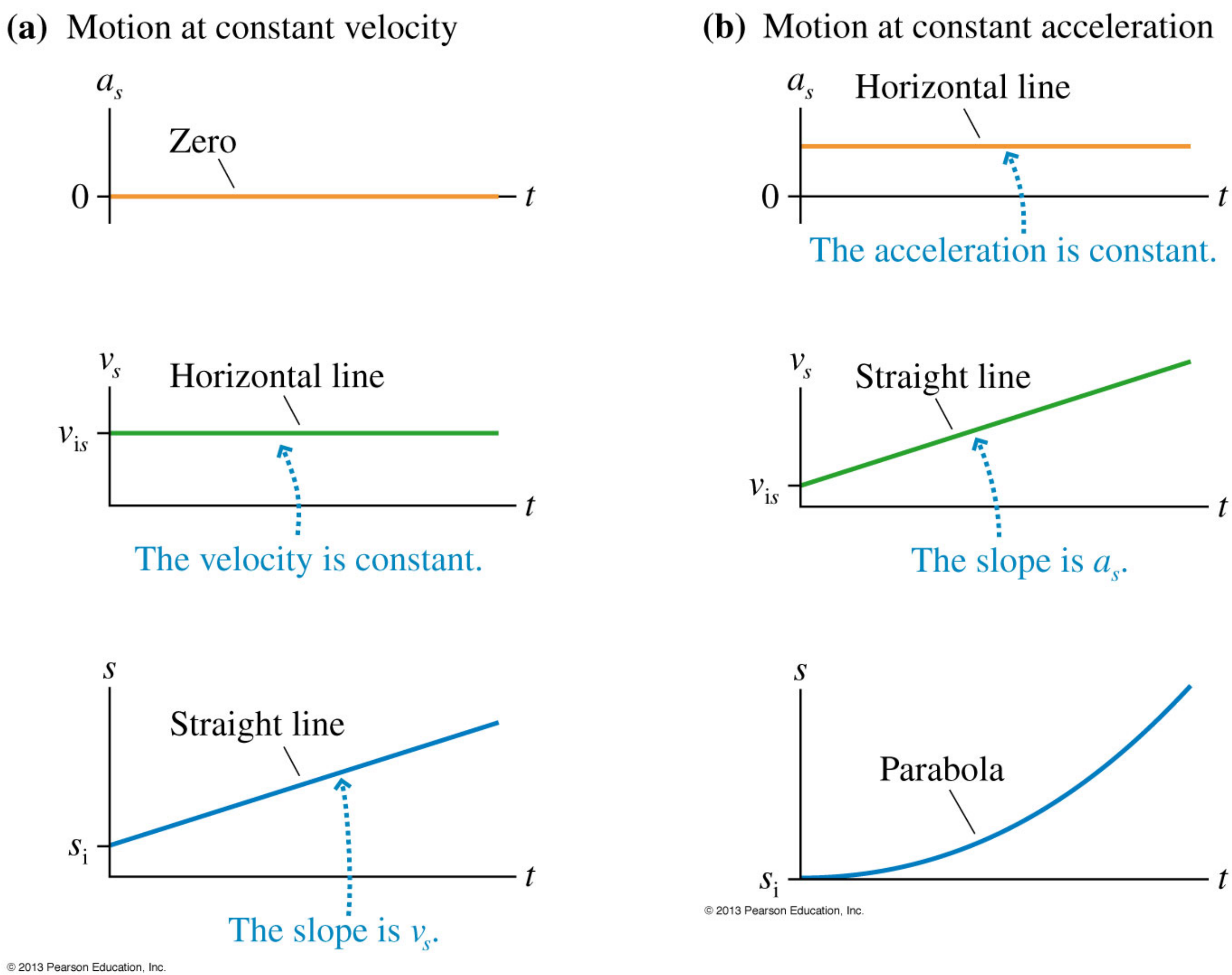
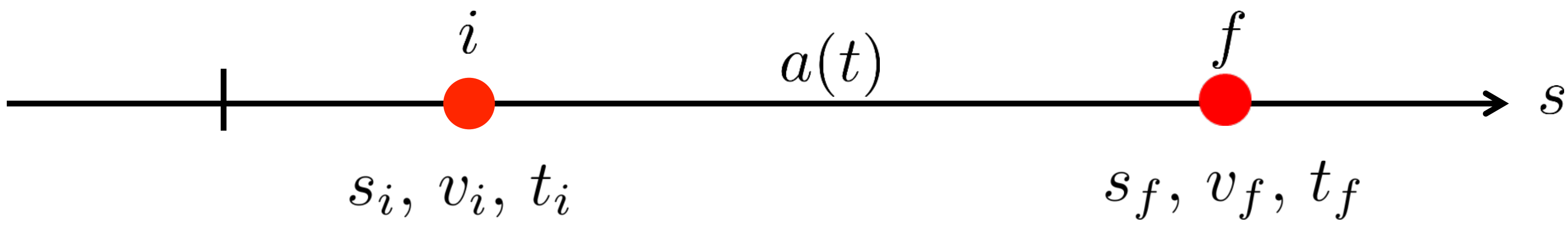
Objectives today: (Sec 2.4 + 2.5 + 2.7)

