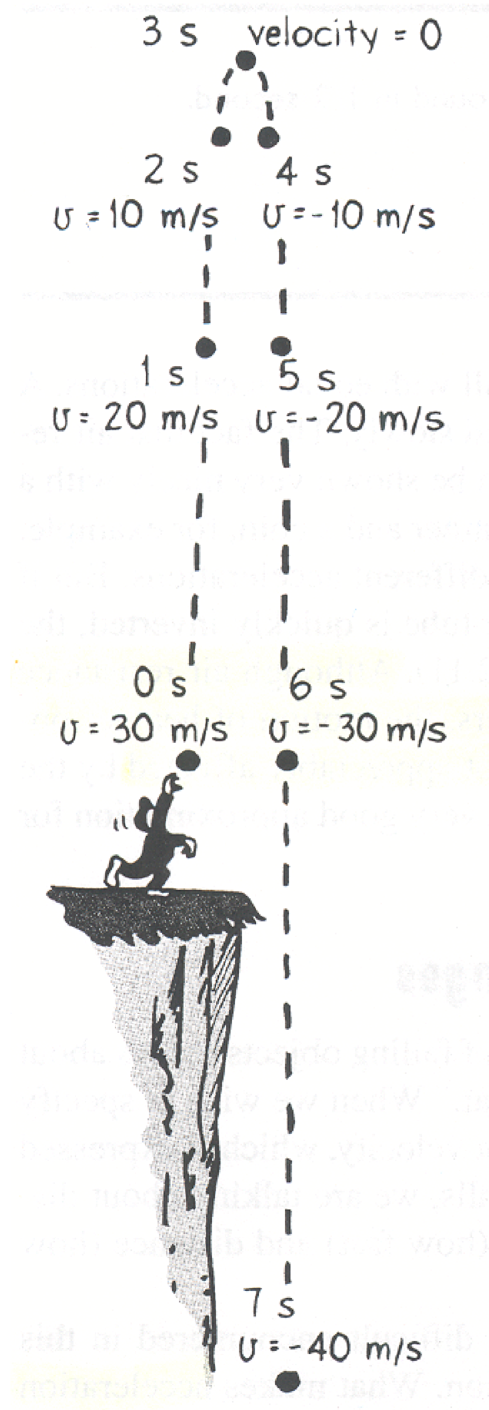
Gravity and Projectiles

Acceleration of Gravity

- Loses speed for each interval of time it rises on an upward throw
- Gains at same rate on its downward path

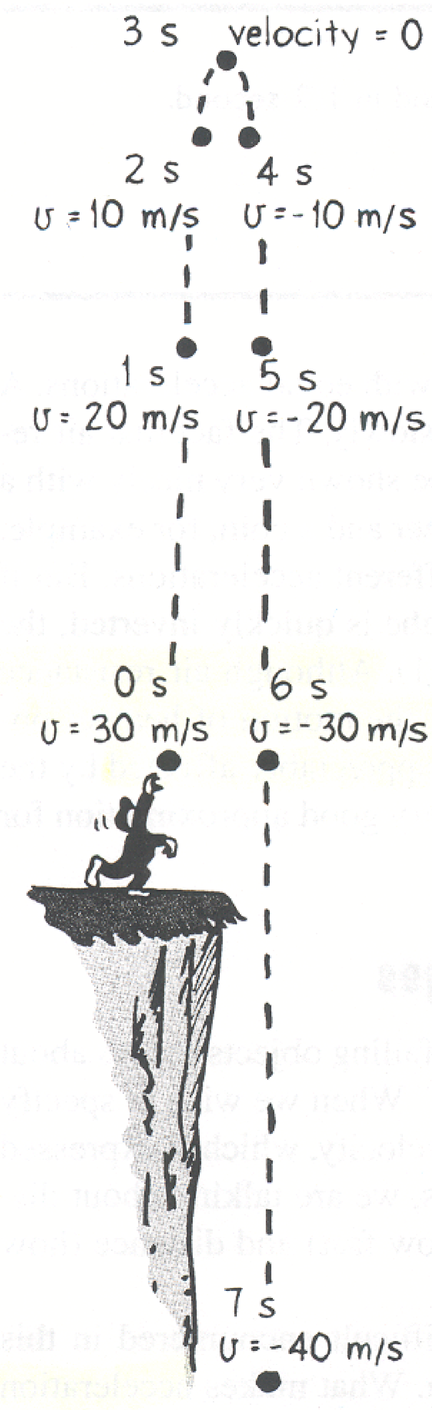


Upward motion

- Acted upon by gravity, just like a falling object
- Goes up slower and slower, until upward velocity reaches zero
- Goes shorter and shorter distances in same time interval
- Slows at 10 m/s^2, the acceleration of gravity

Distance, velocity, time of upward-moving object

- Velocity at position on the way up is the same as velocity in the same position on the way down (neglecting air resistance)
- Velocity reaches zero, object begins to fall
- Then is falling under the influence of gravity



Types of Motion

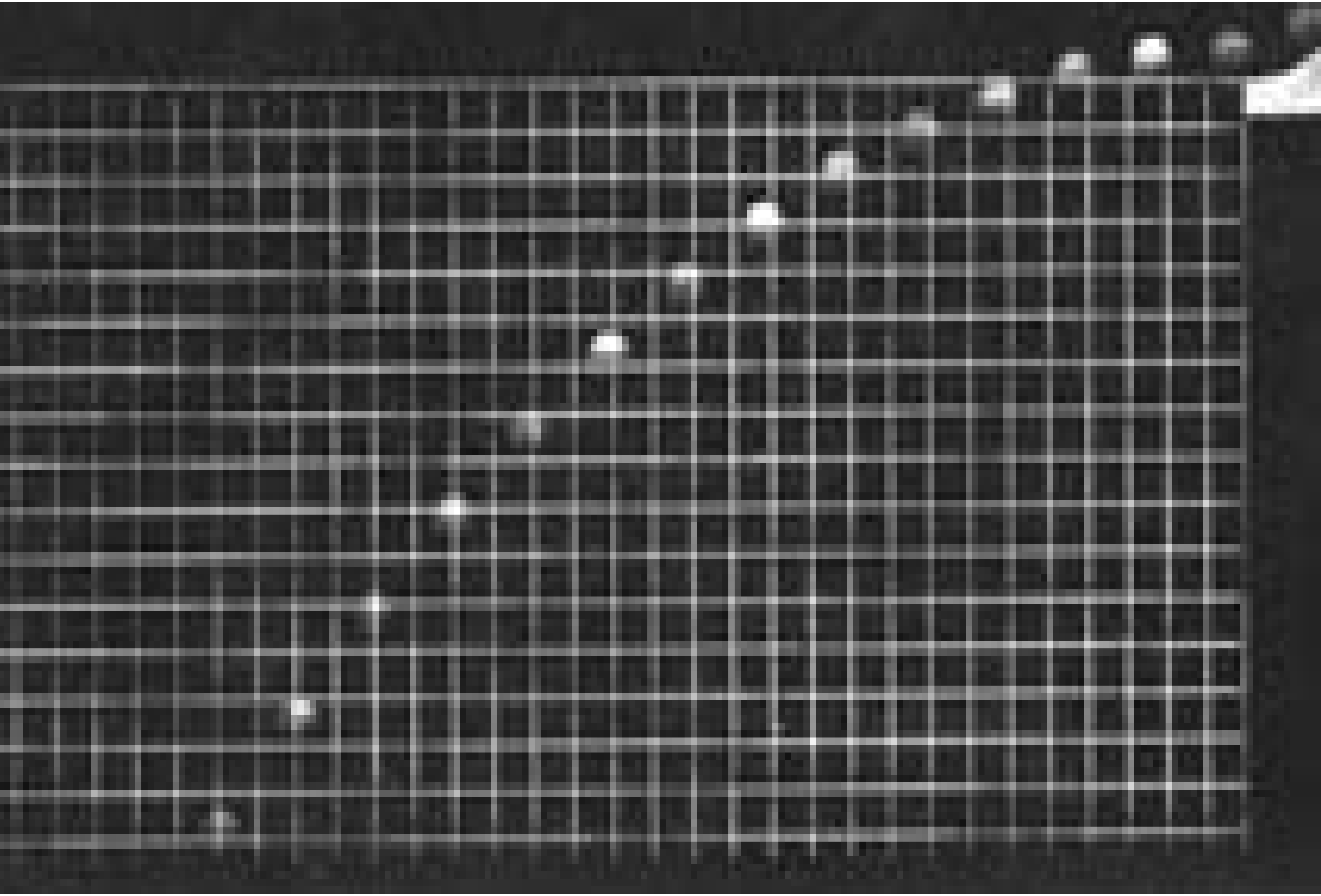
- Linear—in a straight line
- Non-linear—curved path
- Projectiles have curved path called “parabola”
- Parabolic curves are parabolas

Projectiles

- Move both horizontally and vertically
- Vertical motion influenced by gravity
- Horizontal motion not influenced by gravity
- Are NOT dependent upon one another

Roll the Ball

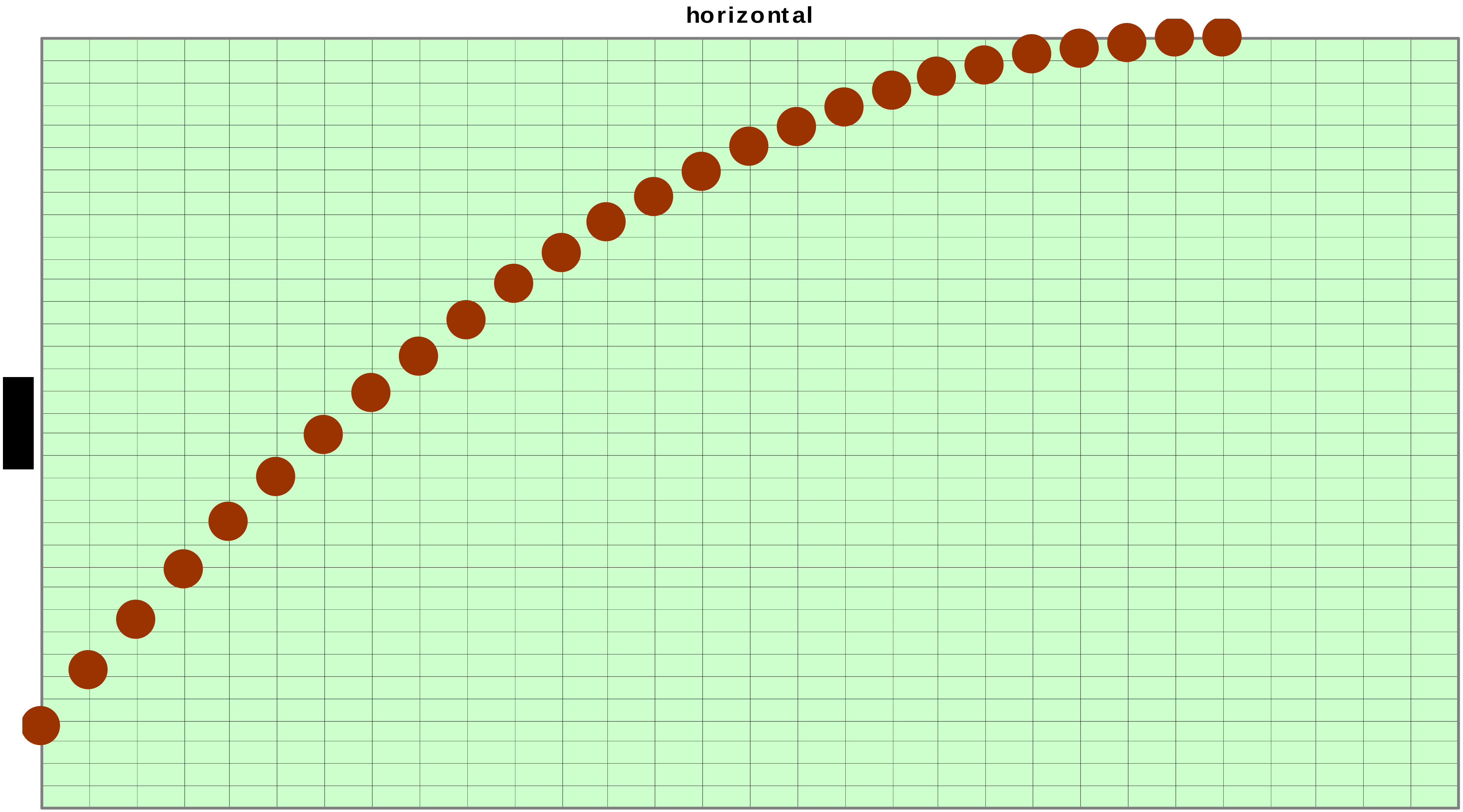
- Freely falling object
  – Has acceleration downward
- Pushed away from table
  – Has velocity outward
- Combines to have a parabolic path



