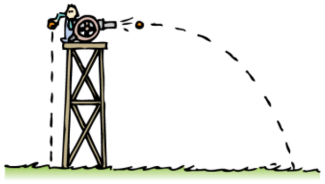
Chapter 5
Projectile Motion



THE BIG IDEA

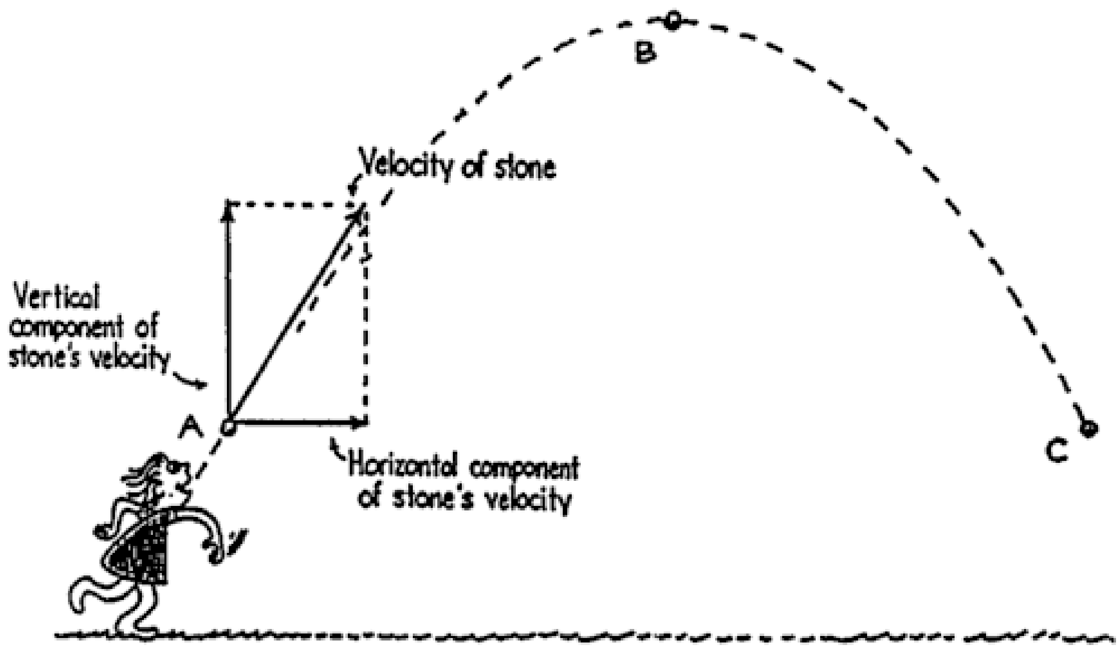
Projectile motion can be described by the horizontal and vertical components of motion.

I. Vector and Scalar Quantities (5-1)

A. *Vector Quantity*– describes both direction and magnitude (size)

1. Includes quantities like velocity (speed and direction), and acceleration

2. speed is magnitude of velocity vector



Let's say you are taking a trip to Hawaii. The distance to Hawaii is 4100km and you travel at 900km/hr.

How long should it take you to reach Hawaii?

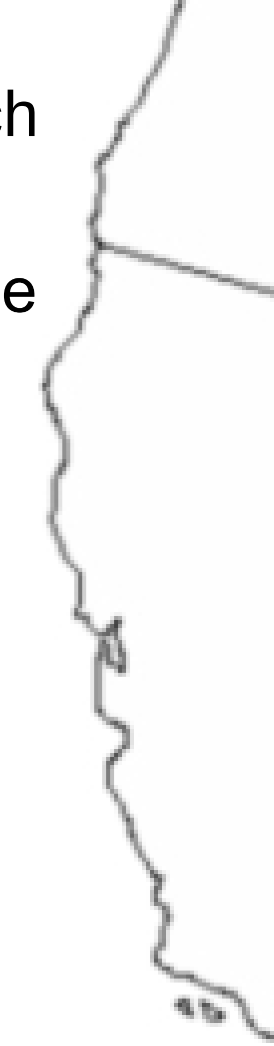
Let's do the math.

$$\frac{(4100\text{km})}{(900\text{km/h})} = \frac{(4100\text{h})}{(900)} = 4.56 \text{ hours}$$

It should take you the same amount of time to return….. Right?   Does it?   Why not?

Remember, we can use vectors to describe things such as velocity. Vectors tell us direction and magnitude

Let’s look at the velocity vectors that might describe the airplane’s velocity and the wind’s velocity



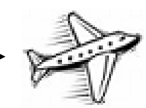
Airplane vector to Hawaii = 

Wind vector =

subtract vectors =

What is the difference in speed?

What about the direction?

Airplane vector from Hawaii = 

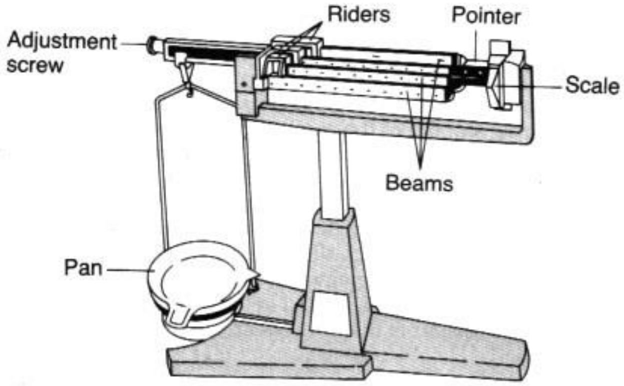
Wind vector =

Add together =

B. ***Scalar Quantity***– specified by **magnitude** <u>only</u>

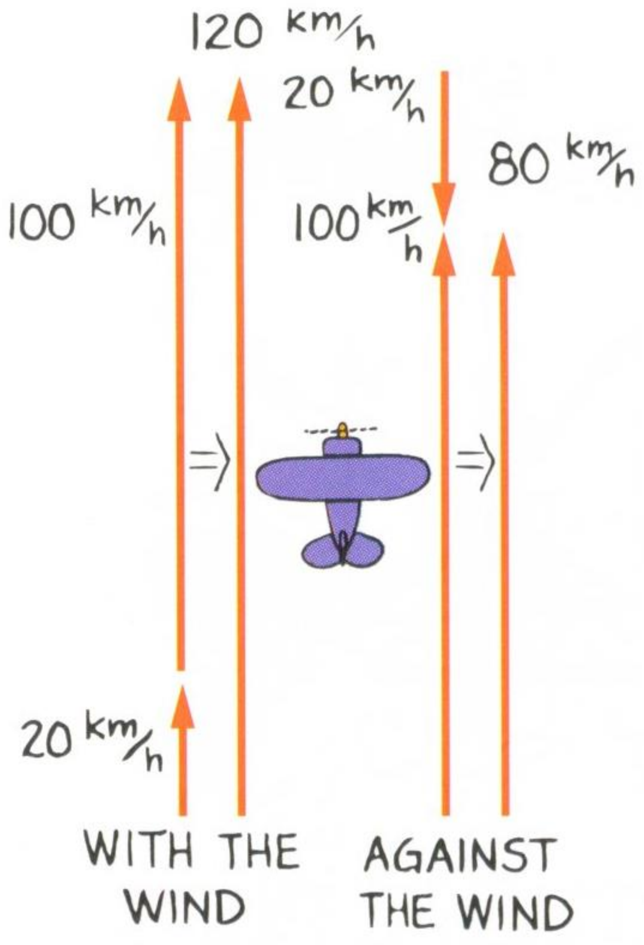
1. can be added, subtracted, multiplied, and divided like ordinary numbers

2. includes: mass, volume, time, etc.



II. Velocity Vectors (5.2)

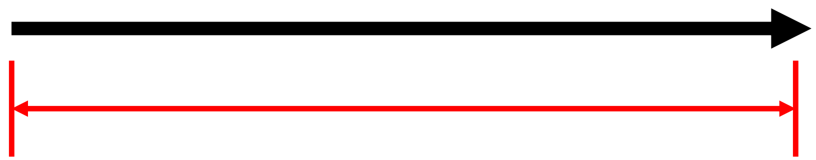
A. An **arrow** is used to represent the ***magnitude*** and ***direction*** of a vector quantity.



1. **Length of arrow** (drawn to scale) indicates **magnitude**

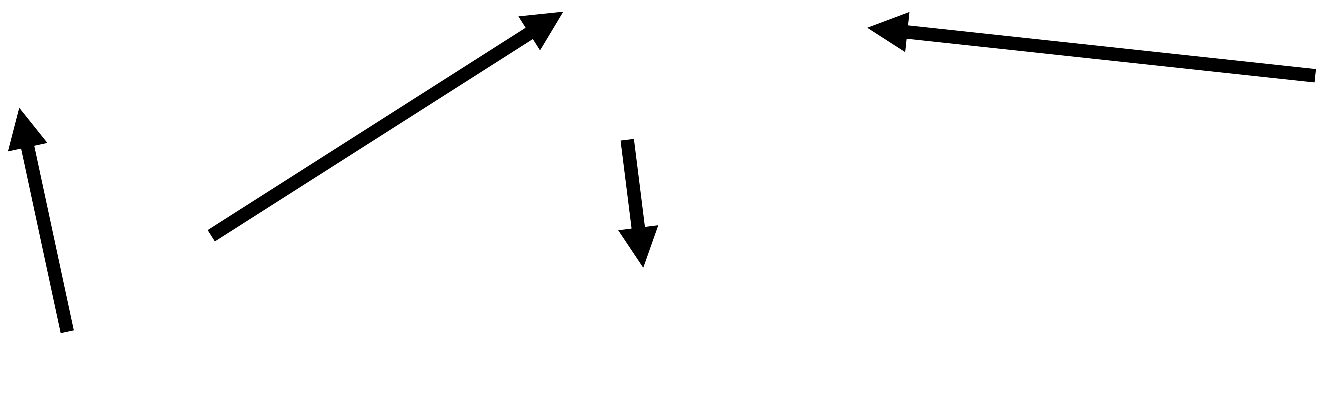
2. **Direction of arrow** indicates **direction** of vector quantity

Arrow-tipped line segment

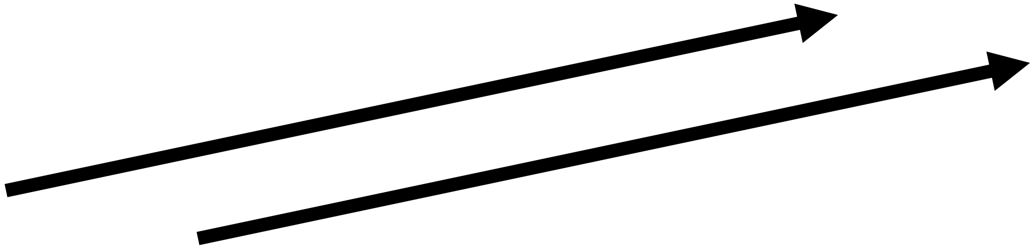


Length represents **magnitude**

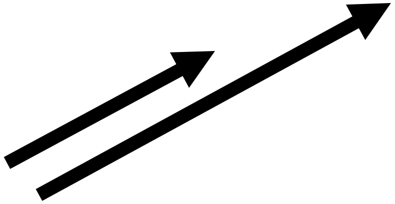
Arrow points in specified **direction** of **vector**



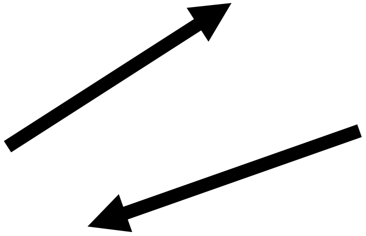
Vectors are equal if: ***magnitude*** and ***directions*** are the **same**



Vectors are **<u>not</u>** equal if: have **different *magnitude*** or ***direction***



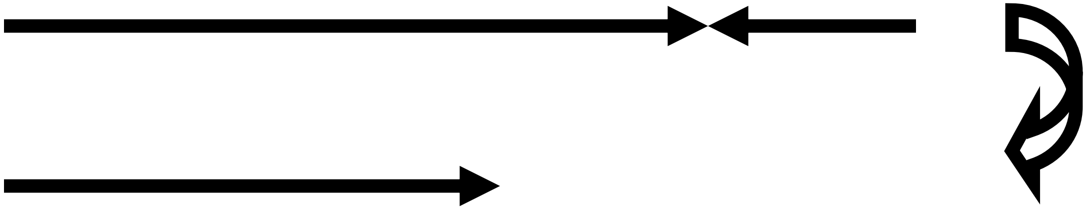
or



B. ***Parallel vectors***– simple to add or subtract

add

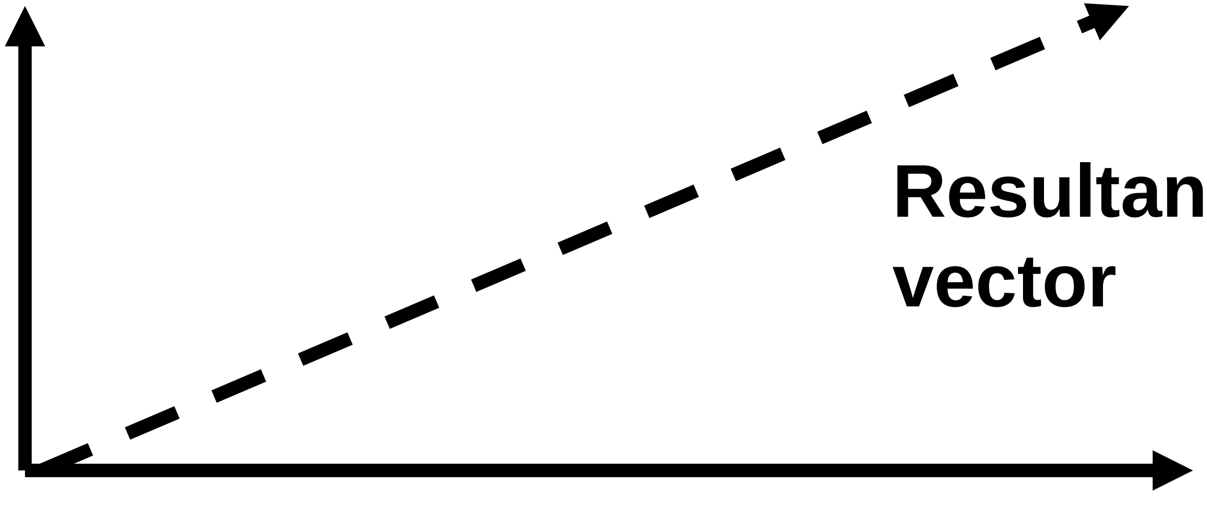
subtract



C. Combining vectors that are NOT parallel

1. Result of adding two vectors called the ***resultant***

2. Resultant of two **perpendicular** vectors is the **diagonal** of the rectangle with the two vectors as sides

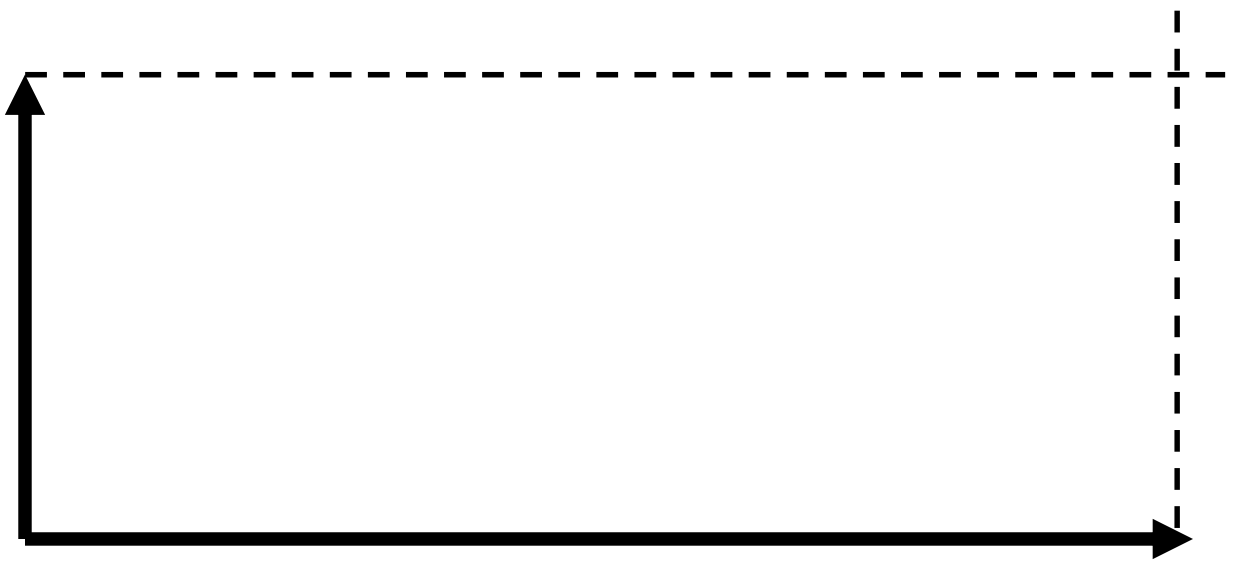


3. Use simple three step technique to find resultant of a pair of vectors that are at **right angles** to each other.

a. **First**– draw two vectors with their tails touching.

