Free Fall

1

ConcepTest 3 **Free Fall**

A ball is thrown straight up into the air. At the top of its rise (maximum height), what is the magnitude of the ball's acceleration?

1. a > g
2. a = g
3. 0 < a < g
4. a = 0
5. a < 0

What is the velocity of the ball at that point?

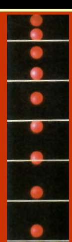
0 of 5

2

ConcepTest 2 **Kinematics**

What is the direction of the velocity and the acceleration for the ball in the following stop-action photo?

1. v is up, a is up
2. v is up, a is down
3. v is down, a is up
4. v is down, a is down
5. hmm, I just don't know



0 of 5

3

ConcepTest 5 **Free Fall**

A rock is thrown straight down from a bridge. Immediately after being released, what is the magnitude of the rock's acceleration?

1. a > g
2. a = g
3. 0 < a < g
4. a = 0
5. a < 0

Follow-up: Just before hitting the river, what is the rock's acceleration?

0 of 5

4

Tangible

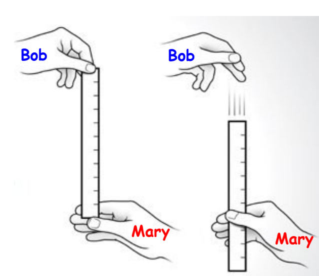
Dropping a $100 bill

w = 15.6 cm
w/2 = 7.8 cm
t = 0.126 s

5

Tangible

Measuring Reaction Time



6

There are times when being a whiz at physics can be a definite drawback.

Is this right?

50 ft = 15.2 m
v = 17.3 m/s
87 mi/hr = 38.9 m/s

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7

see page 51

PROBLEM-SOLVING APPROACH

The first step in solving a seemingly complicated problem is to break it down into a series of smaller steps. In worked examples in the text, we use a problem-solving approach that consists of four steps: *strategize, prepare, solve,* and *assess*. Each of these steps has important elements that you should follow when you solve problems on your own.

STRATEGIZE The Strategize step of the solution is where you address the *big-picture* questions about the problem. Here, you take a step back from the details of the problem to ask:

- **What kind of problem is this?** From reading the problem statement, try to categorize the problem in terms of what you've learned in the chapter. If, for instance, the problem refers to a bicyclist riding at a constant 7.0 m/s, this suggests the problem is about uniform motion.
- **What's the correct general approach?** What principles, strategies, and tactics that you've learned are relevant in solving this problem? For example, if you're given a position-versus-time graph and are asked to find the velocity, the principle that the velocity is related to the slope of the position graph is likely to be important.
- **What should the answer look like?** Is a numerical answer asked for? Do you need a graph or a sketch?

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8

MP™ Problem-Solving Strategy

PREPARE The Prepare step of a solution is where you identify important elements of the problem and collect information you will need to solve it. It's tempting to jump right to the Solve step, but a skilled problem solver will spend the most time on this step, the preparation. Preparation includes:

- **Drawing a picture.** In many cases, this is the most important part of a problem. The picture lets you model the problem and identify the important elements. As you add information to your picture, the outline of the solution will take shape. For the problems in this chapter, a picture could be a motion diagram or a graph—or perhaps both.
- **Collecting necessary information.** The problem's statement may give you some values of variables. Other important information may be implied or must be looked up in a table. Gather everything you need to solve the problem and compile it in a list.
- **Doing preliminary calculations.** There are a few calculations, such as unit conversions, that are best done in advance of the main part of the solution.

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9

SOLVE The Solve step of a solution is where you actually do the mathematics or reasoning necessary to arrive at the answer needed. This is the part of the problem-solving strategy that you likely think of when you think of "solving problems." But don't make the mistake of starting here! The Prepare step will help you be certain you understand the problem before you start putting numbers in equations.

ASSESS The Assess step of your solution is very important. When you have an answer, you should check to see whether it makes sense. Ask yourself:

- **Does my solution answer the question that was asked?** Make sure you have addressed all parts of the question and clearly written down your solutions.
- **Does my answer have the correct units and number of significant figures?**
- **Does the value I computed make physical sense?** In this book all calculations use physically reasonable numbers. You will not be given a problem to solve in which the final velocity of a bicycle is 100 miles per hour! If your answer seems unreasonable, go back and check your work.
- **Can I estimate what the answer should be to check my solution?**
- **Does my final solution make sense in the context of the material I am learning?**

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10

A policeman hiding behind a billboard sees a speeding car zoom by him at a constant speed of 35 m/s. The policeman starts from rest and takes up the chase, accelerating at 5 m/s² until he catches the culprit.

