Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

II SEMESTER M.TECH (THERMAL SCIENCES & ENERGY SYSTEMS/CAAD/MET)

END SEMESTER EXAMINATION (REGULAR) APRIL 2018

SUBJECT: COMPUTATIONAL FLUID DYNAMICS (MME 5242)

REVISED CREDIT SYSTEM

Note: (i) Answer ALL questions
(ii) Missing data,if any, may appropriately be assumed and stated explicitly
(iii) Draw neat schematic sketches wherever applicable and appropriate

1A. Convert x–directional Navier-Stokes (Momentum) Equation (no derivation) using scaling laws to deduce **scale-free equation** as given below: 04

$$\frac{\partial u'}{\partial t'} + u'\frac{\partial u'}{\partial x'} + v'\frac{\partial u'}{\partial y'} + w'\frac{\partial u'}{\partial z'} = -\frac{1}{F^2} - P\frac{\partial p'}{\partial x'} + \frac{1}{R}\left(\frac{\partial^2 u'}{\partial x'^2} + \frac{\partial^2 u'}{\partial y'^2} + \frac{\partial^2 u'}{\partial z'^2}\right)$$

where, prime signs indicate the corresponding scale-free properties and F and R represents the Dimensionless Froude and Reynold's Numbers where as $P = \frac{P_\infty}{\rho U_\infty}$ is the Non-dimensional Pressure Coefficient, with P_∞ and U_∞ being the free stream pressure and velocity and ρ is the density of the medium.

1B. Deduce the Velocity Correction Equations. Hence derive **Pressure Correction Equation** for Convection dominated Diffusion in a 2-D incompressible flow. 06

2A. Enumerate the **Basic Laws of Discretization** for Control Volume Method. 02

2B. Water is flowing in a pipe of diameter 25 mm. It enters the pipe with a temperature of 150^{o}C. The velocity at inlet is 8 m/s which can be assumed to remain constant along the pipe length. The diffusive flux (Γ) through the pipe can also be assumed to be constant at 850 kg/m/s. The length of the pipe is 800 mm. Water leaves the pipe at a temperature of 30^{o}C. Apply the following discretization schemes and obtain the temperature distribution along the pipe using Control Volume **technique.** Use three equally spaced unknown control volumes to discretize the domain in each case. 08
(1) Central Difference Scheme (CDS)
(2) Upwind Differencing Scheme (UDS)
(3) Exact Analytical Method.

3A. Enumerate the advantages and disadvantages of Euler, Crank-Nicholson, and Pure Implicit Numerical Methods. 04

3B. Derive the Non-dimensional GDE and its finite element discretization for a 2-Dimensional steady state heat transfer in a **Square Plate** with uniform internal heat 06 generation and with all its edges subjected to constant temperature of T_∞.

4A. Derive the **Reynolds Transport Equation** and explain its analogy to Substantial Derivative of a flow property. 04

4B. What is meant by Numerical False Diffusion? Explain the same in the case of constant temperature hot and a cold fluid flowing in a non-aligned steady flow in a two-dimensional flow field. 04

4C. Give the mathematical Implementation of the following boundary conditions for a typical CFD problem citing the example. 02

(1) Axisymmetric condition
(2) Wall condition
(3) Fully developed flow at the exit
(4) Inlet condition for compressible flow.

5A. A steel fin of thermal conductivity 45 W/m.K and having uniform rectangular cross section 25mm X 20 mm and length 200 mm, is fitted to an engine head at 375^0C. It is exposed to ambient convective air having convective heat transfer coefficient of 20 W/m^2.K. The average bulk temperature of the cooling air is 35^oC. The fin can be treated as slender with negligible heat transfer from the open end face of the fin. Apply **Finite Difference Method** to solve temperature distribution assuming five equally spaced grids, undergoing steady one dimensional heat transfer. 05

5B Using time averaged parameters, derive the following Navier Stokes equation for a general turbulent flow in the form, 05

$$\frac{\partial \bar{u}}{\partial t}+\frac{\partial \bar{u}\bar{u}}{\partial x}+\frac{\partial \bar{u}\bar{v}}{\partial y}+\frac{\partial \bar{u}\bar{w}}{\partial z}=\frac{\bar{D}\bar{u}}{Dt}$$