The Physics of Baumgartner Skydiving

Formulas and Constants

Definitions

m: The mass of Baumgartner and his equipment.
A: The projected area of the Baumgartner.
C: The drag coefficient of Baumgartner.
g: The acceleration due to gravity.
ρ: The density of the troposphere around Baumgartner.
v: The velocity of Baumgartner.
t: The time pass after Baumgartner began falling.
h: The distance between ground and Baumgartner.
T: The temperature of the troposphere around
p: The pressure of the troposphere around Baumgartner.
dt: A very short time.

m	110kg
AC	0.7322m^2/ 140.68m^2
g	−9.8m/s^2
dt	0.001s

Figure 1: Baumgartner and his equipment

Calculation of Constant

We hypothesized that $A, C, m, g,$ is constant. We found out m is about 110 kilograms and set $g = -9.8$m/s^2. Reaching the terminal velocity signified that the resistance equals gravity, so we got $mg = \frac{1}{2}\rho v^2 CA$.

According to the official simulation before he skydived, Baumgartner reached the terminal velocity (-1173km/hr ≒ -326m/s) at a height of about 28000 meters. We substituted h into the function of density and got ρ. Then found AC ≒ 0.8395m^2 by using $mg = \frac{1}{2}\rho v^2 CA$.

According to the practical situation, Baumgartner reached the terminal velocity (-1357.6km/hr ≒ -377m/s) at a height which is similar to the simulation when he was **nosedived**. Through the same way, we found another AC ≒ 0.6274m^2.

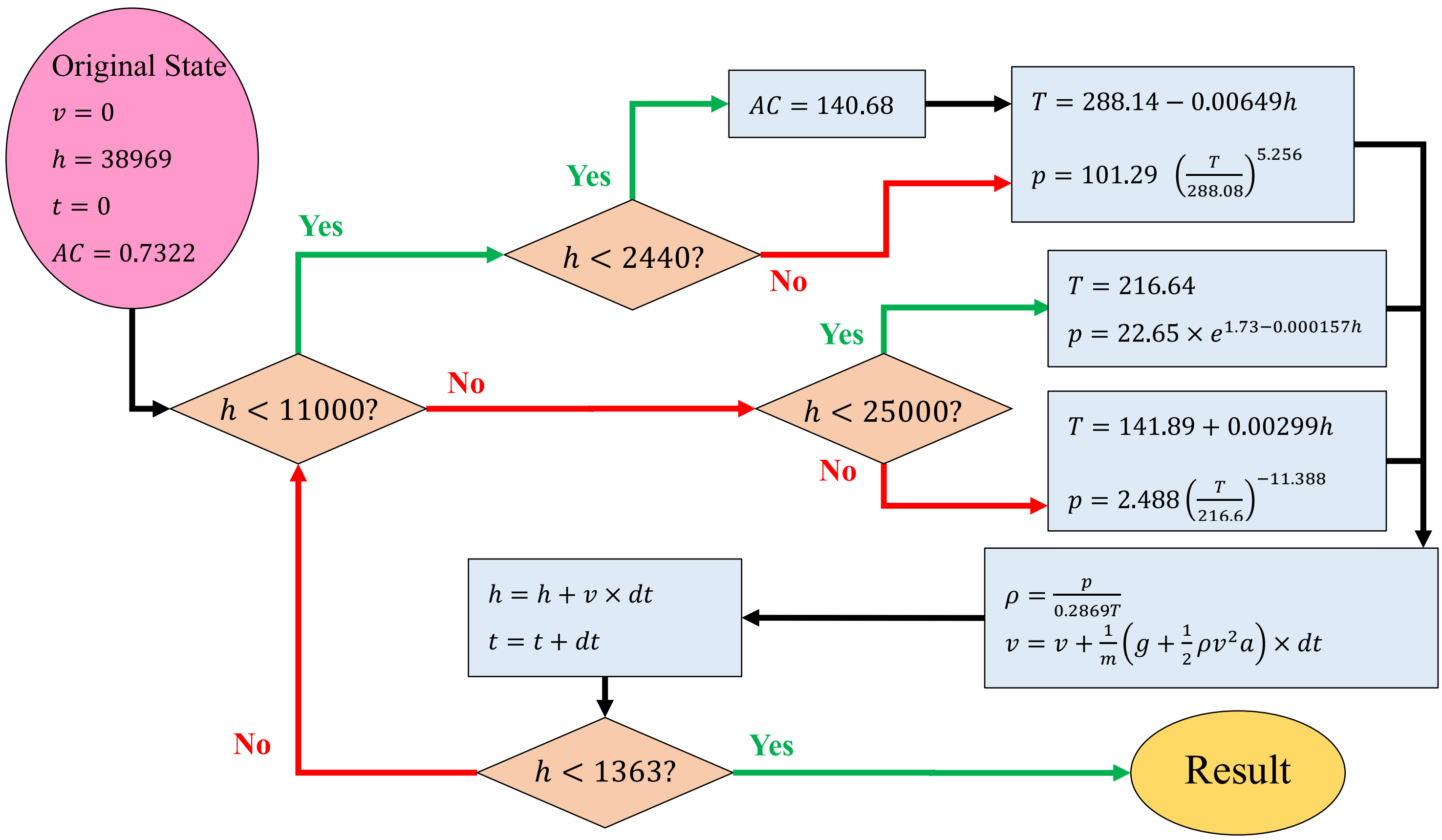
The previous AC didn't include the nosedived situation, so we take the average of these two as the AC ≒ **0.7322**m^2 of Baumgartner before he opened the parachute.