How long does it take him to catch the speeding car?

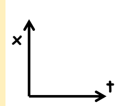
t = 14 s

Kinematic equations for motion with constant acceleration:

$$(v_x)_f = (v_x)_i + a_x\,\Delta t$$

$$x_f = x_i + (v_x)_i\,\Delta t + \tfrac{1}{2}a_x(\Delta t)^2$$

$$(v_x)_f^2 = (v_x)_i^2 + 2a_x\,\Delta x$$



3+2=5

Can you represent this problem graphically?

11

A policeman hiding behind a billboard sees a speeding car zoom by him at a constant speed of 35 m/s. The policeman starts from rest and takes up the chase, accelerating at 5 m/s² until he catches the culprit.

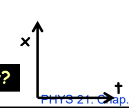
How long does it take him to catch the speeding car?

t = 14 s

SOLUTION

$$x_{car} = v_{car}t \quad = \quad x_{police} = \frac{1}{2}a_{police}t^2$$

$$v_{car}t = \frac{1}{2}a_{police}t^2 \quad \Rightarrow \quad t = \frac{2v_{car}}{a_{police}} = \frac{2\left(35\,\frac{m}{s}\right)}{5\,\frac{m}{s^2}} = 14\,s$$



Can you represent this problem graphically?

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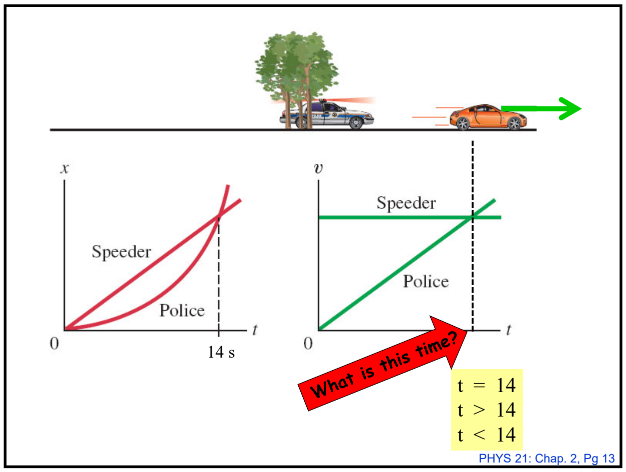

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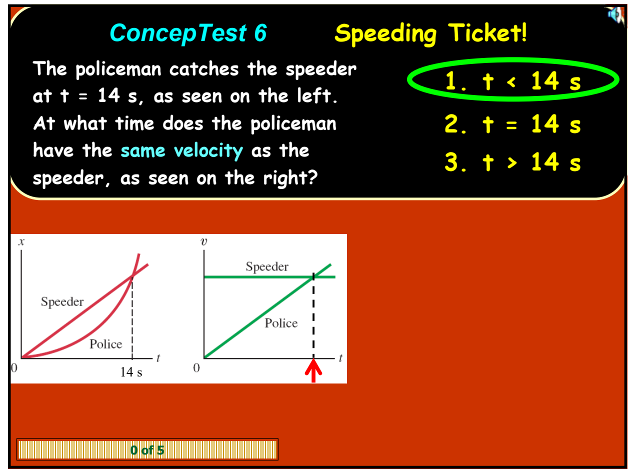

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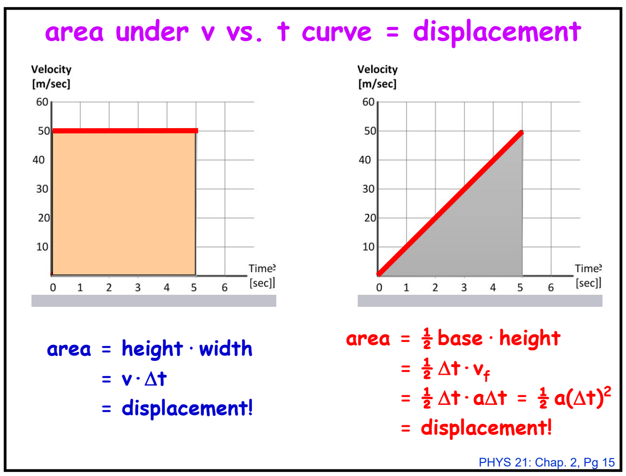