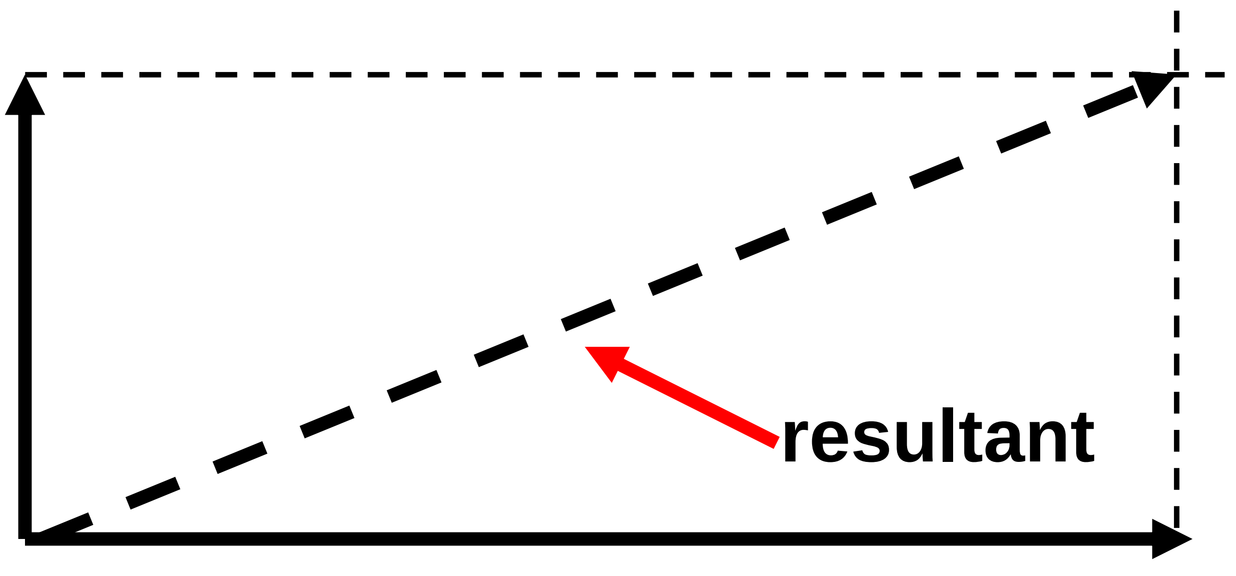
3. Use simple three step technique to find resultant of a pair of vectors that are at **right angles** to each other.

b. **Second**-draw a parallel projection of each vector with dashed lines to form a rectangle



3. Use simple three step technique to find resultant of a pair of vectors that are at **right angles** to each other.

c. **Third**-draw the diagonal from the point where the two tails are touching

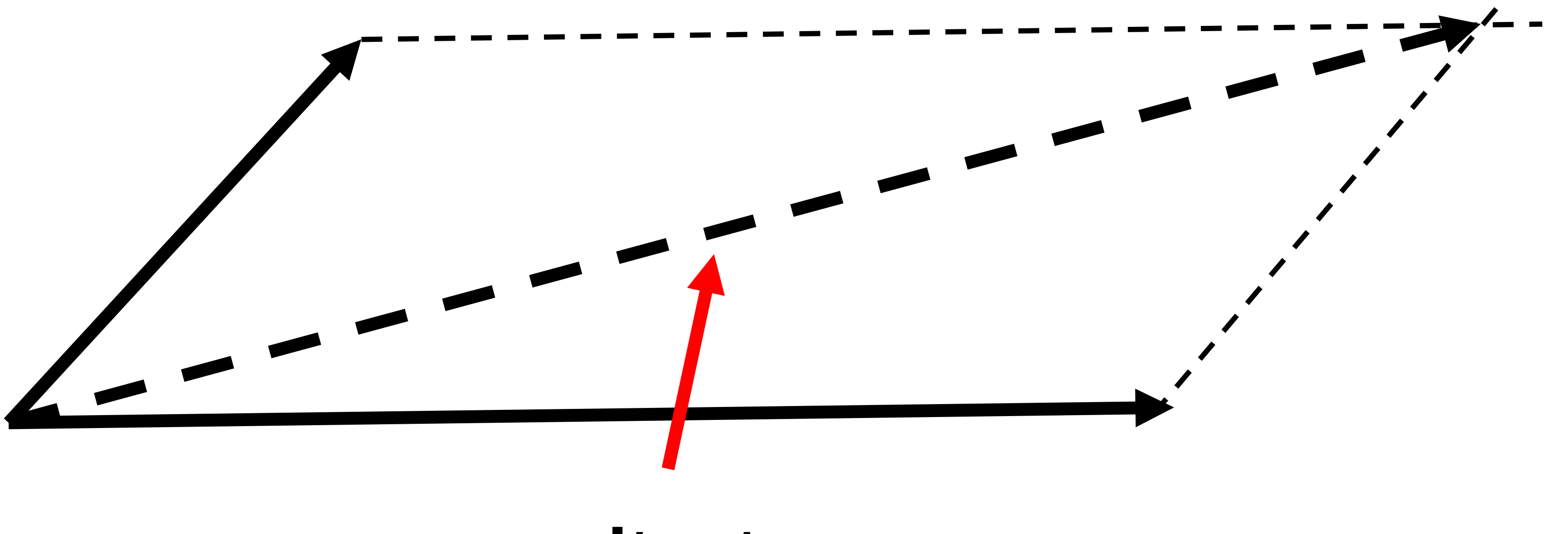


4. Adding vectors not at right angles

a. Construct parallelogram

b. Construct with two vectors as sides

c. Resultant is the diagonal

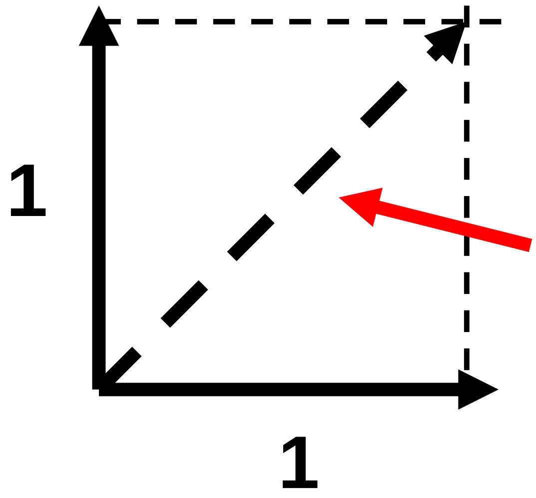


5. Adding vectors when parallelogram is a square (two vectors of equal length and at right angles to each other)

a. Construct a square

b. The length of diagonal is $\sqrt{2}$ or 1.414 times either of the sides

c. Resultant is $\sqrt{2}$ times either of the vectors



Resultant = $\sqrt{2}$

5.2 Velocity Vectors

think!

Suppose that an airplane normally flying at 80 km/h encounters wind at a right angle to its forward motion—a crosswind. Will the airplane fly faster or slower than 80 km/h?

5.2 Velocity Vectors

think!

Suppose that an airplane normally flying at 80 km/h encounters wind at a right angle to its forward motion—a crosswind. Will the airplane fly faster or slower than 80 km/h?

Answer: A crosswind would increase the speed of the airplane and blow it off course by a predictable amount.

III. Components of Vectors (5.3)

A. Technique to determine the vectors that made up a resultant vector (working backwards)

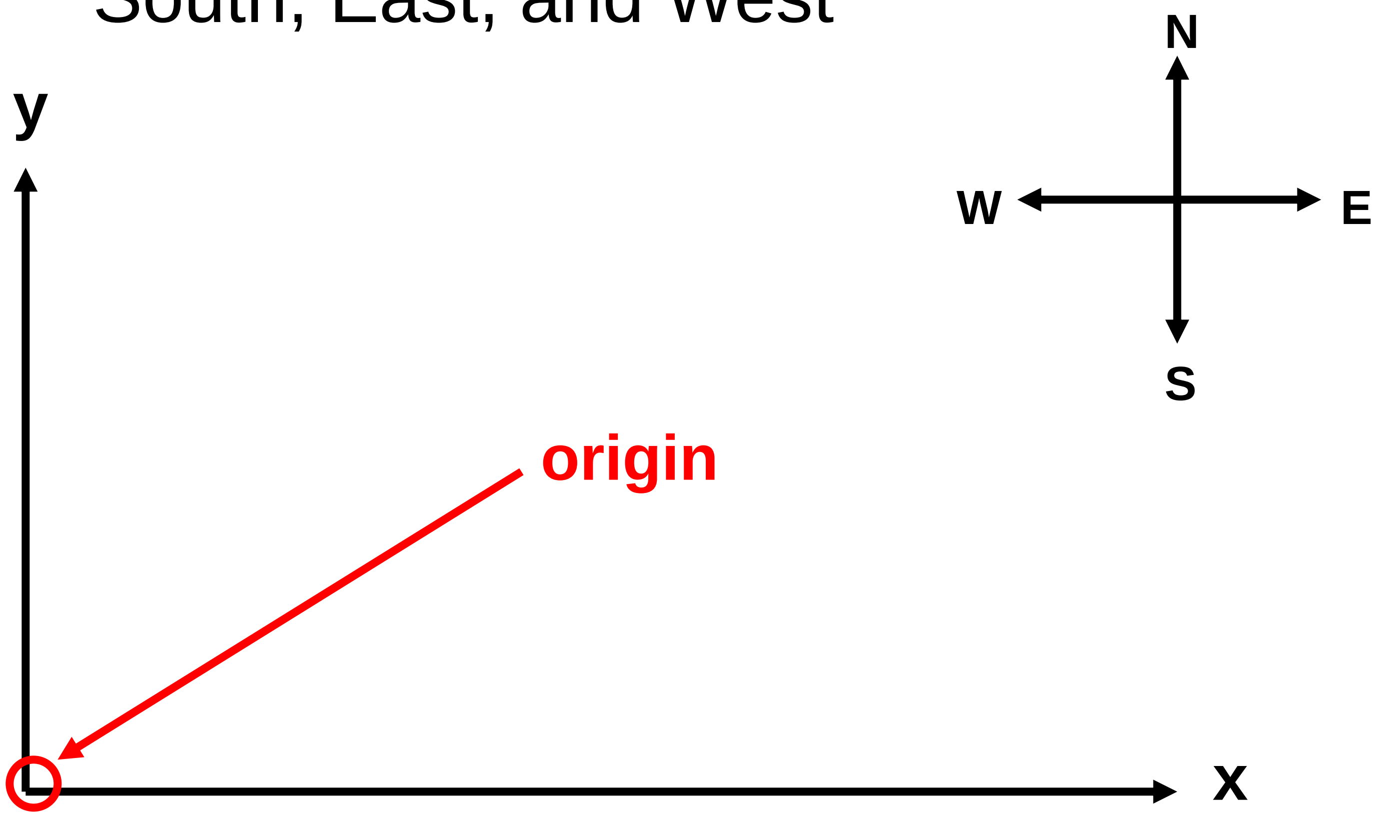
1. Any vector can be “resolved” into two component vectors at right angles to each other

a. These two vectors are called ***components***

b. Process of determining components is called ***resolution***

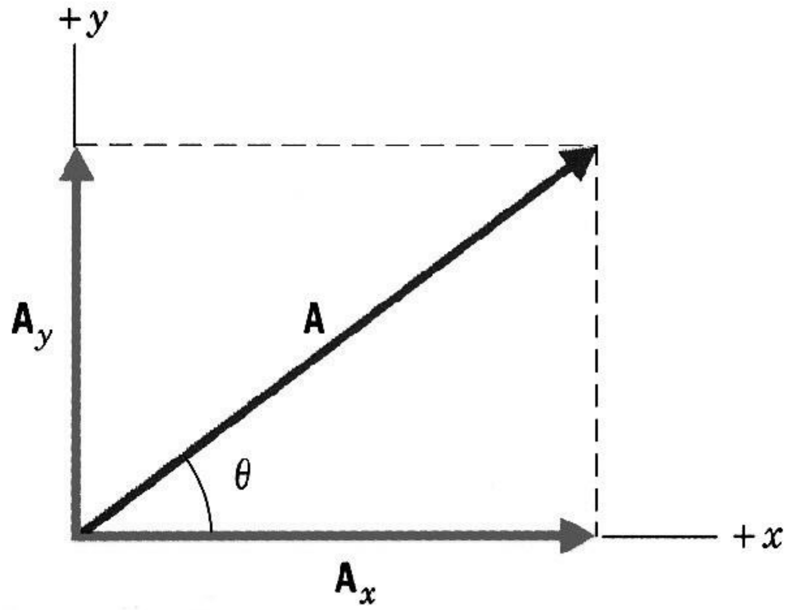
Components of Vectors

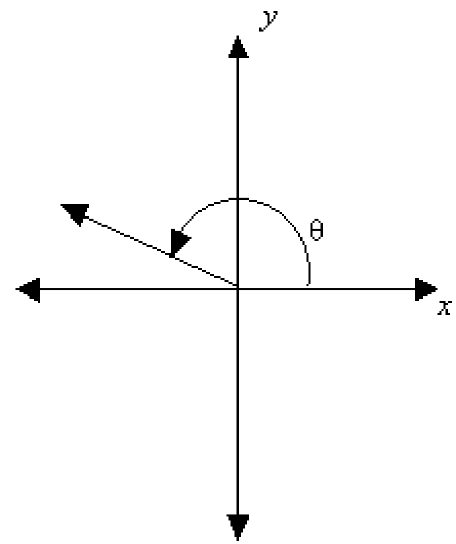
- Need a **coordinate system**
- Choose **origin** and **direction** axes point
- When describing motion on earth, use North, South, East, and West



