Free Fall

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Learning Outcome

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

- ☐ Recognize the kinematic characteristics of *free fall*
- ☐ Draw *v-t* graph of free fall or thrown up
- ☐ Deduce the equation of motion for the free falling object from the equation of motion of UAM
- ☐ Using equations to solve free fall problems
- ☐ Recognize the kinmatic characteristics of throwning upward
- ☐ Using equations to solve upward throwing problems

Leadin

Everyone seems to hear about Galileo Galilei's experiment in Leaning Tower of Pisa. However,most historians agree that Galileo's famous experiment atop the Leaning Tower of Pisa never took place. But Galilei was correct by refuting old Aristotelian dogma. That's the start of kinematics and even the start of physics. So he is memorized as the father of physics.

Figure 1: illustration dipicts the experiment

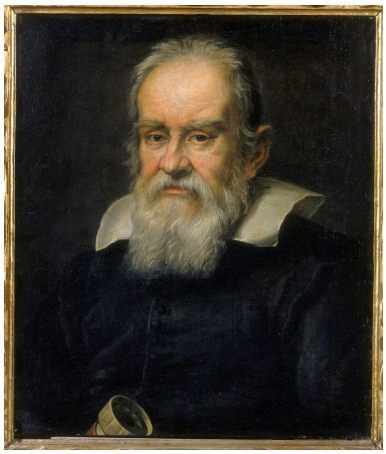

Figure 2: Galileo Galilei
1564-1642

Free Fall

An object which is only subject to the gravity or weight will experience free fall motion.

Watch this video to correct the wrong concept that heavier object will fall faster than the light one.

Acceleration of Free Fall

In the video, the feather is always in align with the bowling ball during the whole process, what's more, if *v-t* relationship[1] is found to be a UAM. Such acceleration is caused by the gravity, thus it is named as '*acceleration due to gravity*' or '*acceleration of free fall*', the value of which is measured to be:

Summary

$$g = 9.81\,\mathrm{m\,s^{-2}}$$

But two things to mention are that: 1) sometimes we utilize $g = 10\,\mathrm{m\,s^{-2}}$ for calculating convenience; 2) acceleration is not constant on Earth, in high altitude region or low latitude region, the acceleration is slightly lower than $9.81\,\mathrm{m\,s^{-2}}$.

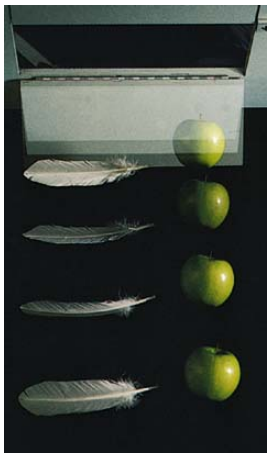

Figure 3: both feather and apple are free falling

[1] we will carry out the experiment to determine the relationship and acceleration

Equation of Motion for free fall

The *v-t* graph for free fall is quite similar to UAM, but usually an object is released *from rest*, which means the initial velocity , u, is 0. which lead to the following $v-t$ graph.

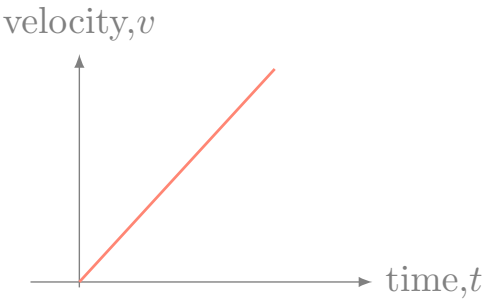

Figure 4: the v-t graph of free fall

Task

In figure 4, label the u, v, t, $h$and g.

According to the figure, which direction is considered to be the positive direction? Why?

Because $u = 0$, and using g as the acceleration, using h as the displacement, the equation from UAM can be changed as the following:

$$v = 0 + gt = gt \tag{1}$$

$$h = \frac{1}{2}\_\_\_\_\_ \tag{2}$$

$$v^2 = \_\_\_\_\_ \tag{3}$$

Still, there are more formulae to be derived. If we take multiflash photo of an free falling object. A clearly pattern can be seen

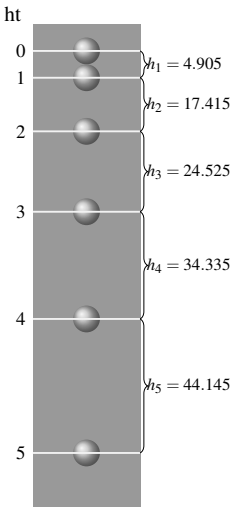

Figure 5: the time lapses between any two consecutive positions are the same

Task

In figure 5, determine the time lapse.

If a stone is released from rest from a cliff with a height of 88.88 m, and air resistance can be ignored. Determine:
a). After how many seconds did the stone hit the sea.
b). The velocity at which the stone hit the sea.

Thrown Up

In the edge of the cliff, you might not release the stone from rest, maybe you just throw it upward with an initial velocity, just as dipictured in figure 6. Let's discuss how such motion can be investigated.

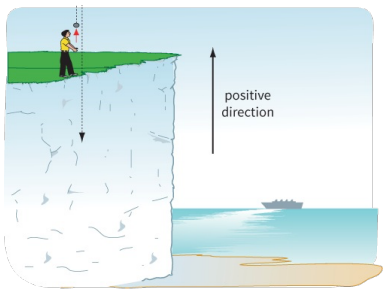

Figure 6: A stone will go up and then down

Qualitative Analysis

Describe the motion of the stone after it has been thrown from hand.

Another Perspective

You might seperate the motion into two parts, which is quite intuitive and easy. One is the slowing down phase, or *decelerating phase*; The other is speeding up phase or *accelerating phase*.

Task

Under which circumstance would an object will accelerate or decelerate?

However, with the vector nature of displacement, velocity, and acceleration as well as using *pm* sign to show direction, The process can be viewed as a whole, if we set up is the positive direction. Then the acceleration of free fall can be denoted as $-9.81\,\mathrm{m\,s^{-2}}$.

v-t graph of throwing upward

If an object is thrown upward with an initial velocity u, then the *v-t* graph descibing the motion would be:

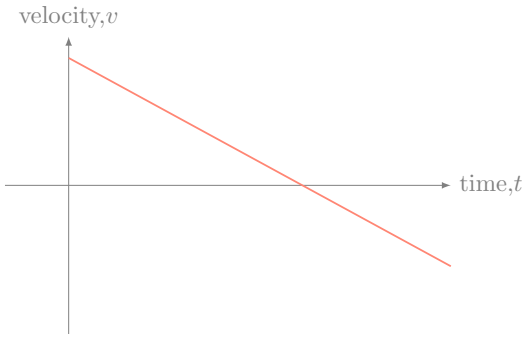

Figure 7: the *v-t* graph of throwing upward

Task

Label the time when the object is at its heighest position, and determine the velocity accordingly

a) Express the time, in terms of u and g, which is required for an object to reach the highest position
b) Express the time needed for an object to come back the starting position. The answer should be expressed in terms of u and g and any other coefficients or consant needed.