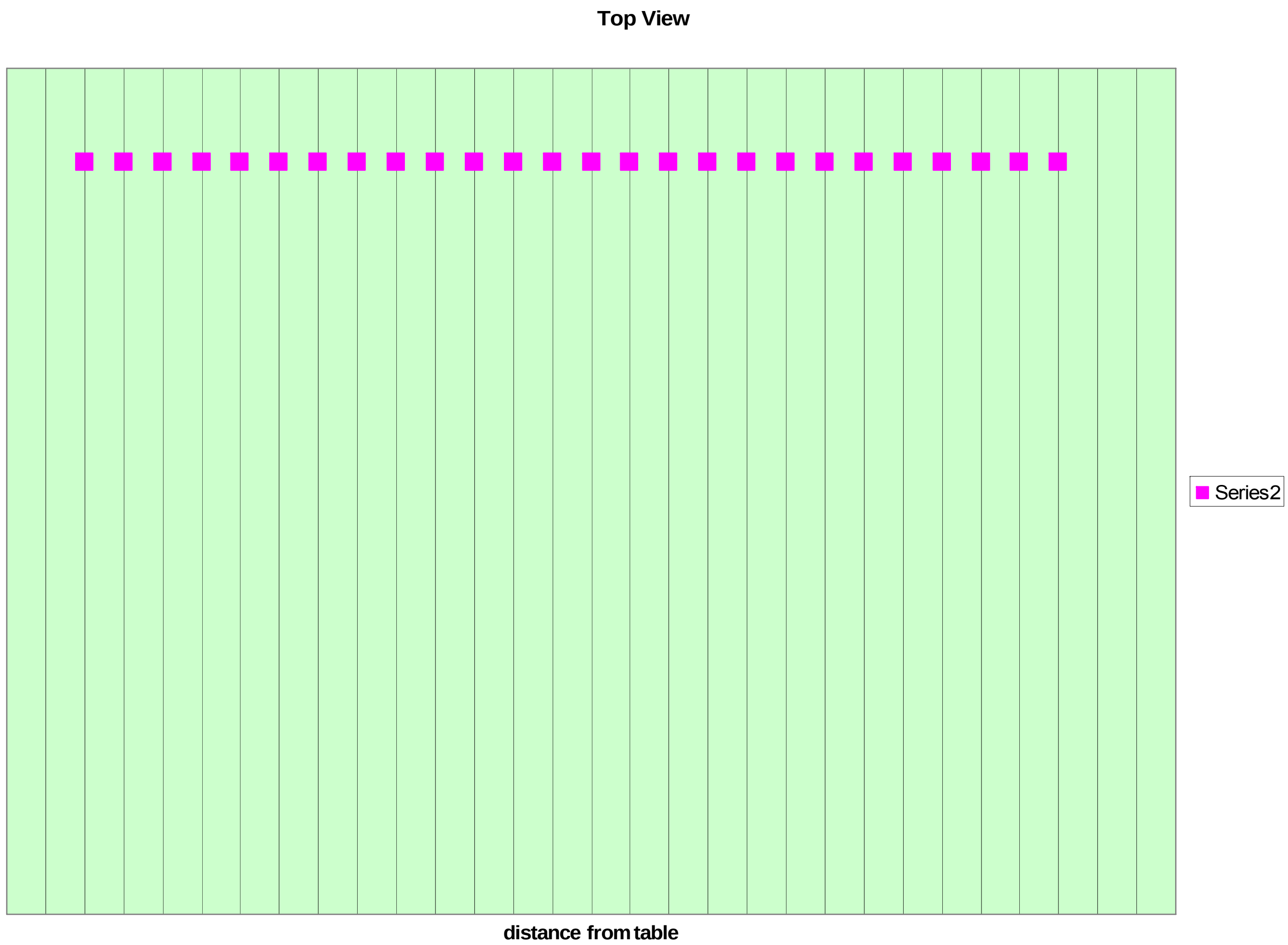
http://galileo.rice.edu/lib/student_work/experiment95/paraintr.html

Path of Ball from Side

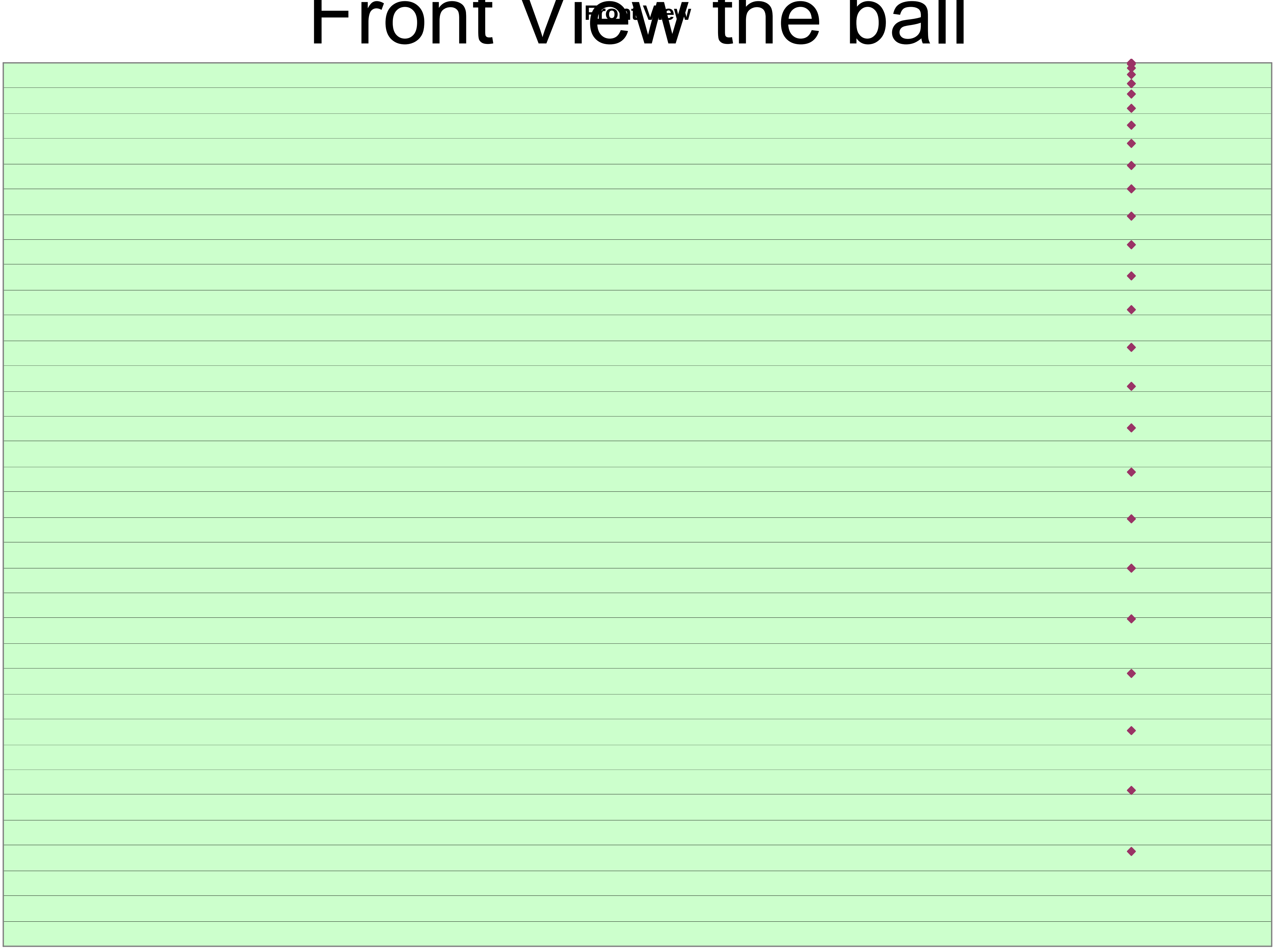
Ball Rolling off table



Top View of the ball



Front View the ball



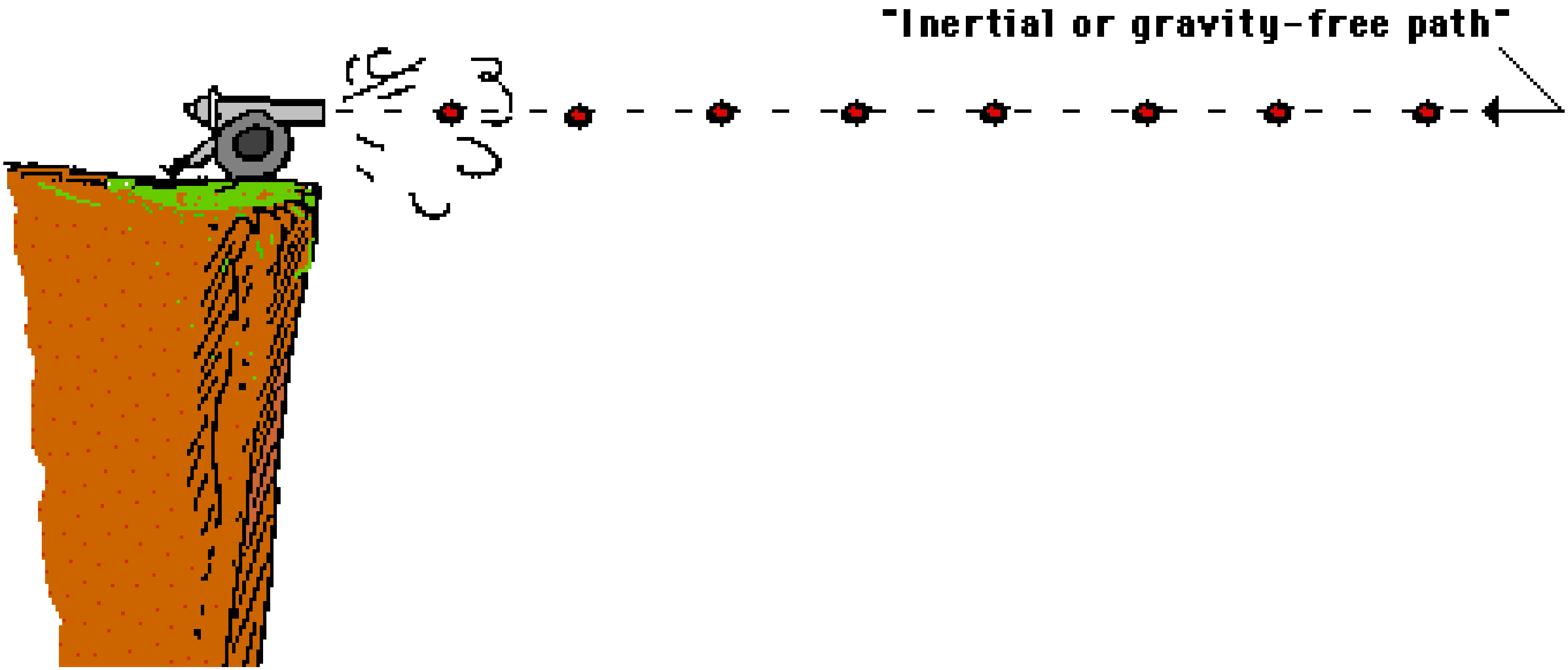
Projectile motion

- Each component acts separately
- Same horizontal distance in each time increment
- Vertical distance increases for each time increment that passes

What if??

- What if you dropped a cannon ball off the cliff at exactly the instant a cannon was fired in the horizontal direction?
- Which cannon ball would hit the ground first?

Cannonball without gravity



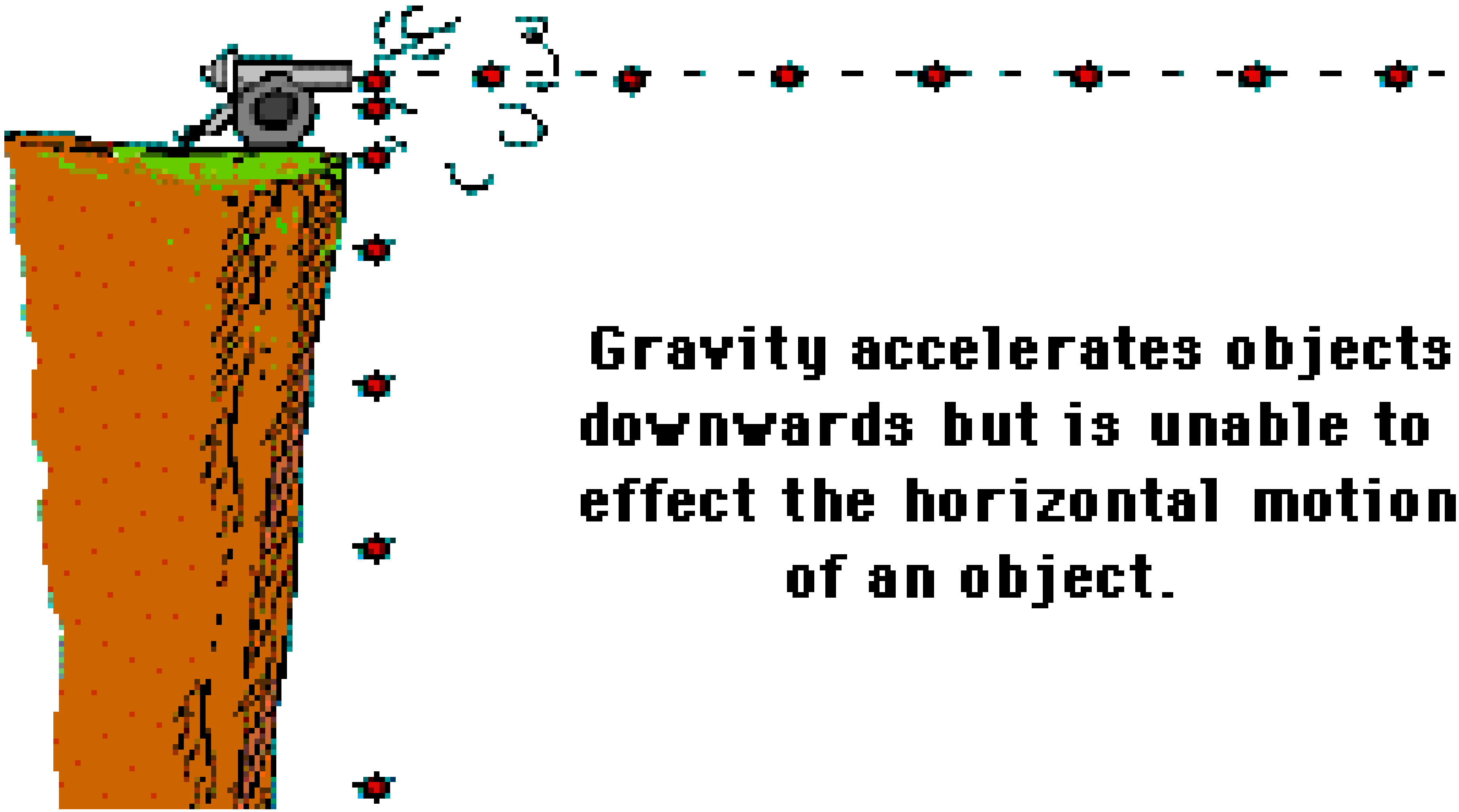
Without gravity, an object in motion will continue in motion with the same speed and in the same direction.