- **Direction** of vector specified relative to coordinates

- Defined by **angle (θ)** makes with x-axis (measured counterclockwise)





Vector Resolution

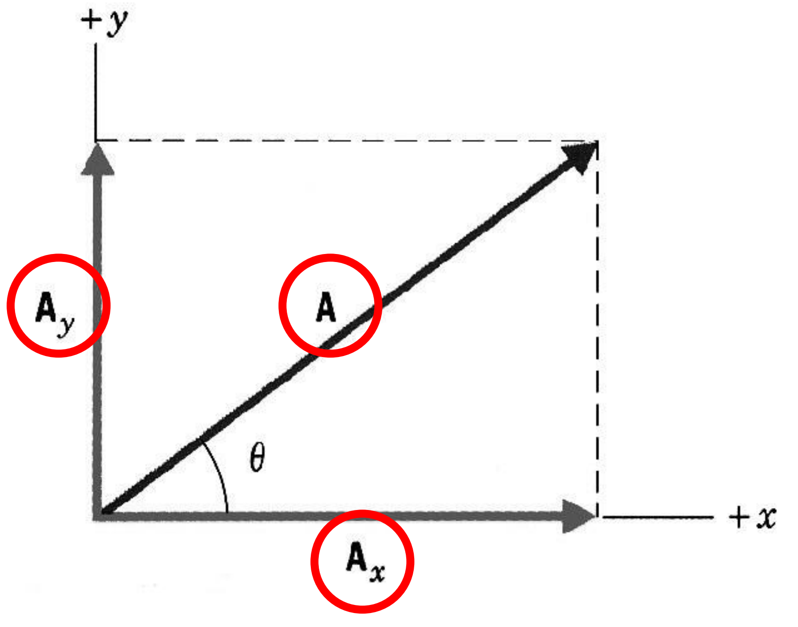
•Vector **(A)** broken up into (or resolved into) two ***component vectors***

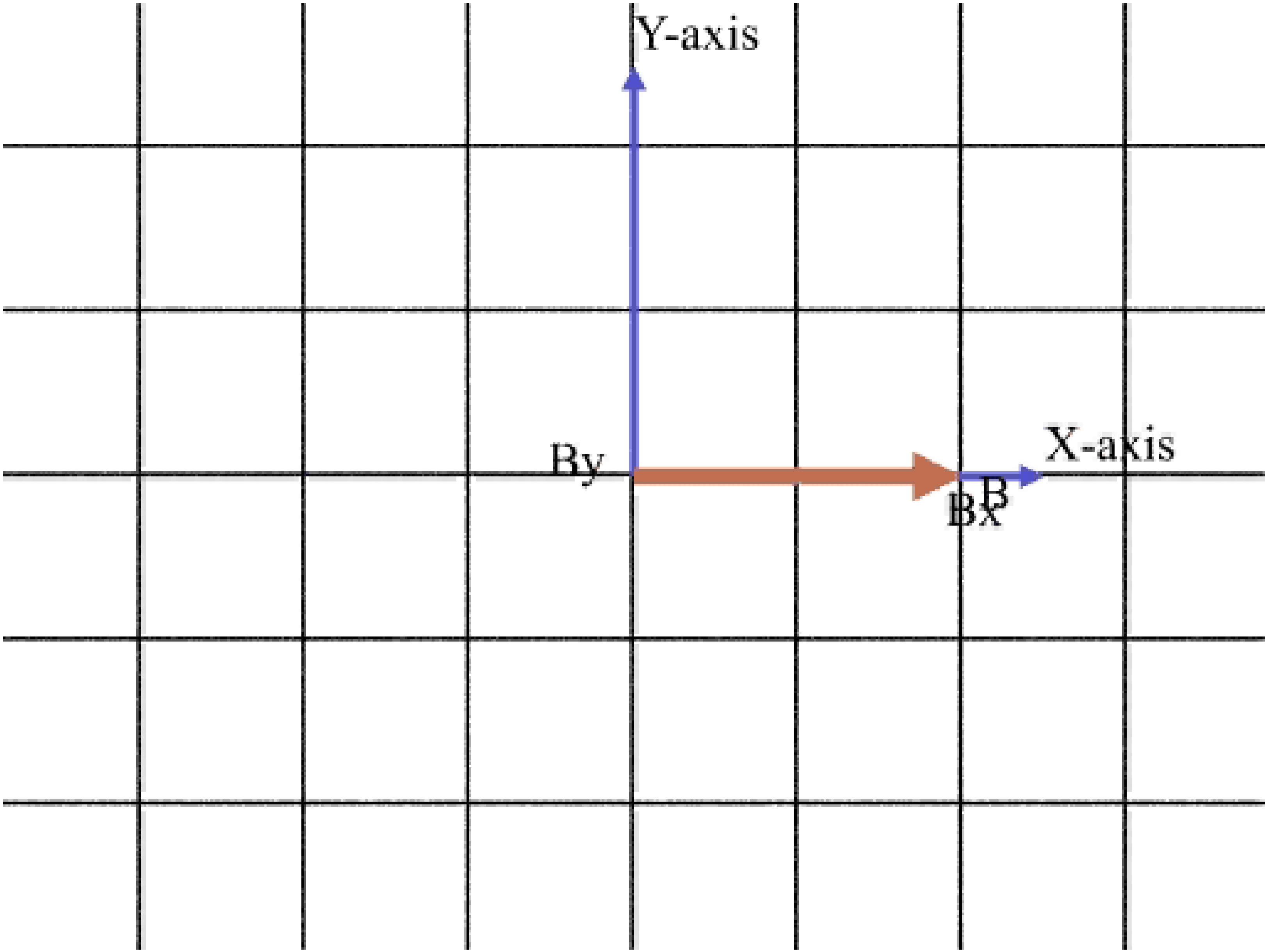
•***Ax- parallel to x-axis***

•***Ay- parallel to y-axis***

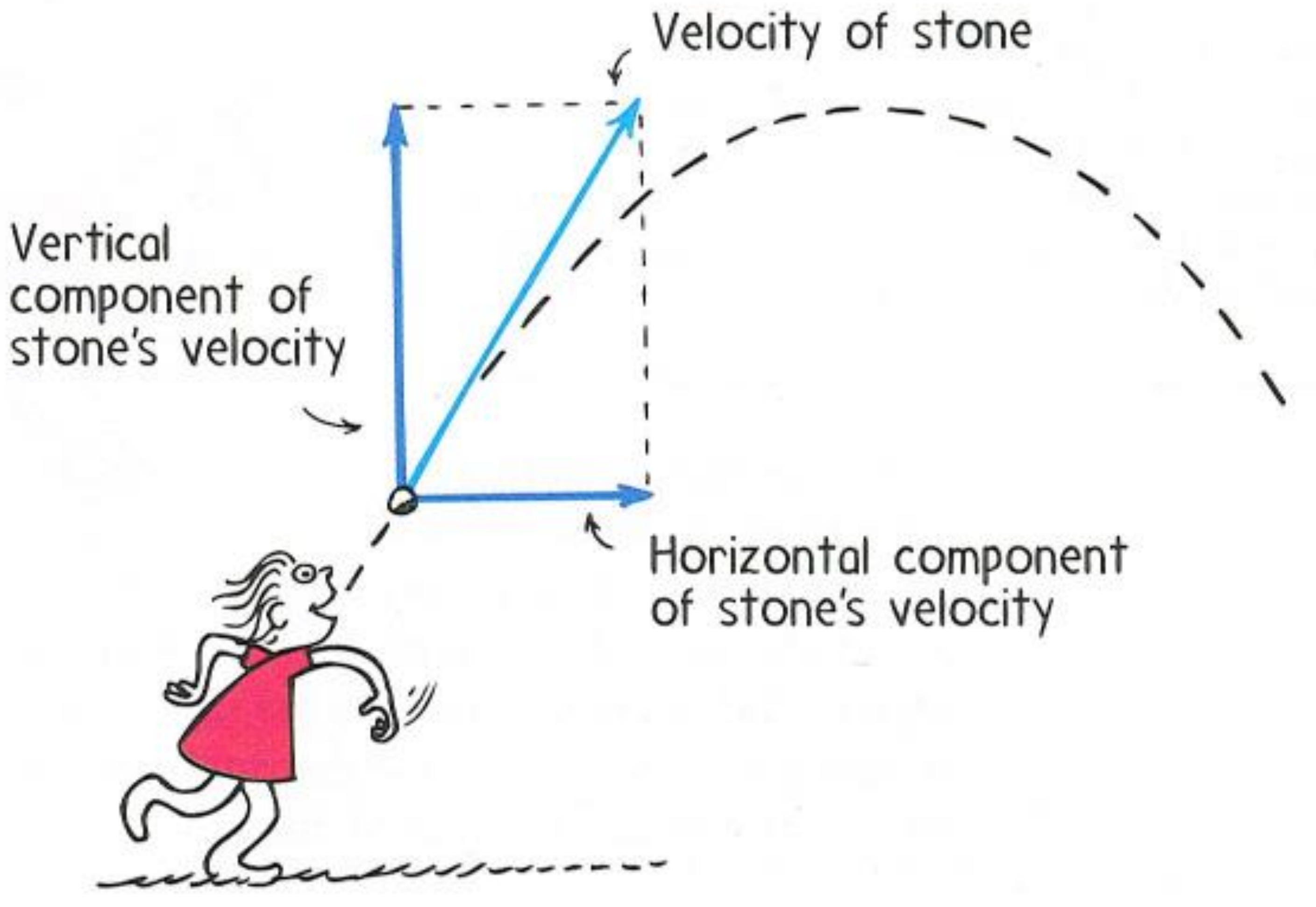
•Original vector **sum** of two **component** vectors

$$\boldsymbol{A = A_x + A_y}$$




Y-axis
By
X-axis
B
Bx

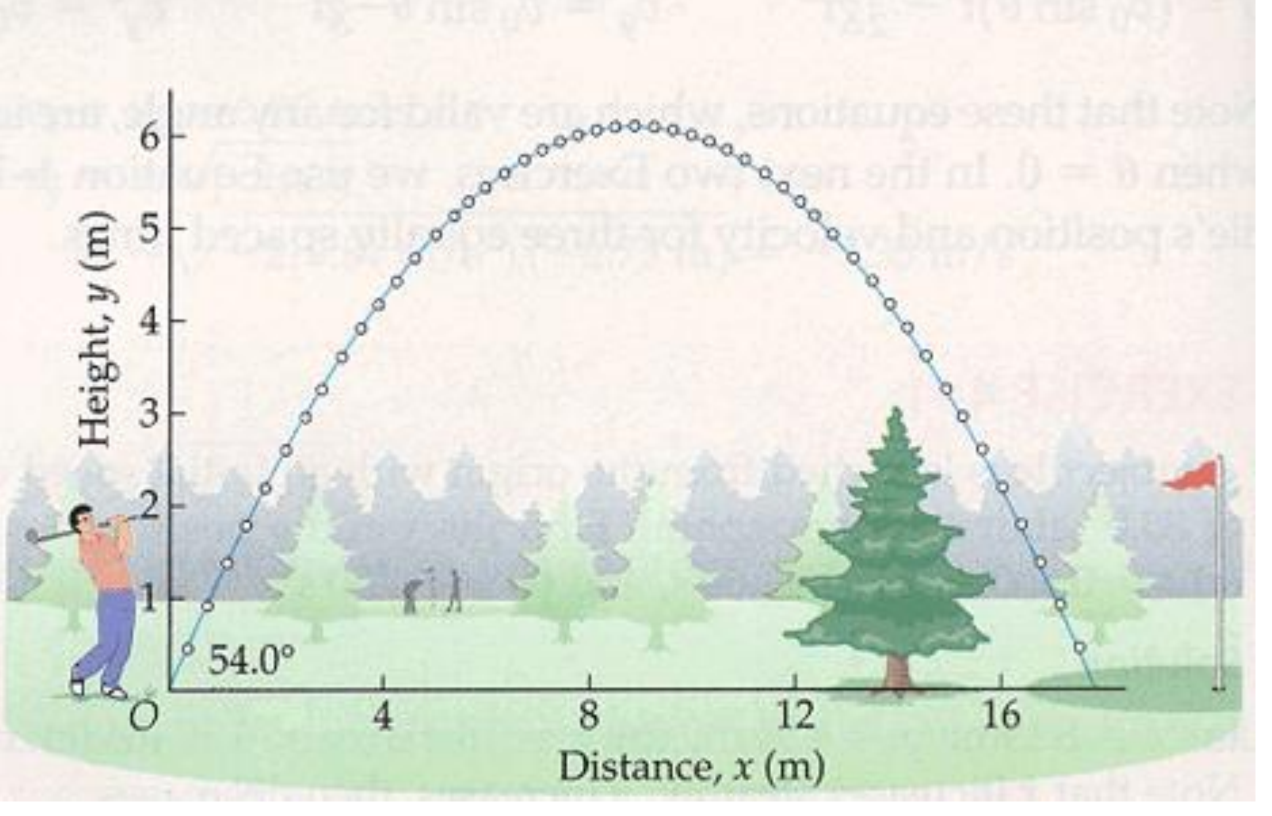
c. can resolve into **vertical** and **horizontal** ***components***



IV. Projectile Motion (5.4)

A. ***projectile***-any object that moves through the air or through space, acted on only by gravity (and air resistance, if any)

1. follow curved path near Earth's surface



2. Can look at vertical and horizontal components separately.

- a. **Horizontal component** for projectile same as ball rolling freely along a level surface (when friction is negligible). Has constant horizontal velocity
    - 1). Covers equal distance in equal time interval
    - 2). With no horizontal force acting on ball there is <u>no</u> horizontal acceleration (same for a projectile)

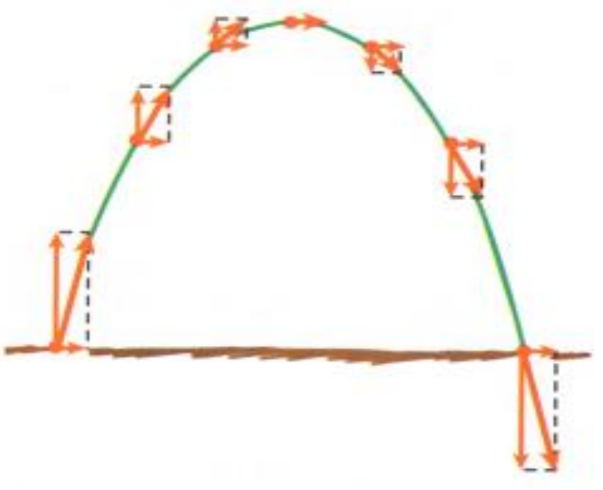
b. Vertical component of a projectile's velocity is like motion of free falling object.