- Derive the three equations of kinematics for motion with constant acceleration
- Apply the three kinematic equations above to solve problems
- Give you a chance to take my money!
- ~~Measure *g*~~

Constant Acceleration 1D Kinematics: Graphs (Sec. 2.4)



Review of General 1D Kinematics



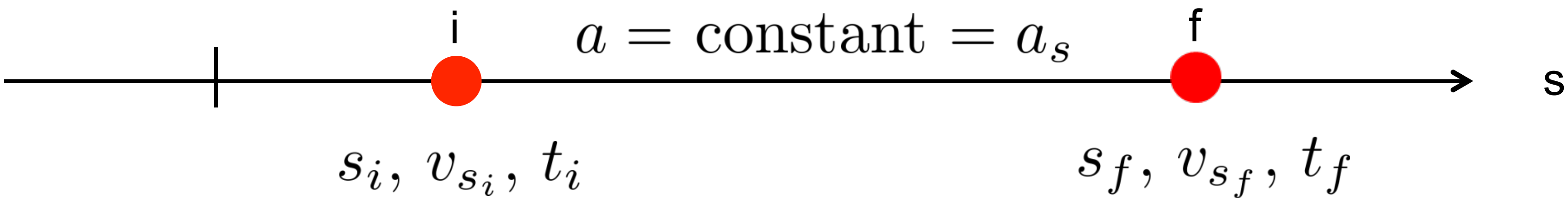
The instantaneous velocity and acceleration are (Sec. 2.2 + 2.7):

$$v_s = \frac{ds}{dt} \qquad a_s = \frac{dv_s}{dt}$$

If we know the position and velocity at the initial point i, we find can the position and velocity at point f by **(Sec. 2.3 + 2.7)**:

$$s_f = s_i + \int_{t_i}^{t_f} v_s dt \qquad v_f = v_i + \int_{t_i}^{t_f} a_s dt$$

Constant Acceleration 1D Kinematics: Equations



In many problems that we'll do, the acceleration will be constant . . . Why?

Let's derive the *1st equation of 1D kinematics with constant acceleration* ***(This is Eqn. 2.19 in the book)***:
Let's do a quick math review before diving in…

Algebra Review Activity - 1

Consider the Equation:

