College Physics I: 1511 Mechanics & Thermodynamics

Professor Jasper Halekas
Van Allen Lecture Room 1
MWF 8:30-9:20 Lecture

Last Time: Kinematics Equations

$$v_f = v_o + at$$

$$x_f = x_o + v_o t + \frac{1}{2}at^2$$

$$v_f^2 = v_o^2 + 2a(x_f - x_o)$$

$$x_f = x_o + \frac{1}{2}(v_f + v_o)t$$

Kinematic Equations: Vector Form

$$\vec{x} = \vec{x}_0 + \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$$

$x = x_o + v_{xo}t + 1/2\ a_x t^2$

$y = y_o + v_{yo}t + 1/2\ a_y t^2$

$z = z_o + v_{zo}t + 1/2\ a_z t^2$

Vector Position & Velocity

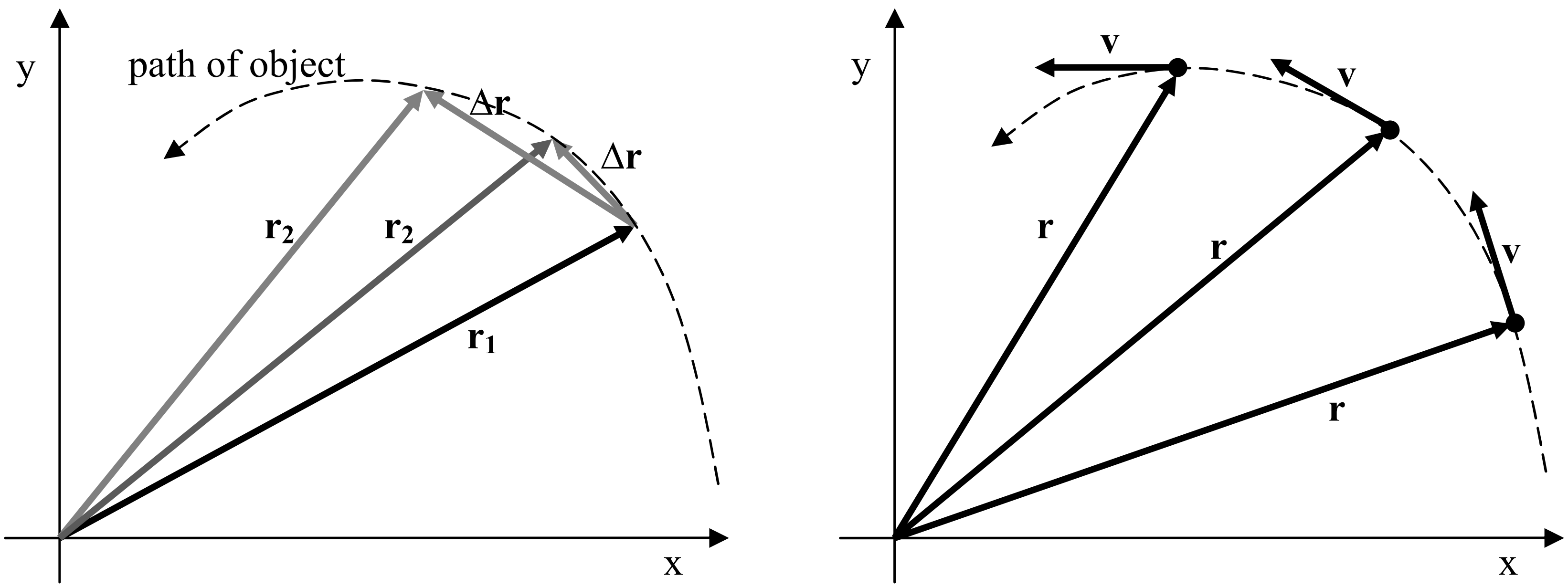
$$\text{Average Velocity } \langle\vec{V}\rangle = \frac{\Delta\vec{R}}{\Delta t}$$