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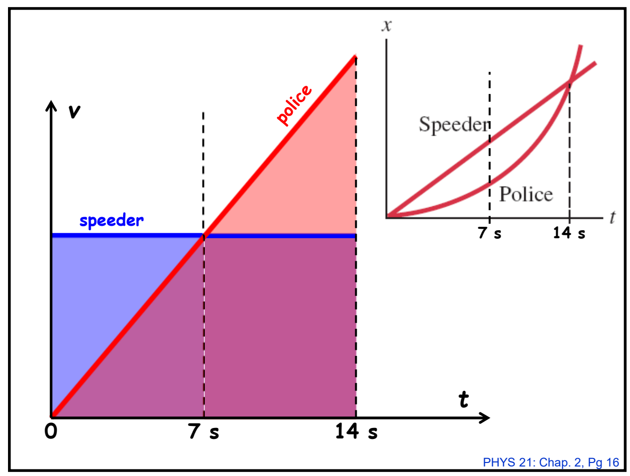

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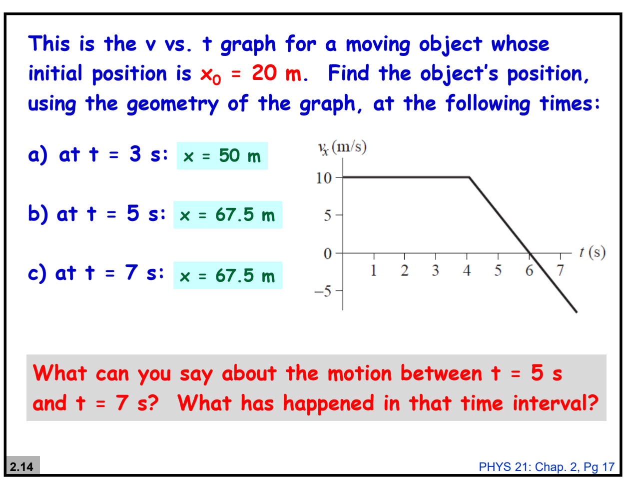

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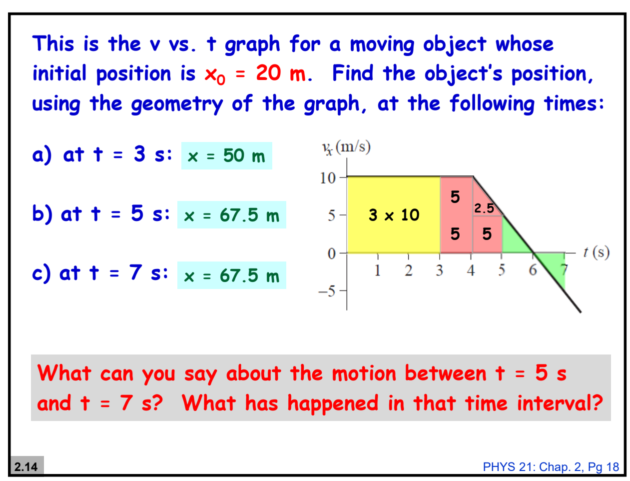


18

A driver has a reaction time of 0.5 s, and the maximum deceleration of her car is 6 m/s^2.
She is driving at 20 m/s when suddenly she sees a deer in the road 50 m in front of her.

Can she stop the car in time to avoid the deer?

x_{tot} = 43.3 m

Kinematic equations for motion with constant acceleration:

$$(v_x)_f = (v_x)_i + a_x\,\Delta t$$

$$x_f = x_i + (v_x)_i\,\Delta t + \tfrac{1}{2}a_x(\Delta t)^2$$

$$(v_x)_f^2 = (v_x)_i^2 + 2a_x\,\Delta x$$

3+2: 5

2.45

19

A driver has a reaction time of 0.5 s, and the maximum deceleration of her car is 6 m/s^2.
She is driving at 20 m/s when suddenly she sees a deer in the road 50 m in front of her.