$$x = x_0 + \frac{1}{2}at^2$$

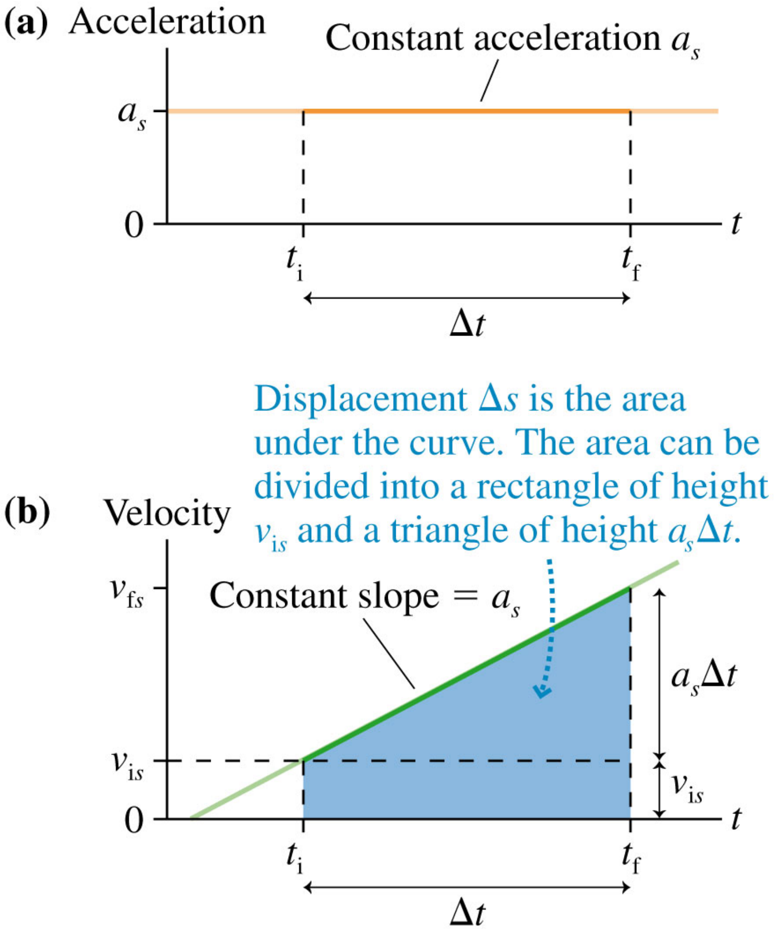
Find an expression for t in terms of x, x_0 and a

Algebra Review Activity - 2

For the set of equations below, solve for x and y.

$$2x - 3y = -3$$
$$4x + 2y = -2$$

Now let's derive the *2nd equation of 1D kinematics with constant acceleration…(**Eqn. 2.21 in book**)*



The *3rd equation of 1D kinematics with constant acceleration falls right out from the first two…* ***(Eqn. 2.23 in book)***

$$v_{\mathrm{f}s}{}^2 = v_{\mathrm{i}s}{}^2 + 2a_s\,\Delta s$$

The Kinematic Equations of Constant Acceleration (Sec. 2.4)

The kinematic equations for motion with constant acceleration

$$v_{fs} = v_{is} + a_s \Delta t$$

$$s_f = s_i + v_{is} \Delta t + \frac{1}{2} a_s (\Delta t)^2$$

$$v_{fs}^2 = v_{is}^2 + 2 a_s \Delta s$$

Whiteboard Problem 2.7, Ch2 #16

When you sneeze, the air in your lungs accelerates from rest to 150 km/h in ≈ 0.50s. What is the acceleration of the air in m/s^2?

Problem-Solving Strategy:

- Draw a picture or graph of the situation
- Identify your known and unknown variables
- Decide what quantity the question is asking for
- Choose the appropriate kinematic equation and apply it
- You may need to apply two kinematic equations simultaneously.

http://www.dailymail.co.uk/sciencetech/article-2600044/The-slow-motion-video-reveals-sneezes-travel-far-thought-create-cloud.html