where

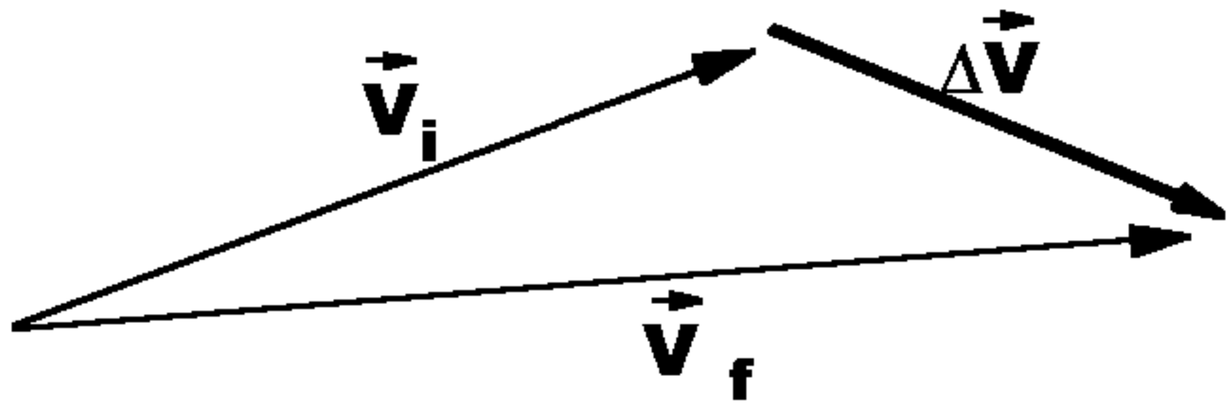
$$\Delta t = t_2 - t_1 = t_f - t_i$$

$$\Delta\vec{R} = \vec{R}_2 - \vec{R}_1 = \vec{R}_f - \vec{R}_i$$

Vector Position & Velocity: 2-d



Vector Velocity & Acceleration: 2-d



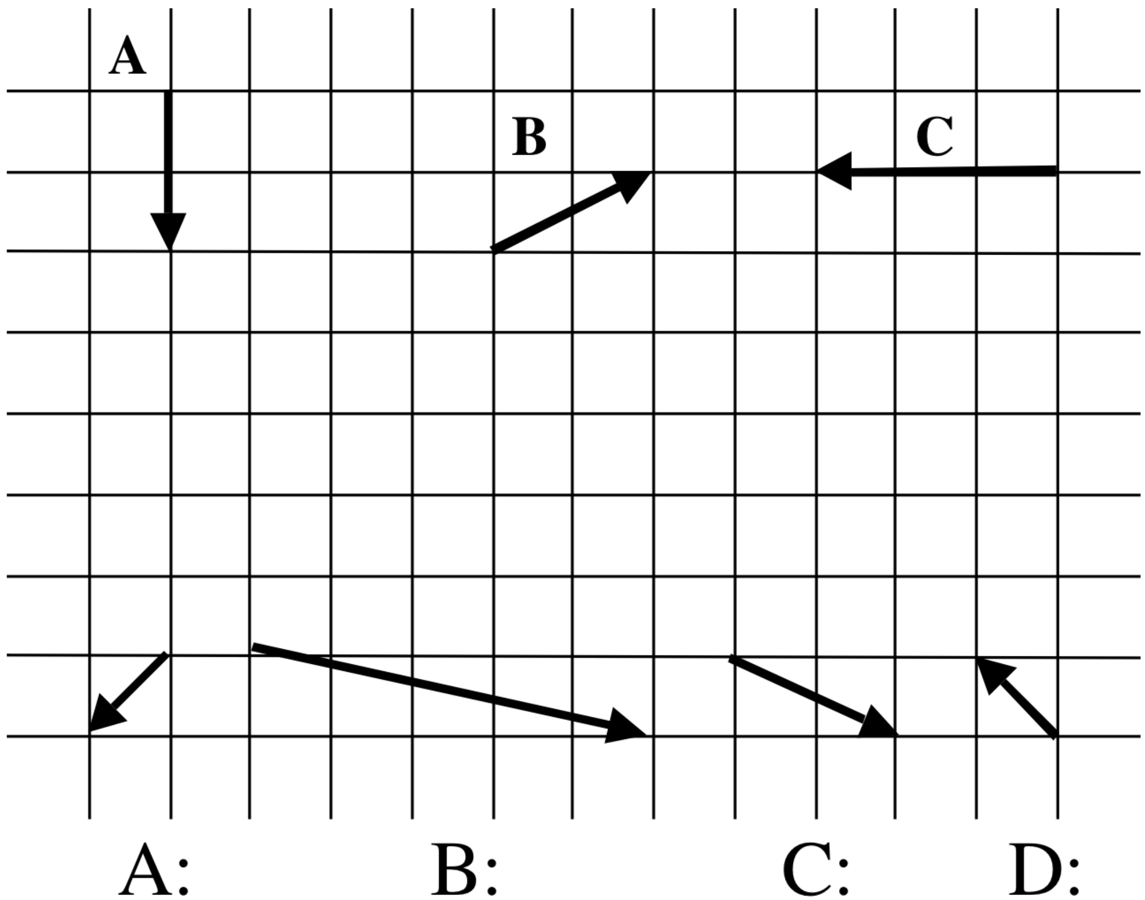
$$\textbf{Average Acceleration } \langle\vec{a}\rangle = \frac{\Delta\vec{v}}{\Delta t}$$

where

$\Delta t = t_f - t_i$ and $\Delta\vec{v} = \vec{v}_f - \vec{v}_i$

Concept Check

Three vectors, **A, B,** and **C** are shown.
Which of the vectors at the bottom is **A+B-C**?



