle. These welds are commonly referred to as Tee joints which are two pieces of metal perpendicular to each other or Lap joints which are two pieces of metal that overlap and are welded at the edges.
9. **What are the factors considered for locating weld joints?**
   The following are the factors:
   1) Economic layout and preparation and low scrap loss inmaterial
   2) Accessibility of joint
   3) The possibilities of subassembly.
   4) Appearance
   5) Shrinkage and distortion
   6) Ease of assembly with simplicity in fixtures.
10. **Mention the parameters for selection of welding joints.**
    1) Current 2)Length of arc 3)Angle 4) Manipulation speed

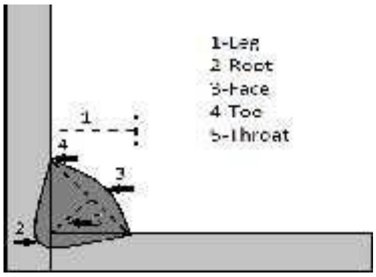
11. **List the various factors affecting the strength of a weldedjoint.**

The following are the factors affecting the strength of welding :
1) Type of joint and weld 2) Size of weld 3) Location of the weld to the parts joined
4) Strength of the deposited weld metal

5) skill of welder 6) Type of equipment used for welding

12. What is weld throat?

The throat of the weld is the distance from the center of the face to the root of the weld. Typically the depth of the throat should be at least as thick as the thickness of metal to be weld.



13. Classify aluminum alloys.

The classification of aluminum alloys are 1)Wrought alloy 2) Cast alloys

14. Mention the welding process used for aluminum and its alloys.

1) Aluminum does not show any colour change on heating
2) Aluminum has got high coefficient of linear expansion
3) Aluminum is weak when hot and thus extra care is required

15. List the solid state welding process used for welding aluminium alloys.

The different types of solid state welding are
1) Cold welding 2) explosive welding
3) Diffusion welding 4) Ultrasonic welding.

16. Why Aluminum castings undergo welding process?

The reasons for Aluminum castings:

a. Correct foundry defects
b. Repair castings broken in service.

17. State the variables affecting the welding characteristics of copper alloys.

The following are the variables affecting the characteristics:

a. Higher thermal conductivity
b. Thermal expansion
c. Susceptibility for hot cracking
d. Oxidation
e. Fluidity of molten copper

18. Mention the welding process used for welding copper.

The high thermal conductivity of copper means that not only are high heat input shielding gases required thickness increase but preheat necessary at section thickness exceeding 2mm a very rough guide recommended pre heat and welding current levels is given in the table for tig and mig welding

19. List the welding process used for joining brass material.

The welding process are: 1) TIG welding 2) MIG welding 3) Shielded Metal arc welding 4) Oxy acetylene gas welding

20. Mention the different groups of stainless steels.

1)Ferritic stainless steel 2)Martensitic stainless steel 3)Duplex stainless steel 4)Austenitic stainless steel

21. List the weldability considerations for austenitic stainless steels.

Following are the weldability considerations for austenitic stainless steels: 1)Electrical resistance
2) Melting point
3) Thermal conductivity
4) Thermal expansion

22. Mention the methods used for welding straight chromium (Ferritic and martensitic) stainless steels.

Following are the methods of welding Ferritic and martensitic stainless steels

a. Shielded Metal Arc welding

b. TIG welding
c. MIG welding
d. Submerged Arc welding
e. Resistance welding

23. List the weldability considerations for austenitic stainless steels.

1. Most stainless steels are considered to have good weldability and maybe welded by several welding processes including the arc welding processes, resistance welding, electron and laser beam welding, friction welding and brazing.
2. The coefficient of thermal expansion for the austenitic types is 50%greater than that of carbon steel and this must be considered to minimize distortion.
3. The low thermal and electrical conductivity of austenitic stainless steel is generally helpful in welding.