1). Only force in vertical direction is **gravity**

2). Vertical component changes with time

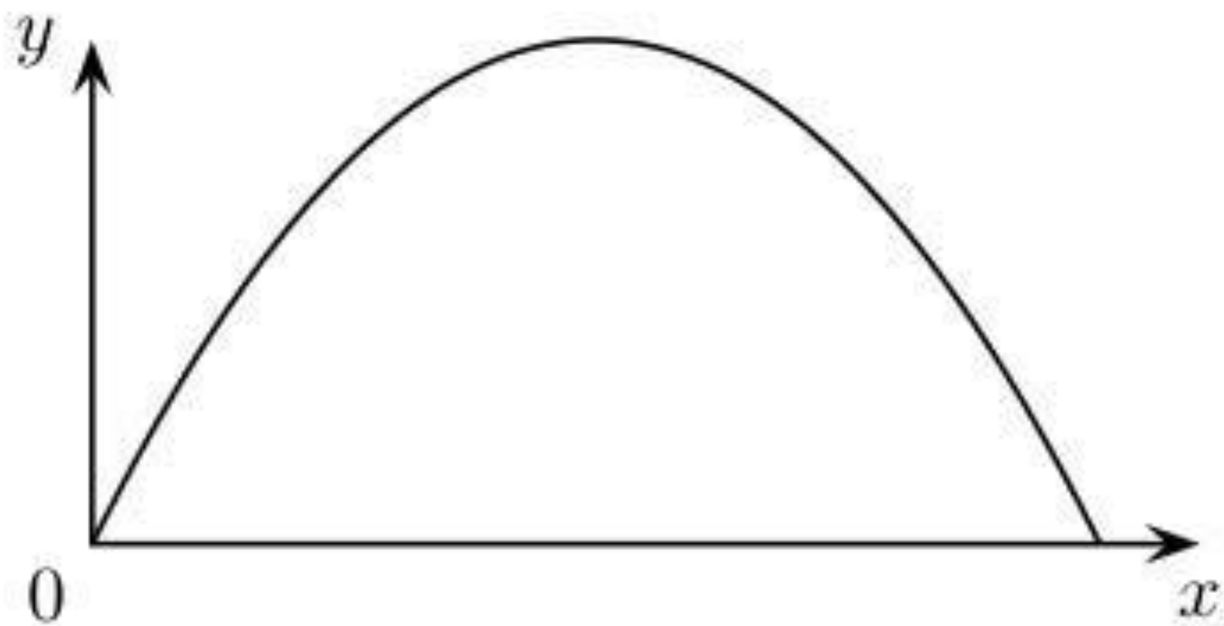
c. horizontal and vertical components are completely **independent** of each other.

1). Combine to produce variety of curved paths that projectiles follow.



3. Path of projectile accelerating in the vertical with constant horizontal velocity forms a ***parabola***

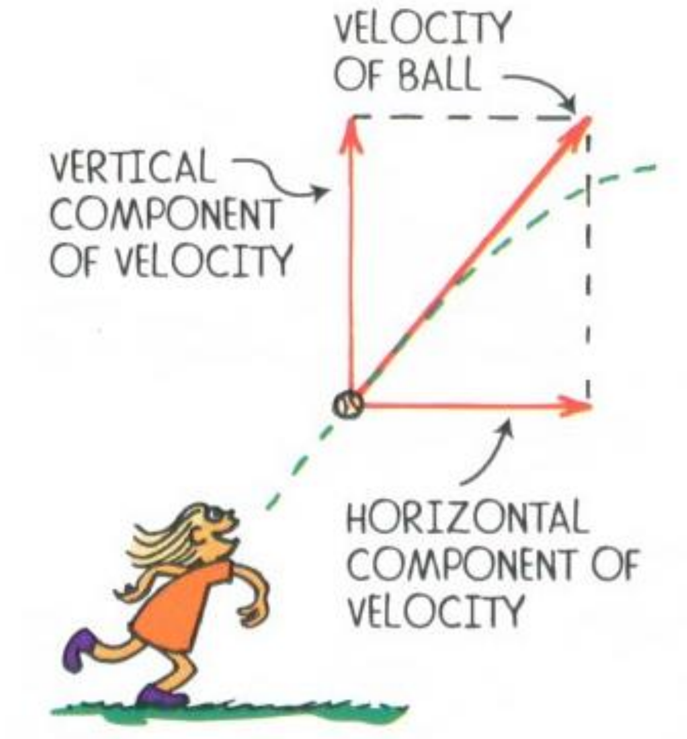
4. When air resistances small enough to neglect (slow moving or heavy projectiles) the curved path are ***parabolic***



V. Projectiles Launched Horizontally (5.5)

A. **Horizontal motion** is **constant**

1. Horizontal component **constant** (moves same horizontal distance in equal time intervals)

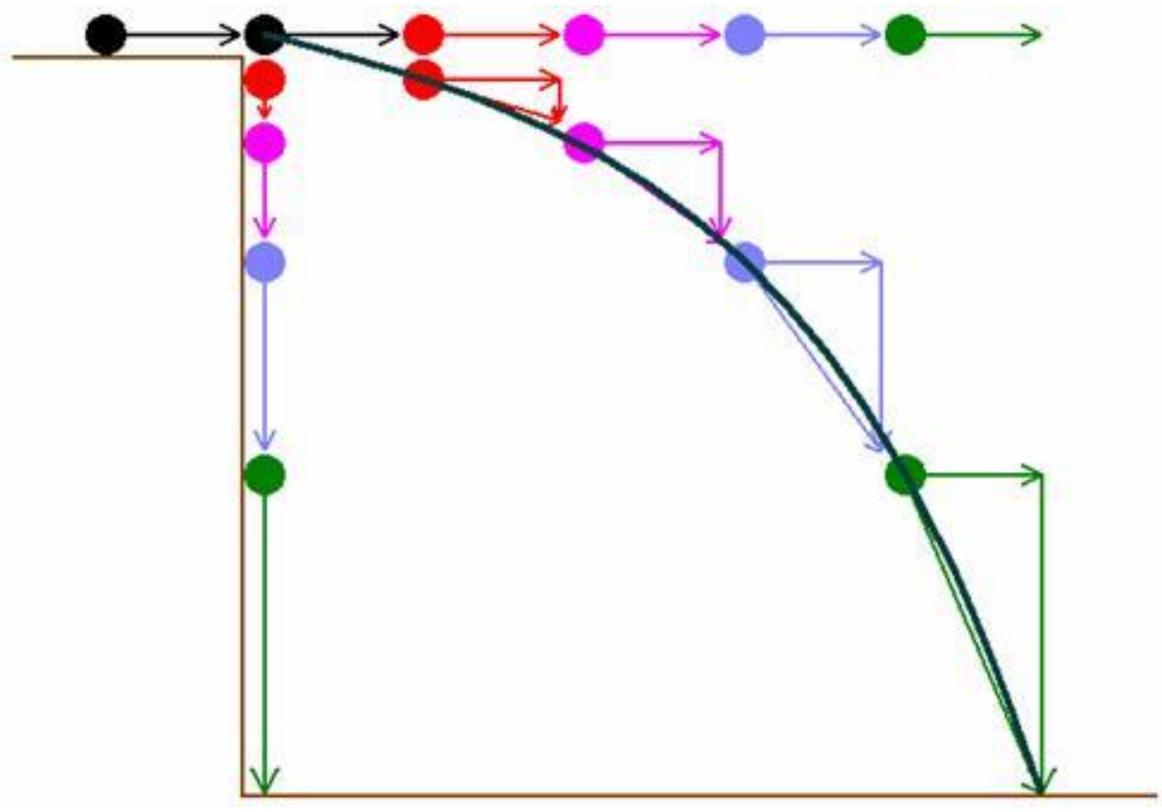


2. **No horizontal component** of **force** acting on it

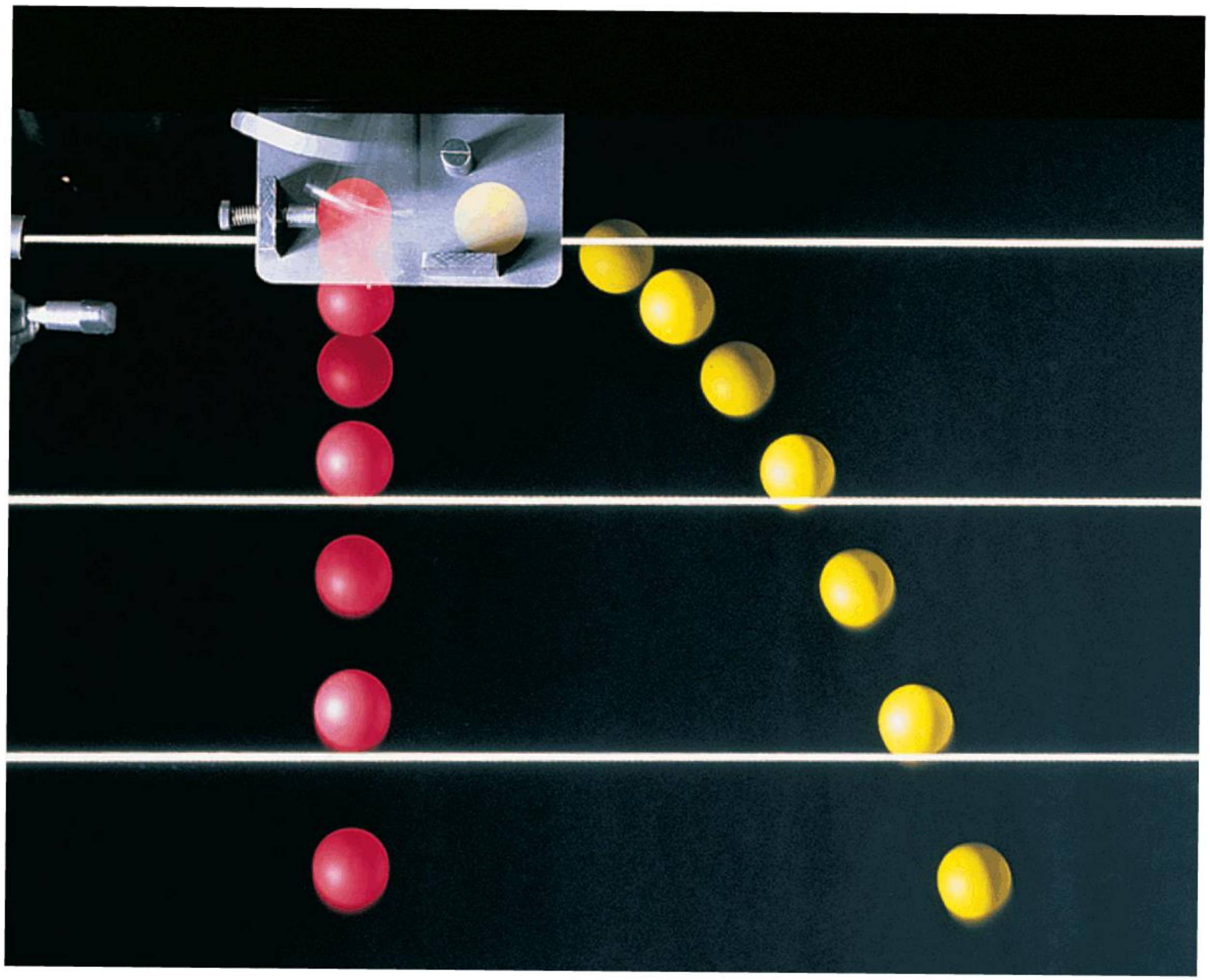
B. **Gravity** <u>only acts</u> **downward**

1. object accelerates downward

2. **Downward motion** of horizontally launched projectile is the <u>same</u> as that for **free fall**



A strobe-light photo of two balls released simultaneously–one ball drops freely while the other one is projected horizontally.



5.5 Projectiles Launched Horizontally

think!

At the instant a horizontally pointed cannon is fired, a cannonball held at the cannon's side is released and drops to the ground. Which cannonball strikes the ground first, the one fired from the cannon or the one dropped?

5.5 Projectiles Launched Horizontally

think!

At the instant a horizontally pointed cannon is fired, a cannonball held at the cannon's side is released and drops to the ground. Which cannonball strikes the ground first, the one fired from the cannon or the one dropped?

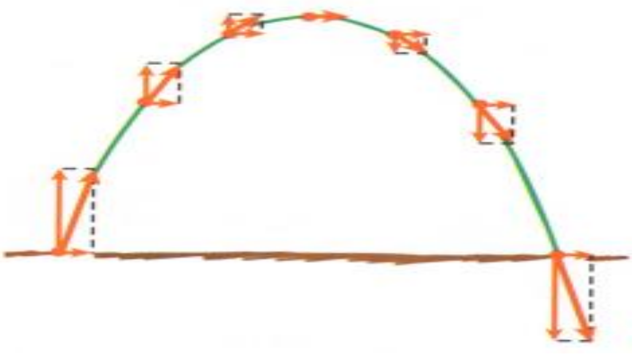
Answer: Both cannonballs fall the same vertical distance with the same acceleration g and therefore strike the ground at the same time.

VI. Projectiles Launched at an Angle (5.6)

A. Vertical distance **independent** of horizontal distance

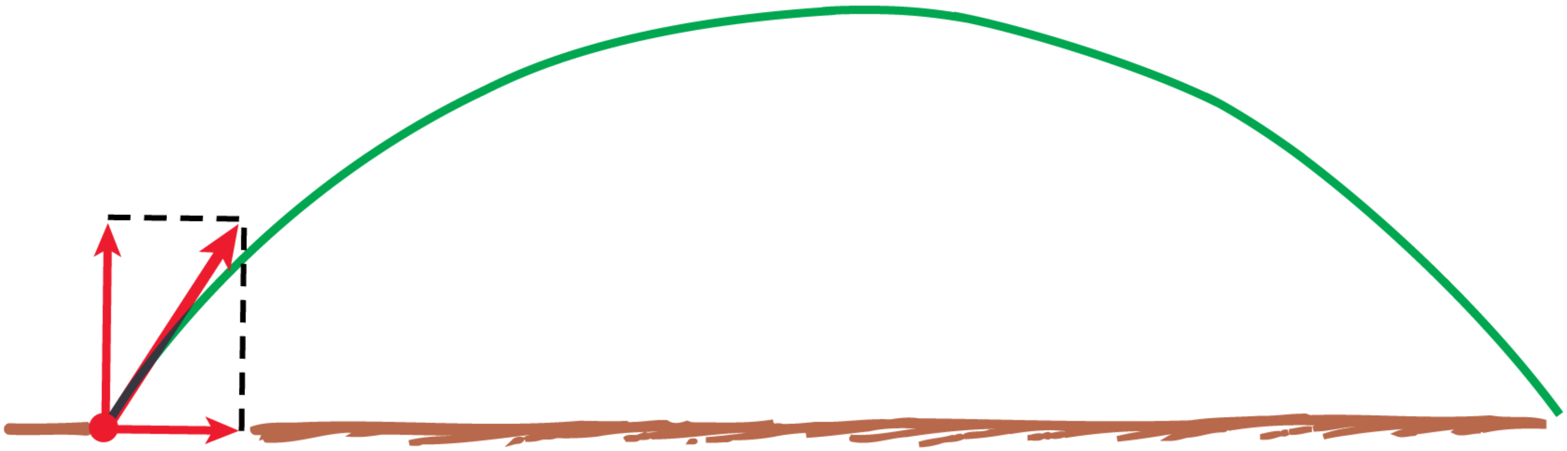
1. If **no gravity** projectile travels in **straight line**

2. Gravity causes projectile to fall below this line the same distance it would have fallen if it were dropped from **rest**.