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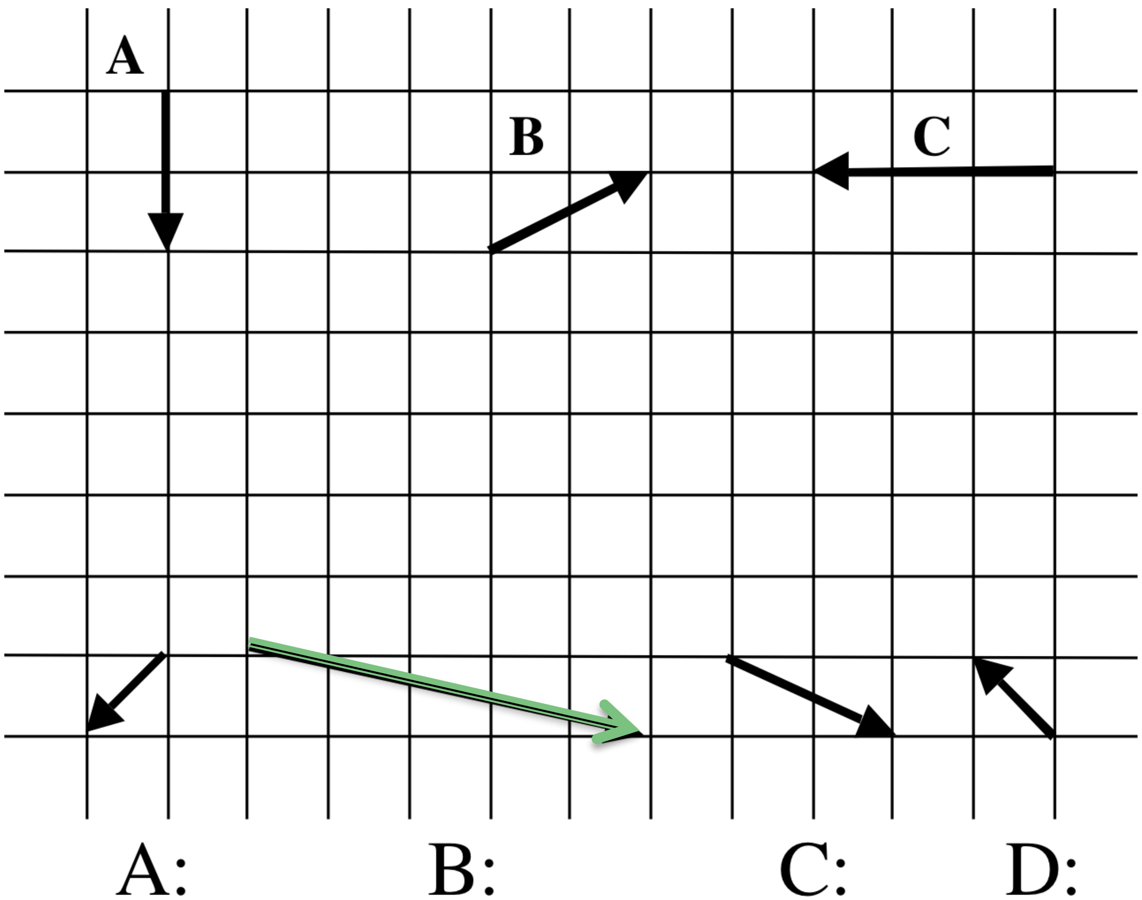
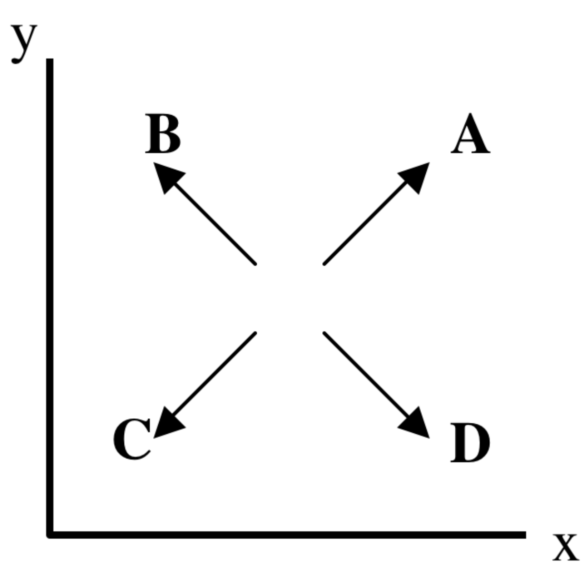


Concept Check

The x- and y-coordinates of a particle as a function of time are $x(t) = b + c\,t, \quad y(t) = d - e\,t$, where b,c,d, and e are positive constants.

Which arrow *could* be the velocity of the particle?



E: (it's zero)

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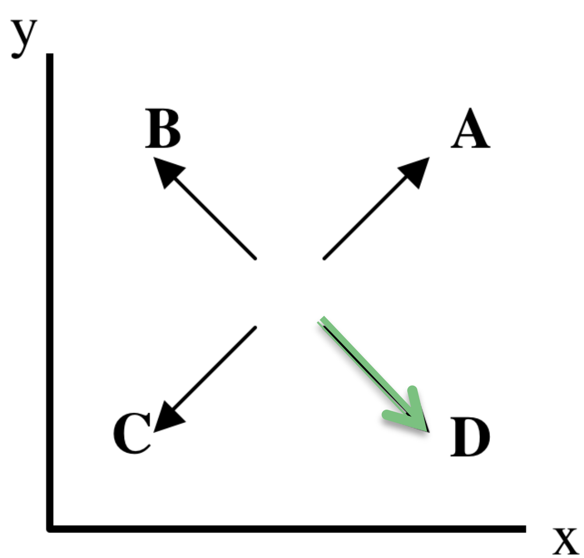

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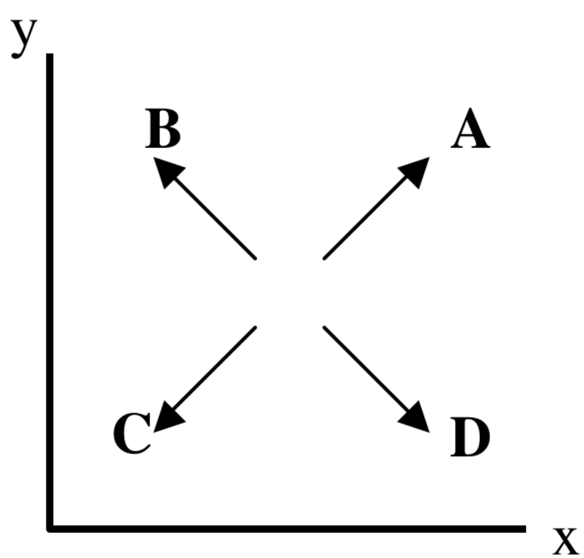

E: (it's zero)

Which direction is the acceleration of the particle?

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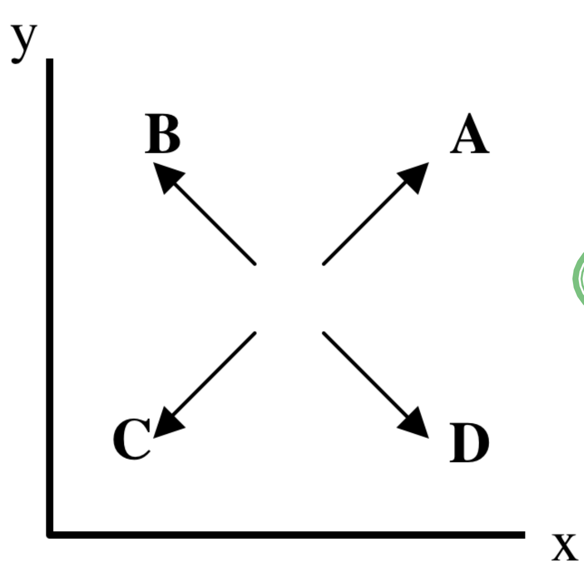