24. List the destructive testing methods of weldments.

1. Macro Etch Testing
2. Fillet Weld Break Test
3. Transverse Tension Test
4. Guided Bend Test

25. Why is testing and inspection carried out after the jobs?

Workplace inspections help prevent injuries and illnesses. Through critical examination of the workplace, inspections identify and record hazards for corrective action. Joint occupational health and safety committees can help plan, conduct, report and monitor inspections. Regular workplace inspections are an important part of the overall occupational health and safety program.

26. Why is Guide bend test done?

The bend test is a simple and inexpensive qualitative test that can be used to evaluate both the ductility and soundness of a material. It is often used as a quality control test for butt-welded joints, having the advantage of simplicity of both test piece and equipment.

27. What the different types are of etch test?

The different types are of etch test are

1. Macro-etch test
2. Micro-etch test

28. List the defects identified from Macro-etch test.

i. Cracks
ii. Slag inclusion
iii. Blowholes
iv. Shrinkage porosity
v. Penetration of the weld

29. List the methods of Non-destructive testing.

1. AET - Acoustic Emission Testing
2. ART - Acoustic Resonance Testing
3. ET - Electromagnetic Testing
4. IRT - Infrared Testing
5. LT - Leak Testing
6. MT - Magnetic Particle Testing
7. PT - Dye Penetration Testing
8. RT - Radiographic Testing
9. UT - Ultrasonic Testing
10. VT - Visual Testing (VI - Visual Inspection)

30. Why is stethoscope test done?

The stethoscope is an instrument used for auscultation, or listening to sounds produced by the body. It is used primarily to listen to the lungs, heart, and intestinal tract. It is also used to listen to blood flow in peripheral vessels and the heart sounds of developing fetuses in pregnant women.

31. Mention the principle involved in Radiography test.

Radiographic Testing (RT), or industrial radiography, is a nondestructive testing (NDT) method of inspecting materials for hidden flaws by using the ability of short wavelength electromagnetic radiation (high energy photons) to penetrate various materials.

In radiographic testing, the part to be inspected is placed between the radiation source and a piece of radiation sensitive film. The radiation source can either be an X-ray machine or a radioactive source (Ir-192, Co- 60, or in rare cases Cs-137).

32. State the principle of ultrasonic testing.

Ultrasonic Testing (UT) uses high frequency sound energy to conduct examinations and make measurements.

Ultrasonic inspection can be used for flaw detection/evaluation, dimensional measurements, material characterization, and more. To illustrate the general inspection principle, a typical pulse/echo inspection configuration as illustrated below will be used.

33. What is eddy current test?

Eddy-current testing (also commonly seen as eddy current testing and ECT) is one of many electromagnetic testing methods used in nondestructive testing (NDT) making use of electromagnetic induction to detect and characterize surface and sub-surface flaws in conductive materials.

34. List the advantages and limitations of eddy current test.

The advantages are

i. Sensitivity to surface defects..
ii. Can detect through several layers.
iii. Can detect through surface coatings
iv. Accurate conductivity measurements.
v. Can be automated.
vi. Little pre-cleaning required.
vii. Portability.

The Limitations are

i. Very susceptible to magnetic permeability changes.
ii. Only effective on conductive materials.
iii. Will not detect defects parallel to surface.
iv. Not suitable for large areas and/or complex geometries
v. Signal interpretation required.
vi. No permanent record (unless automated