5.6 Projectiles Launched at an Angle

The velocity of a projectile is shown at various points along its path. Notice that the vertical component changes while the horizontal component does not. Air resistance is neglected.



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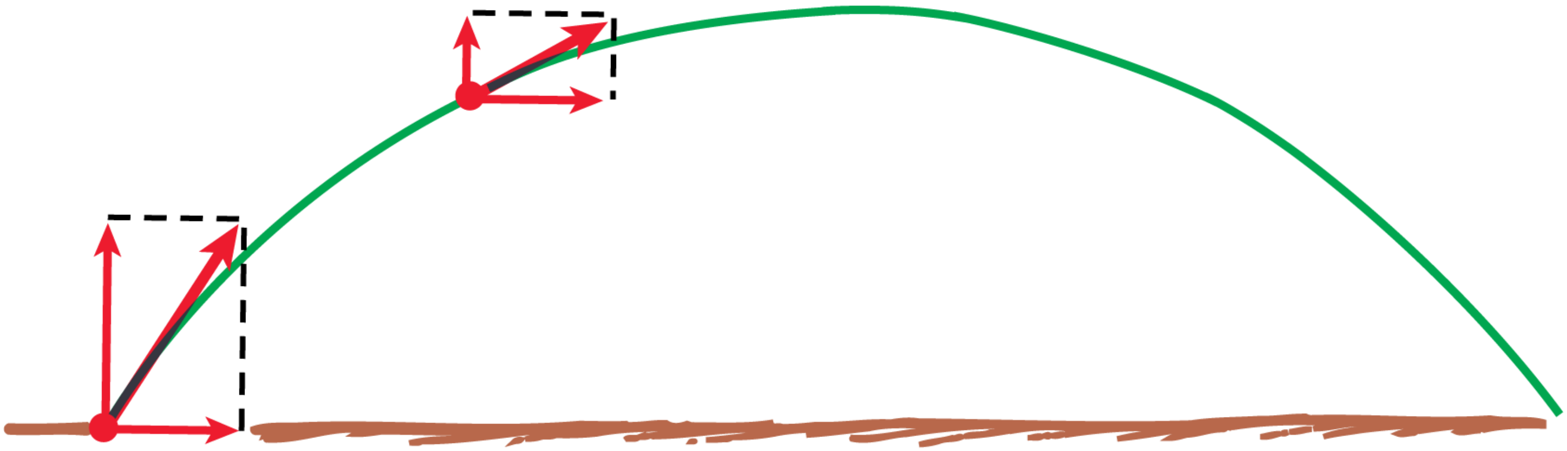

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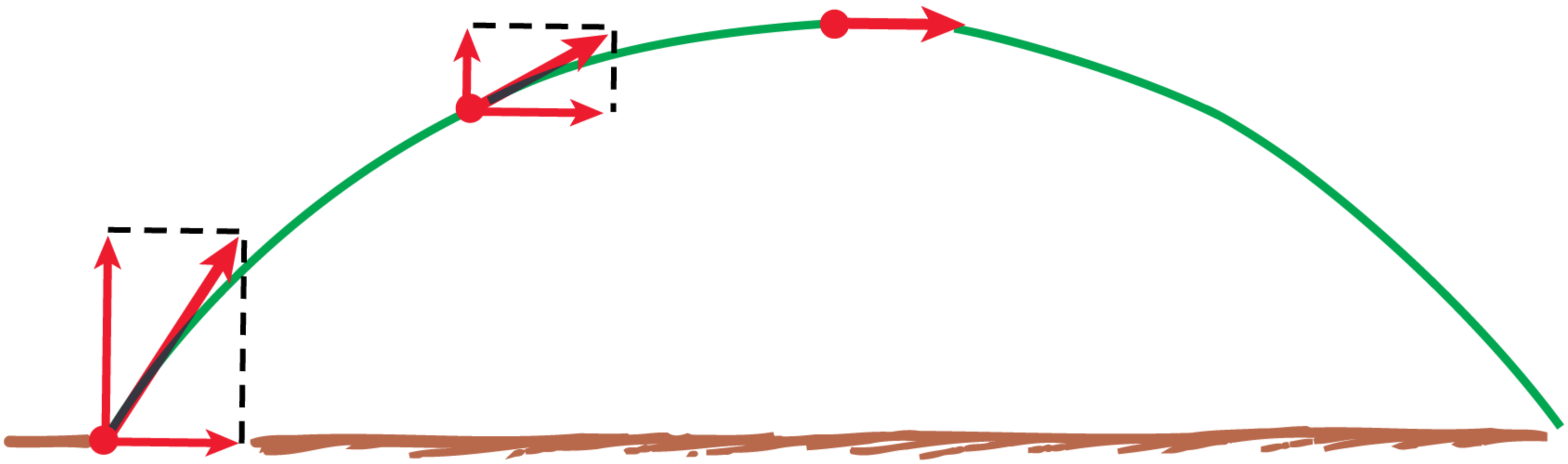

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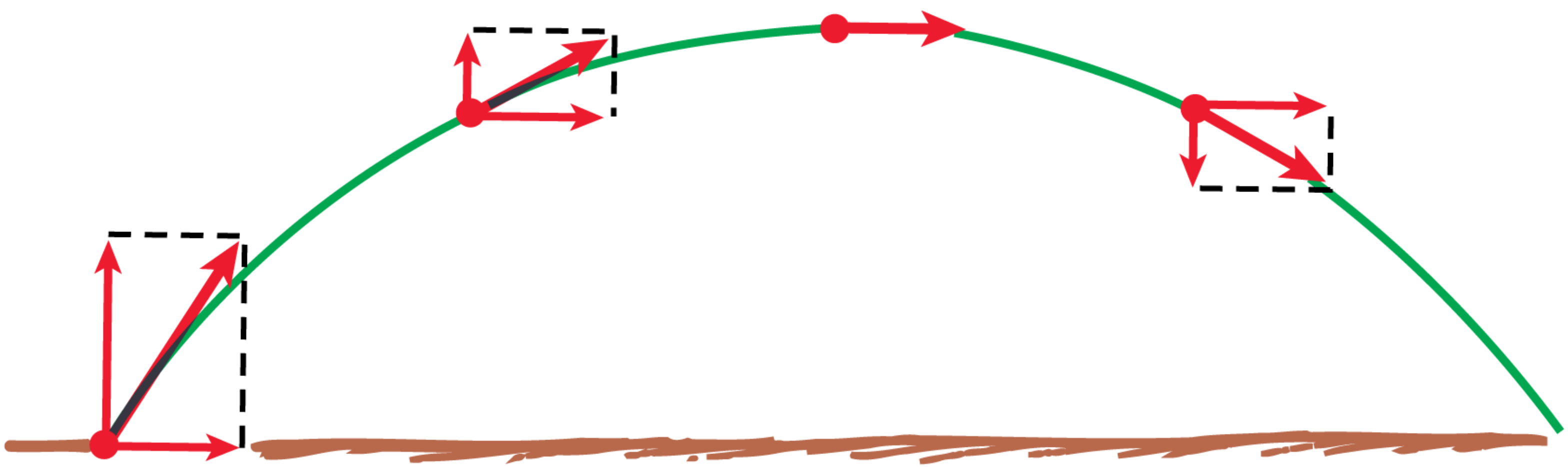

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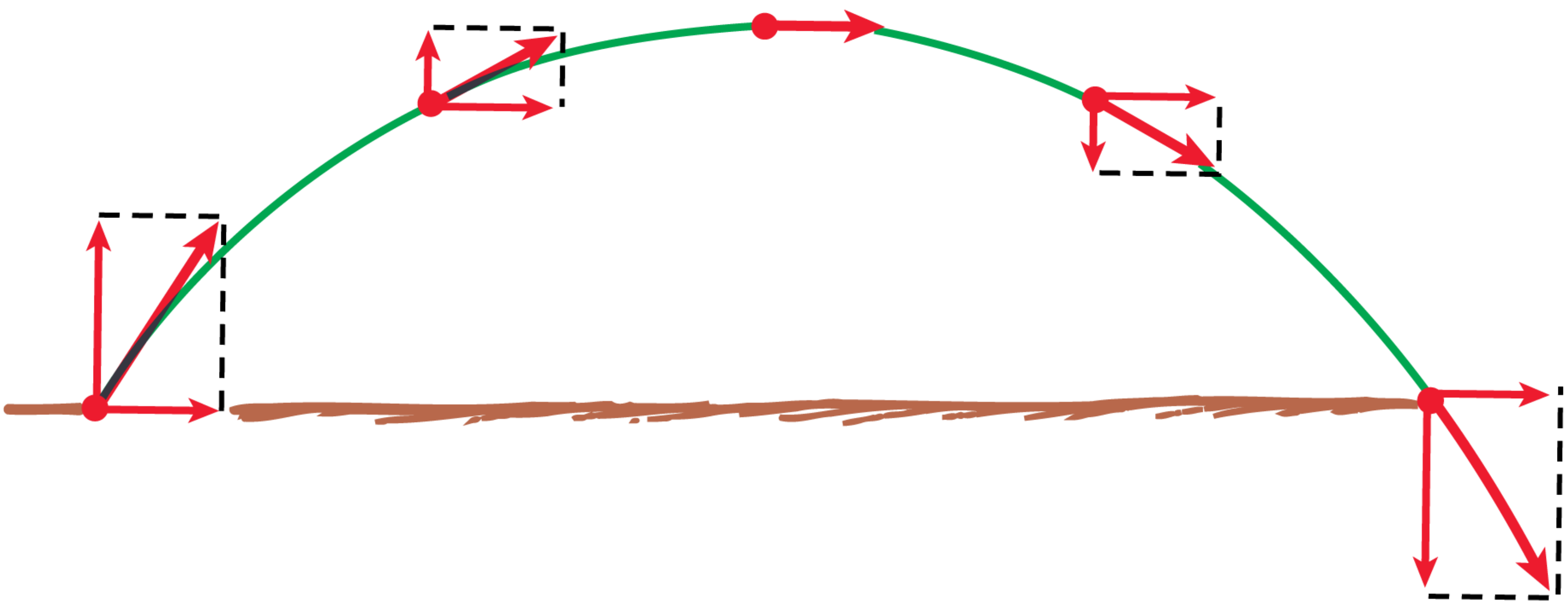



STAND
Coca-Cola
WEEKLY TIMES
'The Fresh Food People'
SAFEWAY
'The Fresh Food People'
SAFEWAY
RURAL FINANCE
Lending to
Victorian farmers

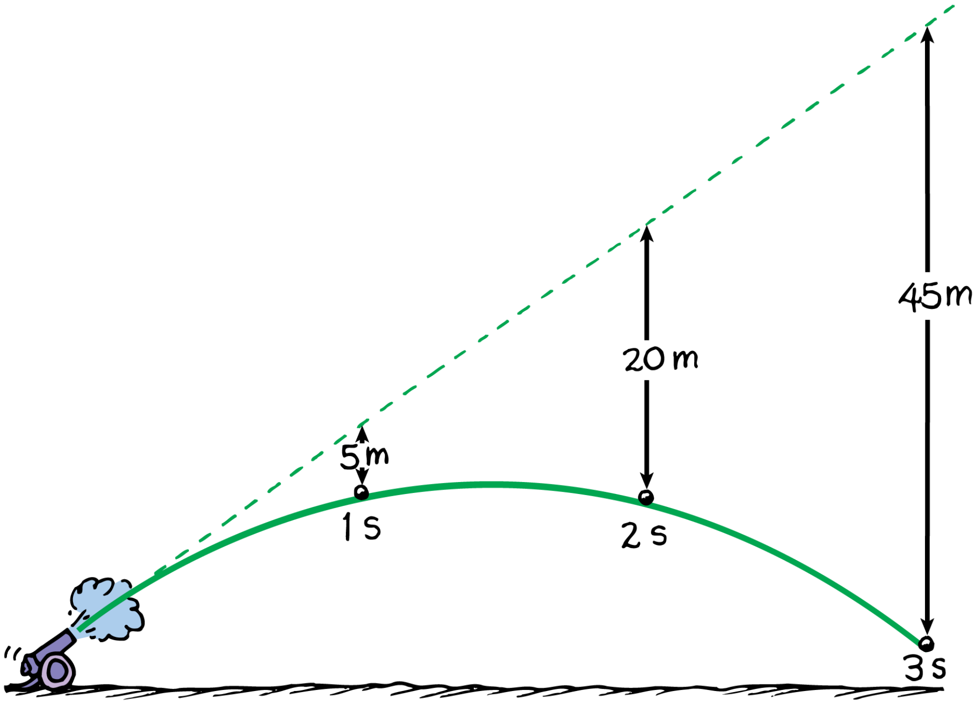
3. Distance below line calculated with **equation**

$$d = \frac{1}{2} g t^2$$

B. Height

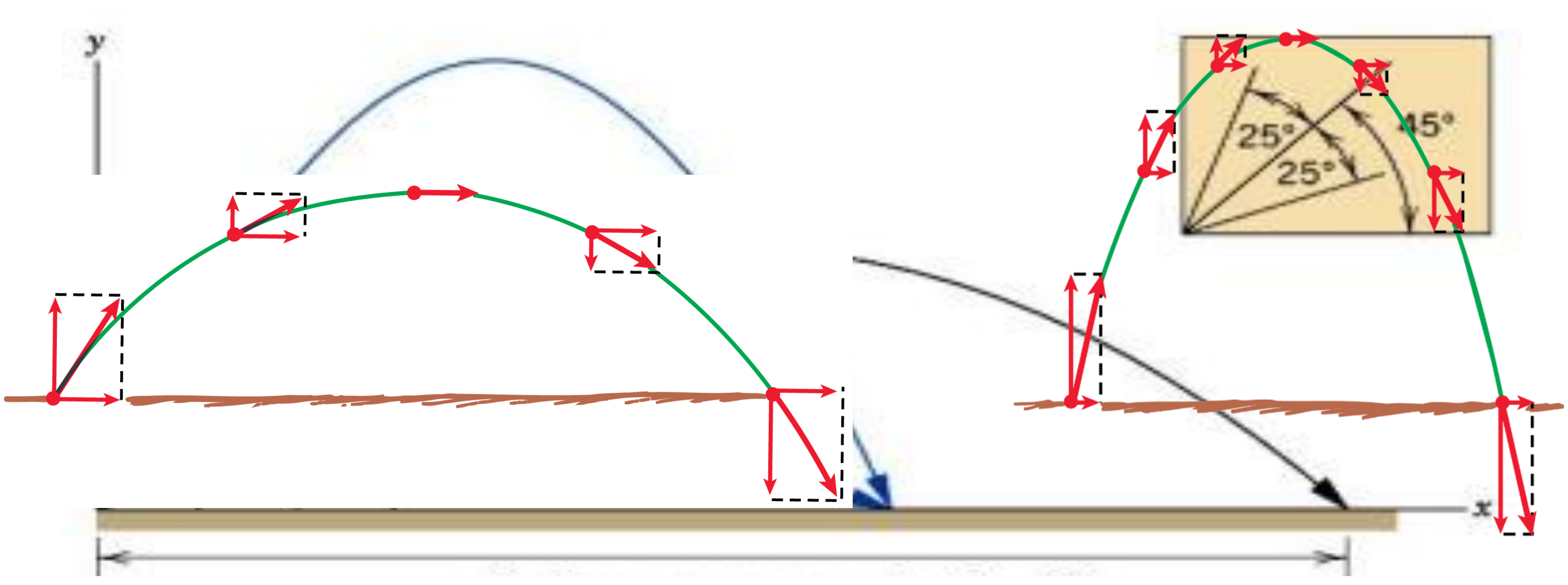
1. Vertical distance a projectile falls below an imaginary straight line path increases continually with time