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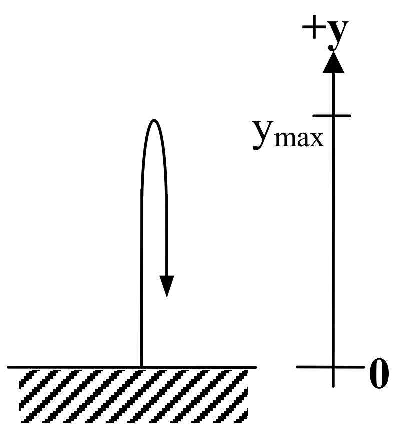
1-d Projectile Motion

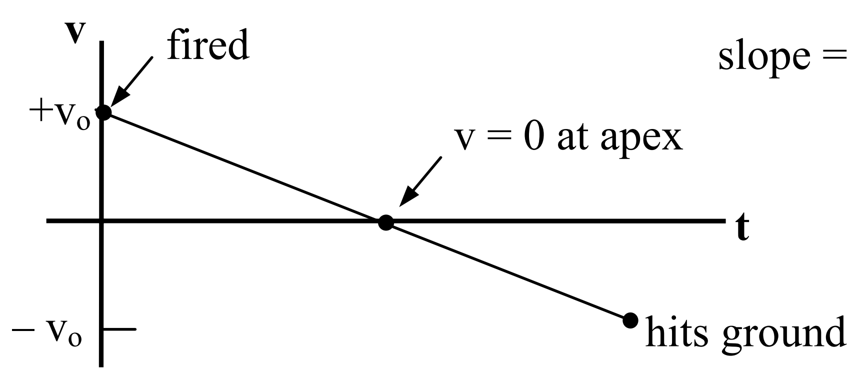


$y_o = 0\,, \quad v_o = +10 \text{ m/s}$

$a = -g = -9.8 \text{ m/s}^2$

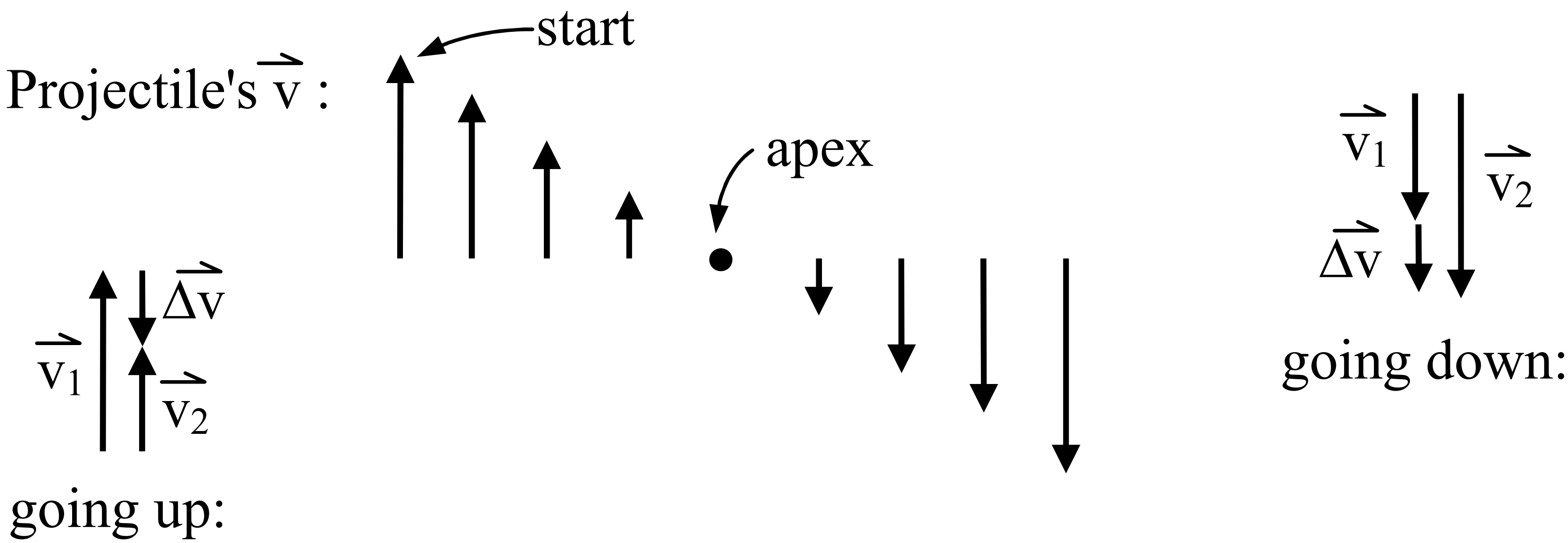
$v = v_o + a\,t = v_o - g\,t$

Graph of v vs. t :



