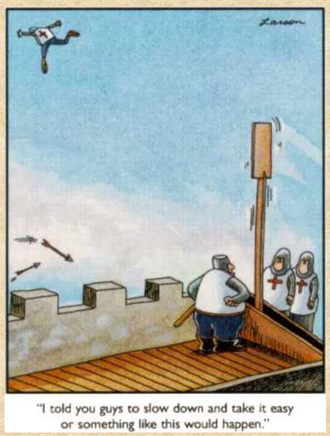


PHYS 11: Chap. 3, Pg 1

1

Chapter 4 – Kinematics in Two Dimensions

- Motion in 2D
- Projectile motion
- Relative motion
- Uniform circular motion
  - angular velocity and angular position
  - centripetal acceleration
- Non-uniform circular motion
  - angular vs. tangential acceleration

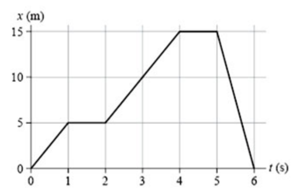
PHYS 22: Chap. 26, Pg 2

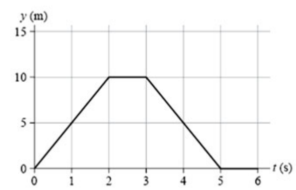
2

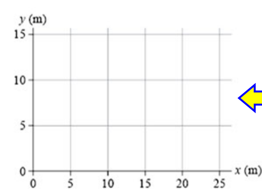
2D Kinematics
(including projectile motion)

3

A particle moving in the x-y plane has these time-dependent plots for its x and y motions.





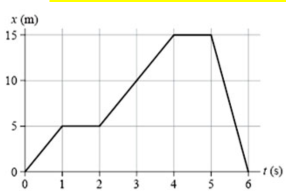


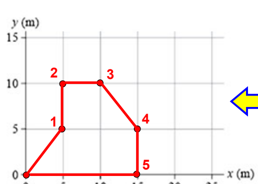
Draw y vs. x plot for the particle.

4.7

4

A particle moving in the x-y plane has these time-dependent plots for its x and y motions.



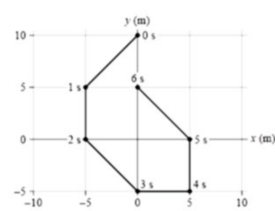


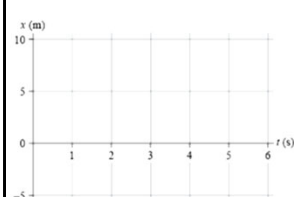
Draw y vs. x plot for the particle.

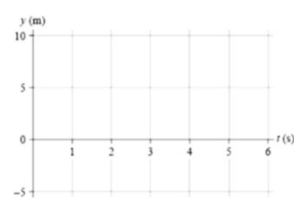
4.7

5

Draw x vs. t and y vs. t plots for this particle.





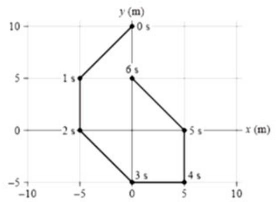


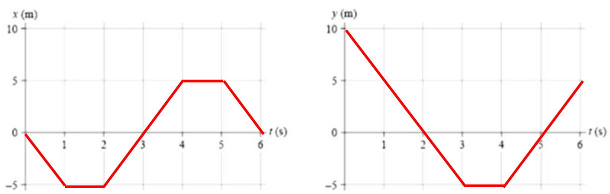
4.8

PHYS 21: Chap. 4, Pg 6

6

Draw x vs. t and y vs. t plots for this particle.





4.8 PHYS 21: Chap. 4, Pg 7

7

Projectile Motion

8

Thanks to the innovative labs of teacher Herb Krenley, physics quickly became Westvale High's most popular course.

