Introduction to Mechanics
Projectiles
Launched Horizontally

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Last time

- relative motion
- relative motion examples

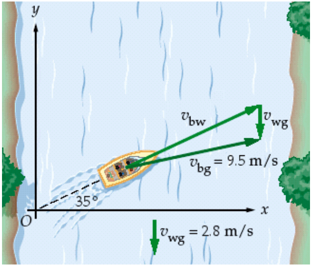
Overview

- one more relative motion problem
- motion in 2D with constant acceleration
- projectile motion
- projectiles launched horizontally

Relative Motion Practice

You are riding on a Jet Ski at an angle of 35° upstream on a river flowing with a speed of 2.8 m/s. If your velocity relative to the ground is 9.5 m/s at an angle of 20.0° upstream, what is the speed of the Jet Ski relative to the water?

(Note: Angles are measured relative to the x axis, which points across the river.)



[1] Walker, "Physics", ch 3, problem 55.

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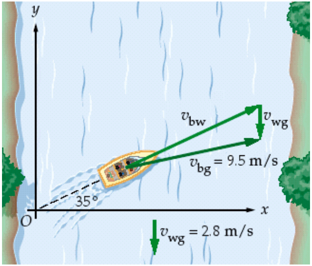

Ans: 11 m/s

[1]Walker, "Physics", ch 3, problem 55.

Relative Motion Practice

For the same river, suppose the Jet Ski is moving at a speed of 12 m/s relative to the water.

(a) At what angle must you point the Jet Ski if your velocity relative to the ground is to be perpendicular to the shore of the river?

(b) If you increase the speed of the Jet Ski relative to the water, does the angle in part (a) increase, decrease, or stay the same? Explain.

(Note: Angles are measured relative to the x axis, which points across the river.)

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Ans: (a) 13° ; (b) decrease

[1] Walker, "Physics", ch 3, problem 56.

Kinematic Equations in 2 Dimensions

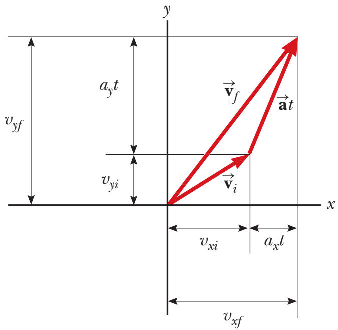
What if velocity is not constant?

If there is acceleration, we can still break down our motional quantities (displacement, velocity, acceleration) into components.

We can solve each component independently.

Kinematic Equations in 2 Dimensions

$$\vec{\mathbf{v}}_f = \vec{\mathbf{v}}_i + \vec{\mathbf{a}}\,t$$



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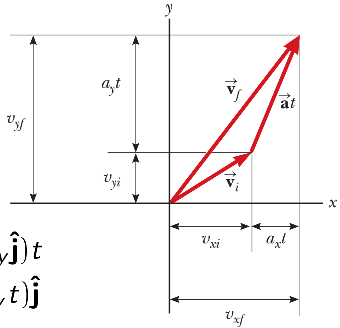


$$\begin{aligned} \vec{\mathbf{v}}_f &= (v_{x,i}\hat{\mathbf{i}} + v_{y,i}\hat{\mathbf{j}}) + (a_x\hat{\mathbf{i}} + a_y\hat{\mathbf{j}})\,t \\ v_x\hat{\mathbf{i}} + v_y\hat{\mathbf{j}} &= (v_{x,i} + a_x t)\hat{\mathbf{i}} + (v_{y,i} + a_y t)\hat{\mathbf{j}} \end{aligned}$$

Equating x-components ($\hat{\mathbf{i}}$-components):

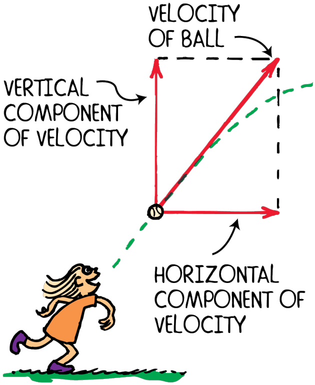
$$v_x = v_{x,i} + a_x t$$

Equating y-components ($\hat{\mathbf{j}}$-components):

$$v_y = v_{y,i} + a_y t$$

Acceleration due to gravity and kinematics

Let's think about the components of the motion separately.



Vertical (y-direction):

constant acceleration, $\vec{\mathbf{g}}$

$$\Delta y = v_{i,y} t - \frac{1}{2} g t^2$$

Horizontal (x-direction):

no acceleration, const. velocity

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

[1] Drawing by Hewitt, via Pearson.

Acceleration due to gravity and kinematics

A constant acceleration gives motion in the shape of a parabola.

