Name: **Enrolment No:**	UPES UNIVERSITY WITH A PURPOSE

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
Online End Semester Examination, January 2021

Course: Finite Volume Methods for Conservation Laws **Semester: I**
Program: M. Tech CFD **Time: 03 hrs.**
Course Code: ASEG 7021 **Max. Marks: 100**
Pages: 04
Instructions: Make use of sketch/plots to elaborate your answer. All sections are compulsory

SECTION A (30 marks)

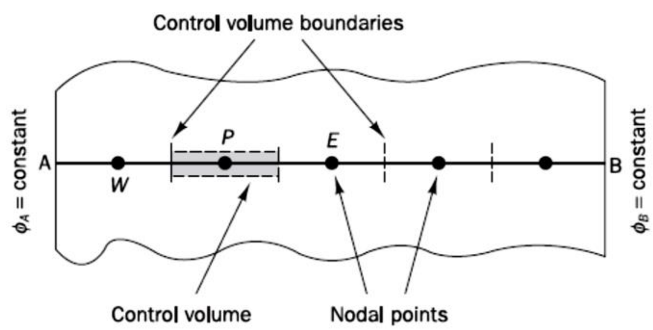
1. Each Question will carry 5 Marks
2. Instruction: Type your answers in the provided space

S. No.		Marks	CO
Q 1	Which of these models will directly give the conservative equations suitable for the finite volume method? a) Finite control volume moving along with the flow b) Finite control volume fixed in space c) Infinitesimally small fluid element moving along with the flow d) Infinitesimally small fluid element fixed in space	**[05]**	**CO2**
Q 2	Which of these terms need a surface integral? a) Diffusion and rate of change terms b) Convection and source terms c) Convection and diffusion terms d) Diffusion and source terms	**[05]**	**CO1**
Q 3	Which of these terms need a volume integral while modelling steady flows? a) Convection term b) Diffusion term c) Source term d) Rate of change term	**[05]**	**CO1**
Q 4	In a one-dimensional flow, the volume integral becomes ___________ a) a line integral b) an area integral c) a surface integral d) a surface integral and the Gauss divergence theorem	**[05]**	**CO2**
Q 5	The discretization of the transient term using the finite volume approach is more like the spatial discretization of ___________ a) the convection term b) the diffusion term c) the source term d) the anti-diffusion term	**[05]**	**CO3**

Q 6	When the first-order implicit Euler scheme is unconditionally stable, the solution is _________ a) stationary for large time-steps b) oscillatory for large time-steps c) stationary for small time-steps d) oscillatory for small time-steps	**[05]**	**CO3**

SECTION B (50 marks)

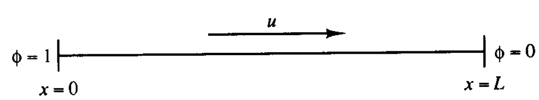
1. **Each question will carry 10 marks**
2. **Instruction: Write short/brief notes, scan and upload the document**

Q 7	Explain in details the philosophy of the SIMPLE method. What is the need for a staggered grid?	**[10]**	**CO2**
Q 8	Consider the steady state diffusion of a property ϕ in a one-dimensional domain defined in figure. The process is governed by $$\frac{d}{dx}\left(\Gamma \frac{d\phi}{dx}\right) + S = 0$$ where Γ is the diffusion coefficient and S is the source term. Boundary values of ϕ at points A and B are prescribed.  Explain the several steps involved in discretizing the geometry and the equation to obtain the appropriate solutions of the governing differential equation.	**[10]**	**CO3**
Q 9	In compressible viscous flows the energy equation is completely decoupled from the continuity and momentum equations, i.e. the solution of energy equation is not required for obtaining pressure and velocity fields. Prove it.	**[10]**	**CO3**

<table>
<tr><td>Q 10</td><td>Classify the steady two-dimensional velocity potential equation:

$$\left(1 - M^2\right)\phi_{xx} + \phi_{yy} = 0$$
where M is mach number. Explain the physical meaning of various classifications based on M.</td><td>[10]</td><td>CO4</td></tr>
<tr><td>Q 11</td><td>What do you mean by initial and boundary conditions? Define various types of boundary conditions which are usually encountered in CFD problems.</td><td>[10]</td><td>CO4</td></tr>
<tr><td colspan="4">SECTION-C (20 marks)
1. Question carries 20 Marks and has internal choice.
2. Instruction: Write long answer, scan and upload the document</td></tr>
<tr><td>Q 12</td><td>A property ∅ is transported by means of convection and diffusion through the one-dimensional domain sketched in figure below. The governing equation below;
$$\frac{d}{dx}(\rho u \emptyset) = \frac{d}{dx}\left(\tau \frac{d\emptyset}{dx}\right)$$
boundary conditions are $\emptyset_0 = 1$ at $x = 0$ and $\emptyset_L = 0$ at $x = L$. Using five equally spaced cells (for first two cases) and the central differencing scheme for convection and diffusion calculate the distribution of ∅ as a function of x for cases:

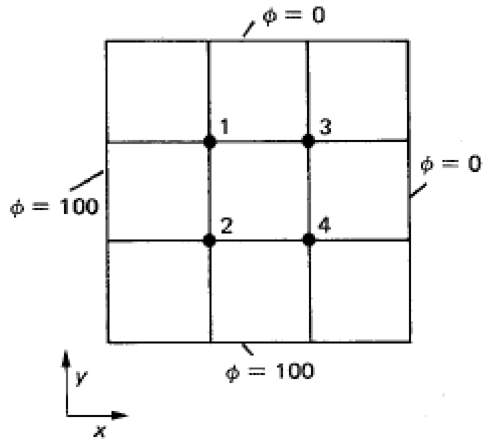
(i) Case 1: u = 0.1 m/s, using 5 cells
(ii) Case 2: u = 2.5 m/s, using 5 cells
(iii) Case 3: u = 2.5 m/s, using 10 cells



and compare the results with the analytical solution given below. The following data apply: length L = 1.0 m, p = 1.0 kg/m^3, Γ = 0.1 kg/m/s.

$$\frac{\phi - \phi_0}{\phi_L - \phi_0} = \frac{\exp(\rho u x/\Gamma) - 1}{\exp(\rho u L/\Gamma) - 1}$$
OR

In a steady two-dimensional situation, the variable ϕ is governed by
$$div\,(\rho \boldsymbol{u} \phi) = div(\Gamma grad\phi) + a - b\phi$$</td><td>[20]</td><td>CO5</td></tr>
</table>

<table>
<tr>
<td></td>
<td>where $\rho = 1$, $\Gamma = 1$, $a = 10$, and $b = 2$. The flow field is such that u = 1 and v = 4 everywhere. For the uniform grid shown in the figure $\Delta x = \Delta y = 1$. The values of ϕ are given for the boundaries. Adopting the control volume design calculate the values of $\phi_1, \phi_2, \phi_3,$ and ϕ_4 by the use of:
(a) The central-difference scheme
(b) The upwind scheme
(c) The hybrid scheme
(d) The power-law scheme


</td>
<td></td>
<td></td>
</tr>
</table>