PHYS 21: Chap. 4, Pg 9

9

A projectile is launched over level ground and lands some distance away.

a) Is there any point on the trajectory where the velocity **v** and acceleration **a** are parallel to each other? If so, where?
no

b) Is there any point on the trajectory where the velocity **v** and acceleration **a** are perpendicular to each other? If so, where?
yes

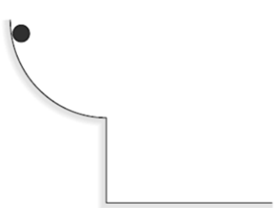
c) Which of the following quantities are *constant* throughout the flight?

x y v v_x v_y a_x a_y

3.30 PHYS 21: Chap. 4, Pg 10

10

A ball rolls down a quarter-circle ramp and then off a cliff. Sketch the trajectory of the ball from the instant of its release until it hits the ground.



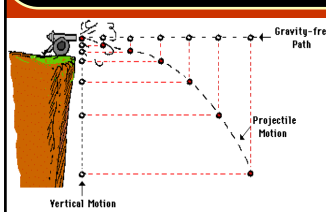
4.9 PHYS 21: Chap. 4, Pg 11

11

ConcepTest 1 Projectile Motion

A ball rolls horizontally off a table, and at the same instant, a second ball is simply dropped from the table? Which ball hits the ground first?

1. the rolling ball hits first
2. the dropped ball hits first
3. both hit at the same time
4. I really have no idea



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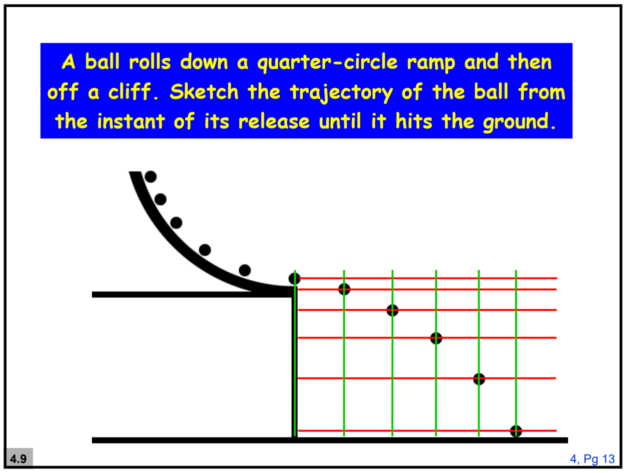
PHYS 21: Chap. 4, Pg 12

12



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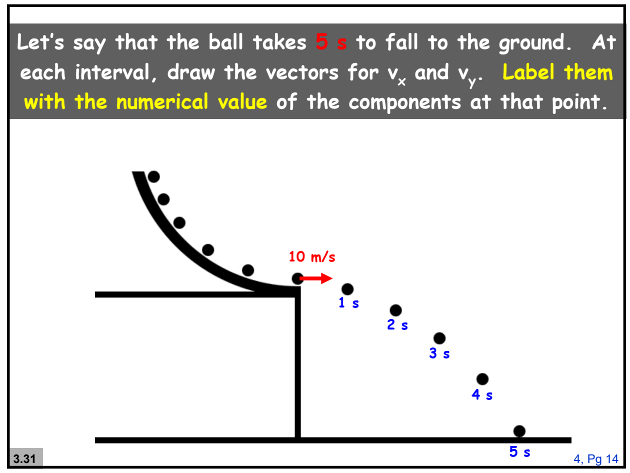

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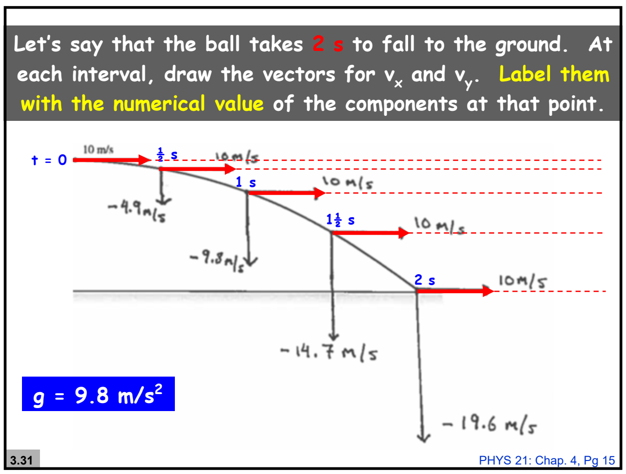

