Review: motion with constant acceleration

Acceleration: change in velocity / time interval

- **a = 0 case**
  - no acceleration → velocity is constant → $v = v_i$
  - position vs. time → $\mathbf{x_f = x_i + v\,t}$, x_i is the starting position
- **acceleration = a = constant**
  - velocity→ $\mathbf{v_f = v_i + a\,t}$, v_i is the velocity at time t = 0
  - position→ if motion starts at $\mathbf{x_i = 0}$, with $\mathbf{v_i = 0}$ (*at rest*) → $\mathbf{x = ½\,a\,t^2}$
- for problems in **free-fall** with $\mathbf{v_i = 0}$, then a = g (= 10 m/s²) → $\mathbf{v_f = g\,t}$ and $\mathbf{y_f = ½\,g\,t^2}$

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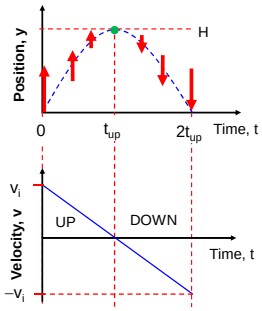
Review: Free fall- object projected vertically up



- Time to reach the maximum height

$$t_{up} = \frac{v_i}{g}$$

- Total time in the air

$t_{up} = t_{down}$, so

$$t_{air} = t_{up} + t_{down} = 2\frac{v_i}{g}$$

2

example

Problem: An object is dropped from rest from a height of 20 m above the ground.
(a) How long will it take to reach the ground?
(b) What is its velocity as it hits the ground?

Solution: initial velocity, $v_i = 0$

$y_f = ½\,g\,t^2$, $v = g\,t$

(a) $$t = \sqrt{\frac{2y_f}{g}} = \sqrt{\frac{2\times 20\ \text{m}}{10\ \text{m/s}^2}} = \sqrt{4\ \text{s}^2} = 2\ \text{s}$$

(b) $$v_f = g\,t = 10\ \text{m/s}^2 \times 2\ \text{s} = 20\ \text{m/s}$$

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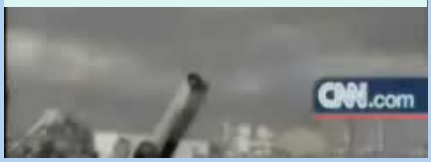
L-5 Projectile motion

- A projectile is an object that is thrown, hit, kicked, shot, etc., and then travels under the influence of gravity.
- It is an example of two-dimensional motion.



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Projectile Examples

- Tennis ball
- Golf ball
- Football
- Softball
- Soccer ball
- bullet
- Hockey puck or ball
- Basketball
- Volleyball
- Arrow
- Shot put
- Javelin

These are all examples of things that are **launched**, then move under the influence of gravity

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Not projectiles

- Jet plane
- Rocket
- Car (unless it looses contact with ground)
- catapult (before rock leaves)
- slingshot (before rock leaves sling)

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Unintended projectile

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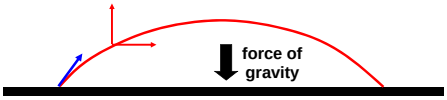
Projectile motion

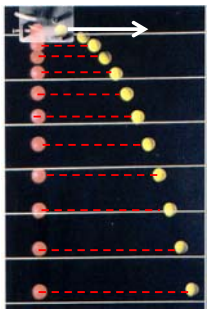


→ The key to understanding projectile motion is to realize that gravity acts in the **vertical (downward) direction**

→ gravity affects **only** the vertical motion, *not the horizontal motion*

Demonstration

- We can show that the horizontal and vertical motions are independent
- The red ball was released and falls vertically down
- The yellow ball was given a kick to the right.
- They track each other vertically step for step and hit the ground at the same time



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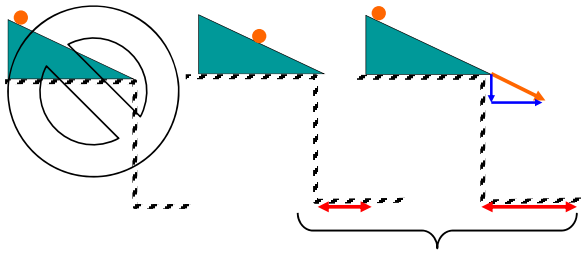
Galileo's inclined plane experiments



NO! **YES!**

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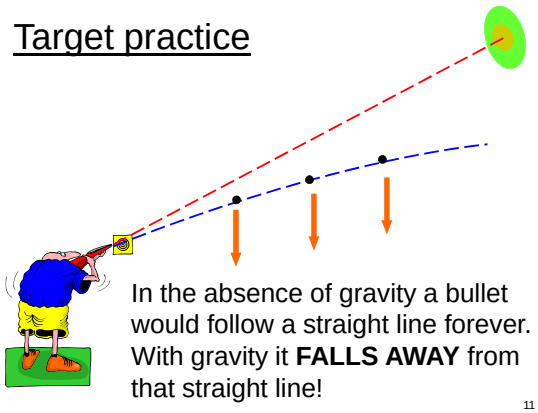
Target practice



In the absence of gravity a bullet would follow a straight line forever. With gravity it **FALLS AWAY** from that straight line!

