GROUP 5

라디오존데의 원리

- 라디오존데의 상승운동을 중심으로

2009-10982 신용환 2009-10984 이경준 2009-10985 이보현

Contents

GROUP 5

필요한 가정
& 기초 자료

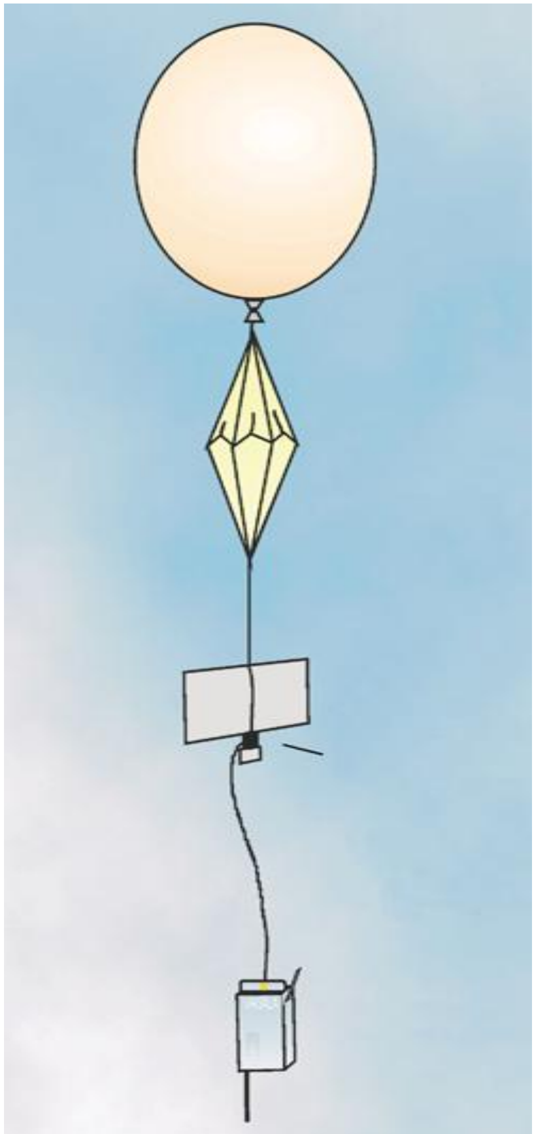
라디오존데란
개념 & 중요성

사용할 공식
& 사용할 프로그램

결과
& 한계점

About Radiosonde

GROUP 5

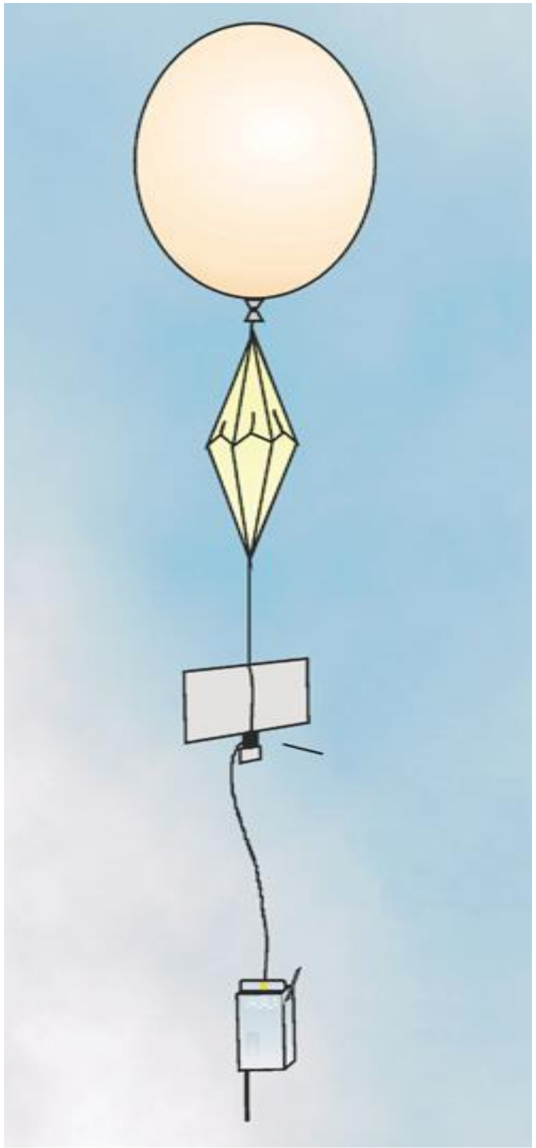


- A rubber or latex balloon filled with either helium or hydrogen.