http://www.physicsclassroom.com/Class/vectors/U3L2a.html

There is gravity

- This is the outside force acting on the object to change its course

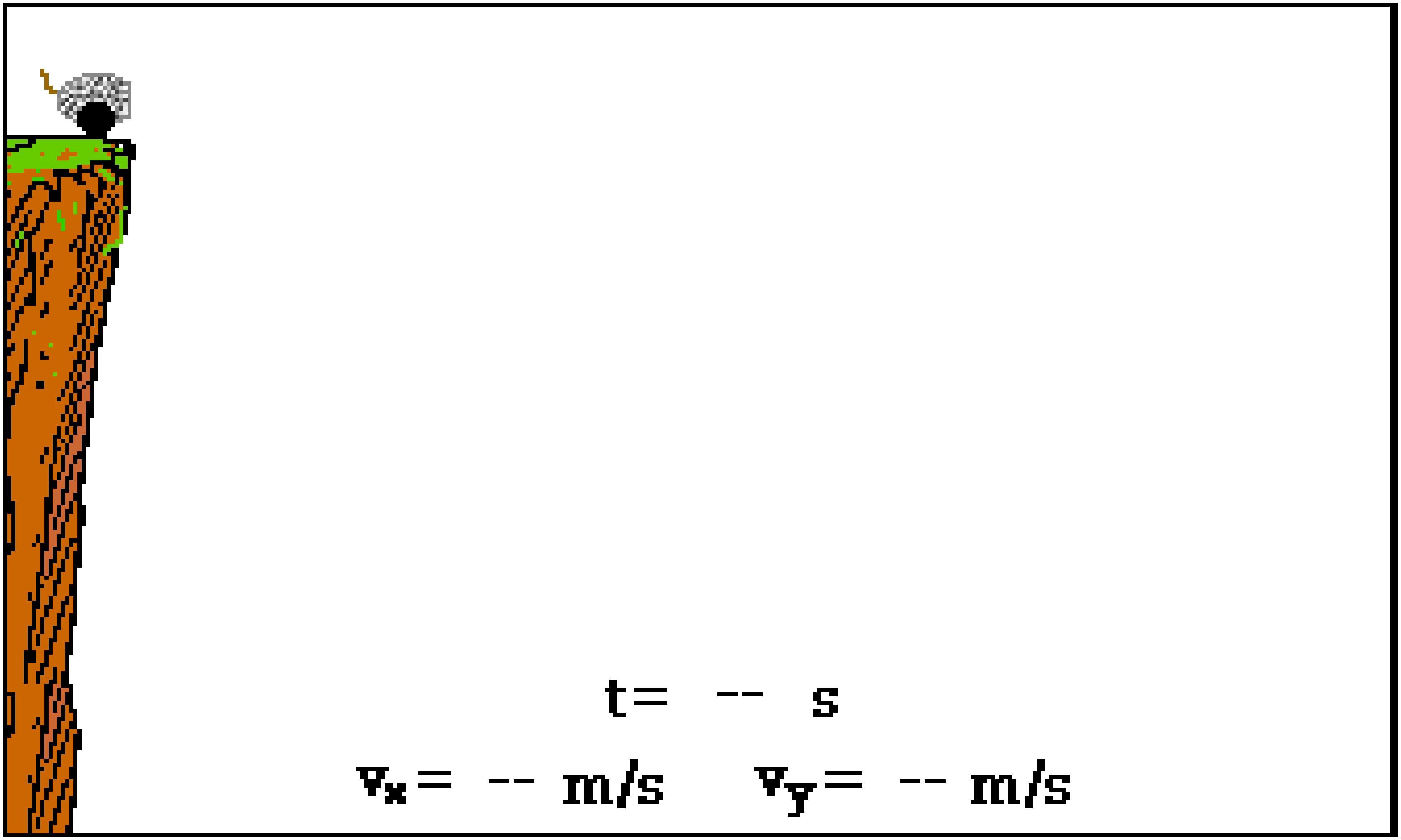
Components of cannonball motion



Gravity accelerates objects downwards but is unable to effect the horizontal motion of an object.

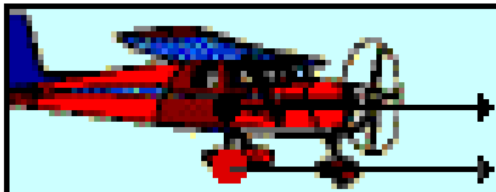
http://www.physicsclassroom.com/Class/vectors/u3l2b.html

Cannonball with gravity



http://www.physicsclassroom.com/mmedia/vectors/hlp.gif

Airplane and Package



- Flying straight and level at 45 m above ground level, at a speed of 40 m/s
- Drops package, which falls to the ground
- Where will package land? (neglect air resistance)

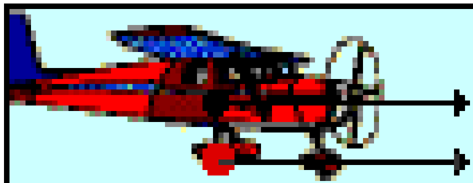
http://www.physicsclassroom.com/mmedia/vectors/pap.gif

Airplane and Package

- Flying straight and level at 45 m above ground level, at a speed of 40 m/s
- Drops package, which falls to the ground
- Where will package land? (neglect air resistance)

a) Straight down from where it was dropped
b) Underneath plane
c) 80 m behind plane
d) More than 120 m behind plane

Airplane and Package



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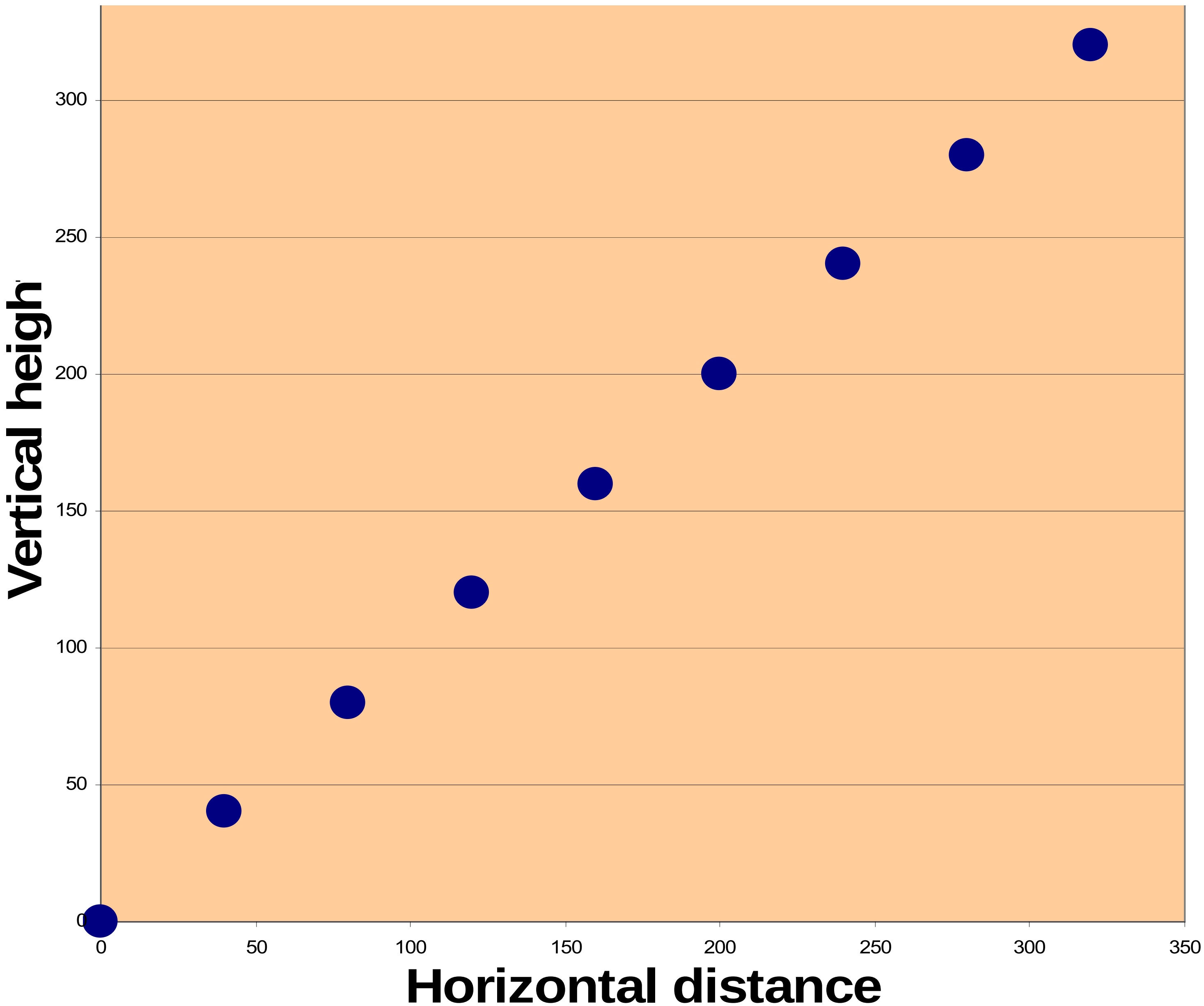
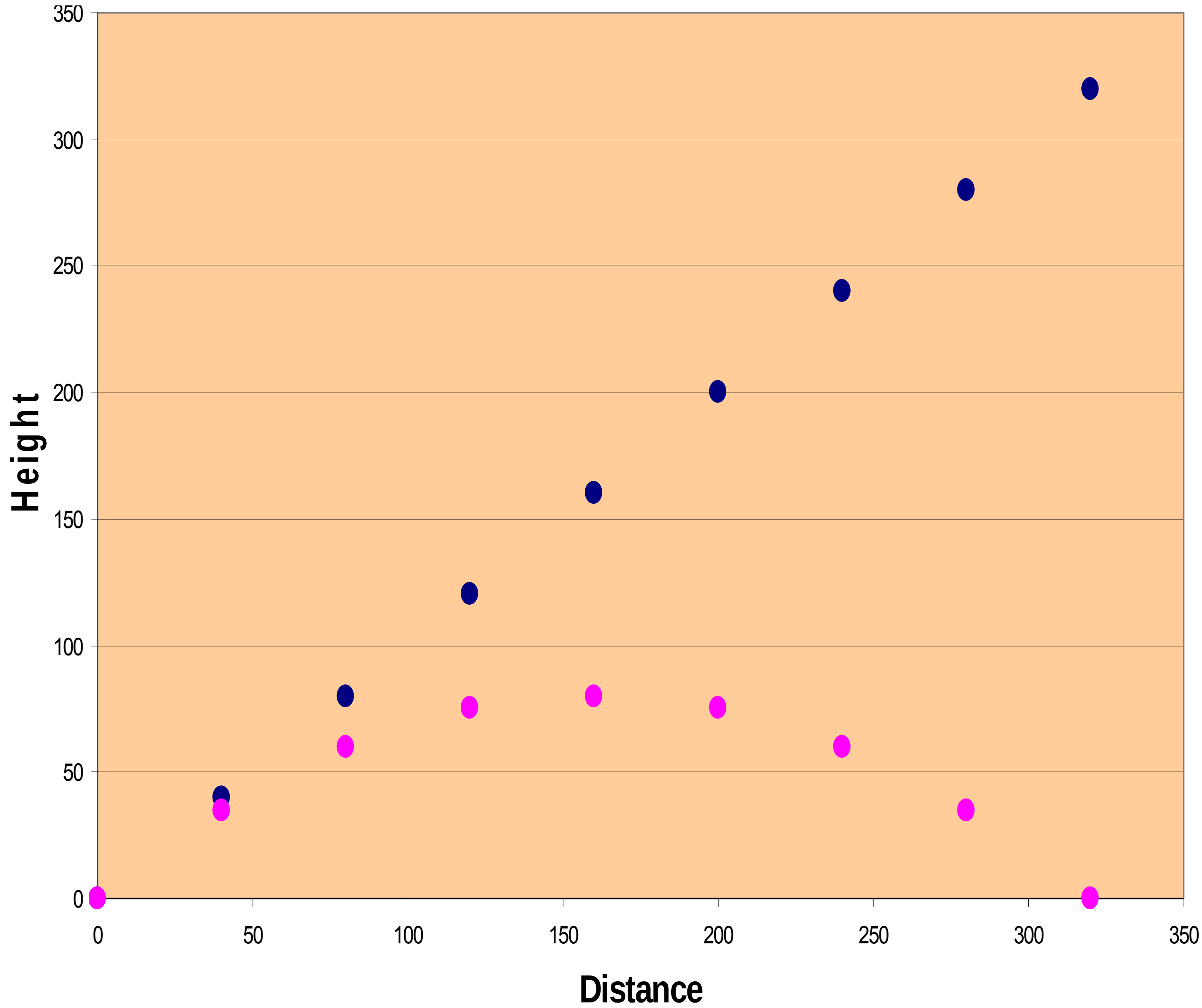
Cannonball without gravity