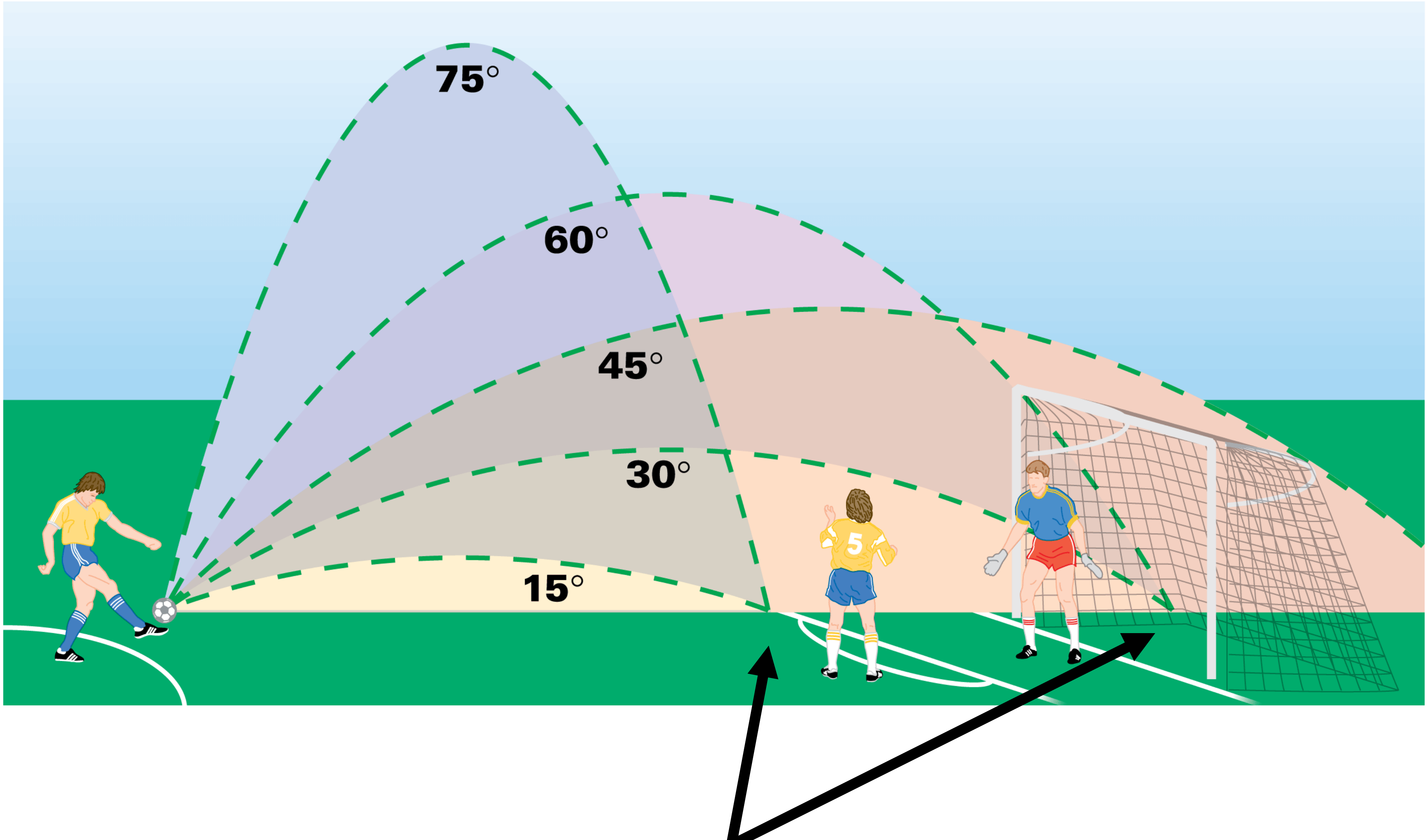
2. Equal to **$5t^2$ meters** $$d = \frac{1}{2}gt^2$$



C. Range

1. Path of projectile forms **parabola** (neglecting air resistance
2. Horizontal range changes with **angle** of launch
    a. **45 degrees** gives **maximum** range
    b. Some angles yield same range (i.e. 30 and 60 degrees)





Notice the positions with the same range using different launch angles. How are these values related?

5.6 Projectiles Launched at an Angle

think!

A projectile is launched at an angle into the air. Neglecting air resistance, what is its vertical acceleration? Its horizontal acceleration?

5.6 Projectiles Launched at an Angle

think!

A projectile is launched at an angle into the air. Neglecting air resistance, what is its vertical acceleration? Its horizontal acceleration?

Answer: Its vertical acceleration is *g* because the force of gravity is downward. Its horizontal acceleration is zero because no horizontal force acts on it.

5.6 Projectiles Launched at an Angle

think!

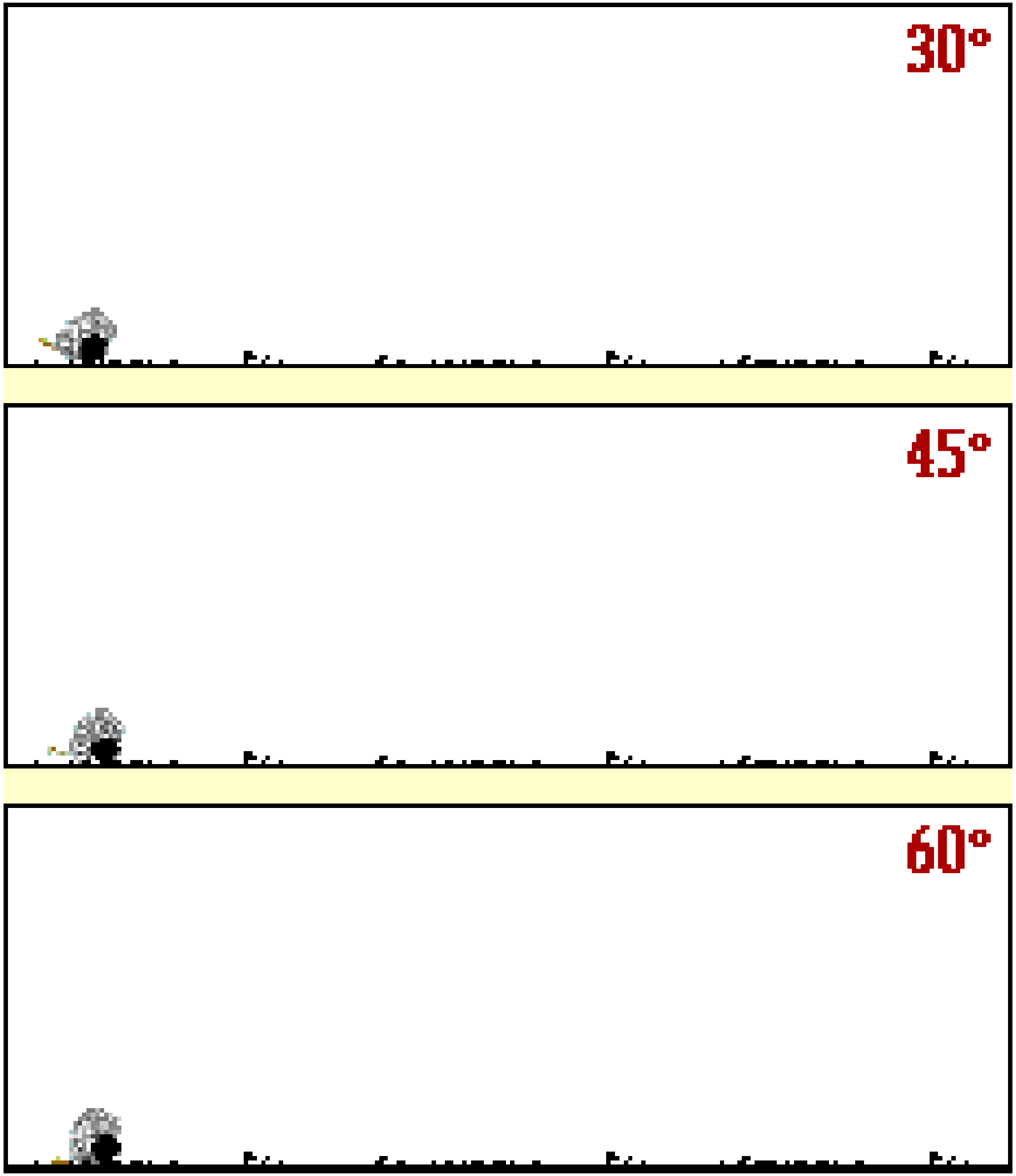
At what point in its path does a projectile have minimum speed?

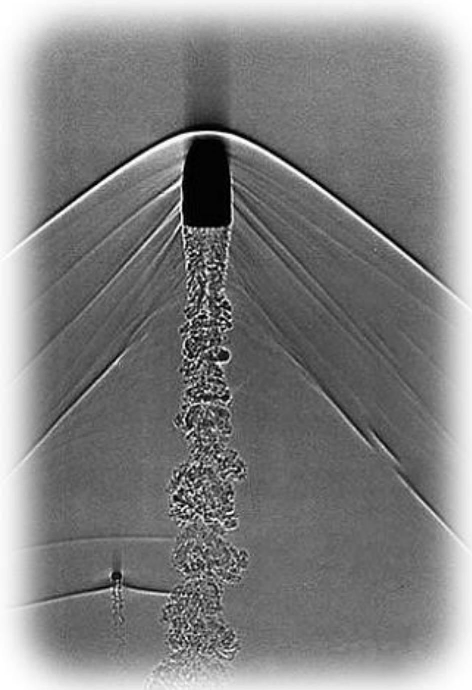
5.6 Projectiles Launched at an Angle

think!

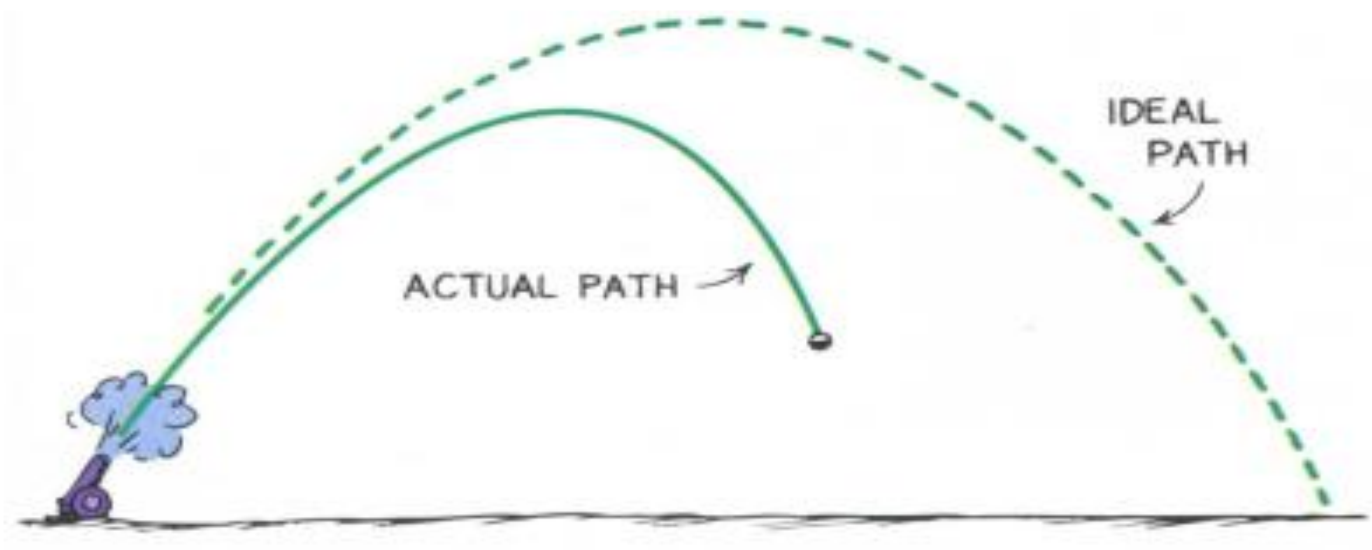
At what point in its path does a projectile have minimum speed?

Answer: The minimum speed of a projectile occurs at the top of its path. If it is launched vertically, its speed at the top is zero. If it is projected at an angle, the vertical component of velocity is still zero at the top, leaving only the horizontal component.


30°
45°
60°



D. Speed- If we take into account **air resistance**, range is diminished and path not true parabola.



14.1 Earth Satellites

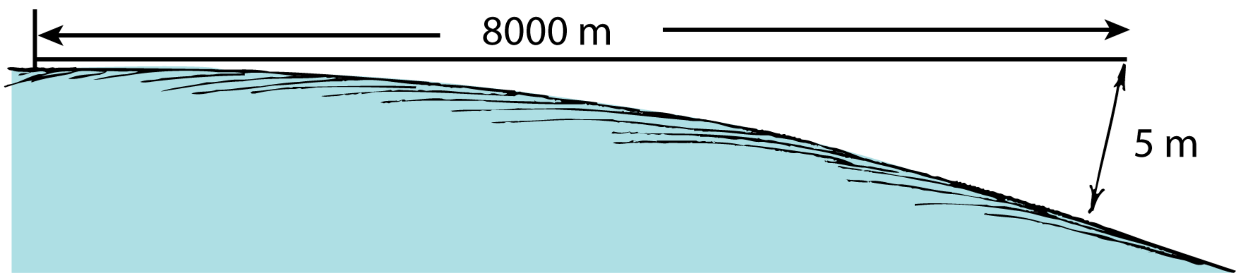
An Earth satellite is a projectile moving fast enough to fall continually *around* Earth rather than *into* it.

