1.7 Starting from the mathematical formulation and analysis of Kelvin-Helmholtz instability, describe the Rayleigh-Taylor instability by using $U_1 = U_2 = 0$.

1.8 In an estuary, salty water is over fresh water locally. The densities of fresh and salty water can be taken as $1020 kg/m^3$ and $1040 kg/m^3$, respectively. Calculate the cut-off wavenumber below which unstable waves grow at the interface, considering surface tension at the interface be 0.020 N/m. Find out the wave length at which the growth rate is maximum.

1.9 Is there an upper limit for critical Reynolds number for pipe flow?

1.10 Obtain the dispersion relation for Rayleigh-Taylor instability, when the fluids on either side of the interface is of finite depth, H_1 and H_2.

1.11 If the vessel for the problem of 1.10 experiences an added acceleration f in the direction of gravity, what will be the dispersion relation?

Chapter 2:

2.1 What are the mechanisms for two- and three-dimensional flows by which energy is created at higher wavenumbers for turbulent flows?

2.2 Derive the energy and dissipation spectra for high Reynolds number turbulent flows in the inertial subrange.

2.3 Relate the time scales of mean and fluctuation fields of an equilibrium turbulent flow. Does this justify the usage of *unsteady RANS* in solving unsteady flows?

2.4 What is the closure problem in turbulence modeling for Reynolds-averaged Navier-Stokes (RANS) equation? What is the basis by which it is solved in engineering codes?

2.5 Explain what is meant by equilibrium turbulence. How this can be used in justifying "Unsteady RANS"? How this is used in constructing sub-grid scale (SGS) model in LES?

2.6 What are the justifications for relating turbulent stresses to the mean strain rates in turbulence models or subgrid scale stress models?

2.7 How is vortex stretching responsible for energy cascade in three-dimensional turbulence?

2.8 What is backscatter or inverse energy cascade? Discuss it in the context of enstrophy cascade in two-dimensional turbulence.

2.9 A viscous incompressible flow is established by a constant pressure gradient between two parallel planes, one of which is also imparted a constant velocity U_0. The two planes are at H distance apart. Find out the velocity distribution and the limiting pressure gradient for the flow to separate.

2.10 How is Kolmogorov length scale important in DNS of turbulent flows?

2.11 Derive the asymptotic suction required at the wall of a two-dimensional boundary layer to maintain the flow to be similar.

2.12 Is the dispersion relation always dependent on governing differential equation? Obtain the dispersion relation for Rayleigh-Taylor instability.

2.13 Show that for an irrotational flow, nonlinearity of the convection term merely redefines the pressure and thus seldom gives rise to instability.

2.14 Solve the Blasius boundary layer equation: $f''' + \frac{1}{2}ff'' = 0$ in $0 \leq \eta \leq \eta_{max}$, computationally as a boundary value problem, where η is the similarity profile introduced in the text. Choose a value of $\eta_{max} = 12$ for your calculation. Is there an inflection point for the Blasius profile?

2.15 Consider the following 1D convection equation,

$$\frac{\partial u}{\partial t} + c\frac{\partial u}{\partial x} = 0, \qquad c > 0 \tag{2.1}$$

Obtain the numerical amplification factor $|G|$ and normalized group velocity $|V_{gN}/c|$, for the following space-time discretization schemes used for this model equation: (i) OUCS3-RK_4, (ii) CD2-RK_4 and (iii) QUICK-RK_4 schemes.

2.16 Considered a wave packet with $k_0 = 50$ in a domain of length 10, with 4096 uniformly distributed points following the initial condition given by,

$$u(x,t)|_{t=0} = e^{-\alpha(x-x_0)^2}\cos[k_0(x-x_0)] \tag{2.2}$$

where x_0 is the center of the wave-packet at $t = 0$, whose central wavenumber is given by k_0. Solve Eq. (2.1), using CD_2 and OUCS3 spatial discretization schemes with RK_4 time integration method. Choose, $\alpha = 30000$, $c = 0.1$ and CFL number $N_c = 0.1$.

Chapter 3:

3.1 For a periodic vortex-train convecting at $Y = 20\delta^*$ over a zero pressure gradient (ZPG) boundary layer, compare the receptivity of the boundary layer when the train moves at (a) $c = U_\infty$ and (b) $c = U_\infty/3$. The distance between successive vortices is $a = 100\pi\delta^*$.

3.2 Why is the local solution upstream of a harmonic point source placed on the wall of a ZPG boundary layer independent of Reynolds number?

3.3 Why do ZPG boundary layers display Klebanoff or breathing mode in response to very low frequency disturbance field? Is there a lower cut-off frequency for this?

3.4 A ribbon is placed outside a boundary layer over a ZPG flow and is vibrated electromagnetically at a constant physical frequency. Formulate the corresponding receptivity problem and state qualitatively the nature of the response field within the boundary layer.

3.5 Identify the eigenvalue(s) in the complex wave number plane for a ZPG boundary layer for $Re = 1000$, for a constant frequency excitation in the ranges (i) $0.003 < \bar{\omega}_0 < 0.03$ and (ii) $0.03 < \bar{\omega}_0 < 0.06$. Give justifications for your identification.

3.6 A pusher propeller driven aircraft wing is being affected due to tip vortices of the propeller blades. How will it affect the transition on the wing? Give a qualitative answer with justification.

3.7 From the neutral curves for boundary layers experiencing different pressure gradients (favourable and adverse), identify viscous and inviscid instabilities of these flows.

3.8 A boundary layer is excited at the wall and the free stream, simultaneously. For this flow, one uses compound matrix method (developed for wall excitation problems) and obtains eigenvalues also on the left half of wavenumber plane. What is the significance of this result?

3.9 Show the coupling between wall modes and free-stream modes of the Orr-Sommerfeld equation.