Can she stop the car in time to avoid the deer?

x_{tot} = 43.3 m

SOLUTION

$$x_1 = v_0 t_1 = \left(20\,\tfrac{m}{s}\right)(0.5\,s) = 10\,m$$

$$v_f^2 = v_0^2 - 2ax_2 \;\Longrightarrow\; x_2 = \frac{-v_0^2}{-2a} = \frac{\left(20\,\frac{m}{s}\right)^2}{2\left(6\,\frac{m}{s^2}\right)^2} = 33.3\,m$$

$$x_{tot} = x_1 + x_2 = 43.3m$$

20

A model rocket is launched straight up with constant acceleration *a*. It runs out of fuel at time *t*.

You need to figure out the maximum height that the rocket reaches.

What is your strategy for solving this problem?
Outline the steps that you would follow to solve it.

2.22

21

Bill can throw a ball vertically at a speed 1.5 times faster than Joe can throw it.

How many times higher will Bill's ball go, as compared to Joe's ball?

2.25 times higher

Kinematic equations for motion with constant acceleration:

$$(v_x)_f = (v_x)_i + a_x\,\Delta t$$

$$x_f = x_i + (v_x)_i\,\Delta t + \tfrac{1}{2}a_x(\Delta t)^2$$

$$(v_x)_f^2 = (v_x)_i^2 + 2a_x\,\Delta x$$

3+2: 5

22

Bill can throw a ball vertically at a speed 1.5 times faster than Joe can throw it.

How many times higher will Bill's ball go, as compared to Joe's ball?

2.25 times higher

SOLUTION

Joe's throw: $v_f^2 = v_0^2 - 2gy_{Joe} = 0 \;\Longrightarrow\; y_{Joe} = \dfrac{v_0^2}{2g}$

Bill's throw: $v_0(Bill) = 1.5 \cdot v_0(Joe)$

$$v_f^2 = (1.5v_0)^2 - 2gy_{Bill} = 0 \;\Longrightarrow\; y_{Bill} = \frac{(1.5v_0)^2}{2g} = \frac{9}{4}\cdot\left(\frac{v_0^2}{2g}\right) = \frac{9}{4}y_{Joe}$$

23

You are standing on the roof of a building, 30 m above the ground. You drop a ball off the roof – it leaves your hand with zero velocity.
When the ball is ***halfway to the ground***, you throw a second ball downward such that this second ball reaches the ground at the ***same time*** as the first ball.

With what speed did you have to throw the second ball?

v = 38.1 m/s

Kinematic equations for motion with constant acceleration:

$$(v_x)_f = (v_x)_i + a_x\,\Delta t$$

$$x_f = x_i + (v_x)_i\,\Delta t + \tfrac{1}{2}a_x(\Delta t)^2$$

$$(v_x)_f^2 = (v_x)_i^2 + 2a_x\,\Delta x$$

3+2: 5

24

You are standing on the roof of a building, 30 m above the ground. You drop a ball off the roof – it leaves your hand with zero velocity.
When the ball is ***halfway to the ground***, you throw a second ball downward such that this second ball reaches the ground at the ***same time*** as the first ball.

With what speed did you have to throw the second ball?

SOLUTION

$$t_{tot}(ball1) = \sqrt{\frac{2y_{tot}}{g}} = \sqrt{\frac{2(30m)}{9.8m/s^2}} = 2.47s$$

v = 38.1 m/s

$$t_1(ball1) = \sqrt{\frac{2y_1}{g}} = \sqrt{\frac{2(15m)}{9.8m/s^2}} = 1.75s$$

$$t_2(ball1) = t_{tot}(ball1) - t_1(ball1) = 0.72s = t(ball2)$$

$$y_2(ball2) = v_0 t_2 + \frac{1}{2} g t_2^2 \Rightarrow v_0 = \frac{y_2 - \frac{1}{2} g t_2^2}{t_2} = 38.1 m/s$$

25

A rock is thrown vertically upward with a speed of 19 m/s. Exactly 1.0 s later, a ball is thrown upward along the same path with a speed of 27 m/s.

a) At what time will they hit each other?

t = 1.79 s

b) At what height will the collision occur?

h = 18.3 m

$$(v_x)_f = (v_x)_i + a_x \Delta t$$

$$x_f = x_i + (v_x)_i \Delta t + \tfrac{1}{2} a_x (\Delta t)^2$$

$$(v_x)_f^2 = (v_x)_i^2 + 2a_x \Delta x$$

What would happen if the order is reversed, i.e., if the ball is thrown 1.0 s before the rock?