slope = constant = – g

1-D Velocity & Acceleration



Time aloft

$$y_f = y_0 + v_{y0} t + \tfrac{1}{2} a t^2$$

$$= v_{y0} t - \tfrac{1}{2} g t^2$$

$$= 0$$ after it falls to ground

$$v_{y0} t - \tfrac{1}{2} g t^2 = 0$$

$$v_{y0} t = \tfrac{1}{2} g t^2$$

$$v_{y0} = \tfrac{1}{2} g t$$

$$2 v_{y0} = g t$$

$$\boxed{t = 2 v_{y0} / g}$$

Time to top

$$v_{yf} = v_{y0} + a t$$

$$= v_{y0} - g t$$

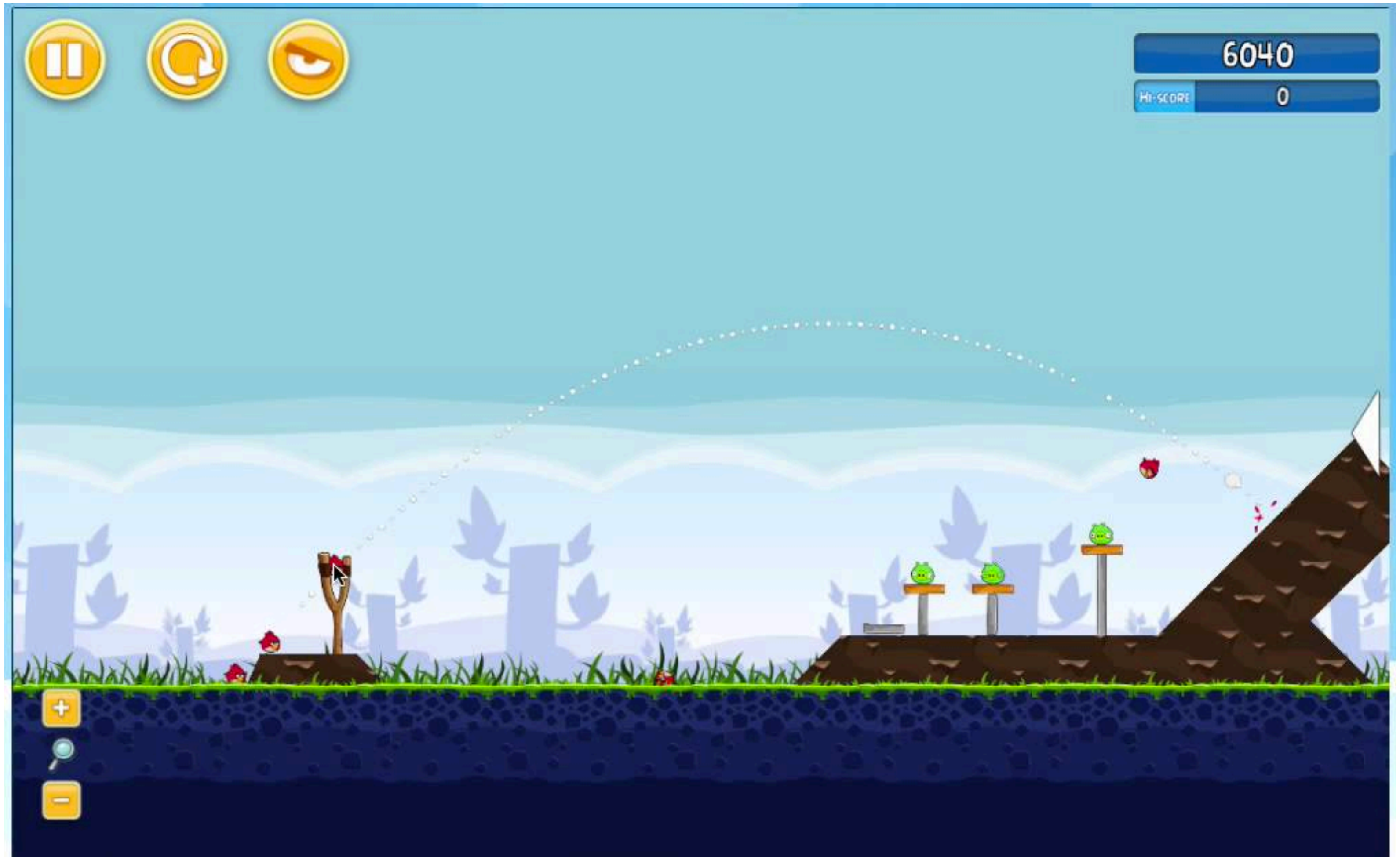
$$= 0 \text{ @ top}$$

so $v_{y0} = g t$

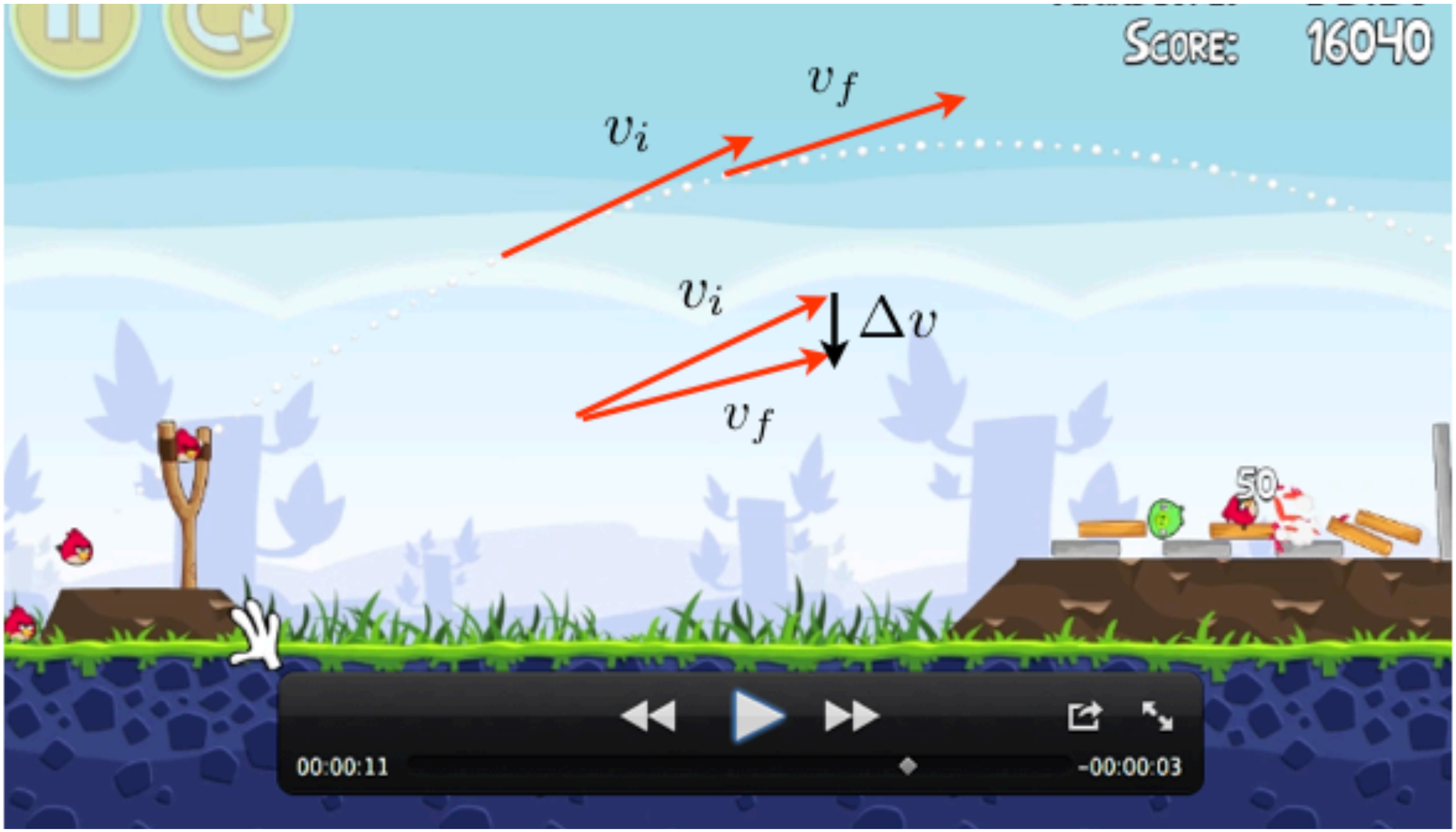
or $\boxed{t = v_{y0} / g}$

– Half of total time going up, half going down

2-d Projectile Motion

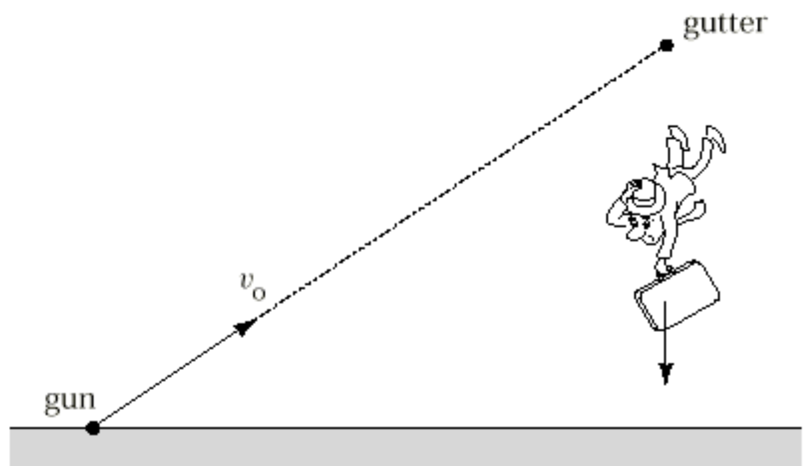


Projectile Motion



Concept Check

