Turbulent Jets and Plumes

1. A flow of $Q=20 \text{ m}^3/\text{s}$ is to be discharged to a water body of large dimensions. The discharged water is $10^\circ\text{C}$ warmer than the receiving water. In order to quickly lower the temperature of the discharge, it is released via horizontal jets near the bottom.

Determine the number of diffuser openings required so that the discharge water is only $2^\circ\text{C}$ warmer than the receiving water at $40 \text{ m}$ from the discharge point. The velocity at the central axis of the jet shall be $0.2 \text{ m/s}$ at $40 \text{ meters}$ from the discharge point. The jets are assumed to remain horizontal (i.e., it is assumed that there is little difference between the density of the discharge and ambient water).

2. Treated wastewater is to be pumped out via a pipe laid on the bottom of the ocean (density in the ocean is $\rho_{\text{rec}}=1030 \text{ kg/m}^3$). The discharge occurs through a horizontally directed circular jet placed $0.5 \text{ m}$ above the bottom (see enclosed figure). Homogenization occurs by the time the jet reaches the surface (at a factor $1:4$). Determine the minimum length of the discharge pipe if it is required that the density difference between the discharge and receiving water shall be $0.3 \text{ kg/m}^3$ after homogenization. The discharge occurs through a diffuser with diameter $D_o=0.15 \text{ m}$. Other given parameters are: wastewater discharge rate $Q_o=0.040 \text{ m}^3/\text{s}$; wastewater density $\rho_o=1005 \text{ kg/m}^3$; and bottom slope 1:100.
3.

An axisymmetric circular jet is pointed vertically upward in water with the same density as that being discharged. The pipe discharge is located at the bottom at $H$ meters below the surface. The water surface causes the jet stream to flow radially outward from the central axis near the surface (see enclosed figure). Strong mixing occurs in the region where the flow changes direction from the vertical to the horizontal, but the entrainment by surrounding water into the jet stream is negligible here.

Determine the concentration of the radially outward flowing discharge water if the mixing zone has a depth of $H/10$. The concentration at the discharge point is $C_o$, the pipe discharge diameter is $D_o$, and the discharge velocity is $U_o$. Assume that the radially flowing discharge is homogenous. Compare the calculated concentration with the centerline concentration at a distance $9H/10$ from the exit.

4.

A pipe discharges wastewater via diffusers at a 10 meter water depth below the sea surface (ambient density $\rho _r=1016.3$ kg/m$^3$). The discharge velocity from the horizontally directed holes is $U_o=2$ m/s and the total discharge rate is $Q_o=0.30$ m$^3$/s. Determine the number of openings required and the size of each opening in the diffuser, if the density difference between the discharge and receiving water should be 0.5 kg/m$^3$ after mixing and homogenization (factor 1:4) at the water surface. Assume a wastewater density of $\rho_o= 999$ kg/m$^3$.

5.

Concentration measurements were carried out at three points (A, B, and C) in a jet discharged to a receiving water. All measurement points were taken along a line perpendicular to the center axis, but none of the points were at the axis. The following
concentrations were obtained: $C_A=7.47$ mg/l, $C_B=13.86$ mg/l, and $C_C=12.8$ mg/l. The measurement transect were located 20 m downstream the jet exit and the distance $L$ between the points along the transect was 1.5 m. Estimate the mean concentration $C_o$ at the jet exit if the diameter is 0.5 m at the exit.

6.

Treated wastewater with a temperature varying between 10 and 15 deg during the day is going to be discharged to a lake. The discharge will be through a horizontal pipe with a diameter of 600 mm. Determine the water depth at the discharge point so that the center-line concentration at the water surface is 1/5 of the initial concentration at the jet exit. The temperature of the receiving water varies between 6 and 20 deg during the year and it is assumed to be homogeneous through the vertical. Density differences are only due to temperature and the discharged flow is 0.25 m$^3$/s.

7.

The density in a receiving water varies according to the following: an upper layer (0-5 m) has a density of 1000 kg/m$^3$, a lower layer (> 10 m) a density of 1010 kg/m$^3$, and between these two layers (5-10 m) the density varies linearly. Treated wastewater is discharged horizontally at a water depth of 15 m at a flow rate of 0.022 m$^3$/s and with a density of 998 kg/m$^3$. At what water depth will the discharged water be trapped and start spreading horizontally in the ambient water and what is the concentration there? The diameter of the exit pipe is 0.15 m.