- As the balloon ascends, it expands.

About Radiosonde

GROUP 5



- Size
- Maximum altitude
- Importance :
  numerical weather prediction.

Question

Q1. 라디오존데의 상승속도

Q2. 대기의 안정도에 따른
라디오존데의 상승운동

Assumption

1. The environment is in hydrostatic equilibrium.

2. The parcel's movement does not disturb the environment.

3. The process is adiabatic.

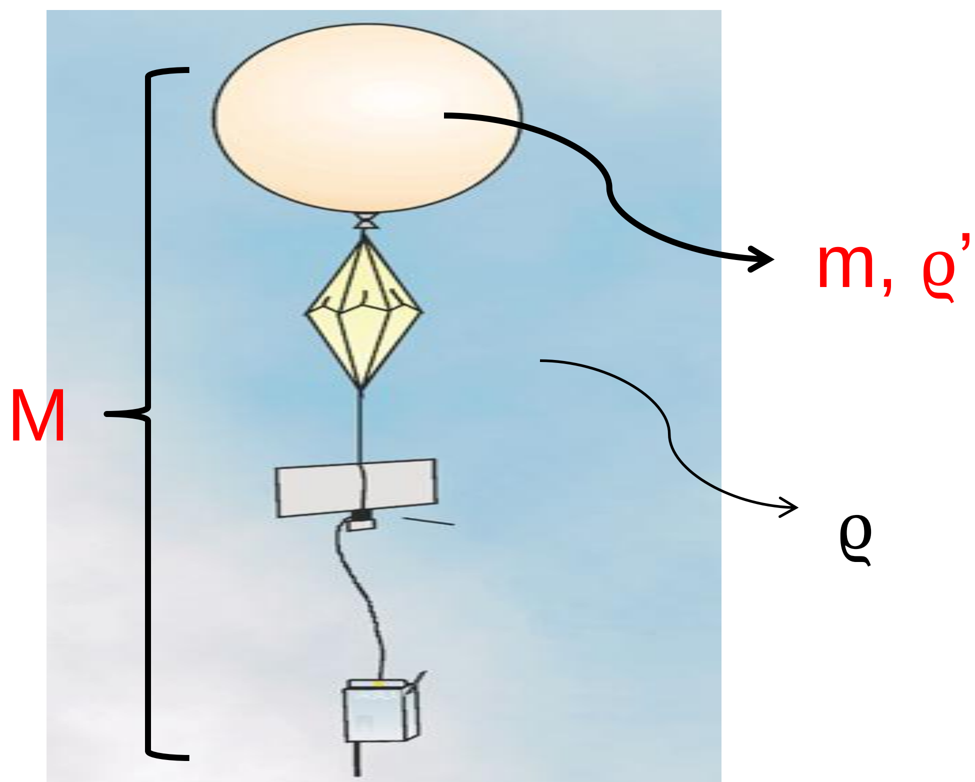
4. At a given level, the pressure of the environment and the pressure of the parcel are equal.

5. Elasticity of balloon is negligible.

6. g is constant (=9.8m/s^2)

Basic datas

- Size of balloon : diameter = 2m
- When z=0, p = 1000mb , T = 300K



Formulas

- Remember ?

$$\rho' z'' = -\rho' g - \frac{dp'}{dz}$$

$$z'' = -g - \frac{1}{\rho'}\frac{dp'}{dz}$$

$$\frac{dp}{dz} = \frac{dp'}{dz}$$

$$\boxed{z'' = g\left(\frac{\rho - \rho'}{\rho'}\right)}$$

Formulas

GROUP 5

$$(m+M)z'' = -(m+M)g - \frac{m}{\rho'}\frac{dp'}{dz} - cv$$

$$c = \frac{1}{2}\rho A C$$

M: 풍선을 제외한
라디오존데 시스템의 질량
cv: 공기저항(Drag force)
C : 끌림상수 약 0.4~1

$$z'' = -g - \frac{m}{m+M}\frac{1}{\rho'}\frac{dp'}{dz} - \frac{c}{m+M}v$$

$$\frac{c}{m+M} = 2\gamma$$

Formulas

Using assumption no.4 ,

$$z'' + 2\gamma z' = -g - \frac{m}{m+M}\frac{1}{\rho'}(-\rho g)$$

$$z'' + 2\gamma z' = -\frac{m}{m+M}g - \frac{m}{m+M}\frac{1}{\rho'}(-\rho g) - \frac{M}{m+M}g$$

$$z'' + 2\gamma z' = \frac{m}{m+M}g\left(\frac{\rho-\rho'}{\rho'}\right) - \frac{M}{m+M}g$$

