1. A rising air parcel in the core of a thunderstorm achieves a vertical velocity of 80 m/s (similar to the midterm) when it reaches a neutral buoyancy altitude at approximately 12 km and 200 mb. Assume the background atmosphere is isothermal at this altitude. How much will the air parcel overshoot the neutral buoyancy level altitude?
    a. Set the kinetic energy/mass of the air parcel at the neutral buoyancy level equal to the work/mass done by the negative acceleration of the air parcel above the neutral buoyancy altitude. The acceleration is proportional to the Brunt Vaisala frequency squared: Eq's 37 & 38 from adiabatic lapse rate notes.
    b. Solve for the height above the neutral buoyancy level at which the potential energy per unit mass equals that of the kinetic energy and therefore at which the parcel stops moving vertically.
2. N_2 collisional crosssection (you'll need this for problem 3)
    a. Given that the diffusivity of air for typical surface conditions is 2e-5 m^2/s, work backwards to determine the approximate collisional crosssectional area of N_2 molecules colliding with other N_2 molecules
3. Exobase: When the mean free path equals a scale height, molecules can potentially overcome Earth's gravity and escape to space.
    a. Determine the approximate pressure level at which the exobase occurs in Earth's atmosphere.
    b. Determine the approximate height of the exobase for N_2.

    Assume the average temperature of the atmosphere up to 90 km is 230K and the air is sufficiently mixed that the mean molecular mass is 28.96 g/mole. Above 90 km, assume the average temperature is 500 K and the scale height depends on the selected molecule, in this N_2.
4. Using the form where $u = \bar{u} + u'$,
    a. Show that the horizontal moisture flux is $\rho_a \overline{uq} = \rho_a \bar{u}\,\bar{q} + \rho_a \overline{u'q'}$
    b. Dscribe the kinds of fluxes that the two terms, $\rho_a \bar{u}\,\bar{q}$ and $\rho_a \overline{u'q'}$ represent.
    c. Explain why for the vertical flux $\rho_a \overline{wq} = \rho_a \bar{w}\,\bar{q} + \rho_a \overline{w'q'} \cong \rho_a \overline{w'q'}$

5. SH Flux into surface

Consider a citrus tree grove where the trees are about 5 m in height and the wind at 10 m is blowing at 2 m/sec with a surface temperature of 0^oC and pressure of 1000 mb.

   a. Calculate an approximate eddy diffusivity

   Assume the temperature at 10 m is 1^oC warmer than the surface temperature

   b. Calculate the vertical sensible heat flux
   c. Is it up or down?

6. Surface evaporative flux increase with global warming

Suppose the Earth's surface were to warm by 4^oC as predicted by some climate models. Suppose that the relative humidity of the air and the winds were to remain the same. Using the aerodynamic formula for latent heat flux, determine the ratio of the new surface latent heat flux to the present surface latent heat flux.

7. Diffusion scaling: The time to cook a hard-boiled egg is ~12 minutes. Based on your understanding of diffusion (see eq. (16) of the diffusion lecture), how long should it take to cool a watermelon in a refrigerator down to the refrigerator's temperature. State whatever assumptions you need to make.

SHOW ALL WORK