2.4 - Free Fall & Gravitational Force

Gravitational Force

The first fundamental force (force not caused by something else) that we encounter is gravity. It is a field force: it acts at a distance, and does not require physical contact to be in effect.

We'll learn more details about it in Unit 5, but it factors into our study of kinematics now.

Lore:

Gravimetry is the measurement of gravity's acceleration. Depending upon what types of minerals are around, there are measurable gravitational anomalies on Earth due to more dense minerals attracting matter toward them.

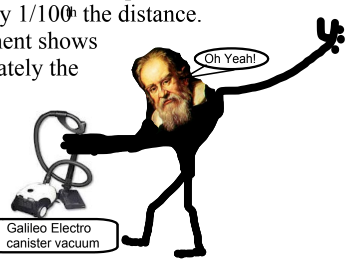
Galileo and Vacuums (Time Travel Opportunity)

Galileo Galilei was a Renaissance scientist who broke away from the teachings of Aristotle, who favored deduction, not experiment to predict relations.

One famous one is: which hits the ground first, a 1 pound or 100 pound object.

Aristotle's teachings were: the 100 pound one hits first, and the 1 pound one goes only 1/100th the distance.

Of course, the experiment shows them hitting at approximately the same time.



Free Fallin'

Acceleration due to gravity makes things fall to Earth.

Our local gravitational constant is 9.81 m/s^2, and is referred to as "little g" in free fall equations (we'll meet Big G later)

Free fall is more than dropped objects – any object solely under Earth's gravitational pull is said to be in free fall – thrown, etc.

Which falling object would you rather catch?

A Note on Vacuums

In the real world, air resistance slows the rate of free fall. In this class, we'll suspend reality on a daily basis and pretend that there are no air resistance effects when making calculations.

When you get to advanced engineering or physics classes later, you can suffer the effects of air resistance compensation.

Feather vs. coin drop demo.

Reference Frame

When dealing with g, we need to get a few things straight:

Typically, the surface of the Earth is 0.0 m.

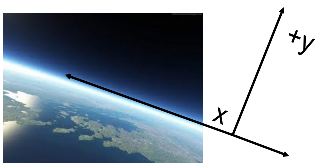
Traveling away from Earth is in the positive direction.

The sign of g is negative, because it is acceleration in a negative direction.

BUT

Kinematics equations with g already are modified to reflect the sign.

y = the vertical component, x = horizontal.



Three Equations of Free Fall

While these are identical in form to what you've seen before, note the negative signs in front of g, and now y replaces x to indicate vertical movement.

Use "9.81 m/s^2" for g.

$$v = v_0 - gt$$

$$y = y_0 + v_0 t - \frac{1}{2} g t^2$$

$$v^2 = v_0^2 - 2g(y - y_0)$$

Also note that next unit we'll start having more subscripts that indicate direction, like v_{x0} and v_{y0}.

Example 1

A stone is thrown straight down with an initial velocity of 2.4 m/s. How far will it have travelled after 3.0 s?

Hint: watch your reference frame. What's the sign of velocity?

Data:
y_0 = 0.0 m
y = ?
v_0 = -2.4 m/s
v = ?
t = 3.0 s
a = g = 9.81 m/s²

What equation do you use?

Example 1

Use the position equation in the vertical direction.

Data:
y_0 = 0.0 m
y = ?
v_0 = -2.4 m/s
v = ?
t = 3.0 s
a = g = 9.81 m/s²

$$y = y_0 + v_0 t - \frac{1}{2} g t^2$$

$$y = 0.0m + (-2.4m/s) \bullet 3.0s - \frac{1}{2} \bullet 9.81m/s^2 \bullet (3.0s)^2$$

$$y = 0.0m - 7.2m - 44.15m$$

$$-51m$$

Our rock therefore traveled 51 m downwards.

Example 2

A stone is thrown straight down with an initial velocity of 2.4 m/s. What's its velocity after 3.0 s?

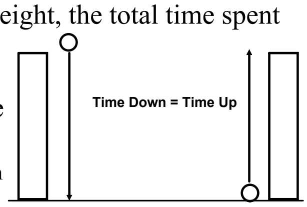
Data:
y_0 = 0.0 m
y = ?
v_0 = -2.4 m/s
v = ?
t = 3.0 s
a = g = 9.81 m/s²

$$v = v_0 - gt$$

$$v = -2.4m/s - 9.81m/s^2 \bullet 3.0s = -31.83m/s \rightarrow 32m/s$$

A Note on Time

For an object dropped from some height to another, or thrown up to the same height, the total time spent in free fall is the same.



Regardless of situation, the velocity at the top will be zero (either v_0 or v, depending on if it's going up or down).

With this in mind, some problems are easier to solve if you "turn them upside down", by assuming that an object thrown up has the same time as one dropped.

Example 3

How long does it take a ball, thrown straight up, to reach a max. height of 15 m?
Hint: use position equation of free fall, assuming the ball is dropped 15 meters.

Data?
x_0 = 15m
x = 0 m
v_0 = 0 m/s
g = 9.81 m/s²
t = ?

$$y = y_0 + v_0 t - \frac{1}{2} g t^2$$

$$y - y_0 = -\frac{1}{2} g t^2$$

$$\sqrt{\frac{2y_0}{g}} = t = \sqrt{\frac{2 \bullet 15m}{9.81m/s^2}} = 1.7\text{s}$$

Homework

2.4 Problems in your Booklet
Due: Next Class

Finish Unit 2 Review Problems: 1 - 9
Scanned: Next Week.

Warning! Kinematics Equations Quiz Tomorrow!