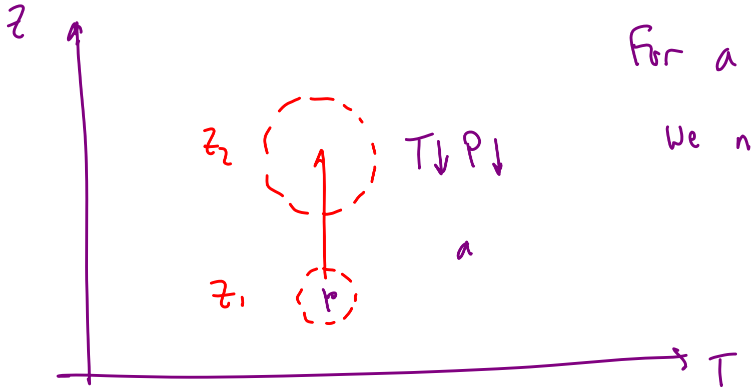
Today, we will:

- Continue our discussion of lapse rate and atmospheric stability
- Do another example problem concerning the Coriolis effect on earth
- If time, begin to discuss **gradient diffusion**

<u>Atmospheric stability</u> (continued)

Last time we concluded that a parcel of air is stable (stable atmosphere) if its density matches that of the surroundings. After a little analysis using the ideal gas law, we showed that for a neutrally stable atmosphere, an air parcel that moves up some small amount must expand and cool such that its new *T* and *P* exactly match the ambient *T* and *P* at its new location.

Conclusion: $T_p = T_a$ for a neutrally stable atmosphere.



For a neutral atmosphere, we need negligible friction & " heat transfer ⇓ isentropic

★ reversible, adiabatic process

parcel of air undergoes adiabatic, isentropic expansion T↓ P↓

such that new T & P exactly match the T & P of the new surroundings

$\therefore \rho_p = \rho_a$

★ See HW #4 to calculate the dry adiabatic lapse rate (neutrally buoyant)

⇓

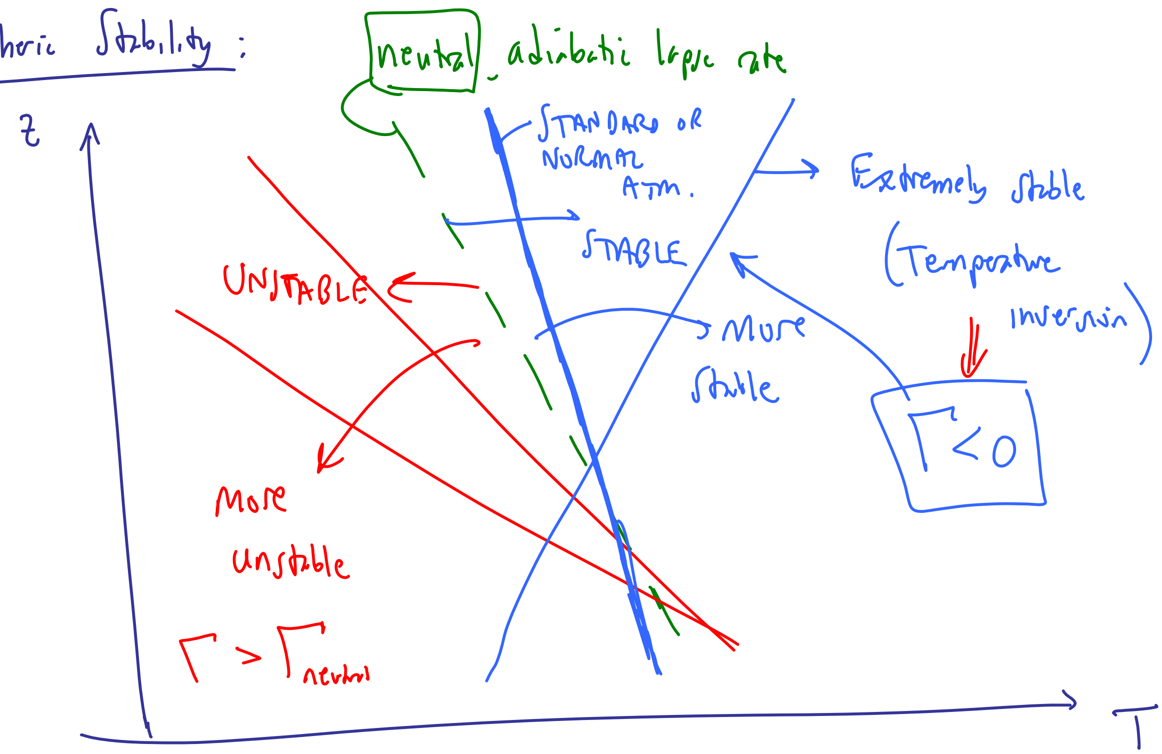
No humidity.

