Terminal Velocity

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Learning Outcome

I highly recommend you to finish this checklist to determine whether you've achieved the learning objectives.

- ☐ Understand the effect of drag force or air resistance
- ☐ Define terminal velocity
- ☐ Draw and interpret the *v-t* graph of object moving through air or liquids with or without *parachute*
- ☐ Analyse the object's force in three stages, including accelerating, decelerating and terminal velocity.

Leadin

The raindrops usually falls from a height of 1000 m or even higher [1], according to the equation of free fall, the veloctiy that a raindrop hits the ground might be $140\,\mathrm{m\,s^{-1}}$ according to $v = \sqrt{2gh}$, nearly the speed of a bullet from a shotgun. But why nobody get hurt when a raindrop hit him/her? why

[1] 2500 m at most.

Air resistance and Drag

The answer to the question in the leadin part is quite simple, the speed can not actually reach that large. Because in real life, the air resistance can not be ignored. it will significantly decrease the final velocity. Usually the speed is around $10\,\mathrm{m\,s^{-1}}$ to $30\,\mathrm{m\,s^{-1}}$. That's the effecet of air resistance or friction. Which should be taken into consideration when designing vehicles or high speed trains.

Figure 1: wind tunnle test

Anything moving in the fluids (including gas and liquid) will experiece resistive force called *drag*. The formula for determine magnitude of drag would not be covered but factors that can influence the magnitude are listed below:

- The ________ of the object
- The ________ of the object
- The ________________ of the fluids

Terminal Velocity

Let's discuss the process of falling of a raindrop. When it first forms and drops, it is only subject to the weight, thus the acceleration of the raindrop euqals to the gravity, causing the raindrop to accelerates downwards with an acceleration of g.

However, as the raindrop is gaining velocity, the air resistance will be directed upward and increase, impeding the falling of the raindrop. The resultant force on the raindrop is smaller than weight, thus accleration is less than g. But keep in mind, the velocity will still increase. Finally, the air resistance will completely cancel out graivty, thus the resultant force on the raindrop will be **zero**. According to the NFL [2], the raindrop will now remain in uniform motion. That velocity is called *Terminal Velocity*

[2] Recall what is NFL

> **Task**
>
> Based on the description, draw the v-t graph of the raindrop falling with air reistance in the following graph.

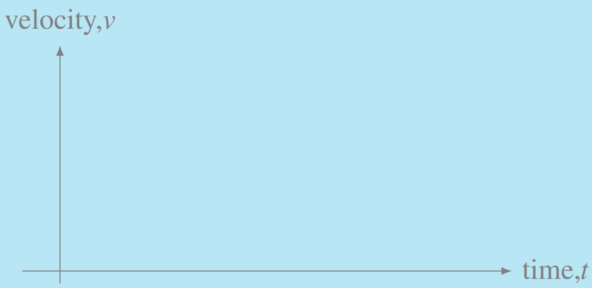

Figure 2: skydivers will always bring two parachutes

Fall with Parachute

Skydivers will never imagine the day without their *Parachute*.

The function of parachute is quite obvious - to minimize the speed when the skydiver lands. But the rational after it deserves a close check.

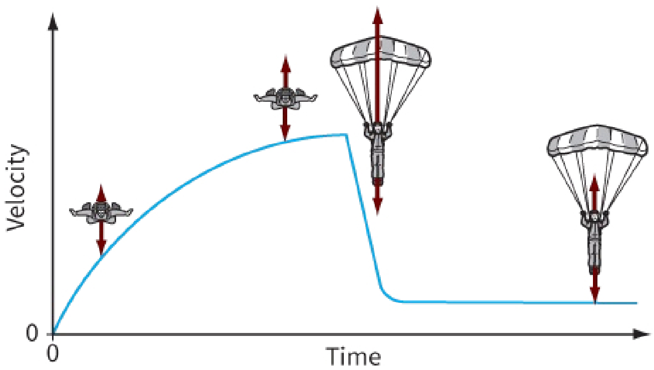

Figure 3: v-t graph of a skydiver

Task

Using figure 3 to explain:
(a). Why two terminal velocity seems to exist
(b). The resultant forces on the skydiver in four stages: at start, first terminal velocity, launch the parachute, and second terminal velocity.