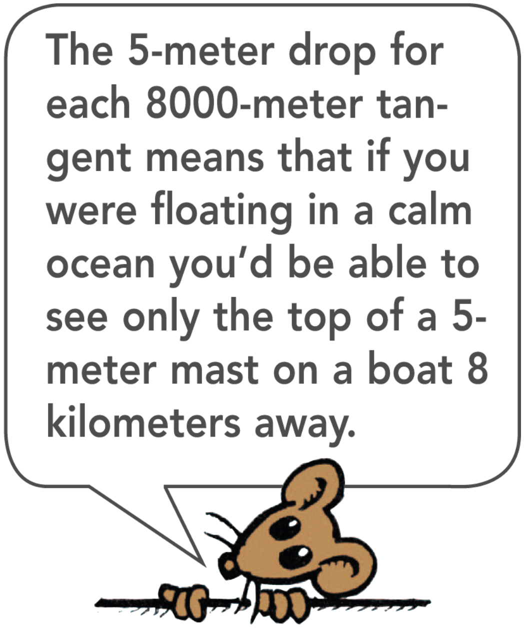
On an imaginary tiny planet, you would not have to throw the stone very fast to make its curved path match the surface curvature.

Because of the planet's small size and low mass, if you threw the stone just right, it would follow a circular orbit.

14.1 Earth Satellites

In the curvature of Earth, the surface drops a vertical distance of nearly 5 meters for every 8000 meters tangent to its surface.



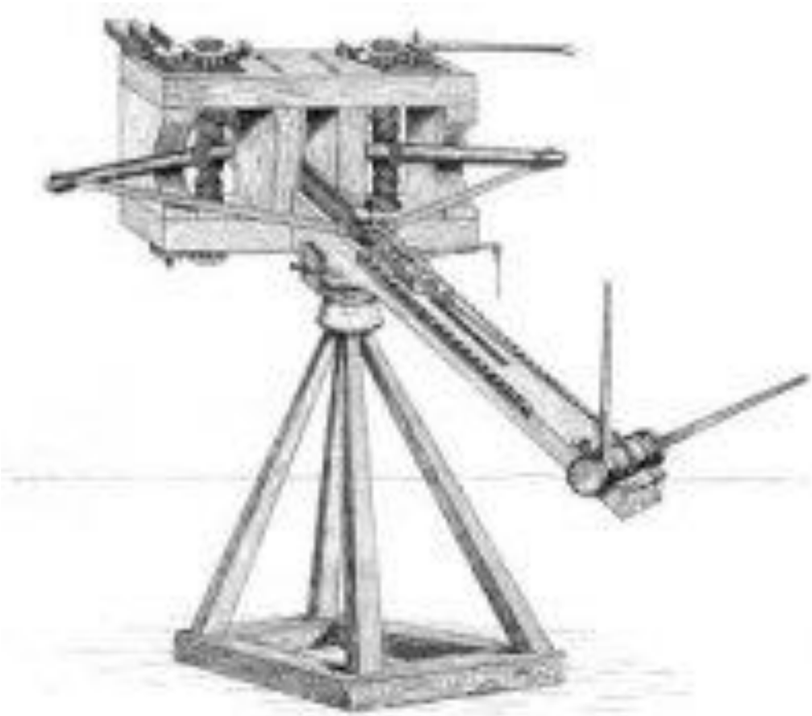


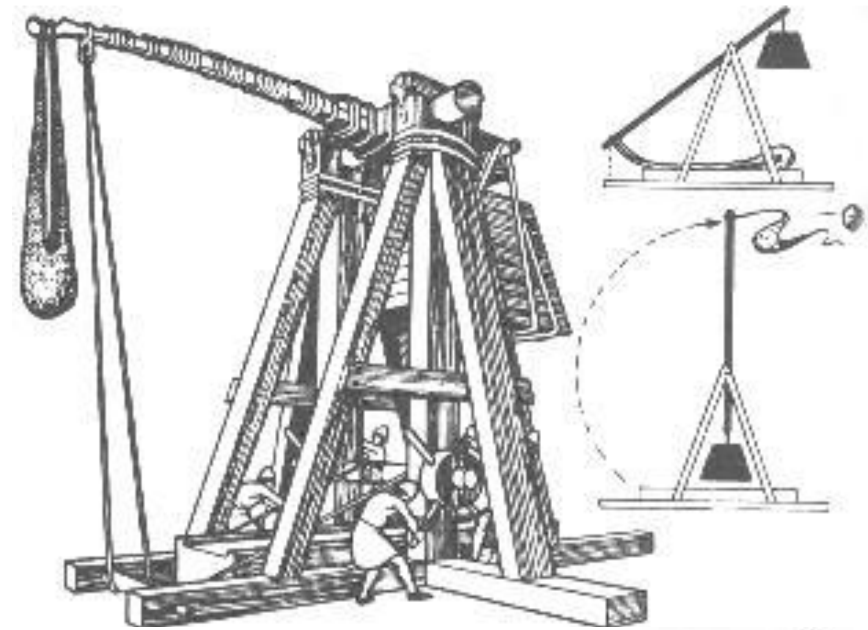
14.1 Earth Satellites

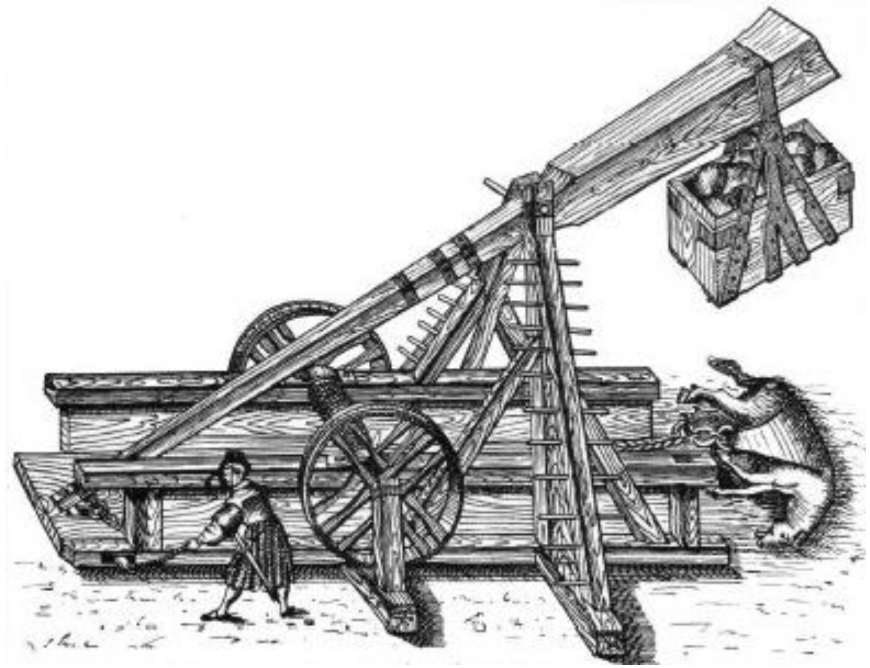
The orbital speed for close orbit about Earth is 8 km/s.

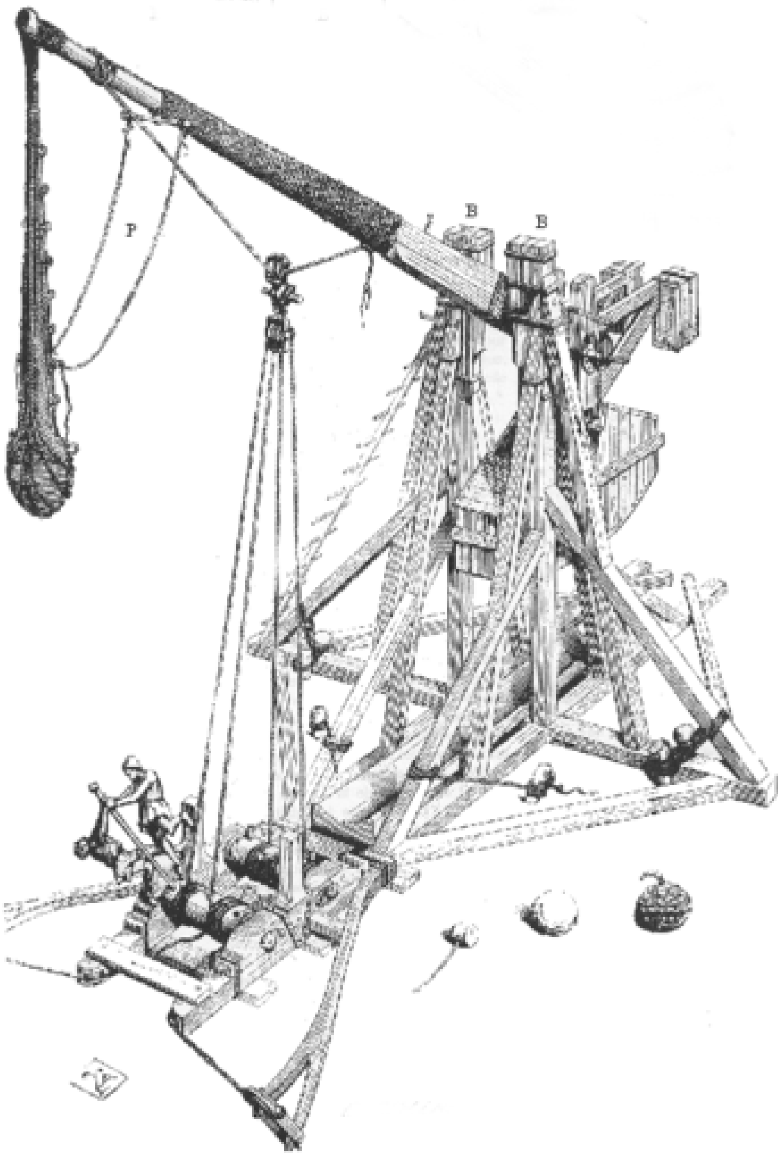
- **That is an impressive 29,000 km/h (or 18,000 mi/h).**
- **At that speed, atmospheric friction would burn an object to a crisp.**
- **A satellite must stay 150 kilometers or more above Earth's surface—to keep from burning due to the friction.**

Brief History of Projectiles





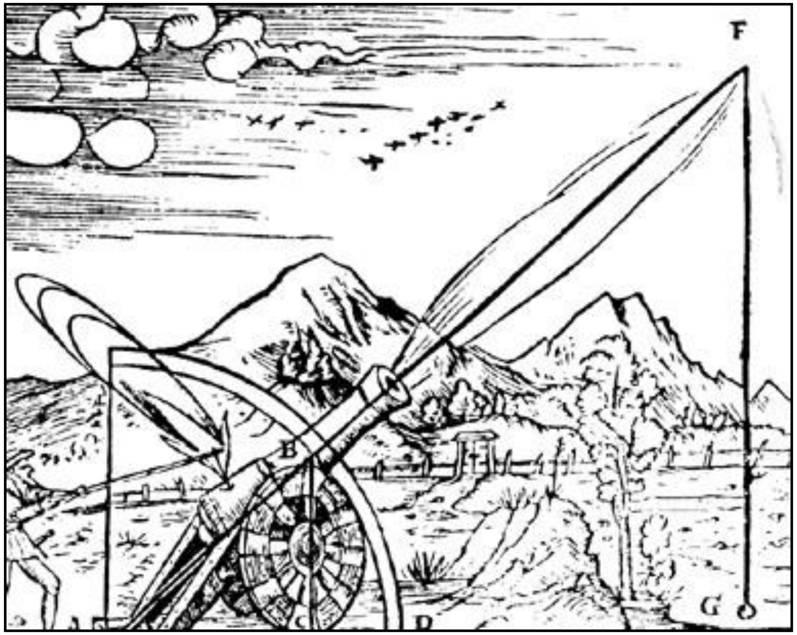




Trebuchets were formidably powerful weapons, with a range of up to about 300 yards. The range of most trebuchets was in fact shorter than that of an English longbow in skilled hands, making it somewhat dangerous to be a trebuchet operator during a siege.

The payload of a trebuchet was usually a large rounded stone, although other projectiles were occasionally used: dead animals, the severed heads of captured enemies, barrels of burning tar or oil, or even unsuccessful negotiators catapulted alive.

History of Projectiles



Aristotle's physical principles applied to projectile motion

Newton's physical principles applied to projectile motion- notice the ***parabolic*** path of projectile

