1. The pressure field at depth \( z = 1000 \text{m} \) in the ocean is found to follow the rule,

\[
p = p_c + p_0 \cos \left( \frac{\pi x}{10^4} \right) \cos \left( \frac{\pi y}{10^4} \right)
\]

The origin of \( y \) is taken to be 30\(^\circ\)N and \( x, y \) are measured in meters. What are the northward and eastward components of geostrophic velocity at \( x = 10^4/2, y = 0 \)? If the fluid density is approximated as uniform, \( \rho = \rho_0 = 1.03 \times 10^3 \text{kg/m}^3 \), how much water (mass) is moving northward between the seasurface and 1000m, between \( x = 0 \) and \( x = 10^4/2 \)? For a numerical answer, let \( p_0 = 250 \text{N/m}^2 \).

2. A ship measures the temperature and salinity in the ocean at \( x = 0 \), and \( x = 100 \text{km} \) at a latitude of 40\(^\circ\)N. When converted to density, the two profiles are found to be closely approximated as,

\[
\rho (x = 0, z) = 1.03 \times 10^3 \text{kg/m}^3 \left( 1 - z/(2 \times 10^4) \right), \\
\rho (x = 100 \text{km},z) = 1.03 \times 10^3 \text{kg/m}^3 \left[ 1 - (z + 1 \times 10^{-7} z^2)/(2 \times 10^4) \right]
\]

where \( z \) is in meters. Compute and plot the northward velocity as a function of \( z \) for \( 0 \leq z \leq 3000 \text{m} \) under the assumption that \( z = -1500 \text{m} \) is a level of no motion. What is different at 10\(^\circ\)N? Take gravity, \( g = 10 \text{m/s}^2 \). What is the surface elevation change between the two locations?

3. A uniform wind blows towards the north such that the windstress on the ocean is \( \tau = \tau_0 (-1, 1) \). Using the equations,

\[
-f v = A \frac{\partial^2 u}{\partial z^2}, \\
-f u = A \frac{\partial^2 v}{\partial z^2}
\]

which govern the Ekman layer, find \( u, v \) as a function of \( z \). (Hint: multiply the second equation by \( i \) and add to the first equation. Solve this equation for the complex quantity \( u + iv \). Treat \( f \) as constant. Consider rotating the \( x, y \) axes. Note that the implied density is \( \rho_0 = 1 \), which for seawater implies cgs units. Alternatively, one can define \( A' = A/\rho \).