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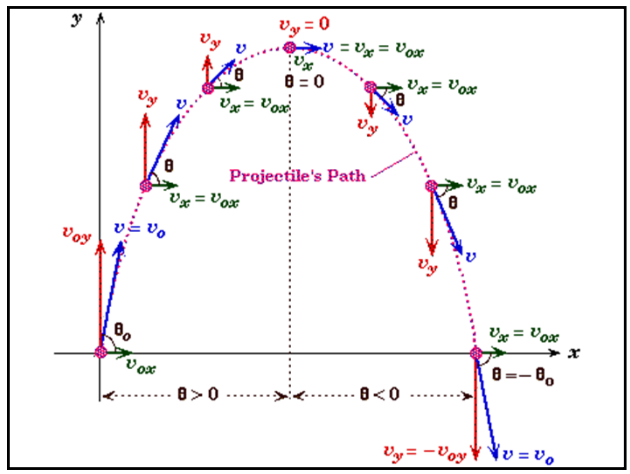

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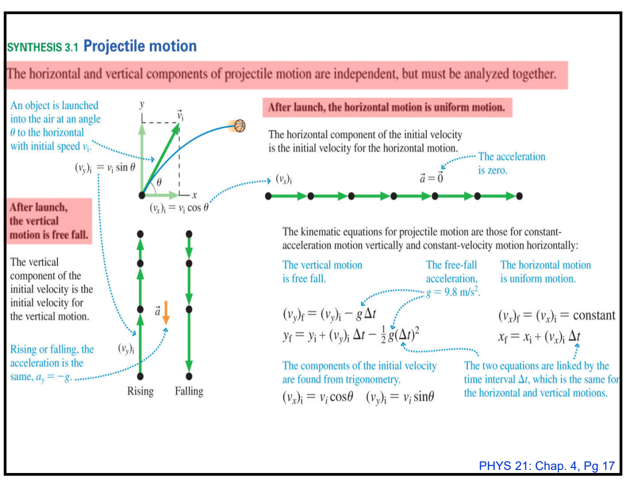

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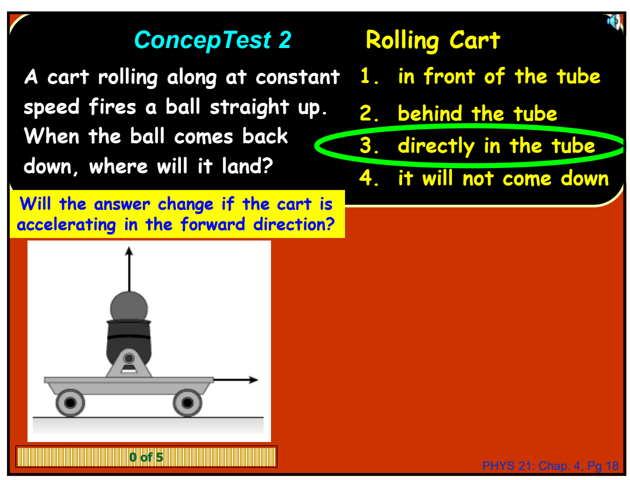

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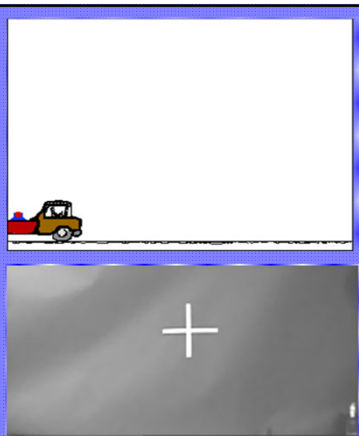


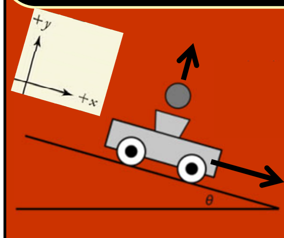
x and y motions are *independent*

19

ConcepTest 2a — Rolling Cart on Incline

The same cart is now rolling down a ramp and shoots the ball out of the tube. Now where does the ball land when it comes back down?