A tranquilizer gun is accurately aimed at a dangerous criminal hanging from the gutter of a building. The target is well within the gun's range, but the instant the gun is fired and the bullet moves with a speed vo , the criminal lets go and drops to the ground. What happens?



The dart

A: hits the criminal regardless of the value of vo .

B: hits the criminal only if vo is large enough.

C: misses the criminal.

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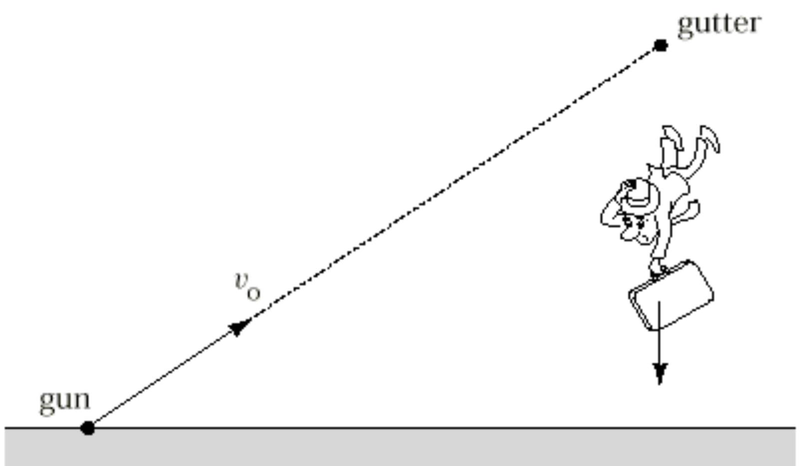

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Key Concept

- Motion in the horizontal and vertical direction are independent!
- You can solve for the horizontal and vertical motion separately
  - Though you will have to use common variables like the elapsed time in both equations