PART-B

UNIT I GAS AND ARC WELDING PROCESSES

1 Define welding and classification of welding and allied processes with neat sketch .

2 Explain gas welding process and their equipments, advantages, disadvantages and applications.

3 Explain arc welding process and their equipments, advantages, disadvantages and applications.

4 Explain the carbon welding technique with a neat sketch, also mention the applications.

5 Briefly explain Shielded Metal Arc Welding (SMAW) with a neat sketch.

6 Explain construction and working principle of submerged arc welding, also give advantages and disadvantages.

7 Explain the working of Tungsten Inert Gas Welding (TIG) and their components.

8 Briefly explain the working principle of Metal Inert Gas Welding and their components with a neat sketch.

9 Explain the construction and working of Plasma Arc Welding (PAW) , their merits and demerits.

10 Draw a neat sketch and explain the working of Electro slag and Electro gas welding.

11 With a neat sketch explain the construction and working of Carbon Arc welding

12 List the components of Electro Gas Welding with a brief explanation. BT4 Analyzing

13 What are all the welding parameters of Flux Cored Arc welding? Explain them.

14 Explain about the Oxyacetylene Gas Welding process and also its advantages.

UNIT II RESISTANCE WELDING PROCESSES

1 Briefly explains the construction and working of Resistance Welding process.

2 Explain the working of Resistance Spot Welding (RSW) and their advantages and limitations.

3 Explain the steps involved in Resistance Seam Welding and its types.

4 Write short notes on process parameters of Resistance Welding.

5 Describe the construction and working of Resistance Projection Welding with their advantages and limitations.

6 With a neat sketch explain the construction and working of Resistance Butt Welding with their advantages and limitations.

7 Describe the construction and working of Flash Butt Welding with a neat sketch 8 Write short notes on Upset Butt Welding and draw a neat sketch. BT2 Understanding

9 Briefly explain the construction and working of Percussion Welding.

10 With a neat sketch explain the construction and working of Stud Welding.

11 Describe the construction and working of Low frequency Resistance Welding with a neat sketch.

12 What are the different types of spot welders used in Resistance Spot Welding? Explain them briefly.

13 What are the steps involved in Electric Resistance Welding (ERW) of tubes.

14 Describe the construction and working of High frequency Resistance Welding with a neat sketch.

UNIT III SOLID STATE WELDING PROCESSES

1 Explain the principle of Solid State Welding process and briefly explain any one type with a neat sketch.

2 Write short notes on Cold Welding process with a neat sketch. 3 Describe the working principle of Diffusion Welding process, and give its advantages, disadvantages.

4 Write the advantages, disadvantages, applications and working principle of Explosive Welding.

5 Explain the working of Ultrasonic Welding and their equipments in detail.

6 Write short notes on Friction Welding with a neat sketch.

7 Describe the working principle of Forge Welding with a neat sketch.

8 Write down the process parameters involved in Diffusion Welding and explain them in details.

9 Explain the types of Friction Welding and its process parameters. BT4 Analyzing

10 What is the working principle of Roll Welding? Explain with a neat sketch.Also mention the advantages and disadvantages.

11 Draw a neat sketch and describe the Hot Pressure Welding.

12 Explain the working of Wedge Reed Ultrasonic Welding system in detail.

13 Write down the process parameters involved in Ultrasonic Welding and explain them in details.

14 Discuss the working principle of Cold Pressure Welding process with a neat sketch.

UNIT IV OTHER WELDING PROCESSES

1 Describe the principle of Thermit Welding and explain its types.

2 Explain about Atomic Hydrogen Welding with a neat sketch.

3 What is the working principle of Electron Beam Welding; explain it with a neat sketch. Also mention the advantages, disadvantages and applications.

