Free fall

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2018 Physics Nobel Prize

Congratulations to Arthur Ashkin and to
Gérard Mourou and Donna Strickland

Last time

- the kinematics equations (constant acceleration)
- examples
- a harder kinematics example

Overview

- falling objects

Free-Falling Objects

One common scenario of interest where acceleration is constant is objects freely falling.

When we refer to free fall, we mean objects moving under the influence of gravity, and where we are ignoring resistive forces, *eg.* air resistance.

Galileo and the Leaning Tower of Pisa

Aristotle, an early Greek natural philosopher, said that heavier objects fall faster than lighter ones.

Galileo tested this idea and found it was wrong. Any two massive objects accelerate at the same rate.

Galileo studied the motion of objects by **experiment**, as well as by abstract reasoning.

Free-Falling Objects

The important point is that at the surface of the Earth, all objects experience this same acceleration due to gravity: $g = 9.8 \text{ m s}^{-2}$.

[1]Figure from Walker, "Physics", 4th ed, page 39.

Free-Falling Objects

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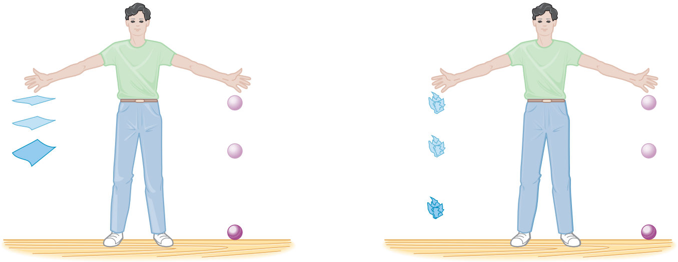
In the absence of air resistance, the acceleration does not depend on an object's mass!



The fact that acceleration due to gravity is independent of mass can be seen in airless environments...

[1]Figure from Walker, "Physics", 4th ed, page 39.

Free-Falling Objects

Objects near the Earth's surface have a **constant** acceleration of **$g = 9.8$ ms^{-2}**. (Or, about 10 ms^{-2})

The kinematics equations for constant acceleration all apply.

Free-Falling Objects

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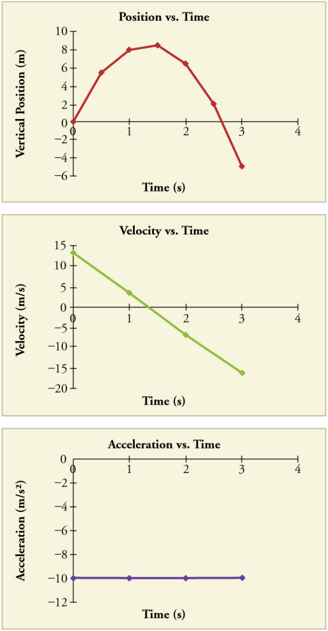
$\mathbf{v} = -31.3 \text{ m/s } \mathbf{j} \qquad t = 3.19 \text{ s}$

Falling Objects



[1]OpenStax Physics

Ex: Free-Fall with Upward Motion

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Know: $\mathbf{v}_0$, $\mathbf{a}$, $\boldsymbol{\Delta y}$ (displacement in y-direction).
Want: t.

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Don't know / care about: $\mathbf{v}$. $\Rightarrow$ Strategy: Use $\boldsymbol{\Delta y} = \mathbf{v}_0 t + \frac{1}{2}\mathbf{a}t^2$

Ex: Free-Fall with Upward Motion

$$
\begin{aligned}
\Delta y &= v_0 t + \frac{1}{2} a t^2 \\
\Delta y &= v_0 t - \frac{1}{2} g t^2 \\
0 &= \frac{1}{2} g t^2 - v_0 t + \Delta y \\
t &= \frac{v_0 \pm \sqrt{v_0^2 - 4(g/2)(\Delta y)}}{g} \\
t &= \frac{5 \text{ m/s} \pm \sqrt{(5 \text{ m/s})^2 - 4(9.8/2 \text{ m/s}^2)(-1.5 \text{ m})}}{9.8 \text{ m/s}^2} \\
t &= 1.26 \text{ s (or } t = -0.24 \text{ s unphysical solution, rejected)} \\
t &= \underline{1.26 \text{ s}}
\end{aligned}
$$

Acceleration in terms of g

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Consider the drag race car in the earlier example. For the car the maximum acceleration was $a = 26.0$ m s^{-2}. How many gs is that?

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Acceleration of a Falling Object

Question

A baseball is thrown straight up. It reaches a peak height of 15 m, measured from the ground, in a time 1.7 s. Treating "up" as the positive direction, what is the acceleration of the ball when it reached its peak height?

A $0\ \text{m/s}^2$

B $-8.8\ \text{m/s}^2$

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Summary

- free fall

Quiz tomorrow.

Homework

- Ch 2 Problems: 45, 49, 63, 89 (free fall - listed last lecture)
- Ch 3 Questions: 1, 4, 7; Problems: 1, 3, 5. (will not be on tomorrow's quiz)