After Baumgartner opened his parachute, his velocity fluctuated between about -2.22 and -5.56 m/s. We thought it is probably because of the instability from stratosphere. We take the average(-3.89m/s) as the velocity after he opened. Through the same way, we got the AC of him and his parachute.

Simulation by Computer Program

Flow Path

※ "=" here is the **program usage.** It means **to change the value of LHS into the value of RHS.**



Program (made by phthon)

QR code: more about the assignment

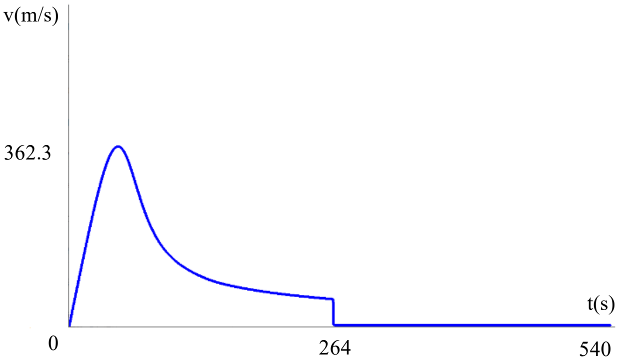


Figure 2: v-t graph

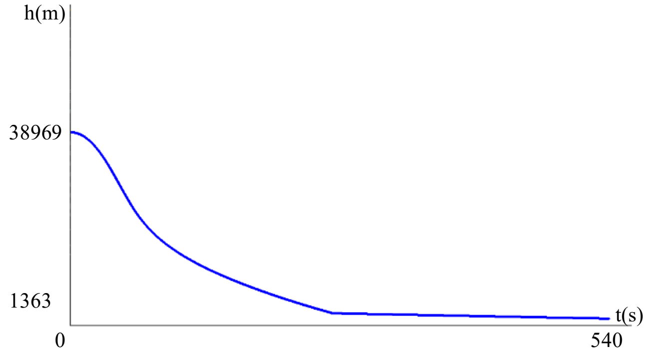


Figure 3: h-t graph

These two figures show the physics relations of height, time, and velocity. The more details of the programs can be found in the website.

The simulation by computer program told us Baumgartner spent 540.8 seconds on falling. It is close to the practical situation. We thought the error probably from unsettle troposphere, AC of Baumgartner and gravity.

The underneath is the sourse code.

```python
import math
import os

h = 38969  # Initial height

v = 0  # Initial speed
g = -9.8  # The gravity field is considered fixed
m = 110  # The mass of Baumgartner and his equipment
t = 0  # Initial time
a = 0.7322  # The product of the coefficient of confrontation and the cross-sectional area of the windward


def T(h):  # Temperature versus height function
    if h < 11000:
        return 288.14 - 0.00649 * h
    elif h > 25000:
        return 141.89 + 0.00299 * h
    else:
        return 216.64


def p(h):  # Air pressure versus height function
    if h < 11000:
        return 101.29 * (T(h) / 288.08) ** 5.256
    elif h > 25000:
        return 2.488 * (T(h) / 216.6) ** (-11.388)
    else:
        return 22.65 * math.e ** (1.73 - 0.000157 * h)


def r(h):  # Density versus height function
    return p(h) / (0.2869 * T(h))


def f(v, a, h):  # Resistance function
    return (1 / 2) * r(h) * v * v * a


dt = 0.001
print('Height is', h)

while True:

    if h < 2440:  # After opening the parachute
        v = v + (g + f(v, 140.6816, h) / m) * dt
    else:  # Before opening the parachute
        v = v + (g + f(v, a, h) / m) * dt

    h = h + v * dt
    t = t + dt

    if h > 2440:
        print('_' * int(39 - (h / 1000)) + "B" + ' ' * int((h / 1000)) + '| V:', int(v), 't:', str(int(t)) + ' '*20, end='\r')
    else:
        print('_' * int(37 - (h / 1000)) + "(>B" + ' ' * int((h / 1000)) + '| V:', int(v), 't:', str(int(t)) + ' '*20, end='\r')

    if h < 1363:  # Landing
        break
print('_' * int(37 - (h / 1000)) + "(>B" + ' ' * int((h / 1000)-1) + '| V:', int(v), 't:', str(int(t)) + ' '*20)
print('Landing!!!!')
print('landing in '+str(int(t))+'(sec)')  # Landing time
print('actually is', t, 'sec.')
os.system('pause')
```

References

Natalie Wolchover. (2012). The Physics of the First-Ever Supersonic Skydive. Retrieved from https://www.livescience.com/23710-physics-supersonic-skydive.html (November 3, 2019)

Drag coefficient. (November 14, 2019). https://en.wikipedia.org/wiki/Drag_coefficient (November 3, 2019)

https://www.zhihu.com/question/59208808

https://www.youtube.com/watch?v=raifrxbHxV0

https://www.youtube.com/watch?v=vvbN-cWe0A0