Atmospheric Sciences 5200
Exercise 2: Entraining Parcel Model

In this exercise, you will use a parcel model similar to the one that you used for Exercise 1 and include entrainment of environmental air. You will then study the impact of entrainment on the parcel's temperature, CAPE, and level of neutral buoyancy (LNB). You will also use a (provided) Matlab function to plot the parcel and environment profiles on a skew-T log p diagram.

1. Modify your parcel program from Exercise 1, `parcel.m`, so that it uses the Matlab function `tskew.m` (available on the course web page) to plot the temperature and dewpoint of an *ascending* adiabatic parcel (with *no conversion of cloud water* to rain) with the initial conditions: $p = 1000$ mb, $\theta = 16°$ C, and $w = 10$ g kg^{-1} to $p = 250$ mb. **What is the parcel's LCL pressure? What is the parcel's temperature at $p = 250$ mb?**

   Insert this Matlab code into `parcel.m` to plot the parcel's temperature and dewpoint:

```
RH = qv_gkg./qvs_gkg
tskew(p_mb, T_C, RH)
```

2. (a) You will calculate and plot the U.S. Standard Atmosphere temperature, pressure, and water vapor mixing ratio versus height using the program `std_atm.m` and function function `TP_std.m` provided on the class web page. The U.S. Standard Atmosphere is described on page 30 of *Thermodynamics Notes*. You can use Eq. (37) (page 30 of *Thermodynamics Notes*) to determine the pressure at each height level. For simplicity, use the approximation $T_v = T$ for this calculation.

   We will use the U.S. Standard Atmosphere profiles as the *environmental profiles* in the remaining problems, so we will refer to them in that way from now one. For that purpose, we could replace the U.S. Standard Atmosphere profiles with any set of observed profiles.

   Calculate and plot the environmental temperature, pressure, and water vapor mixing ratio profiles, $T_e(z), p_e(z)$, and $w_e(z)$, at height intervals of 100 m from 0 to 10 km. Set the environmental relative humidity profile to be 50 percent at all heights. The program `std_atm.m` is an example that plots $T_e(z)$ and $p_e(z)$ at intervals of 1 km. It uses the function `TP_std.m`.

   (b) You will use the parcel program `parcel_HW2_2b.m` (provided on the class web page) which uses the Matlab function `tskew.m` to **plot the environmental temperature and dew point profiles, along with the parcel profiles, on a single skew-T log p diagram.** The code in `parcel_HW2_2b.m` shows how to loop over height z instead of pressure p, how to use the function `TP_std.m` to obtain the environmental profiles of temperature and pressure, and how to set initial conditions. There are ? where you need to add code, but once those are filled in properly, the code should work. Note that we set the parcel pressure p to be the same as the environmental pressure p_e.

You will need to create the function `tskew_m.m` which draws magenta instead of black lines for the temperature and dew point profiles. To do this, copy `tskew.m` to `tskew_m.m` then change the line

```
h=plot(tzm,pz,'k',tdzm,pz,'k--');
```

to

```
h=plot(tzm,pz,'m',tdzm,pz,'m--');
```

(c)**What is the parcel's LNB pressure?**

3. **Modify your parcel program from Problem 2(b) so that it calculates the parcel's CAPE,** using the definition given in section 7.3 of *Thermodynamics Notes*, and the corresponding **maximum vertical velocity**, $W_{\max}$. Also modify the parcel program so that it locates the LFC and LNB.

   To obtain CAPE, do a numerical integration: that is, sum up the contributions from each layer, using the Trapezoidal Method. The code in `CAPE.txt` shows how to calculate CAPE using the Trapezoidal Method.

   What are your calculated values of CAPE, $W_{\max}$, LFC, and LNB?

4. Include entrainment of environmental air by adding these terms

$$
\begin{aligned}
D_\theta \equiv \left(\frac{d\theta}{dz}\right)_{\text{entrainment}} &= -\lambda(\theta - \theta_e), \\
D_w \equiv \left(\frac{dw}{dz}\right)_{\text{entrainment}} &= -\lambda(w - w_e), \\
D_l \equiv \left(\frac{dl}{dz}\right)_{\text{entrainment}} &= -\lambda l,
\end{aligned}
$$

   where

$$
\lambda \equiv \frac{1}{m}\frac{dm}{dz},
$$

   and will be specified. For example, insert the following code into `parcel.m` just before the saturation adjustment:

```
th = th - lambda * (th - the) * dz
```

   The code in `parcel_HW2_2b.m` shows how this code is used in your parcel model.

   (a) Set $\lambda = 1.0$ km^{-1}. **What is the parcel's LNB pressure? Its CAPE? Its maximum vertical velocity?**
   (b) Same as (a) except set $\lambda = 0.1$ km^{-1}.
   (c) Same as (b) except set environmental RH = 0.2.
   (d) Same as (b) except set environmental RH = 0.8.
   (e) **Discuss your results: What is the impact of entrainment on LNB? On CAPE and maximum vertical velocity? How does environmental RH affect the impact of entrainment?**