1. in front of the tube
2. behind the tube
3. directly in the tube
4. depends on the speed of the cart



0 of 5

20

x and y motions are *independent*

Kinematic Equations for Constant Acceleration in 2 Dimensions

x Component (horizontal)	*y* Component (vertical)
$v_x = v_{x0} + a_x t$	$v_y = v_{y0} + a_y t$
$x = x_0 + v_{x0} t + \frac{1}{2} a_x t^2$	$y = y_0 + v_{y0} t + \frac{1}{2} a_y t^2$
$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$	$v_y^2 = v_{y0}^2 + 2a_y(y - y_0)$

Projectile Motion: $a_x = 0$ and v_x = const.

(y positive upward; $a_x = 0$, $a_y = -g = -9.80\ \mathrm{m/s^2}$)

Horizontal Motion ($a_x = 0$, v_x = constant)	Vertical Motion† ($a_y = -g$ = constant)
$v_x = v_{x0}$	$v_y = v_{y0} - gt$
$x = x_0 + v_{x0} t$	$y = y_0 + v_{y0} t - \frac{1}{2} g t^2$
	$v_y^2 = v_{y0}^2 - 2g(y - y_0)$

† If y is taken positive downward, the minus (−) signs in front of g become plus (+) signs.

21

PROBLEM-SOLVING APPROACH 3.1 **Projectile motion problems**

1 **STRATEGIZE** We will solve projectile motion problems by considering the horizontal and vertical motions as separate but related problems.

2 **PREPARE** There are a number of steps that you should go through in setting up the solution to a projectile motion problem:

- Make simplifying assumptions. Whether the projectile is a car or a basketball, the motion will be the same.
- Draw a visual overview including a pictorial representation showing the beginning and ending points of the motion.
- Establish a coordinate system with the x-axis horizontal and the y-axis vertical. In this case, you know that the horizontal acceleration will be zero and the vertical acceleration will be free fall: $a_x = 0$ and $a_y = -g$.
- Draw a vector representing the initial velocity, and find its x- and y-components in terms of the initial speed and the launch angle.
- Define symbols and write down a list of known values. Identify what the problem is trying to find.

3 **SOLVE** There are two sets of kinematic equations for projectile motion, one for the horizontal component and one for the vertical:

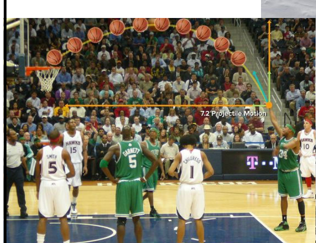
Horizontal	Vertical
$x_f = x_i + (v_x)_i \Delta t$	$y_f = y_i + (v_y)_i \Delta t - \frac{1}{2} g (\Delta t)^2$
$(v_x)_f = (v_x)_i$ = constant	$(v_y)_f = (v_y)_i - g \Delta t$

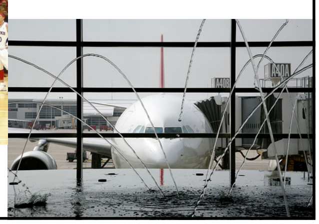
Δt is the same for the horizontal and vertical components of the motion. Find Δt by solving for the vertical or the horizontal component of the motion; then use that value to complete the solution for the other component.

4 **ASSESS** Check that your result has the correct units, is reasonable, and answers the question.

22

Projectile Motion

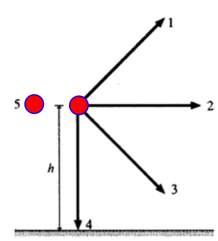




23

Four balls are launched at the same speed from height h. Simultanously, ball 5 is dropped from rest at the same height.