Cannonball with gravity



Banana without gravity

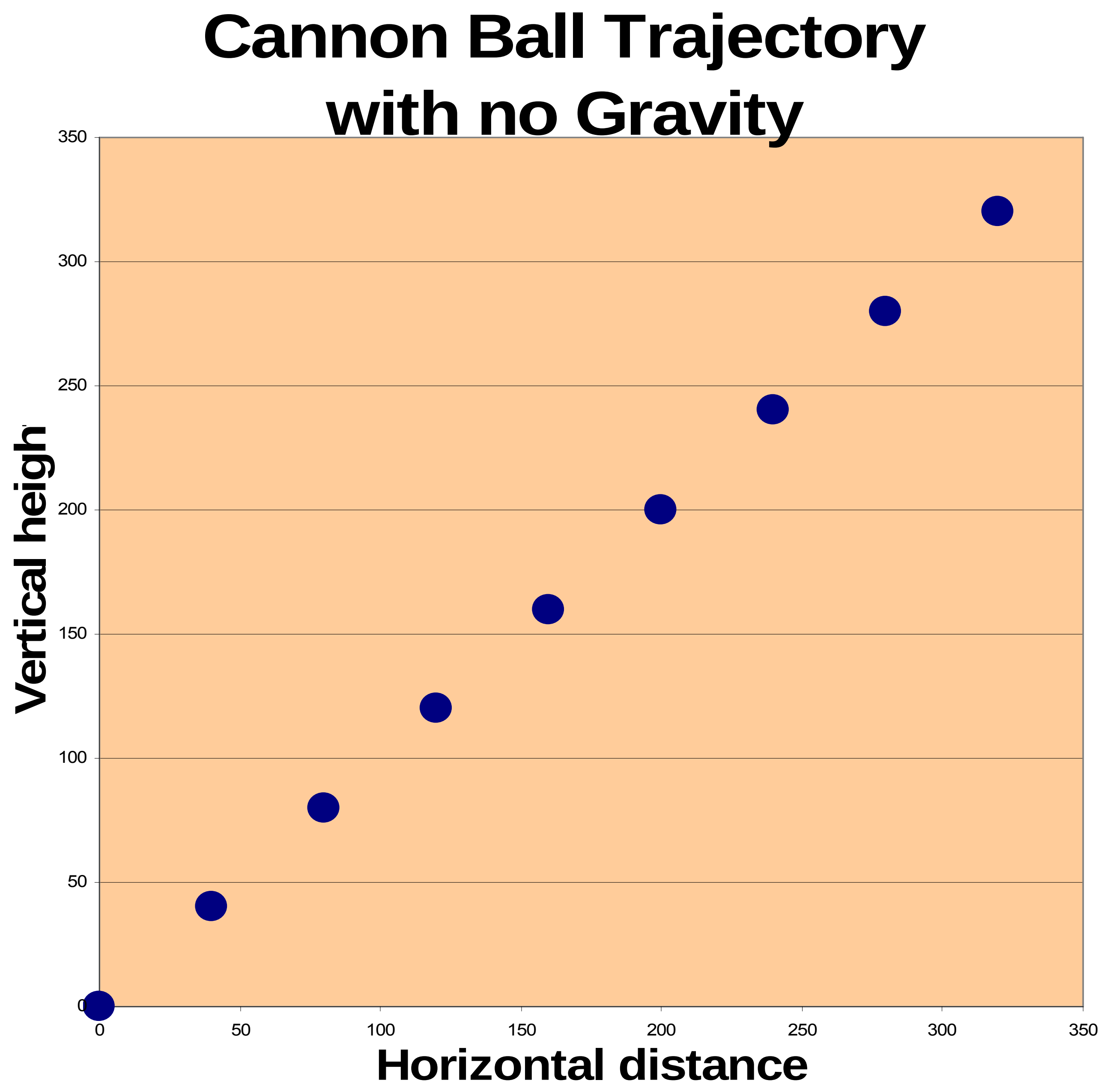
http://www.physicsclassroom.com/mmedia/vectors/mzng.gif

Banana with gravity

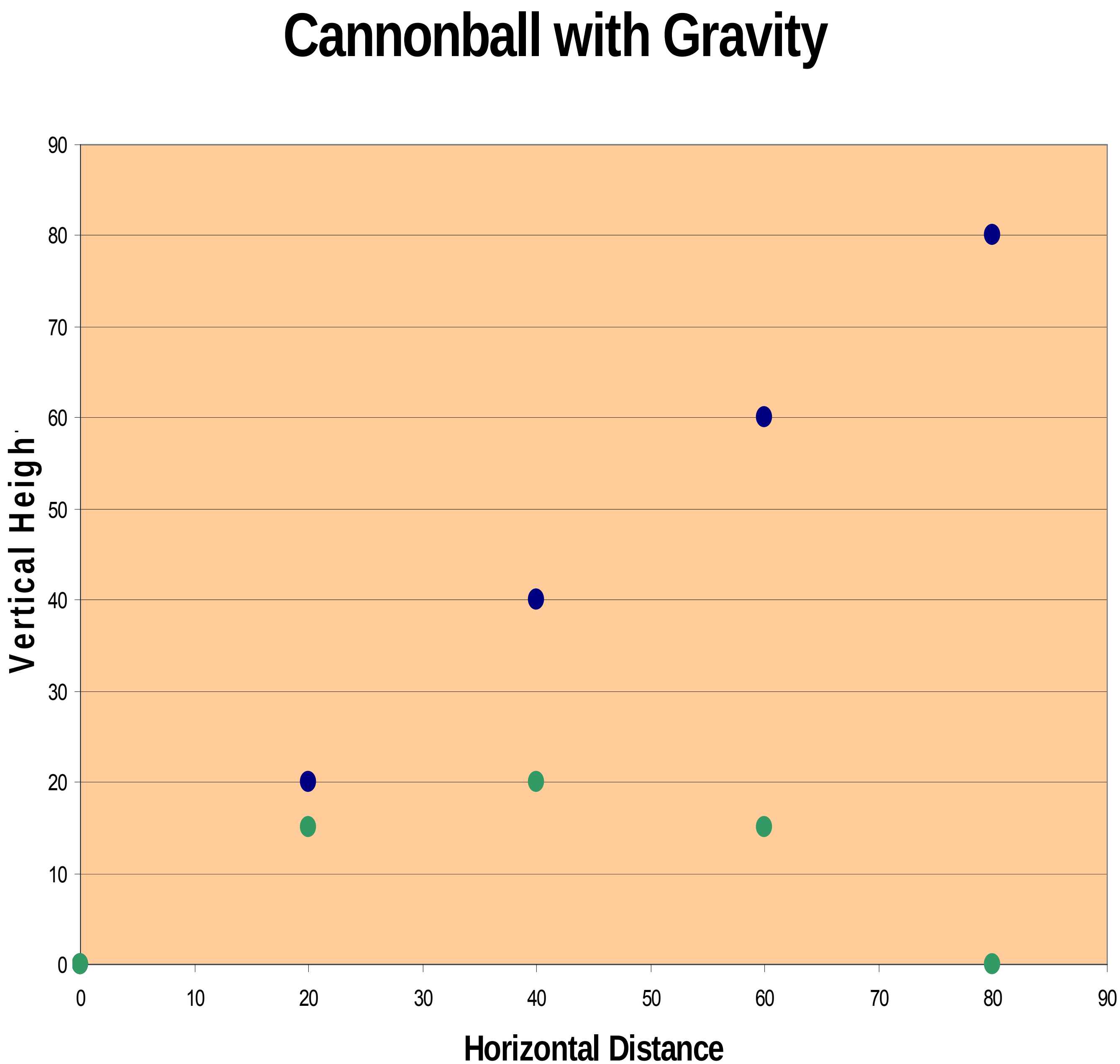
http://www.physicsclassroom.com/mmedia/vectors/mzg.gif

Slower banana

http://www.physicsclassroom.com/mmedia/vectors/mzs.html

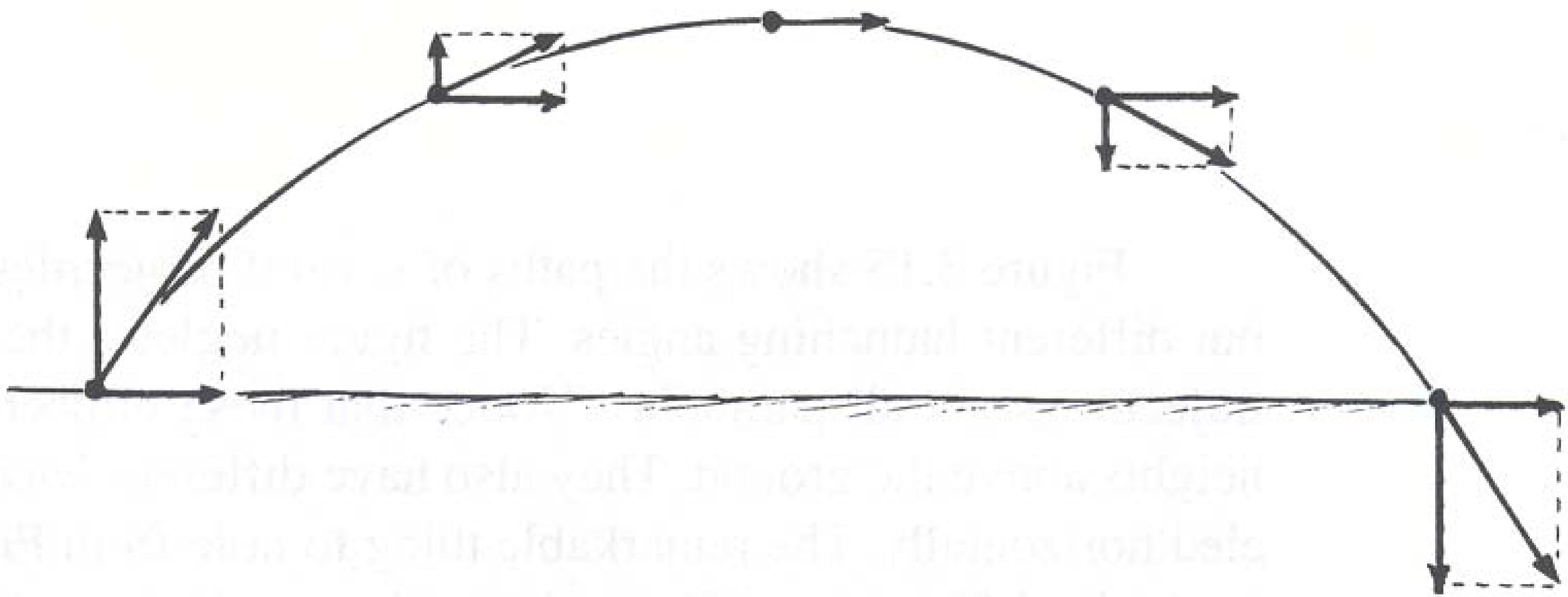


Cannon Ball Trajectory
with no Gravity
Vertical heigh
Horizontal distance
0
50
100
150
200
250
300
350

