Atmospheric Sciences 3510
Midterm Exam
April 13, 2010
100 points

You may use your skew-T log p diagram for any problem for which it is applicable. You may be specifically asked to use it for some problems. A list of physical constants follows the problems.

1. (40 points) A parcel ascends adiabatically over a mountain range starting from 1000 mb, where $T = 29.5°$ C K and mixing ratio = 14 g kg^{-1}, to 550 mb. Then it descends adiabatically back down to 1000 mb.

   (a) Complete the following table of parcel properties. The parcel ascends from time 1 to time 4, then descends. from time 4 to time 6.

time (arbitrary units)	1	2	3	4	5	6
pressure (mb)	1000		650	550		1000
temperature (T, ° C)	29.5					
dewpoint temperature (T_d, ° C)						
saturation mixing ratio (w_s, g/kg)		14			10	
water vapor mixing ratio (w, g/kg)	14	14			10	10
liquid water mixing ratio (w_l, g/kg)	0					
total water mixing ratio ($w + w_l$, g/kg)	14		12	10	10	
Relative humidity (percent)		100	100	100	100	

   (b) Plot the parcel's temperature and dewpoint temperature versus pressure during ascent and descent on the accompanying skew-T log p diagram. *Label each point with its corresponding time.*

2. (10 points) (a) For p = 900 mb, T =15° C, and T_d=5° C, use the skew-T log p diagram to determine mixing ratio (w) and relative humidity.

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

3. (8 points) Use the skew-T log p diagram (or calculations) to the determine the saturation vapor pressure (e_s) for T = -5, 5, 15, and 25° C.

T	-5° C	5° C	15° C	25° C
$e_s(T)$				

4. (20 points) (a) A parcel ascends adiabatically from 1000 mb, where $T = 32°$ C K and mixing ratio = 12 g kg^{-1} to 500 mb. For this parcel, use the skew-T log p diagram to determine the:

saturation pressure* (p_s)	
saturation temperature* (T_s)	
temperature at $p = 500$ mb	
potential temperature at $p = 500$ mb	
water vapor mixing ratio at $p = 500$ mb	
equivalent potential temperature (θ_e)	
wet-bulb potential temperature (θ_w)	

* at LCL

(b) For this parcel, *calculate* the equivalent potential temperature (θ_e). Please *show your calculations.*

(c) Recall that the formula for calculating θ_e is an approximation. How much does your calculated value differ from the (more accurate) value obtained from the skew-T log p diagram?

5. (12 points) Rain falls into subsaturated air and eventually isobarically saturates and cools the air due to evaporation. The initial air temperature is $T = 40°$ C, the initial dewpoint temperature is $T_d = 13.8°$ C, and the pressure is $p = 1000$ mb.
(a) What is the air temperature after it is saturated and cooled?

(b) What is the water vapor mixing ratio after the air is saturated and cooled?

(c) How much rain water per unit mass of air evaporates to saturate and cool the air?

6. (10 points) A sling psychrometer measures temperature $T = 26°$ C and wet-bulb temperature $T_w = 18°$ C at a pressure of 1000 mb. Use the the skew-T log p diagram to determine the dewpoint T_d, mixing ratio w, and relative humidity.

Useful constants

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