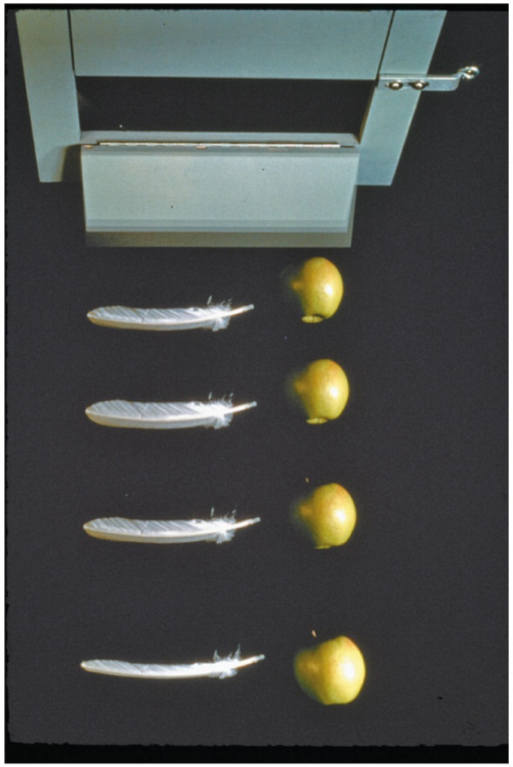
Whiteboard Problem 2.8, Ch2 #64

Bob is driving the getaway car after the big bank robbery. He's going 50 m/s when his headlights suddenly reveal a nail strip that the cops have placed across the road 150 m in front of him. If Bob can stop in time, he can throw the car into reverse and escape. But if he crosses the nail strip, all his tires will go flat and he will be caught. Bob's reaction time before he can hit the brakes is 0.60 s, and his car's maximum deceleration is 10 m/s^2. Is Bob in jail?

Important Application of Constant Acceleration Kinematics: **Free Fall (Sec 2.5)**

- The motion of an object moving under the influence of gravity only, and no other forces, is called **free fall**.
- Galileo: All objects fall at the same rate!
- Strictly true only in vacuum…but how restrictive is this condition?
- Near the surface of the Earth (up to ~10 km high)

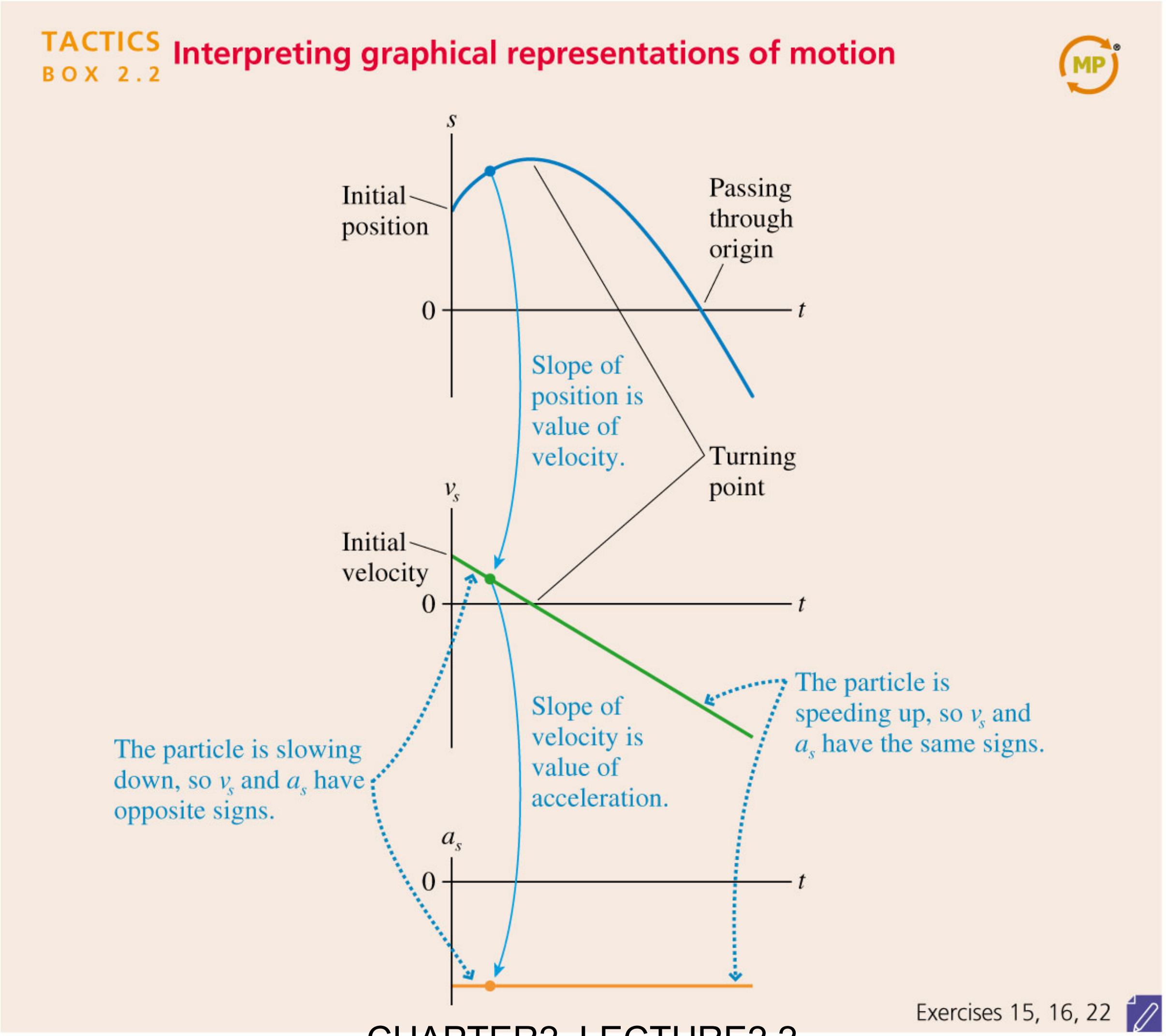
$$\vec{a}_{\text{free fall}} = (9.80 \text{ m/s}^2, \text{vertically downward})$$