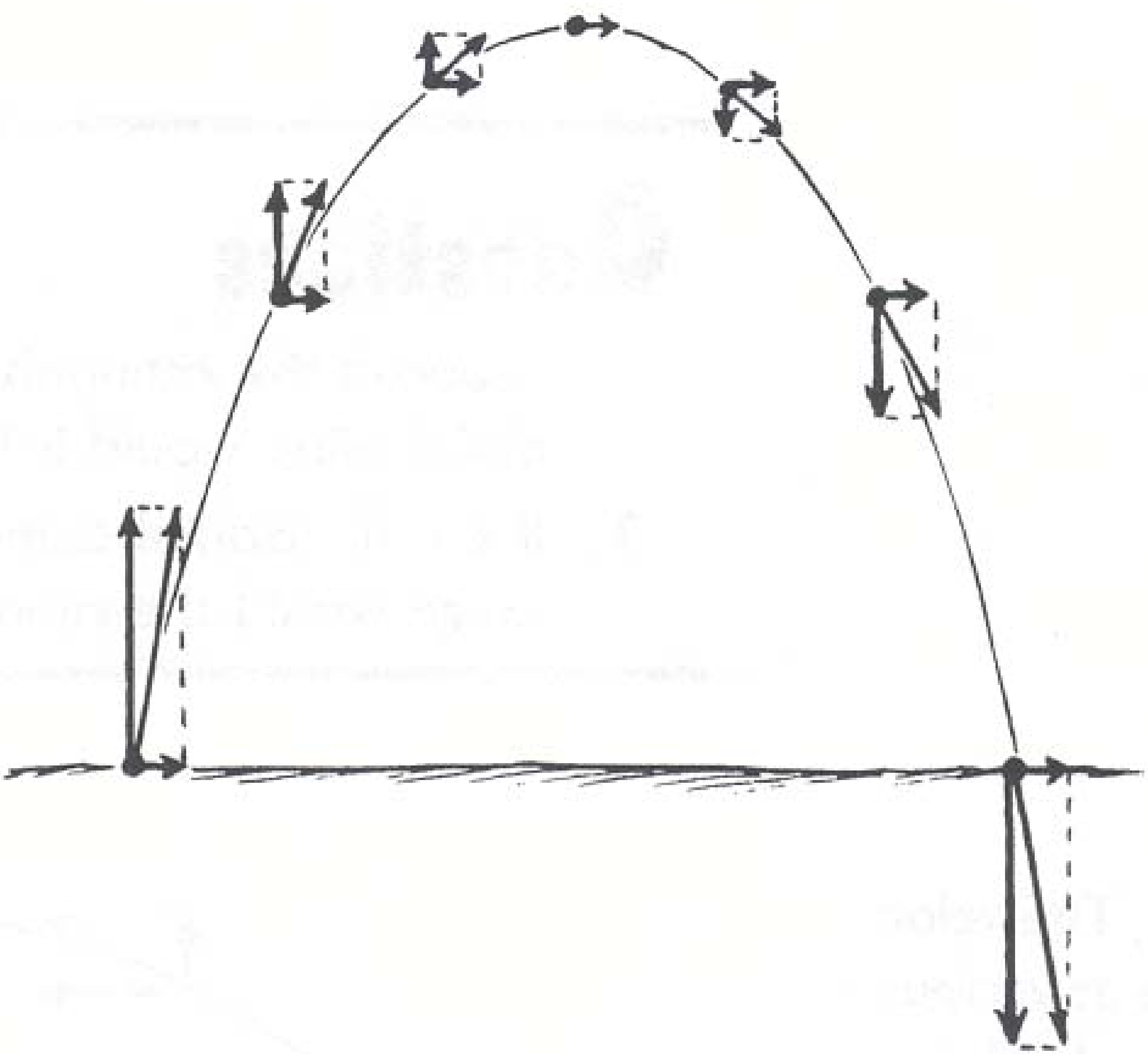


Cannonball with gravity

Vectors of projectile motion

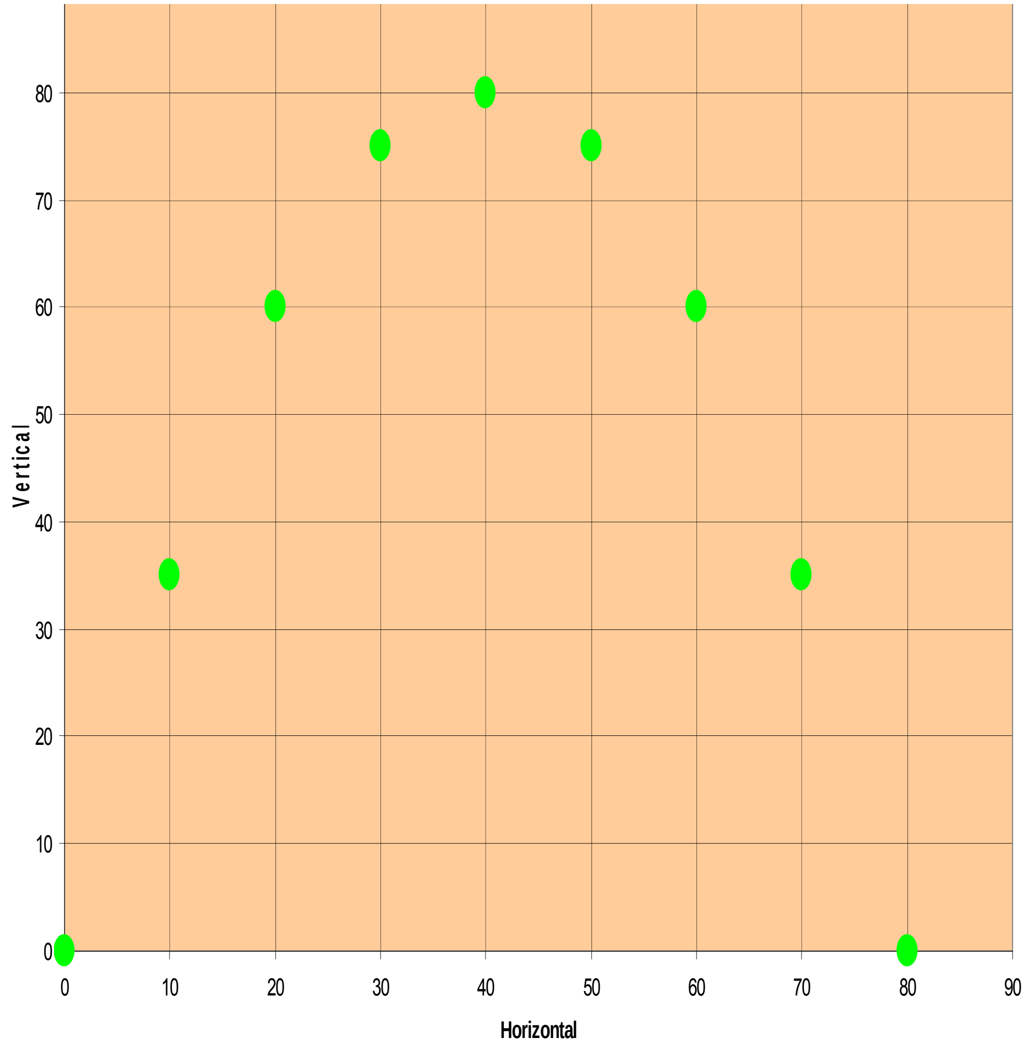


Steeper trajectory

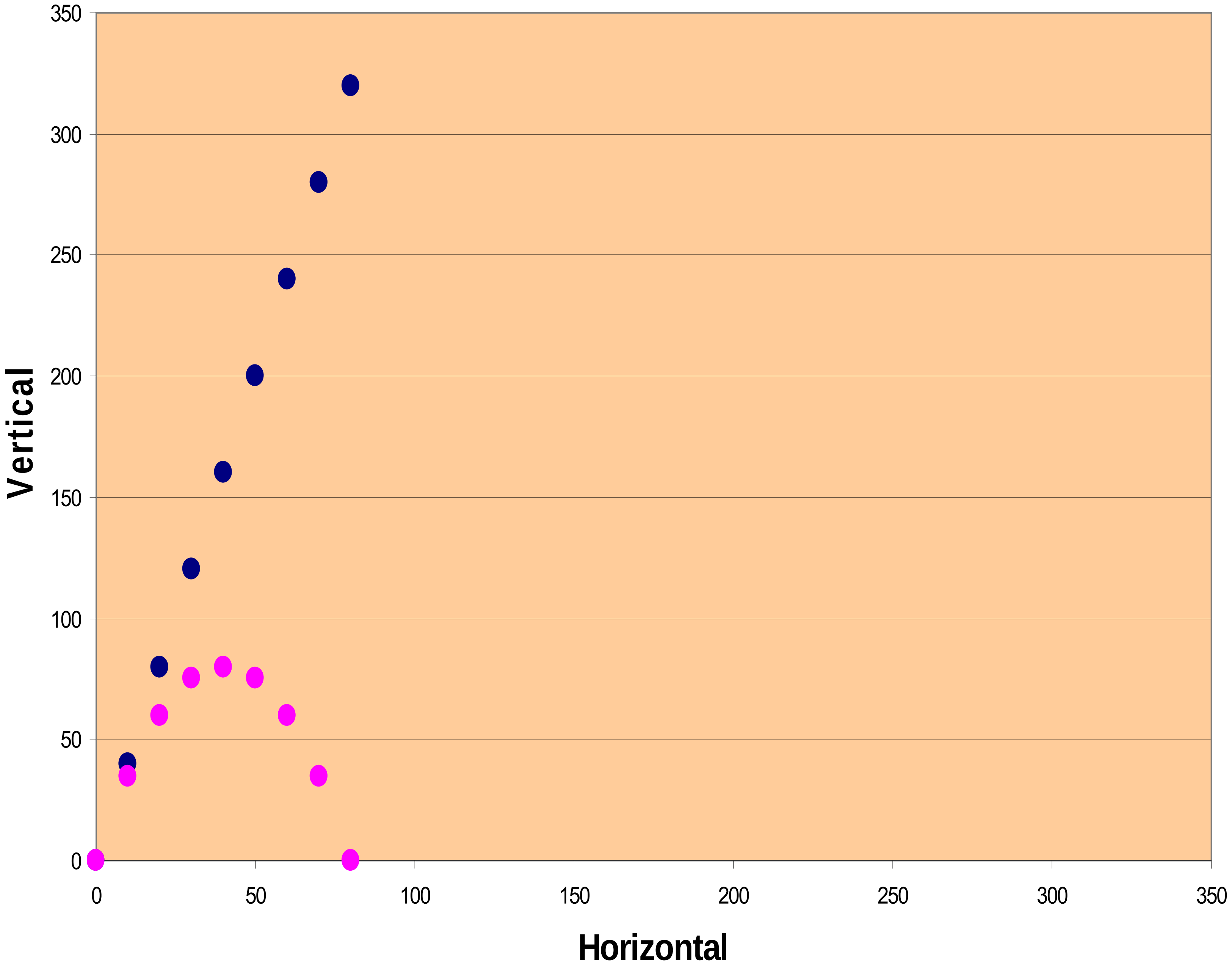


Acceleration of Cannonball

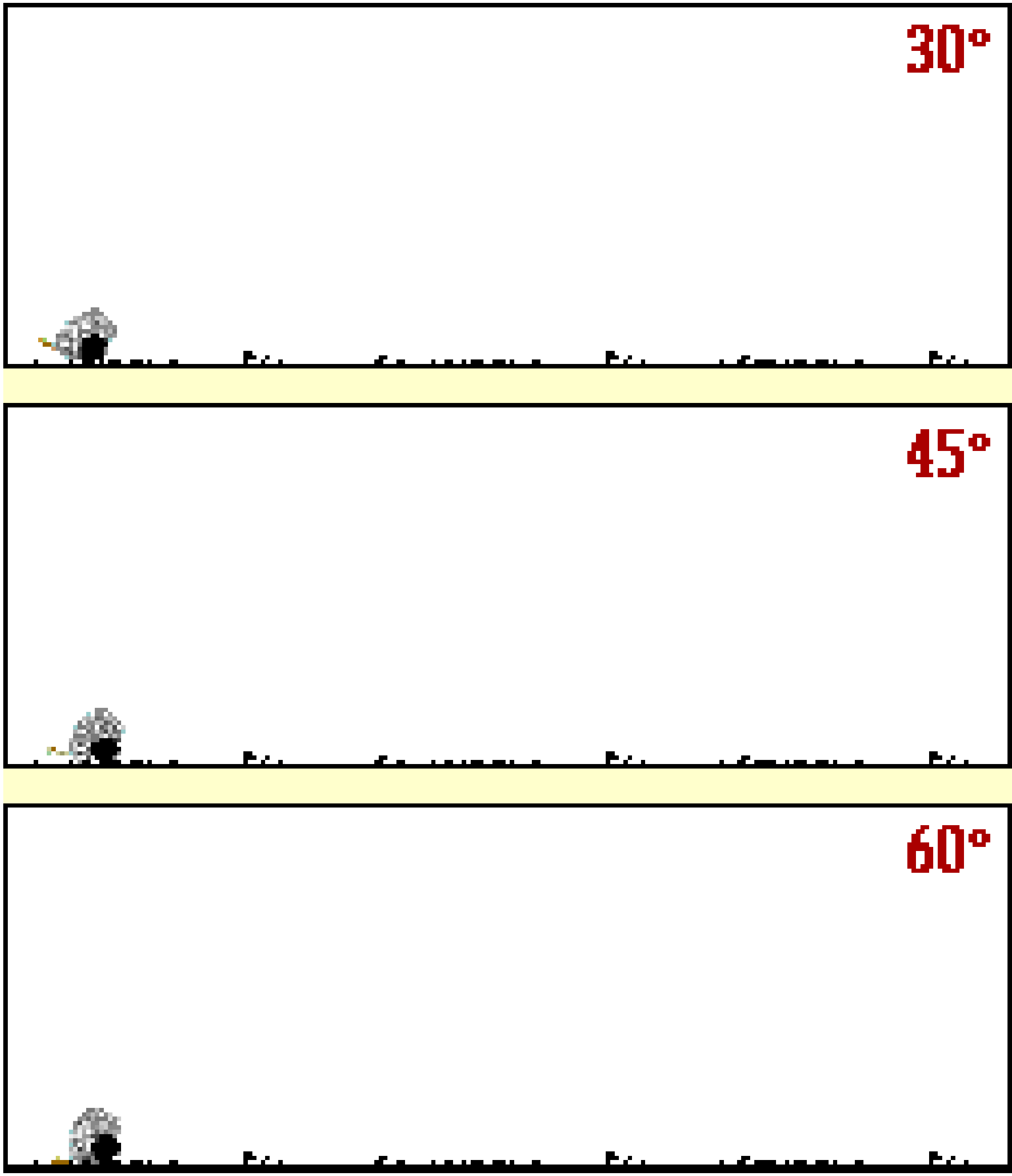
- What is the acceleration in a horizontal direction?
- What is the acceleration in a vertical direction?