Solving 2-d Motion

Vertical Direction

$$y(t) = y_i + v_{iy}t - \frac{1}{2}gt^2$$

$$v_y(t) = v_{iy} - gt$$

$$a_y = -g = -9.8\mathrm{m/s^2} \approx -10\mathrm{m/s^2}$$

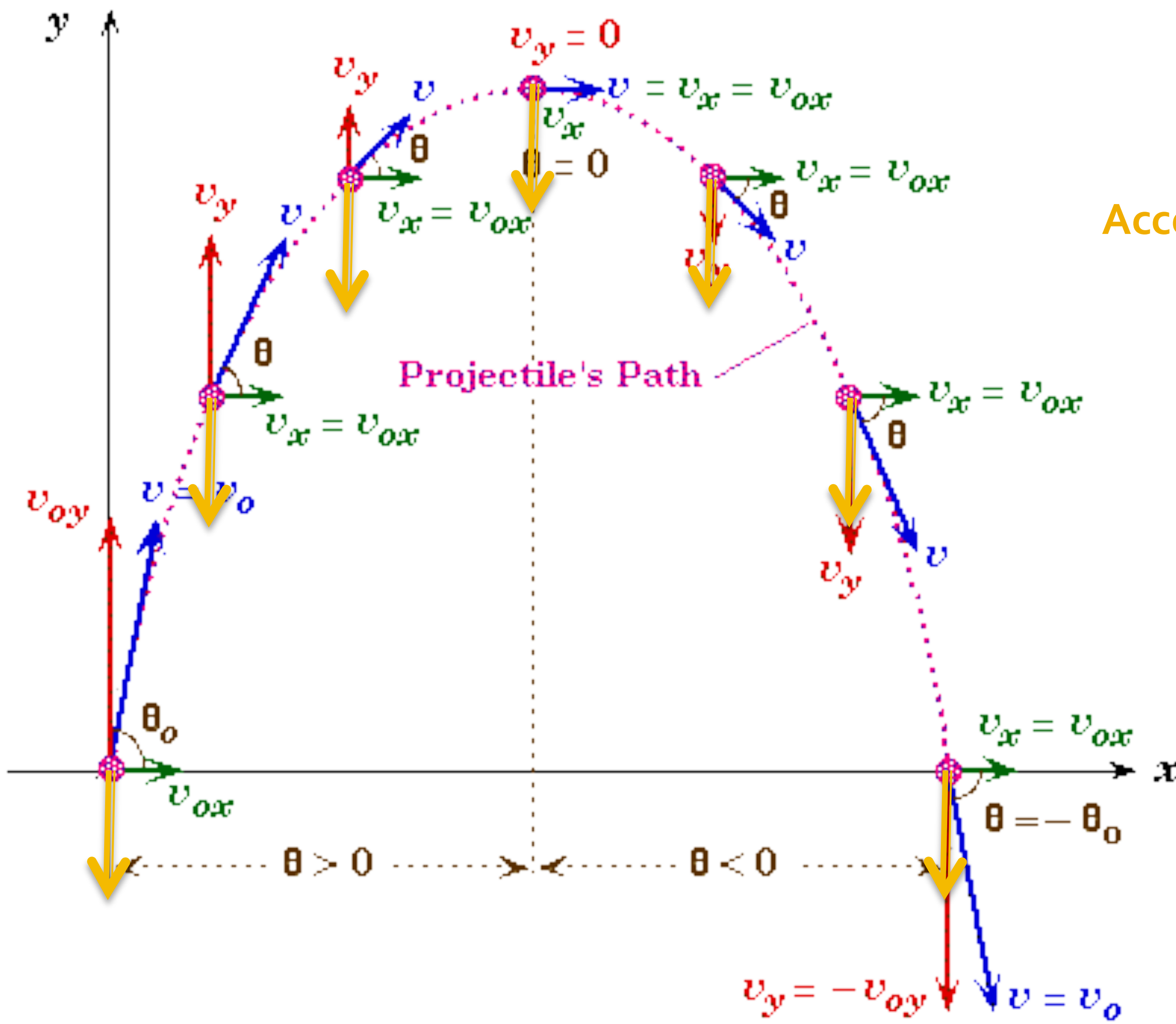
Horizontal Direction

$$x(t) = x_i + v_{ix}t$$

$$v_x(t) = v_{ix}$$

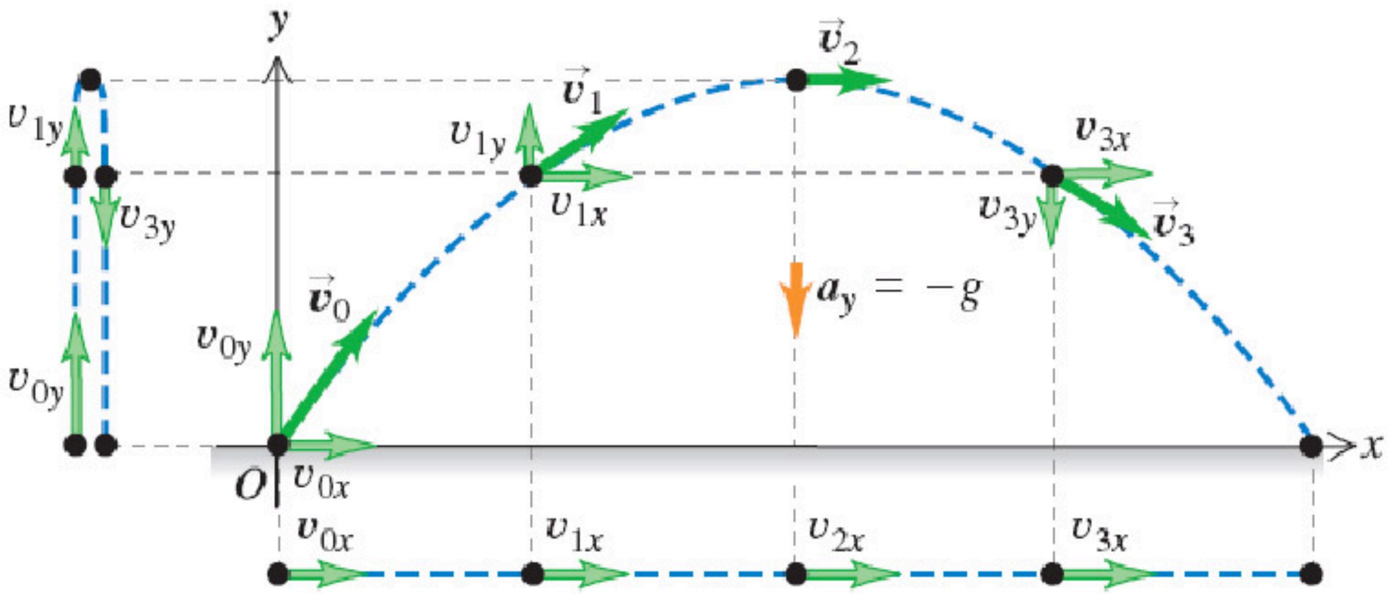
$$a_x = 0$$

2-d Projectile Motion



Acceleration

Solving 2-d Motion



The vertical and horizontal components of a projectile's motion are independent.

$$x = (v_0 \cos\theta_0)t,$$

$$y = (v_0 \sin\theta_0)t - \frac{1}{2}gt^2,$$

$$v_x = v_0 \cos\theta_0,$$

$$v_y = v_0 \sin\theta_0 - gt.$$

Range of projectile

If you know time aloft, you know range.

