EAS 475/587: Atmospheric and Ocean Dynamics
Assignment 1: Due Thursday, Sept. 28 before 3:30pm

1. The centre of a high pressure system at Edmonton's latitude has pressure 103 kPa while the centre of a low pressure system 1000 km to the east has pressure 99 kPa.
   (a) Supposing the pressure varies linearly from one centre to the other, estimate what acceleration air of density 1.2 kg/m^3 would experience due to the pressure gradient force. (Give your answer in m/s^2 and give the direction.)
   (b) Supposing the air directly between the two centres moves southward with speed 10 m/s, what acceleration would the air experience due to the Coriolis force? (Give your answer in m/s^2 and give the direction.)

2. Suppose the stratosphere has a constant temperature of $T = -80°C$ and that the pressure at the tropopause, 10 km above the ground, is $P_0 = 250$ mbar.
   (a) What is the density (in kg/m^3) of air at the tropopause?
   (b) What is the density scale height (in km) in the stratsophere?
   (c) What is the pressure (in mbar) 20 km above the ground?
   (d) What is the potential temperature (in K) 20 km above the ground?
   (e) Suppose a parcel of air at 20 km descends adiabatically to the tropopause. Find its density and buoyancy, and so assess whether this parcel of air will experience a force to make it rise again or continue to fall.

3. For the stratosphere as described in question 2 above, find the buoyancy frequency (in radians per second) for air just above the tropopause and so find the period (in minutes) of vertical oscillations of vertically displaced air.

4. Fresh water at 20°C and 1000 mbar has a density of 998.23 kg/m^3. Use the linear approximation for the density of salt water given in lectures to answer the following questions.
   (a) What is the density (in kg/m^3) if the temperature is raised by 1°C?
   (b) How much salt (in parts per thousand) should be added to water at 21°C so that the salt water has the same density as fresh water at 20°C?
   (c) How much pressure (in bars) should be applied to water with temperature fixed at 20°C so it has the same density as salt water with salinity 0.3 ppt, temperature 20°C and atmospheric pressure 1 atm?
   (d) Estimate the depth (in m) where the ocean has the pressure given by your answer in c).

5. As a result of intense winter storms, in January the top 1 km of the Labrador Sea is well mixed with a potential density of $\rho_{\text{pot}} = 1027.8$ kg/m^3.
   (a) Using the value for the density scale height of the ocean given in class, find the actual density of water at 1 km depth.
   (b) Water at the surface with temperature 2°C convects adiabatically downward to 1 km depth. Use the value of the temperature scale height of the ocean given in class to find the increase of the temperature of the water parcel at 1 km depth.

6. As a crude approximation, suppose the temperature of the troposphere is isothermal with temperature 240 K and that it extends 10 km above the ground around the globe.

   (a) Given the mean radius of the Earth is 6371 km, estimate the mass of the air in the troposphere.

   (b) Given the specific heat for dry air kept at constant volume is $c_v \simeq 718\,\mathrm{J/(kg\ K)}$, how much heat energy (in Joules) should be added to the troposphere in order to raise its temperature by 1°C assuming its volume is fixed?

   (c) The flux of energy from the sun reaching the Earth is $F_s \simeq 1370\ \mathrm{W/m^2}$. If all this energy went to uniformly warming the troposphere, how long (in hours) would it take to raise the temperature by 1°C?

   (d) The oceans cover 71% of the Earth's surface. Crudely approximating the top 10 m of the ocean as having a density 1028 $\mathrm{kg/m^3}$ and given the specific heat of water as $c_v \simeq 4186\,\mathrm{J/(kg\ K)}$, find how much energy it would take to raise the temperature of the top 10 m of the ocean by 1°C.