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EXAM II, ATMO 335, March 24, 2008. OPEN BOOK

1. A 1 kg parcel of dry air is initially at a temperature of 283 K and pressure 1000 hPa. It is transformed (quasi-statically and reversibly) in two steps. i) It is lifted adiabatically to a pressure of 800 hPa. ii) It is then heated at constant pressure by 10 kJ.

   a) What is T at the end of steps (i) and (ii)?

   $T_0 = 283\,\mathrm{K}$;
   $T_1 = T_0 \left(\frac{p}{p_0}\right)^{0.286} = 265.5\,\mathrm{K}$; $T_2 = Q/c_p + T1 = 275.5\,\mathrm{K}$

   b) What is ΔS at the end of steps (i) and (ii)?

   $\Delta_1 S = 0$; $\Delta_2 S = \int_{T_0}^{T_1} \frac{dQ}{T} = \int_{T_0}^{T_1} \frac{c_p\,dT}{T} = c_p \ln \frac{T_1}{T_0} = 36.975\,\mathrm{J\,K^{-1}}$

   c) What is the potential temperature initially?

   $\theta_0 = 283\,\mathrm{K}$ since $\theta_0 = T_0 \left(\frac{1000}{1000}\right)^{\kappa}$

   d) What is the potential temperature at the ends of steps (i) and (ii)?

   i) $\theta_1 = \theta_0$;
   ii) $\theta_2 = T_2(10/8)^{0.286} = 293.6\,\mathrm{K}$;

2. A parcel of air at 283 K and 1000 hPa has relative humidity r=0.50.

   a) What are the saturation vapor pressure and the saturation mixing ratio?

   $e_s = 2.58 \times 10^9 \exp(-5422/283) = 12.33\,\mathrm{hPa}$; $w_s = 0.622 e_s/1000 = 0.0077\,\mathrm{kg\,kg^{-1}}$

   b) What is the virtual temperature?

   $T_v = (1 + 0.60ws \times 0.50)283 = 283.65\,\mathrm{K}$

c) The parcel is embedded in dry air of the same temperature and pressure. Does it rise or sink?

It rises because the moist air has less density than dry air at the same temperature and pressure.

d) What is the vertical acceleration of the parcel?

$a = (T_v - T)g/T = 0.651/283 = 0.023\,\mathrm{m\,s^{-2}}$; or you could compute density change and use the corresponding formula. $\rho_{moist}/\rho_{dry} = T/T_v$

3.

a) On a certain (weird) day the atmosphere is isothermal ($T = 283\,\mathrm{K}$) up to $z \to \infty$. What is the scale height of the atmosphere?

$H = \frac{R_d T_0}{g} = 8250.6\,\mathrm{m}$

b) Assuming the surface pressure is 1000 hPa, what is the height of the 500 hPa level?

$p = p_0 \exp(-z/H)$; $z_{500} = -H \ln \frac{p}{p_0} = 5718.9\,\mathrm{m}$

c) What is the thickness of the 400 to 500 hPa layer?

$\Delta z = H \ln(5/4) = 1841.1\,\mathrm{m}$

d) What is the potential temperature θ as a function of z.

$\theta(z) = T_0 \left(\frac{p(0)}{p(z)}\right)^{\kappa} = T_0 \exp\left(\frac{\kappa}{H} z\right)$

e) Is this atmospheric profile stable at all altitudes? Use the criterion for stability using θ to justify your answer.

This atmospheric profile is stable at all values of z because $\frac{\partial \theta}{\partial z} > 0$ for all z. $\frac{d\theta}{dz} = T_0 \frac{\kappa}{H} \exp\left(\frac{\kappa}{H} z\right) > 0$