Name: Enrolment No:	UPES — UNIVERSITY OF TOMORROW

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
End Semester Examination, May 2022

Course: Transport Phenomena for Geosystems Engg **Semester: IV**
Program: APE(UP) **Time: 03 hrs.**
Course Code: PEAU2007 **Max. Marks: 100**

Instructions: The exam is closed book and closed notes. Adoption of any unfair means will be severely penalized

S. No.		Marks	CO
SECTION A			
Q1	What is the value of the divergence of the position vector?	**4**	**CO1**
Q2	What are the properties of the curl operator?	**4**	**CO1**
Q3	State and explain Fick's law of diffusion.	**4**	**CO2**
Q4	What do you mean by convective energy flux?	**4**	**CO2**
Q5	What is meant by two-phase relative permeability?	**4**	**CO3**
SECTION B			
Q6	Show using the component representation, if **v**, **w** are two vectors, $[\mathbf{v}\times\mathbf{w}].[\mathbf{v}\times\mathbf{w}] + (\mathbf{v}.\mathbf{w})^2 = v^2w^2$ where v and w are the magnitudes **v** and **w** respectively.	**10**	**CO2**
Q7	A Newtonian fluid is in laminar flow in a narrow slit formed by two parallel walls a distance $2B$ apart. It is understood that $B << W$, the width of the slits, so that edge effects are negligible. Derive expressions for the stress and velocity distributions in the slit from the equations of change given below. Assume constant pressure gradient. *Newton's law of viscosity:*	**10**	**CO3**

	Cartesian coordinates (x, y, z): $\tau_{xx} = -\mu\left[2\frac{\partial v_x}{\partial x}\right] + (\frac{2}{3}\mu - \kappa)(\nabla \cdot \mathbf{v})$ (B.1-1)[a] $\tau_{yy} = -\mu\left[2\frac{\partial v_y}{\partial y}\right] + (\frac{2}{3}\mu - \kappa)(\nabla \cdot \mathbf{v})$ (B.1-2)[a] $\tau_{zz} = -\mu\left[2\frac{\partial v_z}{\partial z}\right] + (\frac{2}{3}\mu - \kappa)(\nabla \cdot \mathbf{v})$ (B.1-3)[a] $\tau_{xy} = \tau_{yx} = -\mu\left[\frac{\partial v_y}{\partial x} + \frac{\partial v_x}{\partial y}\right]$ (B.1-4) $\tau_{yz} = \tau_{zy} = -\mu\left[\frac{\partial v_z}{\partial y} + \frac{\partial v_y}{\partial z}\right]$ (B.1-5) $\tau_{zx} = \tau_{xz} = -\mu\left[\frac{\partial v_x}{\partial z} + \frac{\partial v_z}{\partial x}\right]$ (B.1-6) in which $(\nabla \cdot \mathbf{v}) = \frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z}$ (B.1-7) *Equation of continuity:* *Cartesian coordinates (x, y, z):* $\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x}(\rho v_x) + \frac{\partial}{\partial y}(\rho v_y) + \frac{\partial}{\partial z}(\rho v_z) = 0$ (B.4-1) *Navier-Stokes Equation:* *Cartesian coordinates (x, y, z):* $\rho\left(\frac{\partial v_x}{\partial t} + v_x\frac{\partial v_x}{\partial x} + v_y\frac{\partial v_x}{\partial y} + v_z\frac{\partial v_x}{\partial z}\right) = -\frac{\partial p}{\partial x} + \mu\left[\frac{\partial^2 v_x}{\partial x^2} + \frac{\partial^2 v_x}{\partial y^2} + \frac{\partial^2 v_x}{\partial z^2}\right] + \rho g_x$ (B.6-1) $\rho\left(\frac{\partial v_y}{\partial t} + v_x\frac{\partial v_y}{\partial x} + v_y\frac{\partial v_y}{\partial y} + v_z\frac{\partial v_y}{\partial z}\right) = -\frac{\partial p}{\partial y} + \mu\left[\frac{\partial^2 v_y}{\partial x^2} + \frac{\partial^2 v_y}{\partial y^2} + \frac{\partial^2 v_y}{\partial z^2}\right] + \rho g_y$ (B.6-2) $\rho\left(\frac{\partial v_z}{\partial t} + v_x\frac{\partial v_z}{\partial x} + v_y\frac{\partial v_z}{\partial y} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial p}{\partial z} + \mu\left[\frac{\partial^2 v_z}{\partial x^2} + \frac{\partial^2 v_z}{\partial y^2} + \frac{\partial^2 v_z}{\partial z^2}\right] + \rho g_z$ (B.6-3)		
Q8	A certain cylindrical material generates heat per unit volume according to the equation: $S_g(r) = 1 + \left(\frac{r}{R}\right)^2$ where R is the radius of the cylinder and r represents the radius at which the volume element is located. Evaluate using shell energy balance the temperature profile assuming a temperature of T_0 at $r = R$.	**10**	**CO4**
Q9	Explain in detail how you could extend the concept of permeability to describe three-dimensional flow in an anisotropic porous media.	**10**	**CO3**
	SECTION C		
Q10	Consider the one-dimensional two-phase flow of oil and water through a porous media with actual velocity, v_l. The permeability of a given phase (oil or water) is observed to be related to its saturation by the equation, $K_p = K_{p,pure} \exp\left[-(1 - S_p)\right]$ where p is the phase (either oil or water). Given that the viscosities of the oil and water phase are μ_o and μ_w respectively, derive expressions for the propagation velocity for a layer with saturation $S_w = 0.5$. Assume negligible surface tension and gravity effects.	**20**	**CO3**

Q11	Using the concepts of mass and momentum balance, derive expressions for modifications to the black oil model in case of mass transfer from the vapor phase to the water phase	**20**	**CO4**