Consider

$$\boxed{\begin{aligned} p &= \rho R_d T \\ p' &= \rho' R_{He} T' \end{aligned}}$$

Formulas

$$z'' + 2\gamma z' = \frac{m}{m+M} g \left(\frac{\frac{p}{R_d T} - \frac{p'}{R_{He} T'}}{\frac{p'}{R_{He} T'}} \right) - \frac{M}{m+M} g$$

$$z'' + 2\gamma z' = \frac{m}{m+M} g \left(\frac{R_{He}}{R_d} \frac{T'}{T} - 1 \right) - \frac{M}{m+M} g$$

$$z'' + 2\gamma z' = \frac{m}{m+M} g \left(\frac{R_{He}}{R_d} \frac{T_0 - \Gamma' z}{T_0 - \Gamma z} - 1 \right) - \frac{M}{m+M} g$$

Formulas

GROUP 5

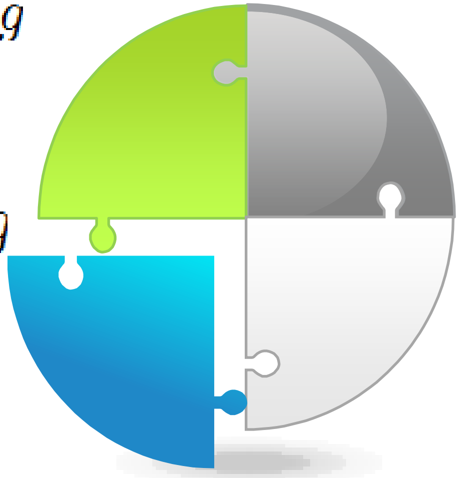
Where

$$\boxed{\frac{1}{T_0-\Gamma z}=\frac{1}{T_0}\frac{1}{(1-\dfrac{\Gamma z}{T_0})}\approx\frac{1}{T_0}(1+\frac{\Gamma z}{T_0})}$$

$$z''+2\gamma z'=\frac{m}{m+M}g[\frac{R_{He}}{R_d}(1-\frac{\Gamma' z}{T_0})(1+\frac{\Gamma z}{T_0})-1]-\frac{M}{m+M}g$$

$$z''+2\gamma z'=\frac{m}{m+M}g[\frac{R_{He}}{R_d}(1+\frac{(\Gamma-\Gamma')z}{T_0})-1]-\frac{M}{m+M}g$$

$$z''+2\gamma z'+\frac{m}{m+M}g\frac{R_{He}}{R_d}\frac{(\Gamma'-\Gamma)}{T_0}z=(\frac{m}{m+M}\frac{R_{He}}{R_d}-1)g$$



Formulas

GROUP 5

$$\boxed{z'' + 2\gamma z' + \frac{m}{m+M} g \frac{R_{He}}{R_d} \frac{(\Gamma' - \Gamma)}{T_0} z = \left(\frac{m}{m+M} \frac{R_{He}}{R_d} - 1\right) g}$$

$$R_{He} = \frac{R^*}{M_{He}} = 2077\, J kg^{-1} K^{-1}$$

$$\rho' = \frac{p_a}{R_{He} T} = 0.16\, kg\, m^{-3}$$

$$m = \rho' V = 0.67 kg$$

$$\boxed{2\gamma = \frac{c}{m+M} = \frac{1}{2} \frac{1}{m+M} \rho A C_d = 1.3 s^{-1}}$$

Formulas

GROUP 5

$$\boxed{c_{p,He} = \frac{5}{2} R_{He} = 5192 JK^{-1} kg^{-1}}$$

$$T = constant \cdot p^{\frac{\gamma-1}{\gamma}}$$

$$\frac{dT}{T} = \frac{\gamma-1}{\gamma}\frac{dp}{p}$$

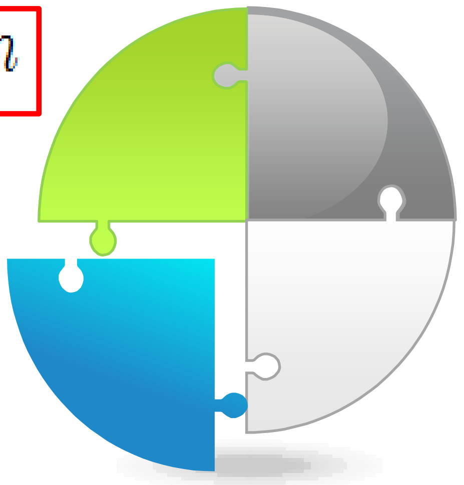
$$\frac{1}{T}\frac{dT}{dz} = \frac{\gamma-1}{\gamma}\frac{1}{p}\frac{dp}{dz}$$

