1) The figure below depicts a two-layer ocean with the interface sloping down a total of 500 meters between point A and point B which is 100 km to the east. The sea level is also tilted, but this slope is too small to be seen in this schematic. The flow is geostrophic and is equal to 1.0 m/s in both layers. However in one layer the flow is to the north while in the other layer the flow is to the south. The lower layer density is not given, but it is greater than the density of the upper layer. The Coriolis frequency is 10^{-4} \text{s}^{-1}.

1a) Which layer is flowing to the north (into the page) and which layer is flowing to the south? Explain your reasoning. (Hint: based on the slope of the interface you should be able to figure out the sign of the shear and thus which layer is flowing which way.)

1b) What is the sea-level difference between points A and B? Which point is higher?

1c) What is the density of the lower layer? (Hint: take the difference between the equations for geostrophic balance in the upper layer and lower layers. Note that the pressure gradient in the upper layer is only due to the surface slope, while the pressure gradient in the lower layer contains contribution from both the sea level slope and the interface slope.)
2) Consider the surface Ekman layer in a constant-density ocean ($\rho_o = 1000$ kg/m$^3$). For a wind stress ($\tau_y$) directed to the North, the solutions for the Ekman spiral are:

$$u(z) = V_0 \exp(az) \cos(az + \pi/4)$$

$$v(z) = V_0 \exp(az) \sin(az + \pi/4)$$

where

$$a = (f/2Az)^{1/2}$$

and

$$V_0 = \tau_y / \rho_o (fA_z)^{1/2}$$

Following Ekman, we will assume that the surface wind stress is related to the surface wind as follows:

$$\tau_y = \rho_{air} c_d (V_{wind})^2$$

(a) What is the magnitude of the surface wind stress if the surface wind speed is 10 m/s? Assume the density of air is 1 kg/m$^3$, and the drag coefficient is $c_d = 0.0025$.

(b) What is the magnitude of the surface current at 45° N? Assume $A_z = 10^{-2}$ m$^2$/s.

(c) Calculate the magnitude and direction of the current for each of the following depths: $z = 0$, $-\pi/6a$, $-\pi/4a$, $-\pi/3a$, $-\pi/2a$, $-3\pi/4a$, $-\pi/a$. Make an x-y plot of the current vectors.

(d) What is the depth of frictional influence (the Ekman depth, $D_E$)?