26

A rock is thrown vertically upward with a speed of 19 m/s. Exactly 1.0 s later, a ball is thrown upward along the same path with a speed of 27 m/s.

a) At what time will they hit each other? **t = 1.79 s**

b) At what height will the collision occur? **h = 18.3 m**

SOLUTION

$$\left.\begin{aligned} y_1 &= 19t - \frac{1}{2} g t^2 \\ y_2 &= 27(t-1) - \frac{1}{2} g (t-1)^2 \end{aligned}\right\}$$ collision occurs when $y_1 = y_2$

$$y_1 = y_2 \Rightarrow 19t - \frac{1}{2} g t^2 = 27(t-1) - \frac{1}{2} g (t-1)^2$$

solve for t (involves some algebra)

then put your value for t back into Eqn. 1 or Eqn. 2 to find the height

27

A ball released from rest on an inclined plane accelerates down the plane at 2 m/s^2. Fill in the table below with the ball's velocities at the indicated times.

(Do not use a calculator! Approach this question conceptually.)

Time (s)	Velocity (m/s)
0	0
1	
2	
3	
4	
5	

2.23

28

A ball released from rest on an inclined plane accelerates down the plane at 2 m/s^2. Fill in the table below with the ball's velocities at the indicated times.

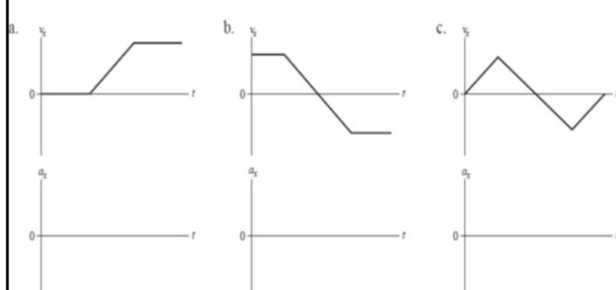
(Do not use a calculator! Approach this question conceptually.)

Time (s)	Velocity (m/s)
0	0
1	**2**
2	**4**
3	**6**
4	**8**
5	**10**

2.23

29

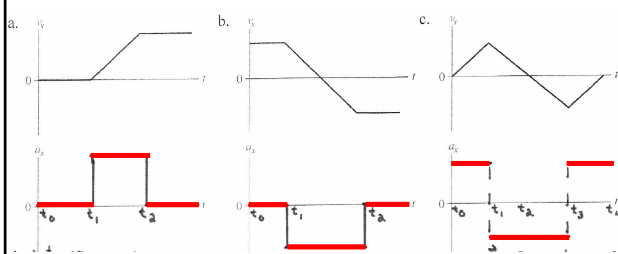
For the v vs. t graphs, draw corresponding a vs. t graphs. Draw a motion diagram for each case.



2.17

30

For the v vs. t graphs, draw corresponding a vs. t graphs. Draw a motion diagram for each case.



2.17 PHYS 21: Chap. 2, Pg 31

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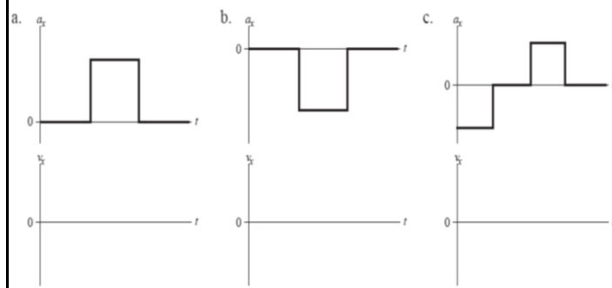
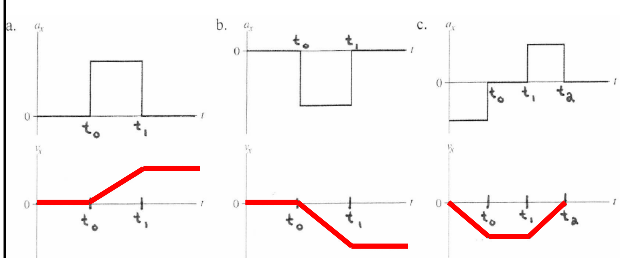
For the a vs. t graphs, draw corresponding v vs. t graphs. Describe the motion in words. Assume that $v_0 = 0$.



2.18 PHYS 21: Chap. 2, Pg 32

32

For the a vs. t graphs, draw corresponding v vs. t graphs. Describe the motion in words. Assume that $v_0 = 0$.



2.18 PHYS 21: Chap. 2, Pg 33

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