$$\frac{dT}{dz} = -\frac{\gamma-1}{\gamma}\frac{g}{R_{He}}\frac{T'}{T}$$

$$\Gamma' = -\frac{dT}{dz} = \frac{\gamma-1}{\gamma}\frac{g}{R_{He}}$$

$$= \frac{g}{c_{p,He}}$$

$$\boxed{\approx 1.9\,{}^\circ C/km}$$



Simulation

GROUP 5

► Z-t diagram

1. Γ = 6.5`C/km

Z(t) = 0.886419*exp(-1.30023t)+26665.8*exp(0.000230728t)-26666.7

2. Γ = 10.0`C/km

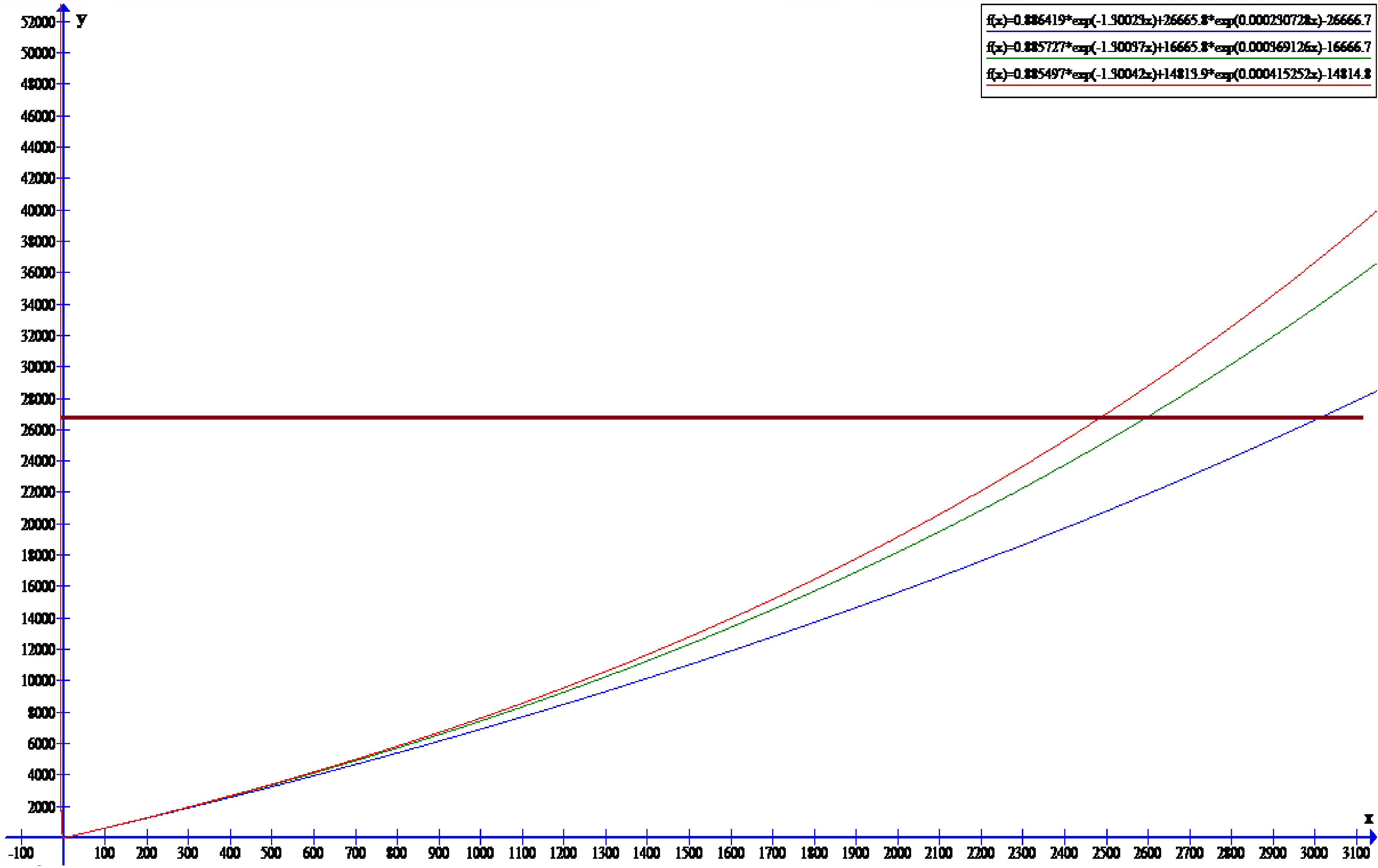
Z(t) = 0.885727*exp(-1.30037x)+16665.8*exp(0.000369126x)-16666.7