Steeper Cannonball

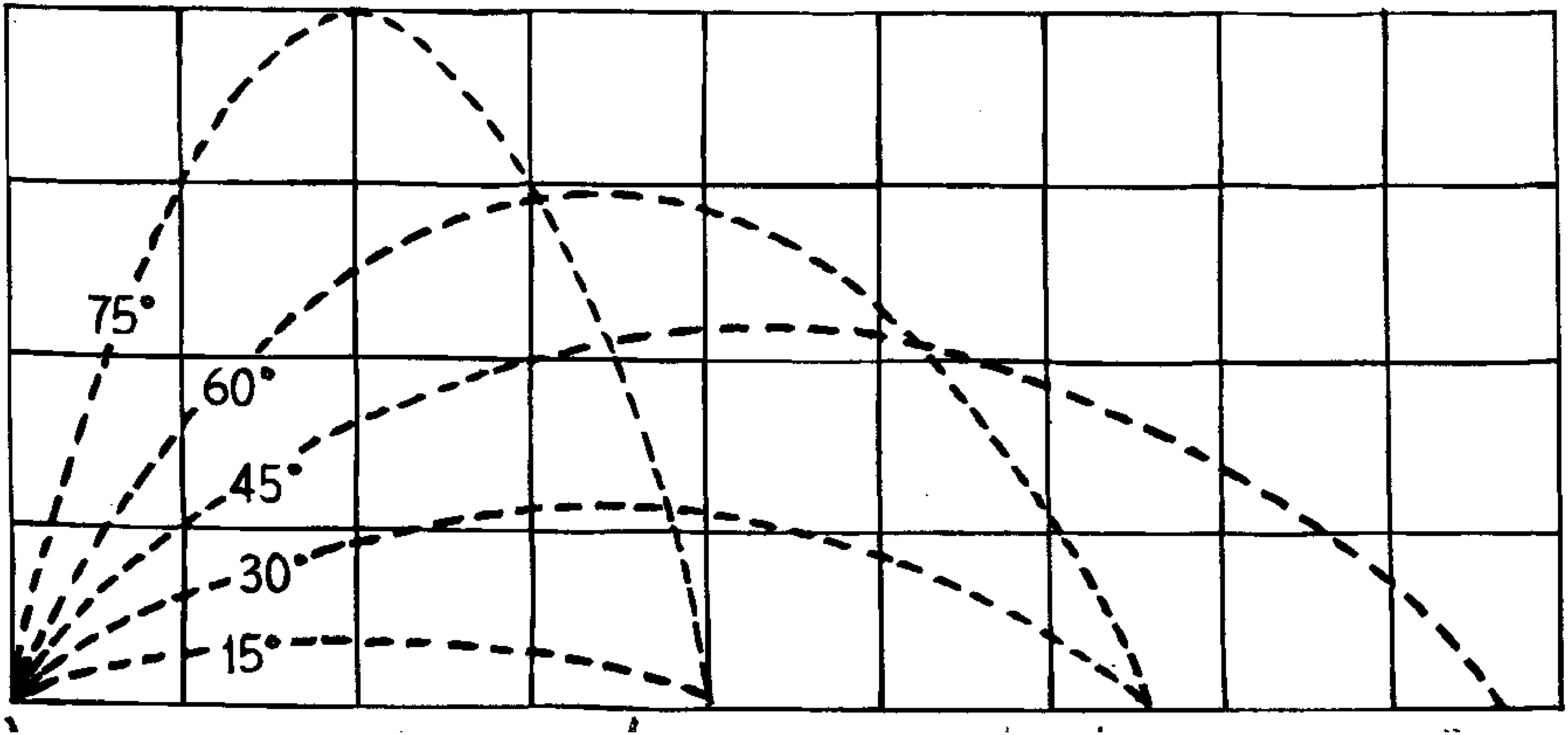


Projectile Range



http://www.physicsclassroom.com/mmedia/vectors/mr.gif

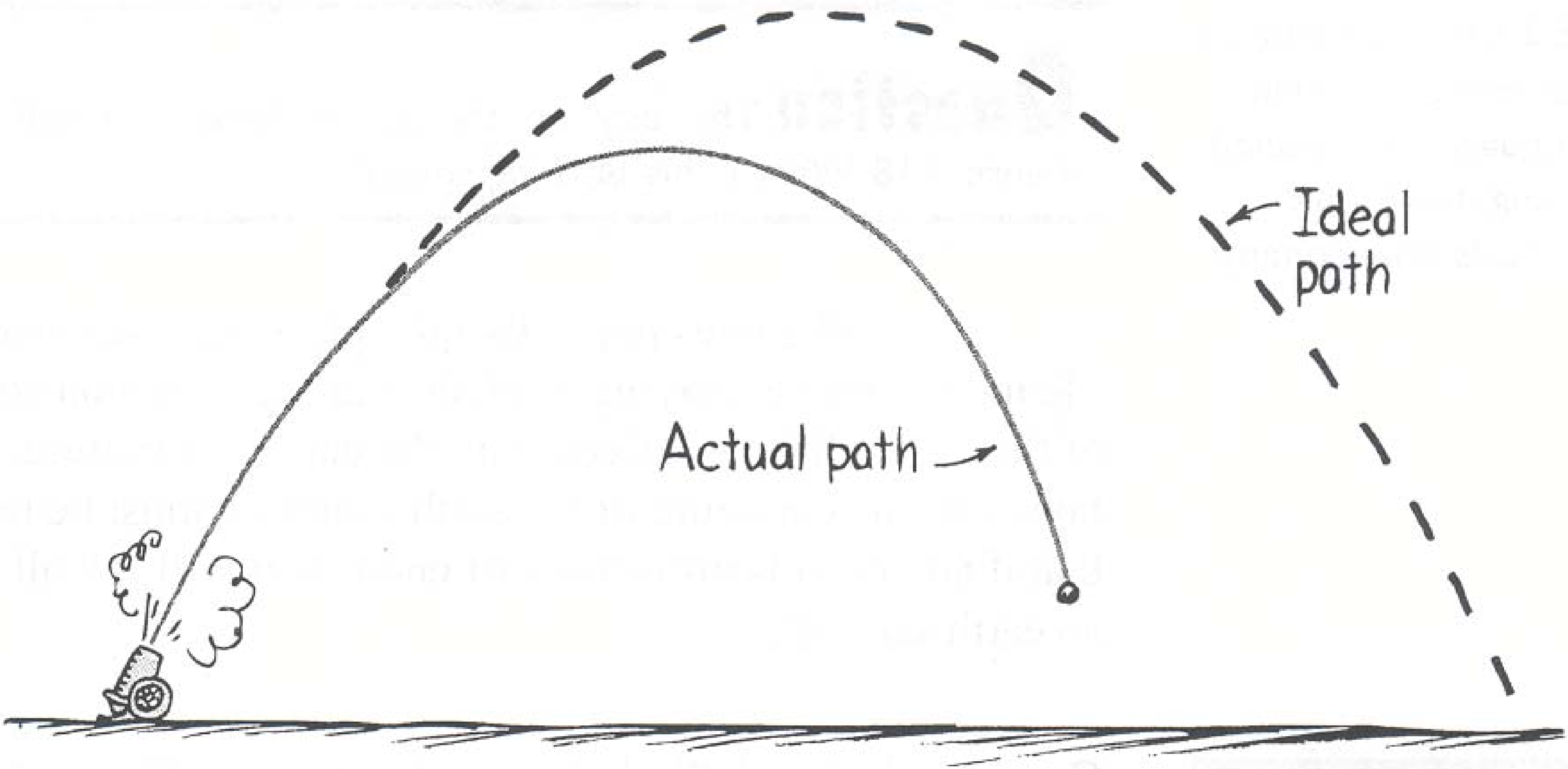
Cannonball Trajectories



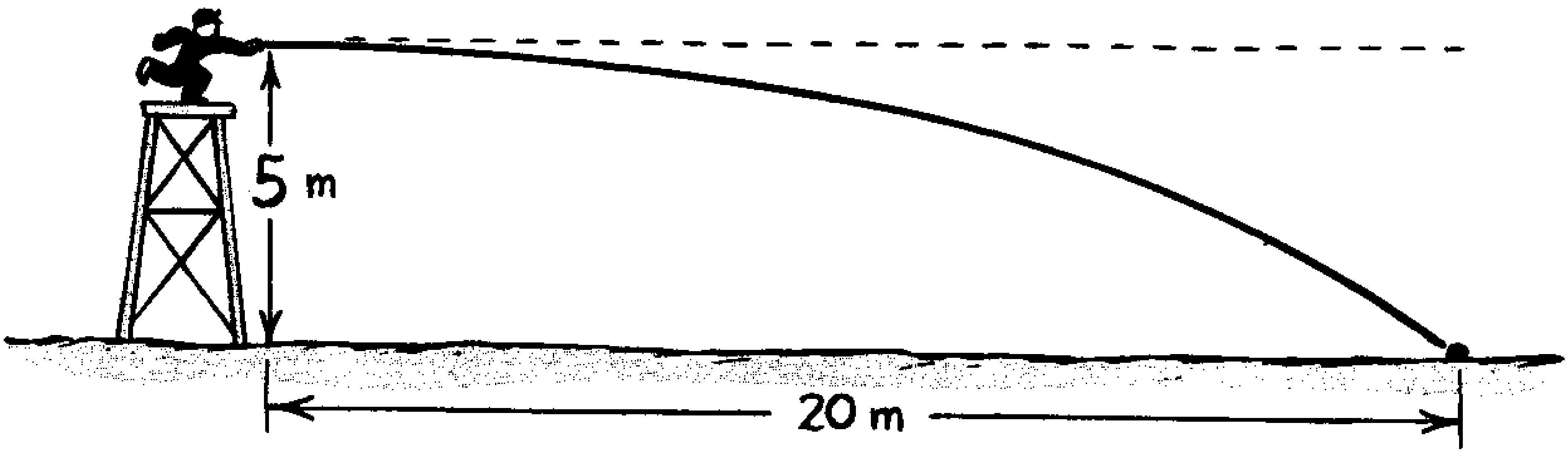
Cannonball trajectories

- Projectile will fall from maximum height in same amount of time it took to rise
- Because the acceleration of gravity slows it at the same rate it increases the speed on the way down

With air resistance



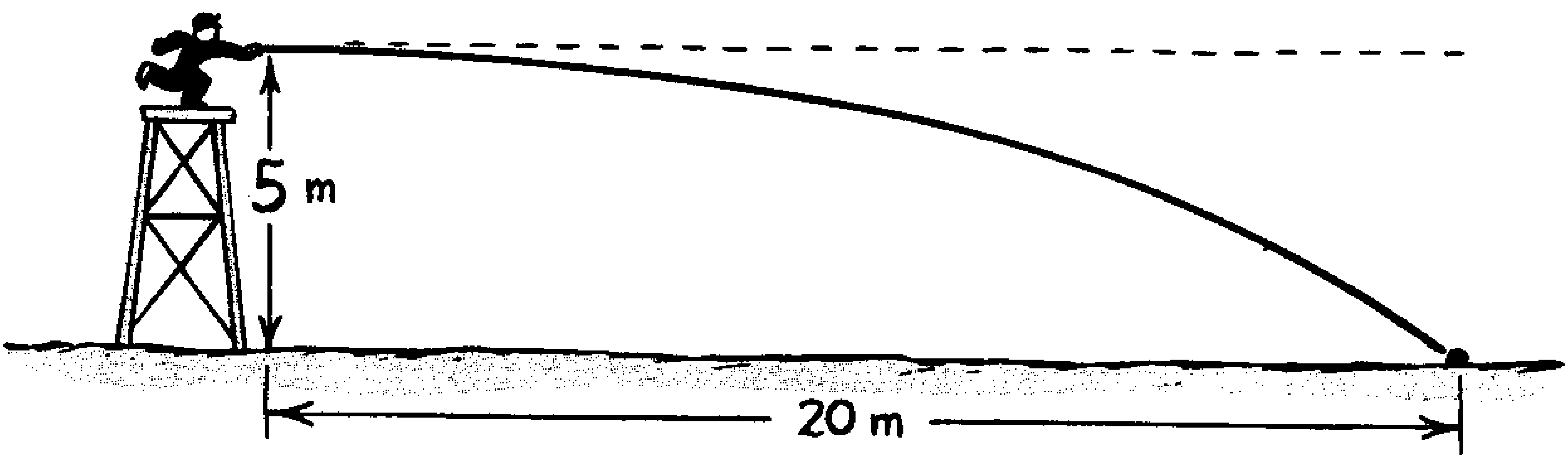
Calculations of distance, speed and acceleration



How fast was this ball thrown?

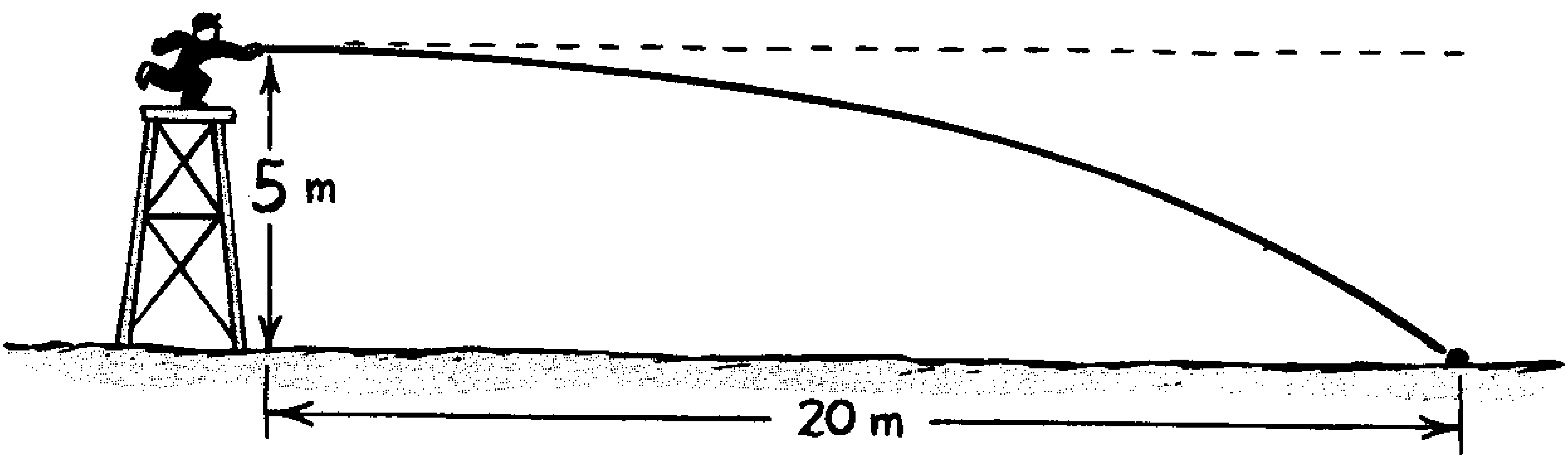
How fast was ball thrown?

- Want to find d_{horz}/t,
- We can calculate t
- $d_{vert} = (½)\, gt^2$,
- We know d_{horz}, d_{vert}, g



How fast was ball thrown?

- $d_{vert} = (½)\ gt^2$
- d_{vert}, = 5 m
- $g = 10\ m/s^2$



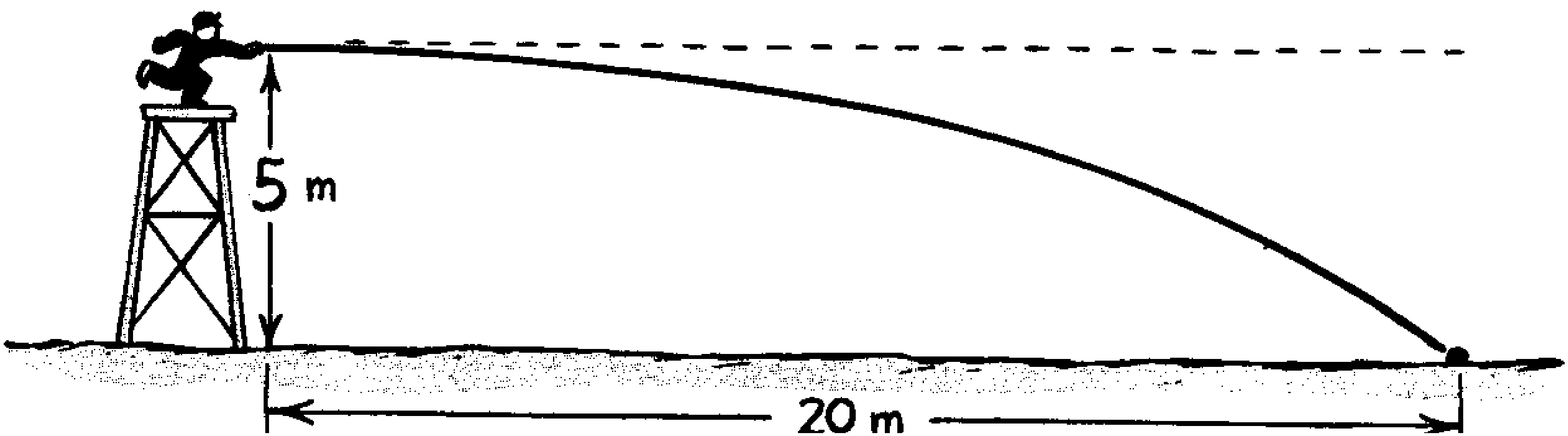
Solve for how long to fall

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

$$5m = \frac{1}{2} (\frac{10m}{s^2}) t^2$$

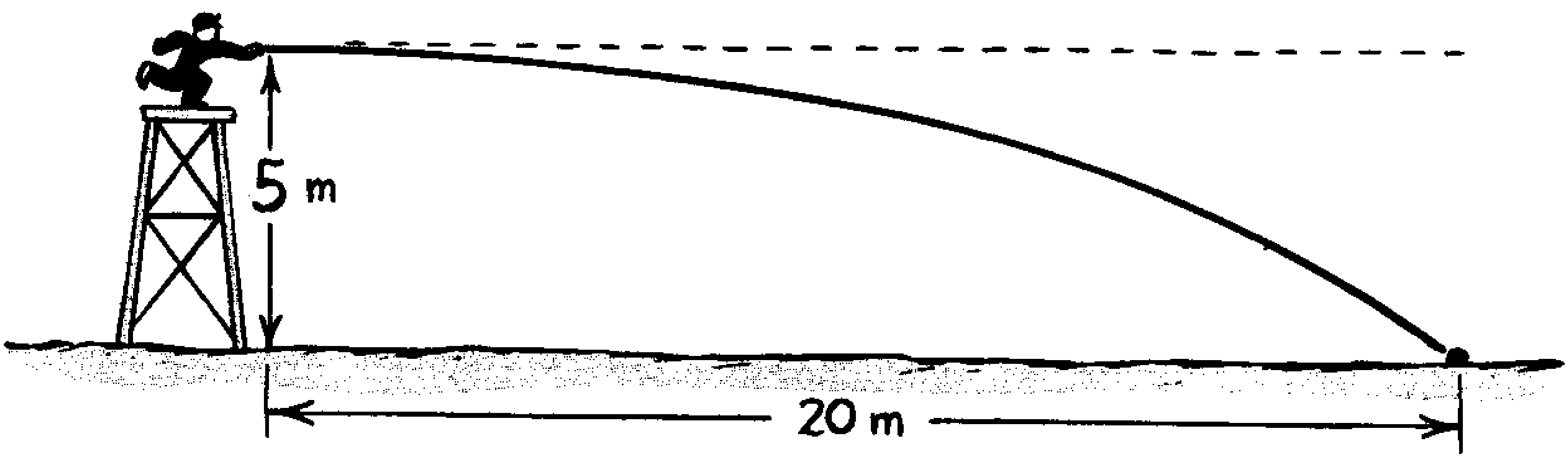
$$t^2 = \frac{5m}{\frac{1}{2} (\frac{10m}{s^2})}$$

