Atmospheric Sciences 5300
Start-of-course Survey Quiz on Thermodynamics

This quiz has two purposes: One is to briefly review concepts and definitions for dry thermodynamics (questions 1 to 8). You should have encountered these in previous ATMOS courses. The other is to expose you to the kinds of questions that you are not expected to be able to answer now but will be able to answer by the end of this course (questions 8 to 20).

Useful Constants

$0\ ^\circ\mathrm{C} = 273.15$ K
1 mb = 100 Pa
$R = R_d = c_p - c_v = 287$ J kg^{-1} K^{-1} (gas constant for dry air)
$g = 9.81$ 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)
$L_e = 2.5 \times 10^6$ J kg^{-1} (latent heat of evaporation)

1. What is the density, ρ, of an ideal gas with $T = 20\ ^\circ\mathrm{C}$ and $p = 900$ mb?

2. What is the mass, M, of a sample of a gas with $\rho = 0.8$ kg m^{-3} and volume, $V = 5$ m^3?

3. What is the mass per unit area of a column of the atmosphere extending from the surface, where $p = 850$ mb, to the top of the atmosphere where $p = 0$?

4. What is the thickness of a layer of the atmosphere given the pressures at the bottom and top of the layer, p_1 and p_2, and the average virtual temperature of the layer, $\overline{T_v}$, for $p_1 = 1000$ mb, $p_2 = 700$ mb, and $\overline{T_v} = 10^\circ$C?

5. What is the temperature change, ΔT, of a volume $V = 2$ m^3 of dry air at $p = 1000$ mb, $T = 250$ K, if heated by a light bulb with heat energy output of $H = 150$ watts (joules per second) for one hour?

6. A parcel of dry air rises and expands adiabatically from $p = p_1$ where $T = T_1$ to $p = p_2$ where $T = T_2$. What is T_2 for $p_1 = 1000$ mb, $p_2 = 500$ mb, and $T_1 = 10°$C?

7. What is the definition of the dry adiabatic lapse rate, Γ_d? What is its theoretical value, in terms of physical constants? What is its numerical value?

8. (a) During a cold air outbreak from Siberia over the Sea of Japan, the temperature of the lowest 300 hPa of the atmosphere warms by 20°C, due to heating by the upper 30 m of the ocean. How much does this ocean layer cool as a result? (The density of water is 1000 kg m^{-3}, and the specific heat capacity of water is 4186 joules kg^{-1} K^{-1}.)

   (b) If the energy transfer from ocean to atmosphere occurs over a 1-day period, what is the average rate of energy transfer (in units of W m^{-2})?

9. How much is a kilogram of air cooled (in °C) by evaporating 5 g of water into it?

10. Define the LCL (lifting condensation level). How do you find it using a skew-T log p chart?

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

12. 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?

13. Define the saturation mixing ratio, w, in words.

14. Define relative humidity, RH.

15. Define the dewpoint temperature, T_d, in words.

16. A radiosonde measures T, p, and RH. How can you obtain T_d from these quantities using a skew-T log p chart?

17. What is CAPE (Convective Available Potential Energy)?

18. What three processes lead to an air parcel having its actual temperature be equal to (2) θ, potential temperature, (2) θ_e, equivalent potential temperature, and (3) T_w, wet-bulb temperature?

19. How do mixing ratio and θ_e change as near-surface air flows into a hurricane isothermally (above an ocean with a constant sea surface temperature) but with pressure decreasing, if the relative humidity remains constant?

20. Why are evaporative coolers effective in Utah but not in Florida?