for air with $k = 1.4$ → $\boxed{\Gamma_{\text{dry adiabatic}} = 9.8\ {}^\circ\text{C/km}}$

If the air is humid, it is more complicated to calculate $\Gamma_{\text{humid adiabatic}}$

$\Gamma_{\text{wet adiabatic}} < \Gamma_{\text{dry adiabatic}}$ Typ. $\approx 9.0\ {}^\circ\text{C/km}$

Atmospheric Stability:

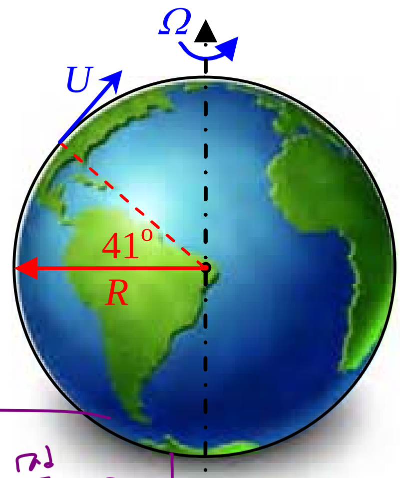


See Powerpoint Slides → METEOROLOGY (on website)

Note: The stability of the atmosphere greatly affects the dispersion of air pollutants from sources of emission, such as smoke stacks

Example: Coriolis Force

Given: A marksman in Central PA (latitude = 41°) shoots a high powered rifle at a target. He has one of those cool laser scopes, and there is no wind. The target is directly north of the shooter. The mass of the bullet is 10 g, it travels at 2000 ft/s (609.6 m/s), and it travels for 1.3 s before it hits the target. The radius of the earth is 6378.1 km.

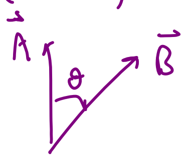


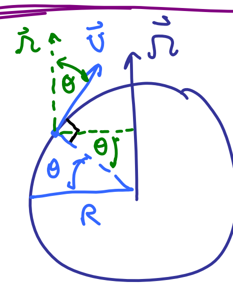
To do: Estimate how far (in cm) the bullet veers off course due to the Coriolis effect. Is it negligible?

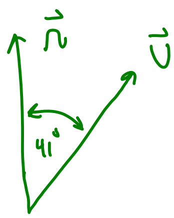
Solution: The Coriolis force is $\boxed{\vec{F}_c = -2m\left(\vec{\Omega}\times\vec{U}\right)}$.

• $\Omega = \left(\frac{1\ \text{rot}}{\text{day}}\right)\left(\frac{\text{day}}{24\ \text{hr}}\right)\left(\frac{\text{hr}}{3600\ \text{s}}\right)\left(\frac{2\pi\ \text{rad}}{\text{rot}}\right) = \boxed{7.2722\times10^{-5}\ \frac{\text{rad}}{\text{s}} = \Omega}$

• $\vec{A}\times\vec{B} = |\vec{A}||\vec{B}|\sin\theta$







$a_c = |\vec{a}_c| = 2\,\Omega\, U\sin\theta = 0.058168\ \text{m/s}^2 = a_c$

• Δs in cm, a_c = constant, $\Delta t = 1.3$ s, $U = 609.6$ m/s

From high school physics, you may recall, $\Delta s = \frac{1}{2}a_c(\Delta t)^2$

OR – Integrate to derive it: If a_c = constant & $V = a_c t$, then

$$\Delta s = \int_{t=0}^{t=\Delta t} V\,dt = \int_0^{\Delta t} a_c\, t\,dt = a_c\int_0^{\Delta t} t\,dt = a_c \left.\frac{t^2}{2}\right|_0^{\Delta t} = a_c\frac{\Delta t^2}{2}\ ✓$$

a_c = constant

So, $\Delta s = \frac{1}{2}a_c(\Delta t)^2 = \frac{1}{2}\left(0.05816798\ \frac{\text{m}}{\text{s}^2}\right)(1.3\ \text{s})^2\left(\frac{100\ \text{cm}}{\text{m}}\right) = 4.91515$ cm

$\boxed{\Delta s \approx 4.9\ \text{cm}}$

NOT NEGLIGIBLE, (depends on the size of the target)