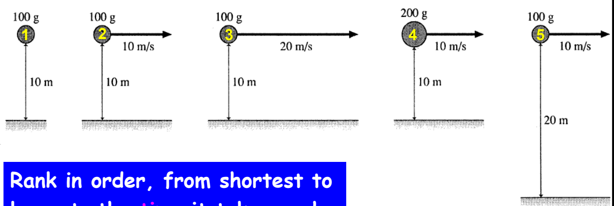
Rank in order, from shortest to longest, the time it takes each of the balls to hit the ground.



4 < 3 < (2=5) < 1

3.39

24



Rank in order, from shortest to longest, the time it takes each of these balls to hit the ground.

(1=2=3=4) < 5

1 < (2=4) < 5 < 3

Rank in order, from shortest to longest, the horizontal distance that each of these balls travels before hitting the ground.

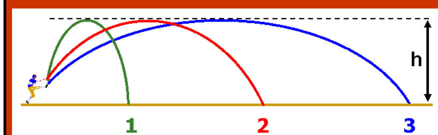
3.34

25

ConcepTest 3 Projectile Motion

Rank in order, from longest to shortest, the time in the air for each of these kicks.

1. 1 > 2 > 3
2. 1 = 2 = 3
3. 3 > 2 > 1



Follow-up: how would you rank the initial launch speeds of the kicks?

3 > 2 > 1

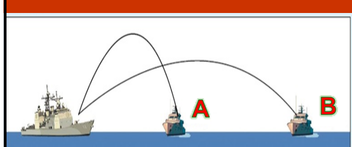
0 of 5

26

ConcepTest 4 Projectile Motion

A battleship simultaneously fires two shells at enemy ships, and the trajectories are shown. Which ship gets hit first?

1. ship A
2. ship B
3. both at the same time



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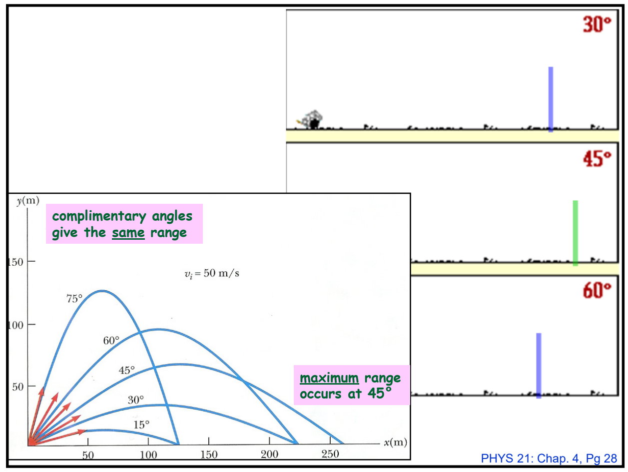
27



PHYS 21: Chap. 4, Pg 28

28

The longest recorded pass in an NFL game traveled **83 yds** in the air from the quarterback to the receiver. If the pass was thrown at a launch angle of **45°**, what was the speed at which the ball left the quarterback's hand?

x = 27.3 m/s

3.64

PHYS 21: Chap. 2, Pg 29

29

The longest recorded pass in an NFL game traveled **83 yds** in the air from the quarterback to the receiver. If the pass was thrown at a launch angle of **45°**, what was the speed at which the ball left the quarterback's hand?

x = 27.3 m/s

$v_{ix} = v(cos\theta)$ $v_{iy} = v(sin\theta)$

$$v_{fy} = -v_{iy} = v_{iy} - gt \quad \Rightarrow \quad t = \frac{v_{fy} - v_{iy}}{-g} = \frac{-2v(\sin\theta)}{-g}$$

$$\Delta x = v_{ix}t = v(\cos\theta)t = \frac{2v^2(\cos\theta)(\sin\theta)}{g} = 83\,yds = 76\,m$$

$$v^2 = \frac{g(76\,m)}{2(\cos 45)(\sin 45)} \quad \Rightarrow \quad v = \sqrt{\frac{g(76\,m)}{2\,(\cos 45)(\sin 45)}} = 27.3\,m$$

3.64

PHYS 21: Chap. 2, Pg 30

30