In the absence of air resistance, any two objects fall at the same rate and hit the ground at the same time. The apple and feather seen here are falling in a vacuum.

Bowling ball and feather dropped in a vacuum
https://www.youtube.com/watch?v=E43-CfukEgs
(beginning to 3:45)

Graphical Representations of Ball thrown upward (**in free fall**)



Take my money!

- Physics works only in vacuum, eh?

- $\Delta y = 15.5$ cm; a_y= 9.8 m/s^2 down; v_i = __

Published literature shows that the average NCAA football player has a reaction time of 0.203 s (measured by having them catch a falling meter stick)

http://biae.clemson.edu/bpc/bp/lab/110/reaction.htm#Mean%20Times

Whiteboard Problem 2.9: Ch2 #22

A rock is tossed straight up with a speed of 20 m/s. When it returns, it falls into a hole 10 m deep.

a) What is the rock's velocity as it hits the bottom of the hole?
b) How long is the rock in the air, from the instant it is released until it hits the bottom of the hole?

CONCEPTUAL QUESTION ON 1D KINEMATICS (CHAPTER 2)

"*Taking air resistance into account*, the time taken to go up by a ball thrown straight up is _______________ the time taken to come back down to the level from which it was thrown."

a) slightly more than
b) slightly less than
c) equal to
d) Not enough information, can't say

Reason: The ball travels the same distance going up as it does going down, obviously. But the average speed going up is faster then the average speed coming back down, hence less time is taken going up.
Put another way, if the acceleration imparted by air resistance is a the magnitude of the net acceleration going up is $g+a$, but coming down is $g-a$. Hence, compared to the case of no air resistance, the ball is brought to rest quicker on the way up (travels less distance upward), and furthermore, on the way down the ball lacks the required acceleration to build up to its original launch velocity.

Whiteboard Problem 2.10: Ch2 #57

51. ||| A lead ball is dropped into a lake from a diving board 5.0 m above the water. After entering the water, it sinks to the bottom with a constant velocity equal to the velocity with which it hit the water. The ball reaches the bottom 3.0 s after it is released. How deep is the lake?

Discuss HW challenge problem Ch2 #80

A rocket is launched straight up with constant acceleration. Four seconds after liftoff, a bolt falls off the side of the rocket. The bolt hits the ground 6.0 s Later. What was the rocket's acceleration?

[Hint: to get started, see the solution to Quiz1 (Green) posted on the Course schedule]

A *challenging* Challenge HW Problem: 2-84

82. A rubber ball is shot straight up from the ground with speed v_0. Simultaneously, a second rubber ball at height h directly above the first ball is dropped from rest.

   a. At what height above the ground do the balls collide? Your answer will be an *algebraic expression* in terms of h, v_0, and g.

   b. What is the maximum value of h for which a collision occurs before the first ball falls back to the ground?

   c. For what value of h does the collision occur at the instant when the first ball is at its highest point?