$$t = \sqrt{\frac{5m}{\frac{1}{2} (\frac{10m}{s^2})}} = 1s$$

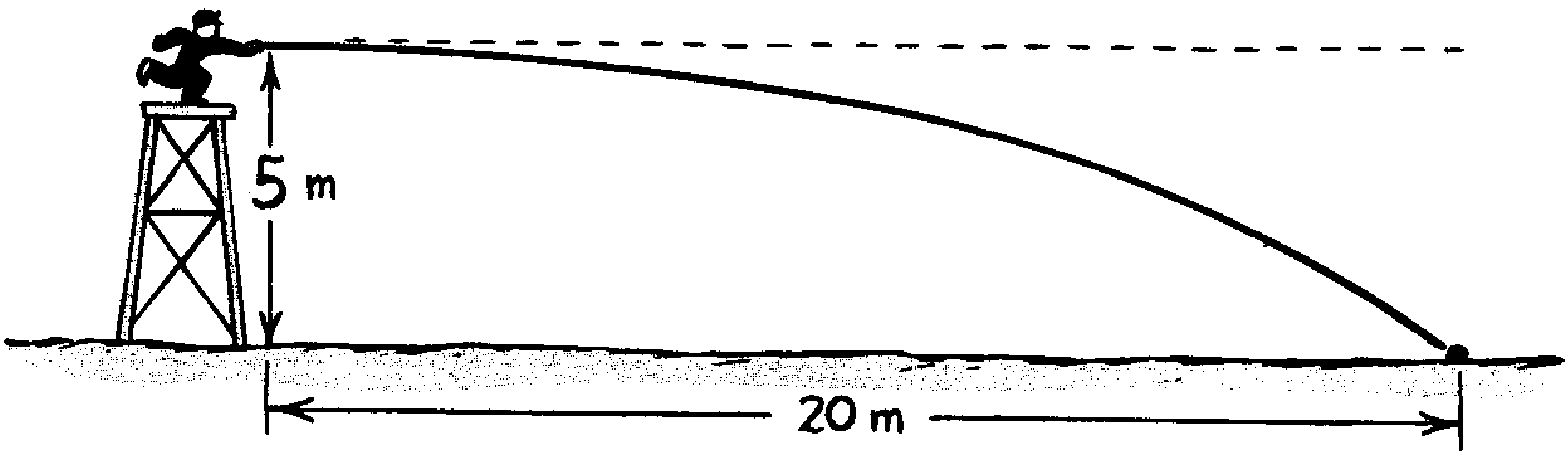


How fast was ball thrown?

- Want to find v
- $v = d_{horz}/t$
- We calculated t = 1s
- Distance=20 m
- v = 20 m/1 s   v=20 m/s



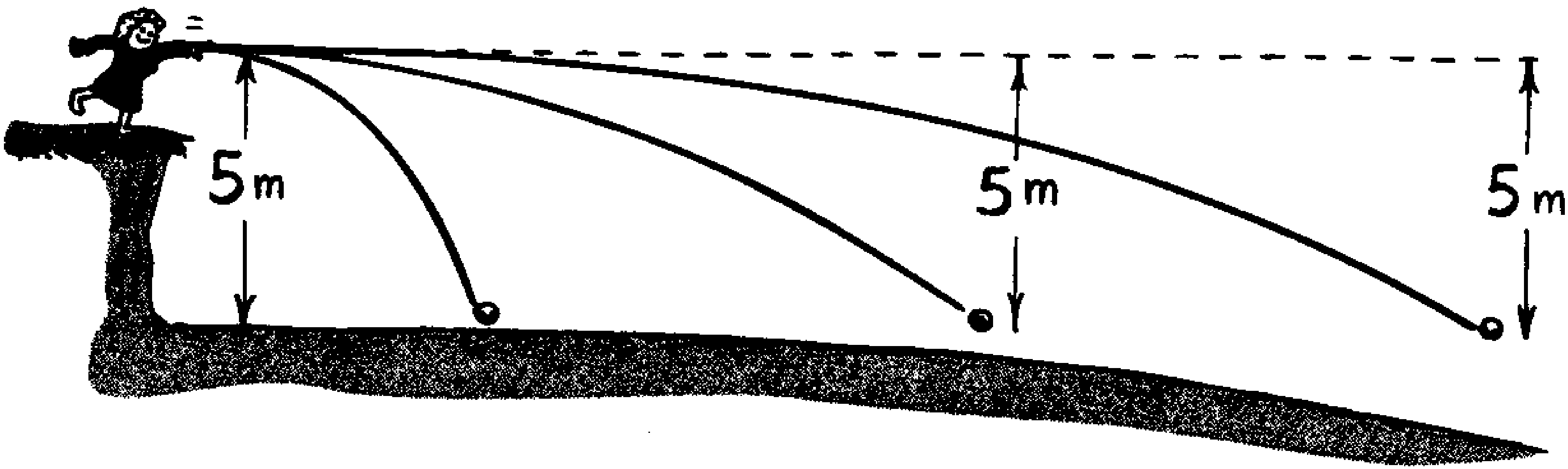
How fast was ball thrown?



$$\frac{20m}{s}\cdot\frac{60s}{\min}\cdot\frac{60\min}{h}\cdot\frac{1km}{1000m}\cdot\frac{0.62mi}{1km}=44.6mi/h$$