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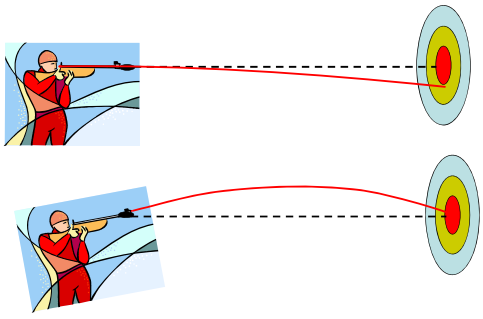
Hitting the target – aim high, not directly at the target



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Sports without gravity

SPACE FUTURE

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Baseball

Every hit ball is a line drive

Pop-ups never Come down.

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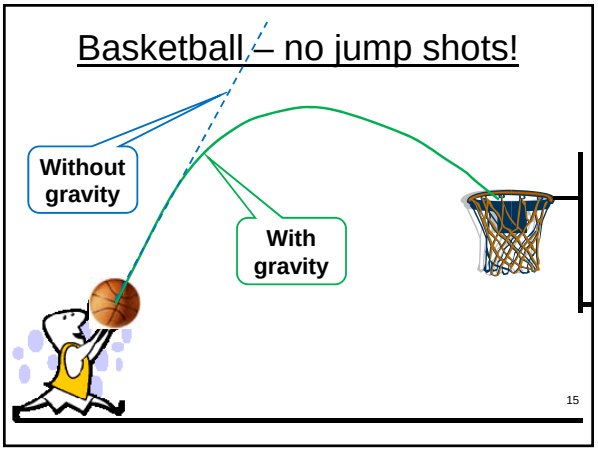
Basketball – no jump shots!



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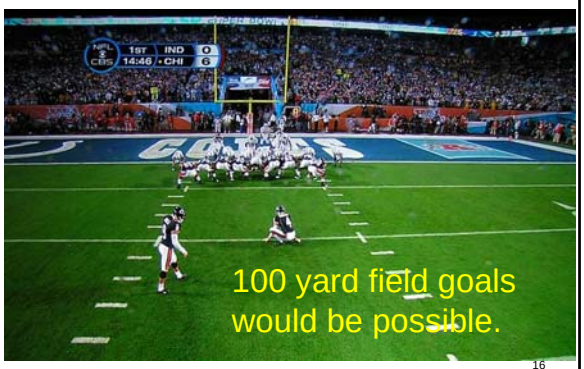
Kicking field goals would be easier!



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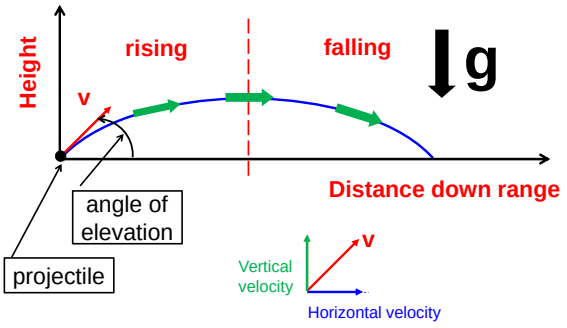
Path of the Projectile: parabola



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Projectile motion – key points

1) The projectile has both a vertical and horizontal component of velocity
2) The only force acting on the projectile once it is released is *gravity* (neglecting air resistance)
3) At all times the acceleration of the projectile is $g = 10\ m/s^2$ *downward*
4) The horizontal velocity of the projectile *does not change* throughout the path
5) On the rising portion of the path gravity causes the vertical component of velocity to decease

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key points-continued

6) At the very top of the path the vertical component of velocity is ZERO
7) On the falling portion of the path the vertical velocity increases
8) When the projectile lands it will have the same vertical speed as it began with
9) The time it takes to get to the top of its path is the same as the time to get from the top back to the ground
10) The range of the projectile (horizontal distance travelled) depends on its initial speed and angle of elevation

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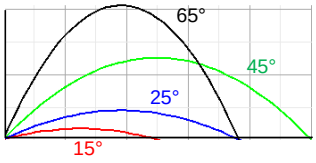
Maximum Range

- When an artillery shell is fired the initial speed of the projectile depends on the explosive charge which cannot be easily changed
- The only control is setting the angle of elevation.
- You can control the range (where it lands) by changing the angle of elevation
- To get maximum range set the angle to 45°



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NEWTON ⇨ *The ultimate projectile: putting an object into orbit*

- Imagine trying to throw a rock around the world.
- If you give it a large horizontal velocity, it will go into orbit around the earth!

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