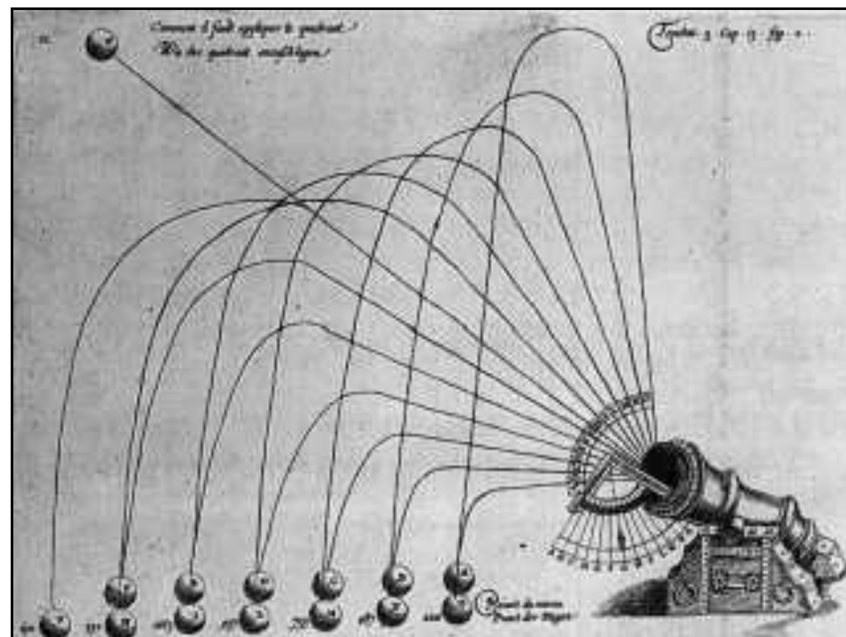
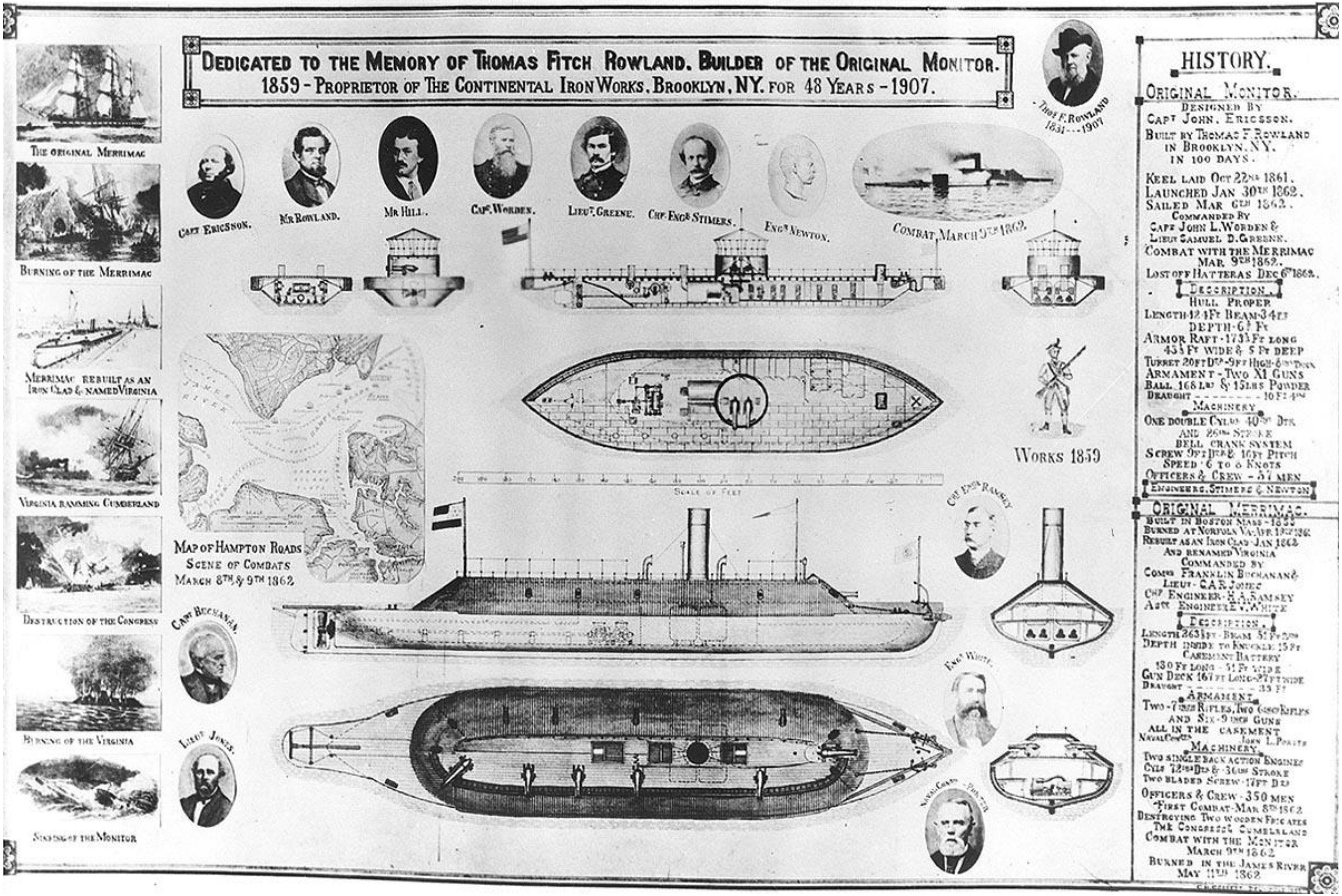
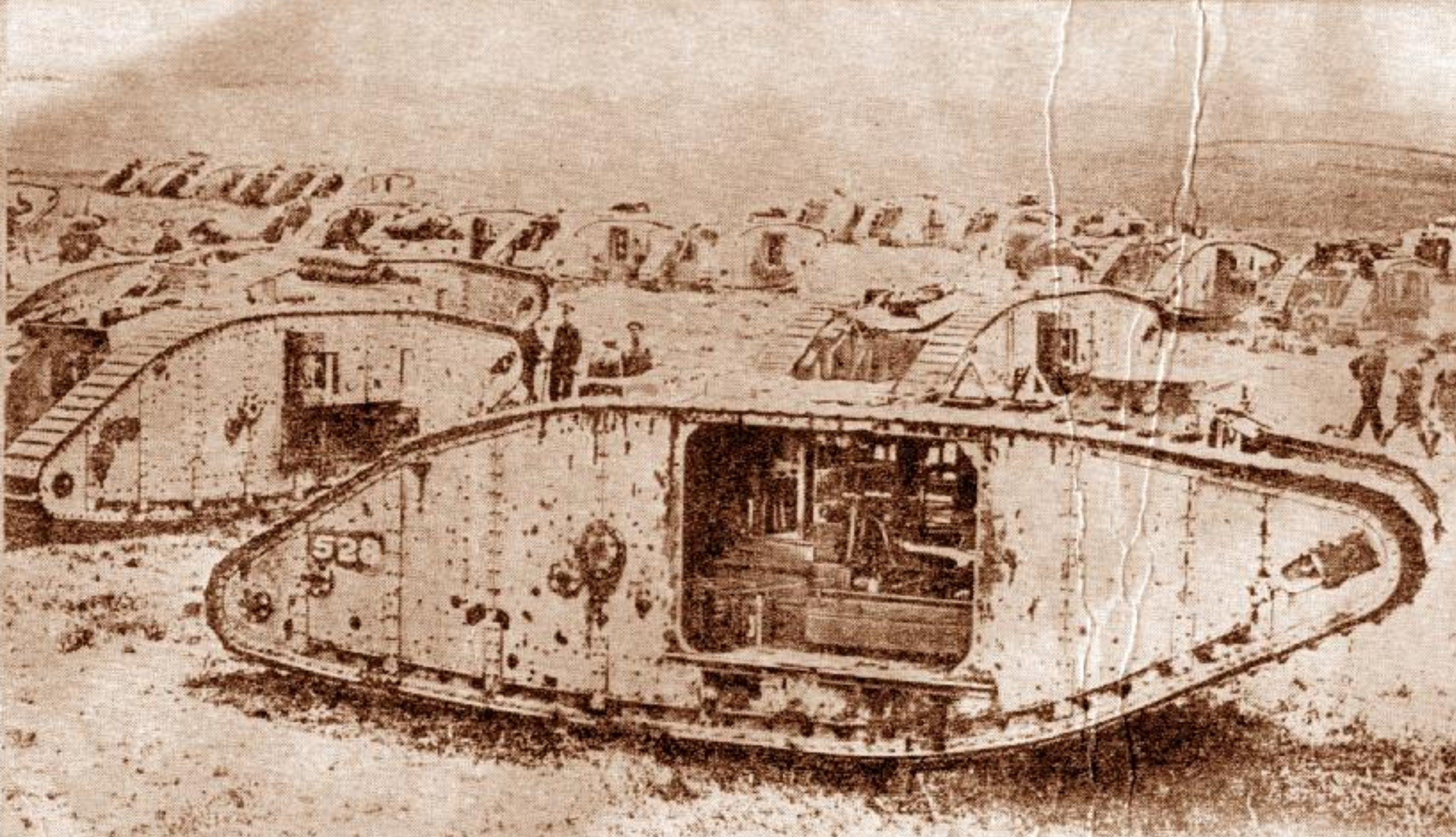


Photo # NH 45978 Montage drawing of USS Monitor and CSS Virginia, by Charles H. Corbett

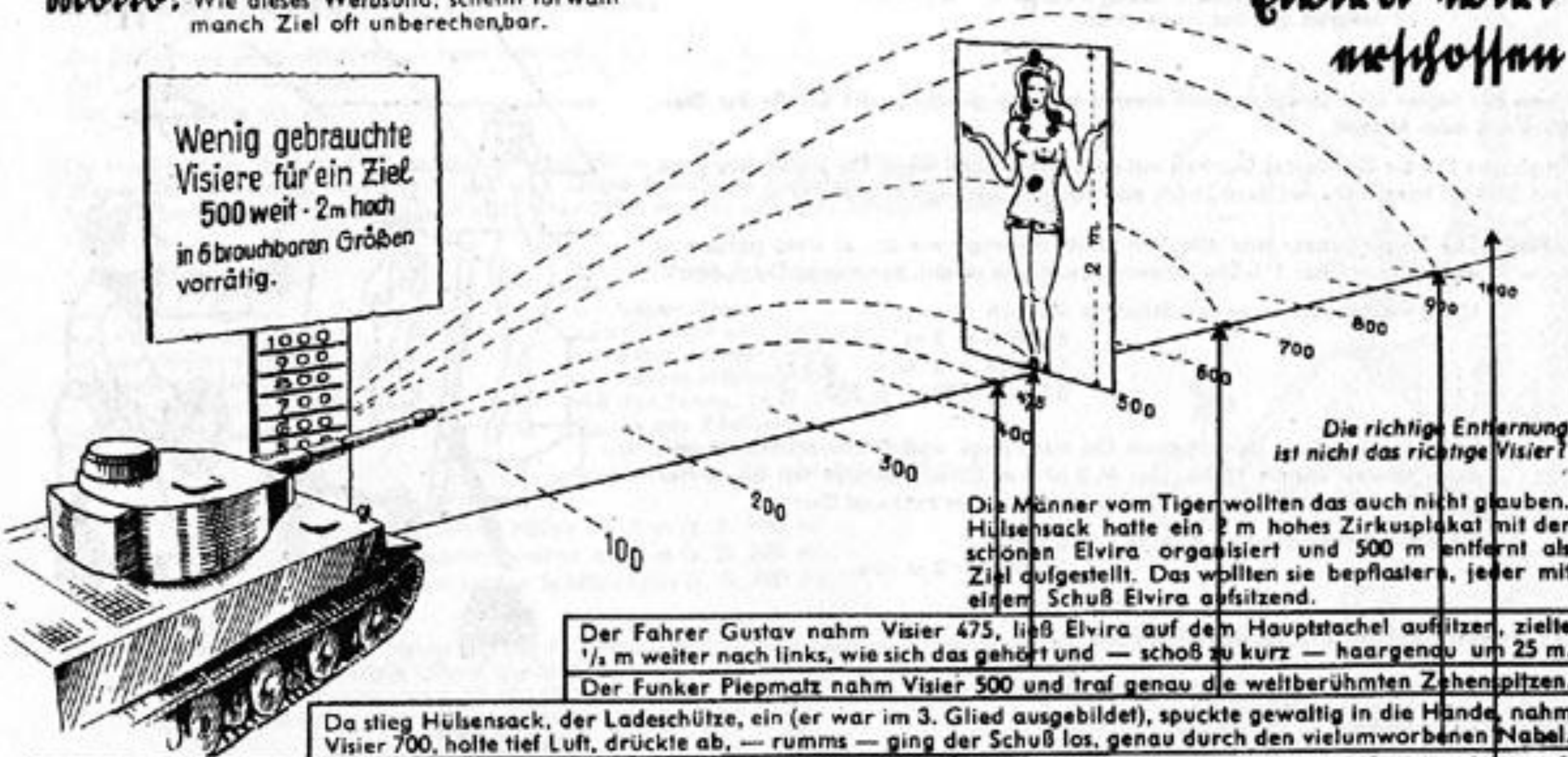




HUNS DON'T LIKE THESE TANKS NOW, AND IF YOU BUY MORE LIBERTY BONDS THEY WILL LIKE THEM LESS

Elvira wird erschossen

Motto: Wie dieses Weibsbild, scheint fürwahr
manch Ziel oft unberechenbar.



Die Männer vom Tiger wollten das auch nicht glauben. Hülsensack hatte ein 2 m hohes Zirkusplakat mit der schönen Elvira organisiert und 500 m entfernt als Ziel aufgestellt. Das wollten sie bepflastern, jeder mit einem Schuß Elvira aufsitzend.

Der Fahrer Gustav nahm Visier 475, ließ Elvira auf dem Hauptstachel aufsitzen, zielte ½ m weiter nach links, wie sich das gehört und — schoß zu kurz — haargenau um 25 m.

Der Funker Piepmatz nahm Visier 500 und traf genau die weltberühmten Zehenspitzen.

Da stieg Hülsensack, der Ladeschütze, ein (er war im 3. Glied ausgebildet), spuckte gewaltig in die Hände, nahm Visier 700, holte tief Luft, drückte ab, — rumms — ging der Schuß los, genau durch den vielumworbenen Nabel.

Der Richtschütze Holzauge schüttelte den Kopf, denn bei Visier 700 hätte der Schuß doch drübergehen müssen. Er ging jetzt aufs Ganze, nahm Visier 1000 und traf den Kopf.

Der Panzerführer Schnellmerker nahm Visier 1100 und schoß drüberweg. Mit diesem Visier war der Zauber also zu Ende.

Visier 25 m zu kurz, kein Treffer! Visier 500 m zu weit, Treffer! ! ! ! ! !

Da staunt der Laie, der Fachmann aber lächelt!

Moral: Die richt'ge Schätzung bringt gar oft
nicht auch den Treffer, den man hofft.

The maximum rang is 38,059 meters (24 miles) when fired with the normal propelling charge of 300 kg, with a muzzle velocity of 816 meter/second.

Gerry Bull never gave up his dream of gun-launching a satellite. In the mid-1980's he was contracted by the nation of Iraq to construct a satellite launching gun system. The Babylon Gun - a massive 1000 mm bore, 156 meter long, satellite launching gun - was seen as a threat by Iraq's neighbors (despite the fact that its sheer size would have made it ineffective as a weapon and easily disabled).

Assessment Questions

1. Which of these expresses a vector quantity?
   a. 10 kg
   b. 10 kg to the north
   c. 10 m/s
   d. 10 m/s to the north

Assessment Questions

1. Which of these expresses a vector quantity?
   a. 10 kg
   b. 10 kg to the north
   c. 10 m/s
   d. 10 m/s to the north

Answer: D

Assessment Questions

2. An ultra-light aircraft traveling north at 40 km/h in a 30-km/h crosswind (at right angles) has a groundspeed of

   a. 30 km/h.

   b. 40 km/h.

   c. 50 km/h.

   d. 60 km/h.

Assessment Questions

2. An ultra-light aircraft traveling north at 40 km/h in a 30-km/h crosswind (at right angles) has a groundspeed of

   a. 30 km/h.

   b. 40 km/h.

   c. 50 km/h.

   d. 60 km/h.

Answer: C

Assessment Questions

3. A ball launched into the air at 45° to the horizontal initially has
   a. equal horizontal and vertical components.
   b. components that do not change in flight.
   c. components that affect each other throughout flight.
   d. a greater component of velocity than the vertical component.

Assessment Questions

3. A ball launched into the air at 45° to the horizontal initially has
   a. equal horizontal and vertical components.
   b. components that do not change in flight.
   c. components that affect each other throughout flight.
   d. a greater component of velocity than the vertical component.

Answer: A

Assessment Questions

4. When no air resistance acts on a fast-moving baseball, its acceleration is
   a. downward, *g*.
   b. due to a combination of constant horizontal motion and accelerated downward motion.
   c. opposite to the force of gravity.
   d. at right angles.

Assessment Questions

4. When no air resistance acts on a fast-moving baseball, its acceleration is
   a. downward, *g*.
   b. due to a combination of constant horizontal motion and accelerated downward motion.
   c. opposite to the force of gravity.
   d. at right angles.

Answer: A

Assessment Questions

5. When no air resistance acts on a projectile, its horizontal acceleration is
   a. *g*.
   b. at right angles to *g*.
   c. upward, *g*.
   d. zero.

Assessment Questions

5. When no air resistance acts on a projectile, its horizontal acceleration is
   a. *g*.
   b. at right angles to *g*.
   c. upward, *g*.
   d. zero.

Answer: D

Assessment Questions

6. Without air resistance, the time for a vertically tossed ball to return to where it was thrown is
   a. 10 m/s for every second in the air.
   b. the same as the time going upward.
   c. less than the time going upward.
   d. more than the time going upward.

Assessment Questions

6. Without air resistance, the time for a vertically tossed ball to return to where it was thrown is
   a. 10 m/s for every second in the air.
   b. the same as the time going upward.
   c. less than the time going upward.
   d. more than the time going upward.

Answer: B