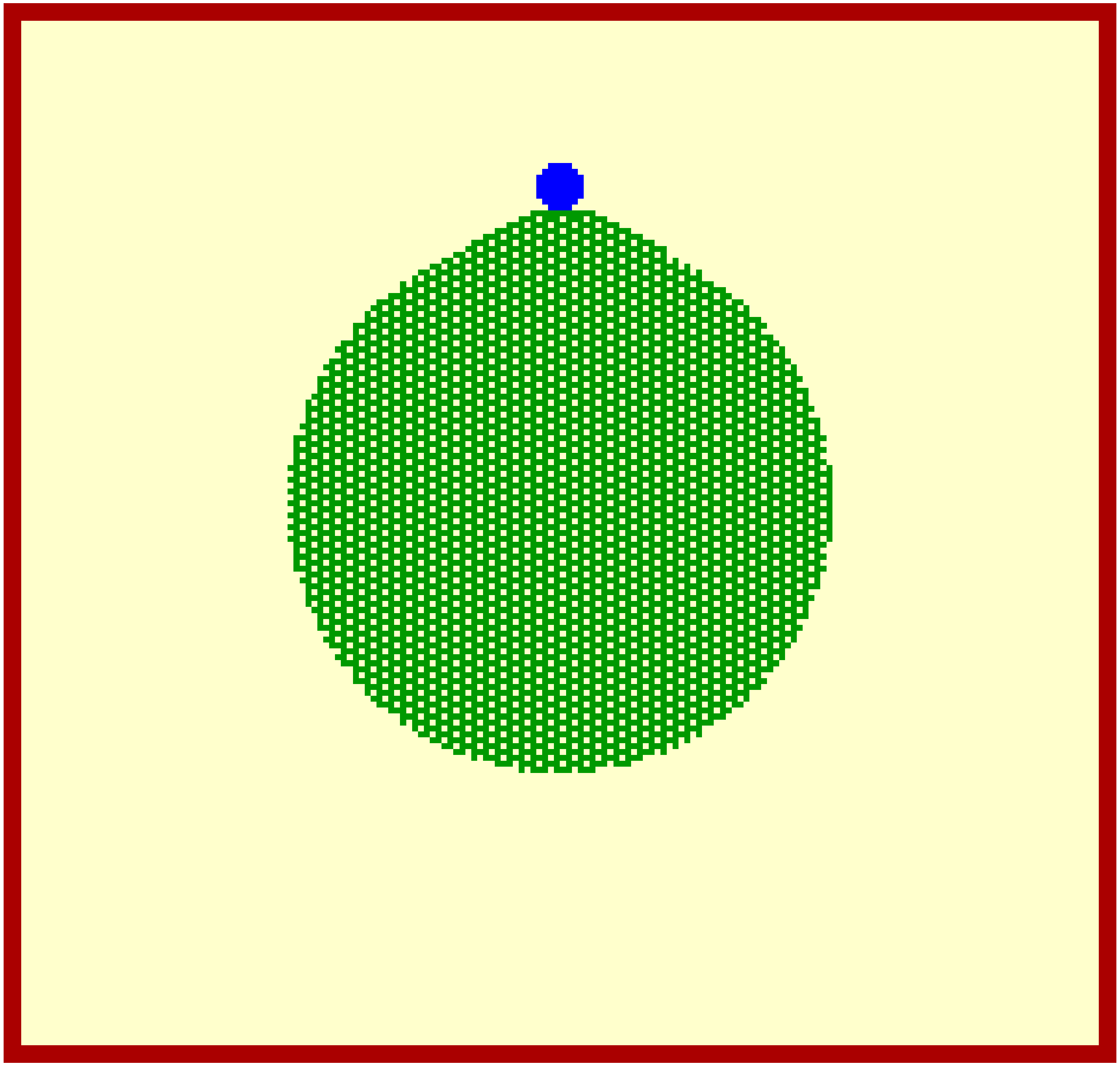
Object thrown horizontally

- Falls the same distance in the same time, no matter the speed of the throw



Satellite as projectile

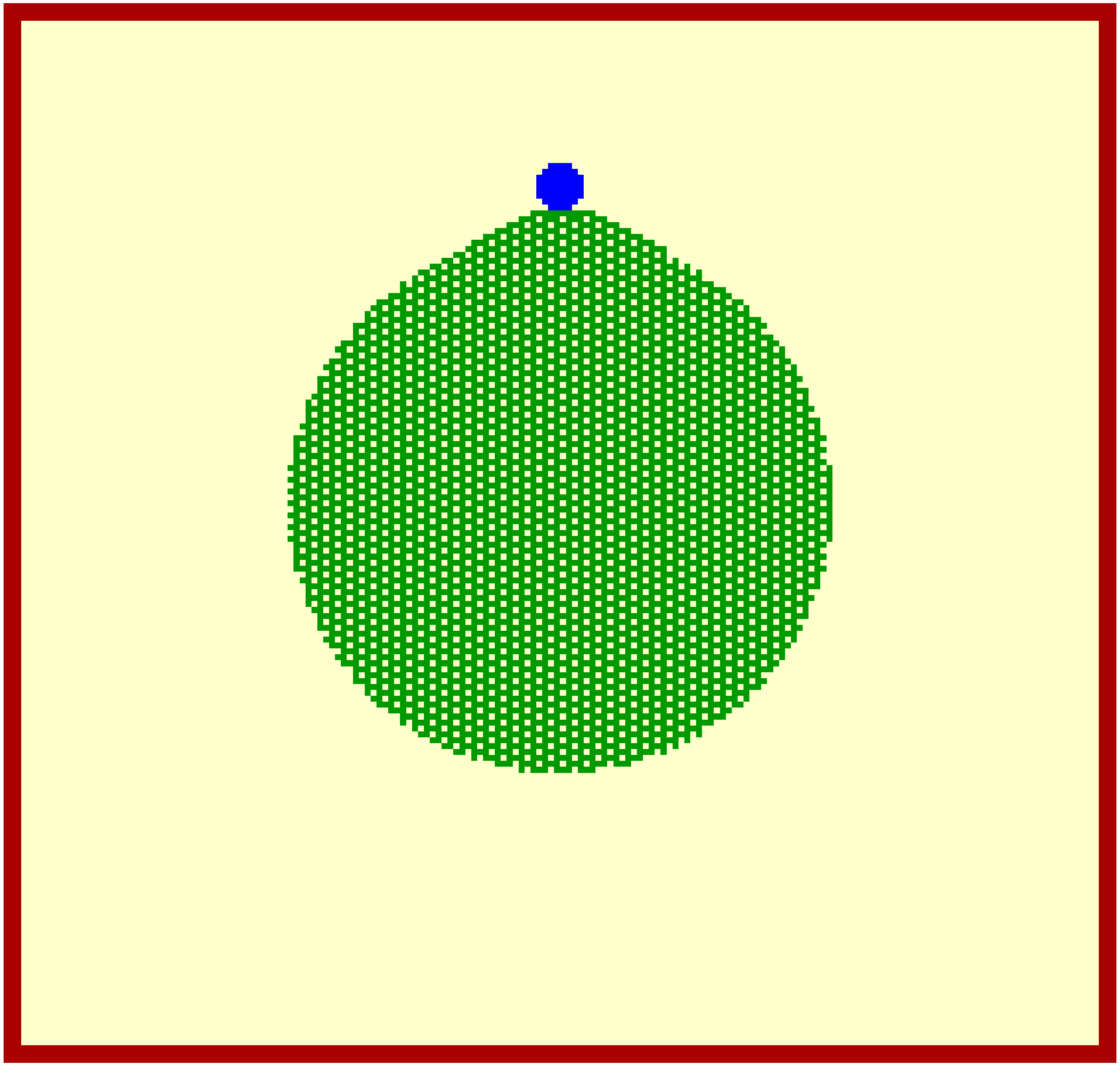
No gravity



No gravity http://www.physicsclassroom.com/mmedia/vectors/tp.gif

Satellite as projectile

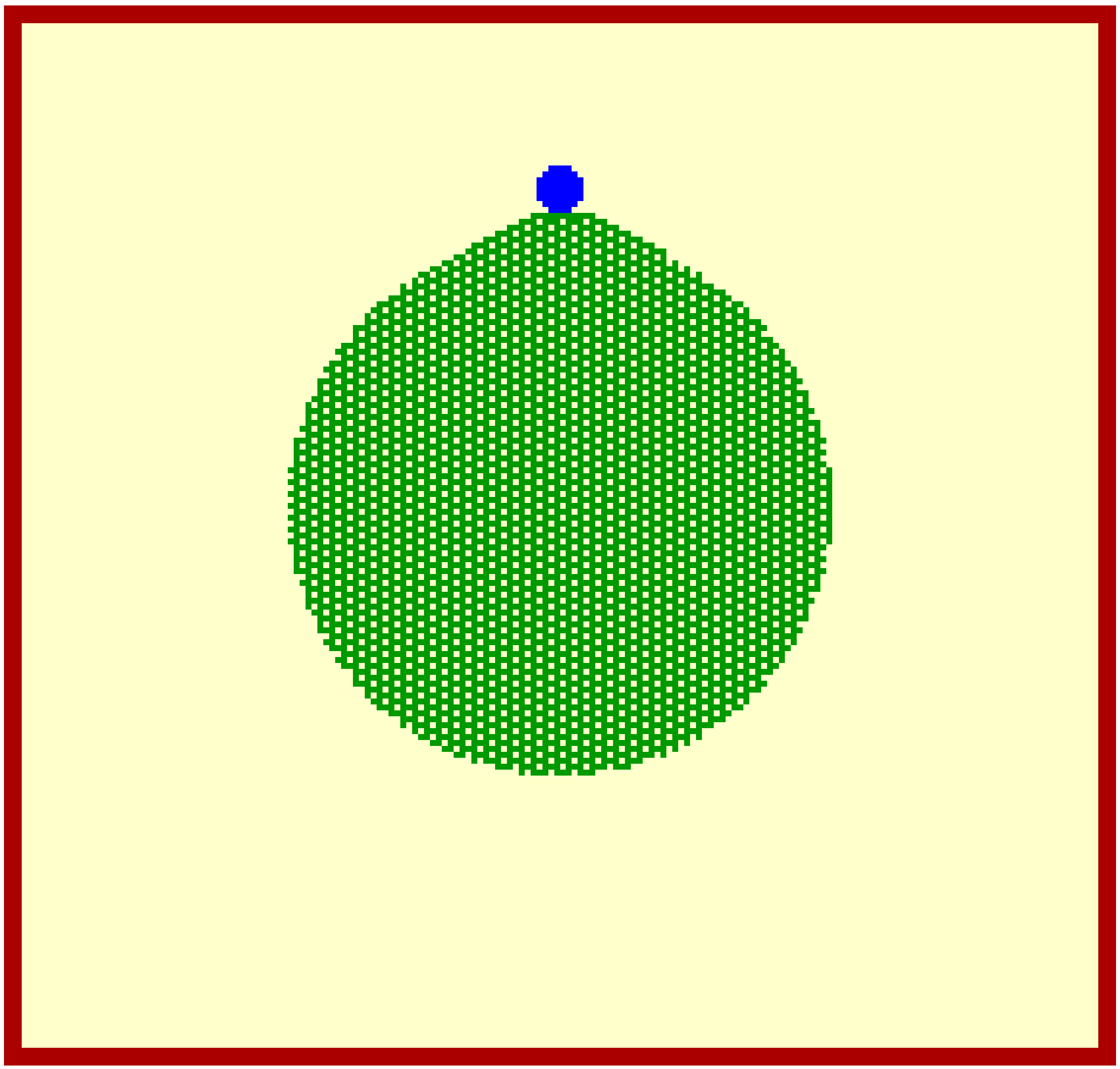
6000 m/s



6000 m/s http://www.physicsclassroom.com/mmedia/vectors/6kms.gif

Satellite as projectile

8000 m/s

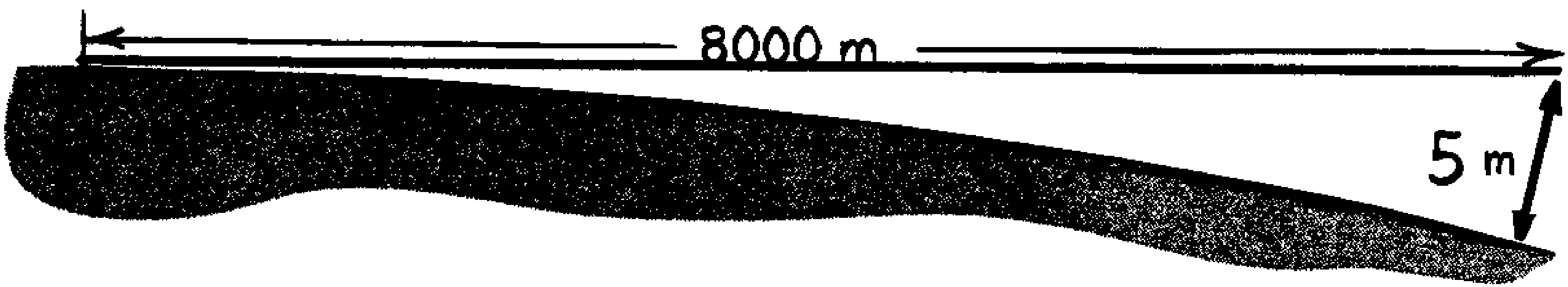


8000 m/s

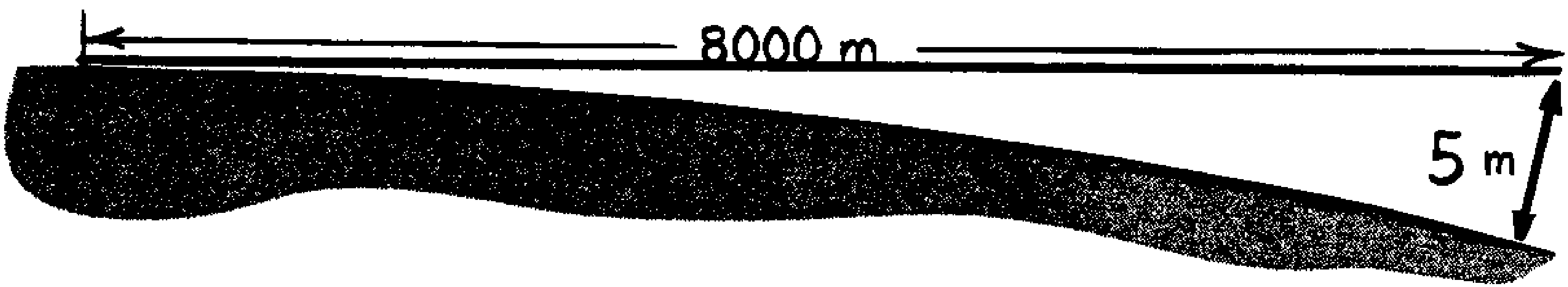
http://www.physicsclassroom.com/mmedia/vectors/co.gif

Object thrown horizontally

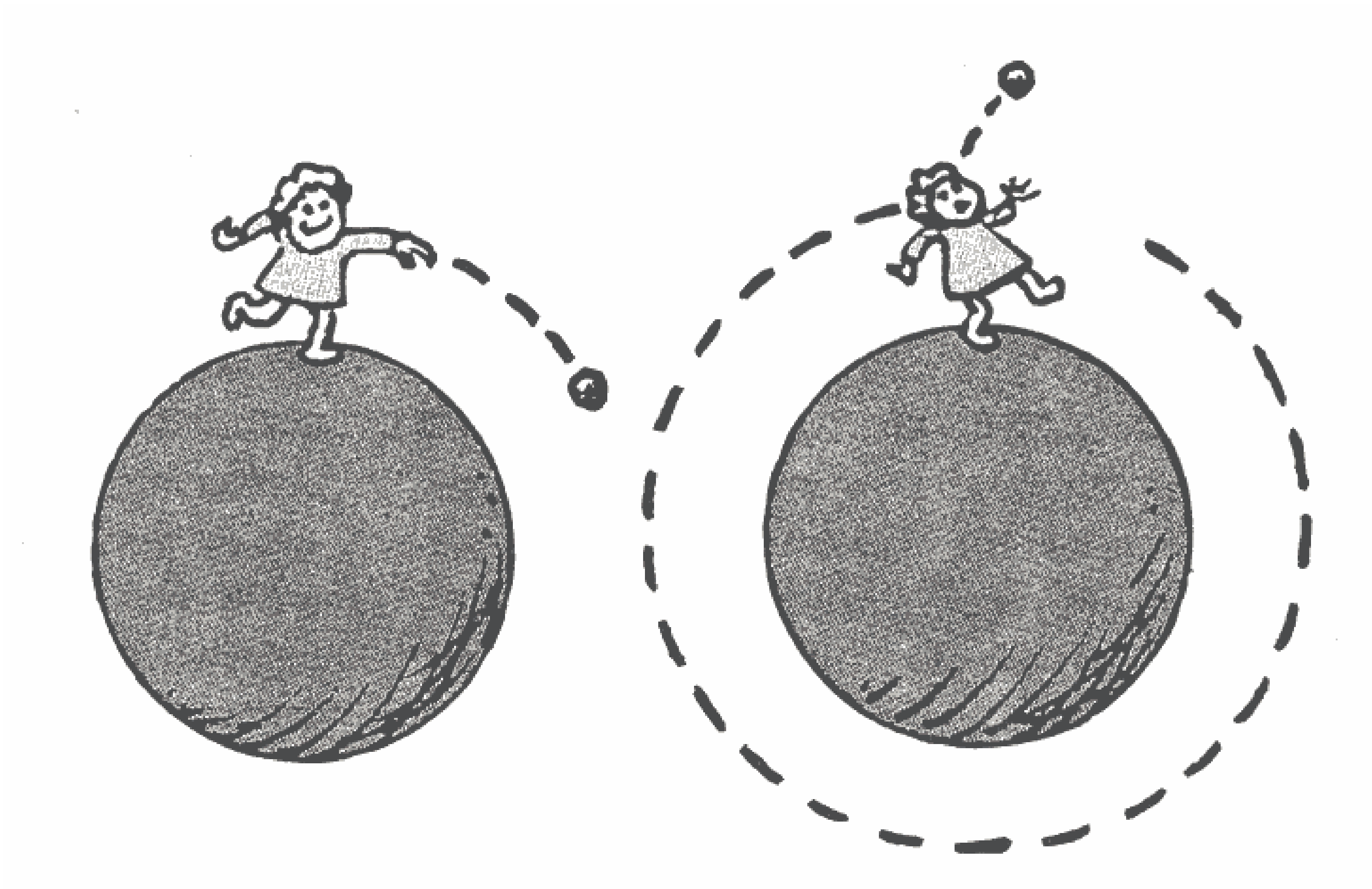
- Falls the same distance in the same time, no matter the speed of the throw
- Earth's surface is 5 meters lower for every 8000 meters horizontal distance



- Earth’s surface is 5 meters lower for every 8000 meters horizontal distance
- If it is thrown 8000m/s, it will never reach the surface
- Because it falls just as fast as the surface departs from a horizontal path



- If it is thrown 8000m/s, it will never reach the surface (nearly 18,000 mi/h)
- Because it falls as fast as the surface departs from a horizontal path



Acceleration of Gravity

- Free fall of object
- Speed increases 10 m/s for every second of fall
- $\frac{10\ m/s}{s} = \frac{10m}{s^2}$

Time elapsed (seconds)	Speed (meters/ second)
0	0
1	10
2	20
3	30
4	40

Speed and distance of falling objects

- Remember that velocity is defined as distance / time
- Average velocity can be determined over time intervals
- average velocity=

$$\frac{V_2 + V_1}{2}$$

Time elapsed (seconds)	Speed (meters/second)
0	0
1	10
2	20
3	30
4	40

Acceleration and falling objects

- Remember that acceleration is defined as change of velocity / time
- Which can be rearranged to report velocity
- And we use the acceleration of gravity for freely falling objects

$$a = \frac{\Delta v}{t}$$

$$at = \Delta v$$

$$gt = \Delta v$$

Freely falling object

- Velocity is a function of how long it has been falling
- Distance is also a function of how long it has been falling because
- And average velocity is sum of two velocities divided by 2

$$gt = \Delta v$$

$$vt = d$$

$$\frac{v_2 + v_1}{2}$$

Freely falling objects

- We will use this equation
- And substitute average velocity calculated from two velocities
- Which will be calculated from

$$vt = d$$

$$v_{average} = \frac{\mathbf{v}_2 + \mathbf{v}_1}{2}$$

$$gt = v$$

Freely falling objects

- So the master equation
- Substitute the average velocity
- Substitute the velocity calculated from the acceleration of gravity
- And remember the object starts at rest

$$vt = d$$

$$\frac{v_0 + v_1}{2} t = d$$

$$gt = v$$

$$\frac{0 + gt}{2} \cdot t = d$$

Distance of falling object

- $v_1=0$
- $v_2=gt$

$$\frac{0+gt}{2}\cdot t = d$$

- Now we have:

$$\frac{gt}{2}\cdot t = d$$

- Which simplifies to:

$$\frac{1}{2}gt^2 = d$$

Time of falling object

$$\frac{1}{2}gt^2 = d$$

- And if you know the distance…you can calculate the time it has fallen
- Multiply both sides by 2
- Divide both sides by g
- Take square root of both sides to get time:

$$2 \cdot \frac{1}{2}gt^2 = 2 \cdot d$$

$$gt^2 = 2 \cdot d$$

$$\frac{gt^2}{g} = \frac{2 \cdot d}{g}$$

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

$$t = \sqrt{t^2} = \sqrt{\frac{2 \cdot d}{g}}$$

Hang time for basketball player

- Spud Webb slam dunk contest
  - http://www.youtube.com/watch?v=BUu7drj9hPw
- He can jump 1.25 m. How long is he in the air?

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

$$t = \sqrt{\frac{2d}{g}} = \sqrt{\frac{2(1.25m)}{10m/s^2}} = 0.5s$$

to fall from top of jump, so double for time in the air