4 Explain the construction and working of Laser Beam Welding with a neat sketch.

5 Draw a neat sketch and explain Friction Stir Welding (FSW) and the steps involved.

6 Explain Dry Underwater Welding with a neat sketch.

7 Explain the welding automation in nuclear reactor. Draw a neat sketch.

8 Write short notes on welding automation in aerospace industry.

9 Discuss briefly about the various process parameters in Friction Stir Welding (FSW).

10 Explain Wet Underwater Welding with a neat sketch. Give its advantages and disadvantages.

11 Describe all the structural features in Friction Stir Welding.

12 Describe Robot Welding System with a neat sketch.

13 Discuss briefly about the various process parameters in Atomic Hydrogen Welding.

14 Write short notes on welding automation in surface transport vehicle.

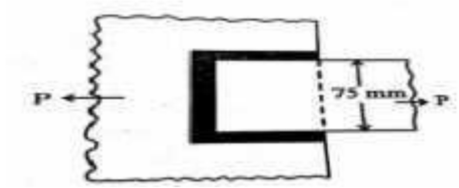
UNIT V DESIGN OF WELD JOINTS, WELDABILITY AND TESTING OF WELDMENTS

1 Explain the types of welded joints with a neat sketch.

2 What are the factors considered for welding design?

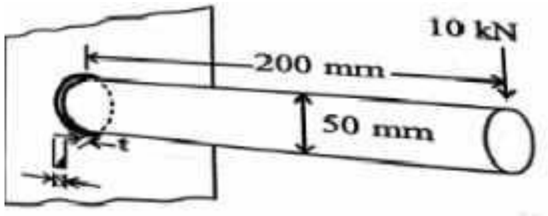
3 Draw neat sketches and explain the welding symbols and sectional representation and form of weld.

4 A plate 75mm wide and 12.5 mm thick is joint with another plate by a single transverse weld and double parallel fillet weld as shown in fig. The maximum tensile and shear stresses are 70 MPA and 56 MPa respectively. Find the length of each parallel fillet weld if the joint is subjected to both static and fatigue loading.



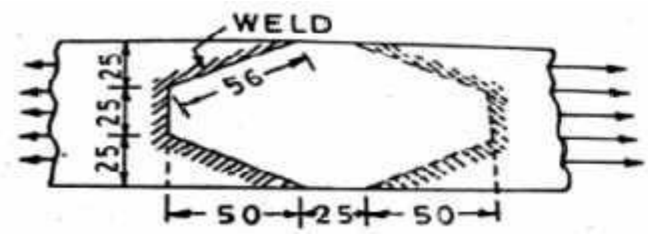
5 Discuss the weldabilty and general guidelines to weld stainless steel and aluminium materials.

6 A 50 mm diameter solid shaft is welded to a flat plate as shown in fig. If the size of the weld is 15mm, find the maximum normal and shear stress in the weld.



7 A plate of 50mm width, carrying a load of 12000kg is to be welded by 4 equal fillets to another plate as shown in fig. Find the necessary size of the fillet.

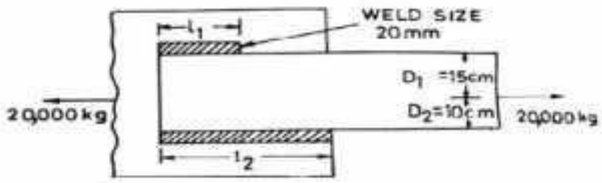
8 A welded lap joint as shown in fig. connects by 6.4mm fillets two 75 x 10mm plates which are in tension allowing a stress of 11kg/mm2 in the end fillets and 8.8kg/mm2 in the diagonal fillets, it is required to find if the joint is suitable. The working stress in the plate is 12.8kg/mm2.



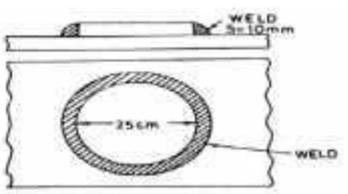
9 Enumerate the principle of performing magnetic particle inspection on weld joints also list down the advantages and disadvantages.

10 Explain the different types of destructive testing with neat sketch .

11 For the structure shown in fig. determine the two fillet weld lengths L1 and L2. Assume working stress in shear in fillet weld as 800kg/cm2 and size of the fillet as 20mm.



12 A circular plate and a rectangular plate have been welded as shown in fig. Find the greatest twisting moment that can be resisted by the fillet weld. Assume permissible shear stress in the weld as 1040kg/cm2.



13 Discuss the liquid penetrate testing and eddy current testing with suitable sketch.

14 Explain the working of ultrasonic testing and radio graphic testing with suitable sketch.