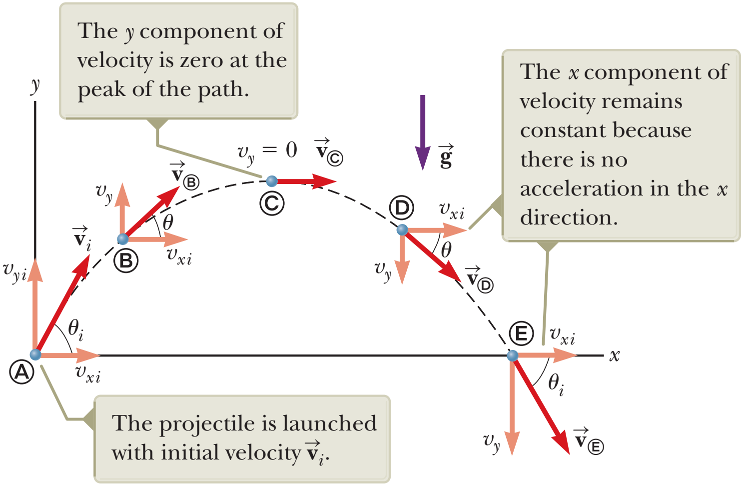
Projectiles

projectile

Any object that is thrown. We will use this word specifically to refer to thrown objects that experience a vertical acceleration g.

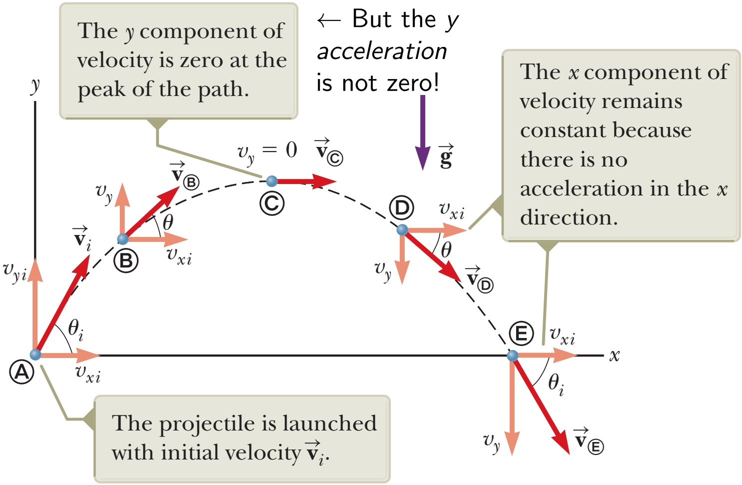
For projectile motion, we assume air resistance is negligible.

Projectile Velocity



[1] Figure from Serway & Jewett, 9th ed.

Projectile Velocity



[1]Figure from Serway & Jewett, 9th ed.

Principle Equations of Projectile Motion

(Notice, these are just special cases of the kinematics equations!)

$$\Delta x = v_{0x} t \qquad v_x = v_{0x} \qquad v_x^2 = v_{0x}^2$$

$$\Delta y = v_{0y} t - \frac{1}{2} g t^2 \qquad v_y = v_{0y} - g t \qquad v_y^2 = v_{0y}^2 - 2g(\Delta y)$$

Upward is the positive direction for these.

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Principle Equations of Projectile Motion

If the projectile is launched straight out horizontally, its motion in the y-direction is the same as for a falling object.

$v_{0y} = 0$, $v_{0x} \neq 0$

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The equations become:

$$\Delta x = v_{0x} t \qquad v_x = v_{0x} \qquad v_x^2 = v_{0x}^2$$

$$\Delta y = -\frac{1}{2} g t^2 \qquad v_y = -gt \qquad v_y^2 = -2g(\Delta y)$$

Horizontal launch example

A ball is thrown horizontally from a cliff at a speed of 10 m/s. What will its speed be (roughly) after 1s?

[1] Hewitt "Conceptual Physics", page 192.

Horizontal launch example

A ball is thrown horizontally from a cliff at a speed of 10 m/s. What will its speed be (roughly) after 1s?

answer: 14 m/s

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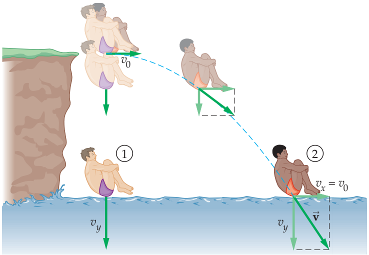
Concept Question



Two youngsters dive off an overhang into a lake. Diver 1 drops straight down, diver 2 runs off the cliff with an initial horizontal speed v_0. Is the splashdown speed of diver 2

(A) greater than,

(B) less than, or

(C) equal to

the splashdown speed of diver 1?

[1] Walker, "Physics", page 90.

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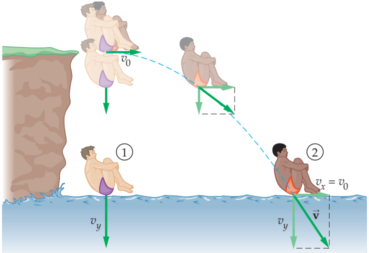

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Summary

- one more relative motion problem
- motion with constant acceleration
- projectile motion
- projectiles launched horizontally

Quiz Thursday

Homework

- relative motion worksheet (answer on scantron and hand in, due Thurs)

Walker Physics:

- Ch 4, onward from page 100. Conceptual Questions: 1, 5; Problems: 3, 5, 9, 11, 13, 15, 17, 25, 84[1]

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[1]Ans: (a) $v_0 = W\sqrt{\frac{g}{2h}}$, (b) $\theta = -\tan^{-1}\left(\frac{2h}{W}\right)$ (minus sign indicates below the horizontal axis).