Example questions for midterm

1.

(a) On a summer day that is clear with no frontal activity over land, sketch diurnal variations of winds at 2 and 500 meters. Explain why.
(b) Describe general characteristics of turbulence.
(c) Describe Taylor's frozen turbulence hypothesis.

2.

Based on the following information derive a) the magnitude and direction of pressure gradient force, Coriolis force, and friction force per unit mass near the surface; b) the average magnitude of the actual wind shear across the boundary layer; and c) the frictional veering of the wind across the boundary layer; and d) the average value of the Richardson number and existence of turbulence in the PBL.

At 45°N, the surface geostrophic wind speed is 17 m s^{-1} at 145 deg (wind directions use meteorological convention);
PBL = 1000 m, assume the winds are geostrophic at this height;
Assume that the measurement at 1 m height is representative of the surface wind and the pressure at 1 m is 1000 mb;
The atmosphere is dry.
The observations are

Height (m)	1	1000
Wind speed (m s^{-1})	10	20
Wind direction (deg)	110	135
Temperature (°C)	25	23

3.

For the Ekman layer in the barotropic atmosphere, the equations of motion can be written as

$$-f(v-v_g) = K(d^2/dz^2)(u-u_g)$$
$$f(u-u_g) = K(d^2/dz^2)(v-v_g) \qquad (1)$$

where K is the effective viscosity.
The boundary conditions are

$u = 0$, $v = 0$, at $z = 0$

$u = u_g$, $v = v_g$, as $z \to \infty$.

The solutions are

$$u-u_g = -e^{-az}[u_g\cos(az) + v_g\sin(az)]$$
$$v-v_g = e^{-az}[u_g\sin(az) - v_g\cos(az)] \qquad (2)$$

where $a = (f/2K)^{1/2}$.

(a) Using Eq.(2), obtain the horizontal shear stress components τ_{zx} and τ_{zy}.
(b) In a coordinate system with the x axis parallel to the geostrophic wind, write down the expressions for the normalized vertical components (u/G and v/G where G is the magnitude of geostrophic wind).
(c) In the same coordinate system draw the wind hodograph using the expressions above as function of az from 0 to 2π.
(d) If f = 10^{-4} s^{-1} and K = 4 m^2 s^{-1}, what is the Ekman layer thickness?