3. Γ = 11.0`C/km

Z(t) = 0.885497*exp(- .30042x)
+14813.9*exp(0.000415252x)-14814.8

Simulation

GROUP 5



Simulation

- Z'-t diagram

1. Γ = 6.5`C/km

$$Z'(t) = -1.15232*\exp(-1.30023x)+6.133134*\exp(0.000230728x)$$

2. Γ = 10.0`C/km

$$Z'(t) = -1.1518*\exp(-1.30037x)+6.15*\exp(0.000369126x)$$

3. Γ = 11.0`C/km

$$Z'(t) = -1.151518*\exp(-1.30042x) +6.1515*\exp(0.000415252x)$$

Simulation

GROUP 5

v

f(x)=-1.15232*exp(-1.30023x)+6.133134*exp(0.000230728x)

f(x)=-1.1518*exp(-1.30037x)+6.15*exp(0.000369126x)

f(x)=-1.151518*exp(-1.30042x)+6.1515*exp(0.000415252x)

Result

- ▶ 라디오존데의 상승속도는 지표 근처에서는 거의 일정하다가 고도가 높아질수록 증가한다.
- ▶ 라디오존데의 실제 상승속도는 약 5m/s로 거의 일정하다.
- ▶ 대기가 불안정할수록 라디오존데는 더욱 exponentially 상승하는 경향을 보인다.

Limitation

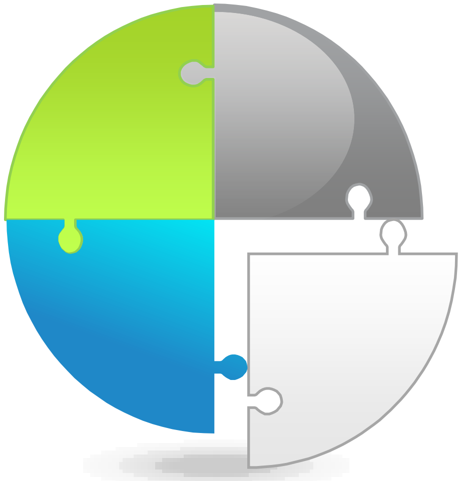
▶ 오차의 원인

1. 고무의 탄성력을 고려하지 않았다.

2. Balloon이 상승할 때 부피가 팽창함에 따른 공기저항력의 증가를 고려하지 않았다.

▶ 헬륨풍선의 기온감률

기온 감률이 일정하지 않다.
(고도가 높아질 수록 기온감률이 감소한다.)



Reference

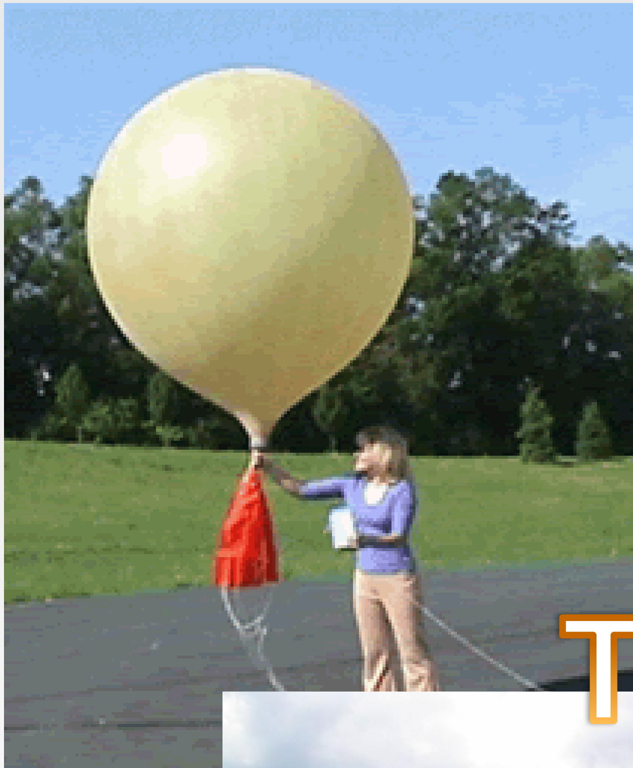
Atmospheric thermodynamics , J. V. Iribarne and W. L. Godson.

Analytic mechanics, Grant R. Fowles

http://www.wolframalpha.com

http://www.gongbo.co.kr

GROUP 5



Thank You



GROUP 5