Meteorology 3510
Final Exam
April 25, 2008
100 points (Each problem is worth 4 points unless otherwise noted.)

1. (2 points) For $T = 30°$ C and $p = 800$ hPa, what is the density, ρ, of dry air?

2. (2 points) Given $\rho = 1.2$ kg m^{-3} and the volume, $V = 6$ m^3, what is the mass, M, of a sample of a gas?

3. What is the mass per unit area of a column of the atmosphere extending from the surface, where $p = 900$ hPa, to the top where $p = 0$?

4. Determine the thickness of a layer of the atmosphere given the pressures at the bottom, 1000 hPa, and top, 900 hPa, of the layer, and the average virtual temperature of the layer, 25° C.

5. On a clear summer afternoon, the atmosphere is receiving an energy flux of 800 W m^{-2} from the underlying land surface, due to conduction and thermal radiation from the ground, which is being warmed by solar radiation. If this energy flux is uniformly distributed through the layer of air between the surface, at $p_1 = 900$ hPa, and $p_2 = 700$ hPa, how much will the average temperature of this layer change over 3 hours?

6. (6 points) During a cold air outbreak from Siberia over the Sea of Japan, the temperature of the lowest 250 hPa of the atmosphere warms by 12° C, due to heating by the upper 40 m of the ocean. How much does this ocean layer cool as a result?

7. What is the thickness of the lowest 200 hPa of the atmosphere if the surface pressure is 800 hPa, the surface temperature is 15° C, and the lapse rate is dry adiabatic?

8. What is the pressure of a dry atmosphere at a height of 3 km if the pressure at 0 km is 1000 mb, the temperature is 30° C, and the lapse rate is 6.5 K km^{-1}?

9. A parcel of dry air rises and expands adiabatically from $p_1 = 900$ hPa where $T_1 = 25°$ C to $p_2 = 500$. What is $T_2 = T(p_2)$?

10. How much is 2 kg of air cooled by evaporating 5 g of water into it?

11. What is the LCL for air with $T = 28°$ C and $T_d = 9°$ C at $p = 900$ hPa?

12. How much water vapor condenses as the parcel described in the previous problem ascends to 500 mb?

13. If half of the condensed water falls out of the ascending parcel described in the previous problem, and the parcel then descends, what is the SEL (Sinking Evaporation Level)? What is T at 800 mb after descent? What is T_d at 800 mb after descent?

14. (6 points) The temperature and dewpoint values measured by a radiosonde are plotted on the accompanying skew T-log p diagram.
(a) A parcel ascends adiabatically from $p = 950$ mb, where its temperature and dewpoint are the same as those measured by the radiosonde, to 100 mb. Plot the parcel's temperature on the skew T-log p diagram.
(b) Indicate the parcel's LCL (lifting condensation level), LFC (level of free convection), and LNB (level of neutral buoyancy) on the skew T-log p diagram. *Label each level with its corresponding pressure.*
(c) Indicate the Negative Area (NA) and Positive Area (PA) on the skew T-log p diagram.
(d) What is the Lifted Index for this parcel?
(e) What degree of instability does this value of the Lifted Index represent?

15. What is the definition of the saturated adiabatic lapse rate, Γ_s? Does it have a fixed value? Is $\Gamma_s > \Gamma_d$?

16. What are the conditions, in terms of the actual lapse rate $\gamma \equiv -dT/dz$, Γ_d, and Γ_s, for absolute instability, absolute stability, and conditional instability?

17. Define T_w, the wet-bulb temperature, in words.

18. For p = 900 mb, T =15° C, and T_d=5° C, use the skew-T log p chart to determine mixing ratio (w), relative humidity (RH), and wet-bulb temperature (T_w).

19. For p = 1000 mb, T =21° C, and w=5 g kg^{-1}, use the skew-T log p chart to determine dewpoint temperature (T_d) and relative humidity.

20. If T = 10° C and RH = 50 percent at p = 800 hPa, determine T_d using a skew-T log p chart.

21. If CAPE = 1200 J kg^{-1}, what is the corresponding maximum possible convective updraft speed? At what level (e.g., LCL, LFC, LNB) would this speed occur?

22. How much specific heating occurs as near-surface air flows into a hurricane, if the air temperature remains equal to the sea surface temperature (27° C) and the pressure decreases from 1020 mb to 920 mb?

23. If the surface air in a hurricane is saturated with a temperature of 28° C, and a pressure of 1000 mb at the hurricane's outer edge and a pressure of 940 mb in the hurricane's center, what is the temperature difference between the center and the edge at 200 mb? Assume that the temperature profile of the atmosphere over a tropical ocean is the same as that of a parcel lifted from the surface dry adiabatically to its LCL then saturated adiabatically.

24. Dry microbursts occur due to evaporative cooling of air, followed by dry adiabatic descent. If the parcel temperature is equal to the environment temperature, -2° C at $p = 540$ mb, and the parcel cools due to evaporation of 2 g/kg of rain as it descends saturated from 540 to its SEL, and the surface pressure is 800 mb, what is the descending parcel's SEL pressure, DCAPE (downdraft CAPE), and maximum possible downdraft speed?

25. (6 points) A jet airplane cruises in the lower stratosphere where the air pressure is 150 mb and the temperature is -50° C. The ventilation system brings outside air into the cabin where the pressure is 700 mb.
(a) The air is first adiabatically compressed to cabin pressure. What is the air's temperature after this step? *Hint: Use the skew T-log p diagram.*

(b) After the air has been compressed to cabin pressure, how much (isobaric) heating per unit mass is required to reach the cabin temperature of 20° C?

(c) How much work is done on the air (per unit mass) during each step?

Useful constants

0° C = 273 K
$\rho_w = 1000$ kg m^{-3} (density of liquid water)
$c_w = 4186$ J kg^{-1} K^{-1} (specific heat capacity of liquid water)
$R^* = 8.31$ J mol^{-1} K^{-1} (universal gas constant)
$m_v = 18.02$ g mol^{-1} (molecular weight of water vapor)
$L_e = 2.5 \times 10^6$ J kg^{-1} (latent heat of evaporation)
$g = 9.8$ m s^{-2} (acceleration of gravity)
$c_p = 1004$ J kg^{-1} K^{-1} (specific heat at constant pressure for dry air)
$c_v = 717$ J kg^{-1} K^{-1} (specific heat at constant volume for dry air)
$R_d = c_p - c_v = 287$ J kg^{-1} K^{-1} (gas constant for dry air)
$m_d = 28.97$ g mol^{-1} (mean molecular weight of dry air)