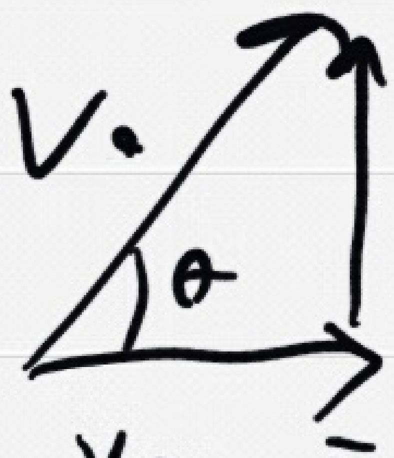
$$t = 2v_{y0}/g$$

$$\Delta x = v_{x0}\, t$$

$$= v_{x0} \cdot 2v_{y0}/g$$

$$= \boxed{2 v_{x0} v_{y0}/g}$$

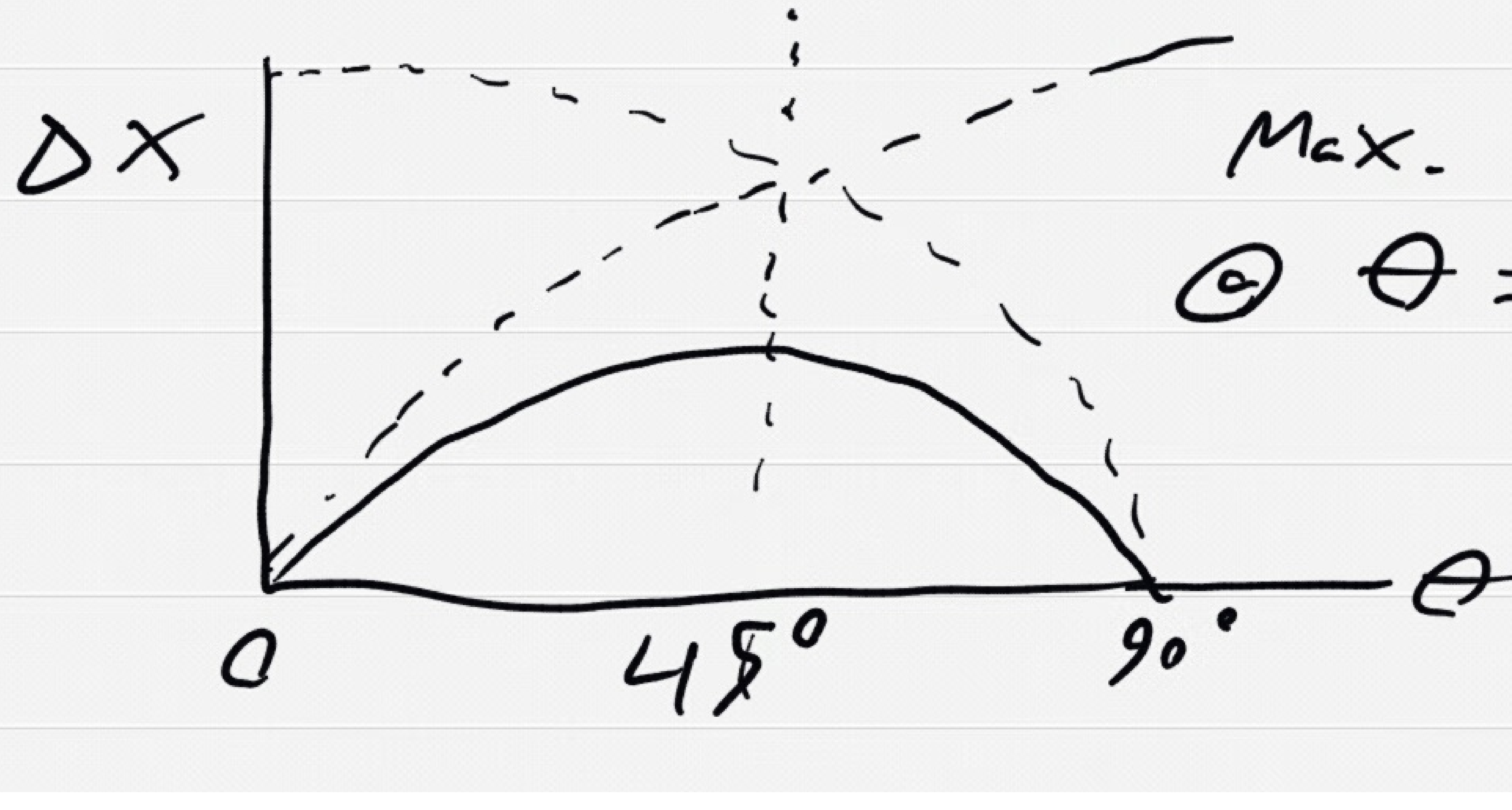
What if you know v_0, θ?



$v_{y0} = v_0 \sin\theta$

$v_{x0} = v_0 \cos\theta$

$$\Rightarrow \Delta x = \frac{2 v_0 \cos\theta\, v_0 \sin\theta}{g}$$



Max. range @ $\theta = 45°$