Physics 111.01

Lecture 4 (Walker: 2.7, 3.1-2)

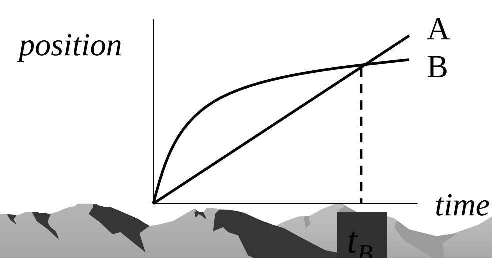
Motion Examples with Acceleration
Gravity & Free Fall
Vector Components

Sept. 9, 2009

ConcepTest

The graph shows position as a function of time for the fronts of two trains running on parallel tracks. Which of the following is true:

1. at time t_B both trains have the same velocity
2. both trains speed up all the time
3. both trains have the same velocity at some time before t_B
4. the trains have the same acceleration
5. all of the above statements are true



Problem Solving Strategy for 1-D Motion with Constant Acceleration

- **Picture** - Determine if problem is asking you to find time, distance, velocity, or acceleration for an object.
- **Solve** - Use the following steps to solve problems that involve 1-D motion and constant acceleration:

1. Draw figure showing particle in initial and final positions. Include coordinate axis and label initial and final coordinates of the position.
2. Select one or more of the constant-acceleration kinematic equations. Solve them algebraically for the desired quantities, then substitute in given values & evaluate answer.
3. Repeat as needed.

- **Check** - Make sure your answers are dimensionally consistent and are in the expected "ballpark".

Problem 63, Walker Chap. 2

A model rocket rises with constant acceleration to a height of 3.2 m, at which point its speed is 26.0 m/s.

(a) How much time does it take for the rocket to reach this height?

(b) What was the rocket's acceleration?

(c) Find the height of the rocket 0.10 s after launch.

Solving the problem

- What is known

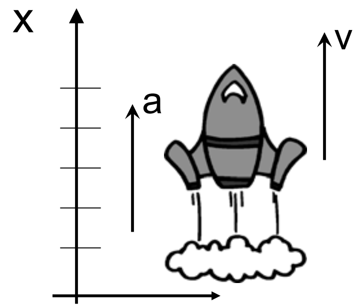
  X_f = 3.2 m

  V_f = 26.0 m/s

Assuming

  v_0 = 0 m/s

  x_0 = 0 m



To be determined:

(a) t_f – time it takes rocket to reach the height x_f

(b) a – the rocket's acceleration

(c) x (t=0.1s)

Solution

Starting equation

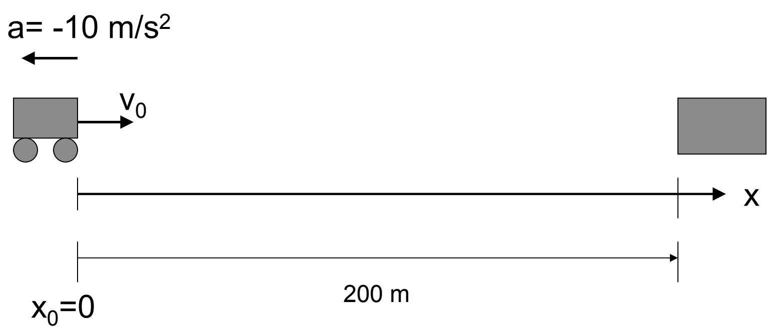
Part (b)

Part (c)

Part (a)

Example: Hit the Brakes!

Man driving at velocity v_0 suddenly sees stopped truck 200 m ahead. He applies brakes and slows with an acceleration of $-10\ m/s^2$, just missing truck. What was v_0? How long did it take to stop?



$0 = v_0^2 + 2(-10\ m/s^2)(200m)$

$v_0^2 = 4000\ m^2/s^2$

$v_0 = 63\ m/s = 141\ mi/h$

Time to stop?

$v = v_0 + at$

$0 = 63\ m/s + (-10\ m/s^2)\ t$

$t = 6.3\ s$

Free Fall

- Objects moving under the influence of <u>only</u> the force of Earth gravity are said to be in <u>free fall</u>
- Force of Earth gravity on object of mass **m** located near surface of Earth has size **mg** and a direction pointing toward the center of the Earth (i.e., downward)
- **g** = 9.80 m/s^2 = 9.80 N/kg
- <u>Newton's Second Law</u> says acceleration of mass m produced by force of size F is given by a = F/m with the same direction that the force has
- The amount of acceleration of a mass m produced by a force of size F = mg would be a = F/m = (mg)/m = g.

Acceleration Due to Gravity

•All objects in free fall near the earth's surface fall downward with a constant acceleration g = 9.80 m/s^2 (called the acceleration due to gravity)

- $\vec{g}$ is always directed downward
  - toward the center of the earth

At San Francisco
g = 9.80 m/s^2.

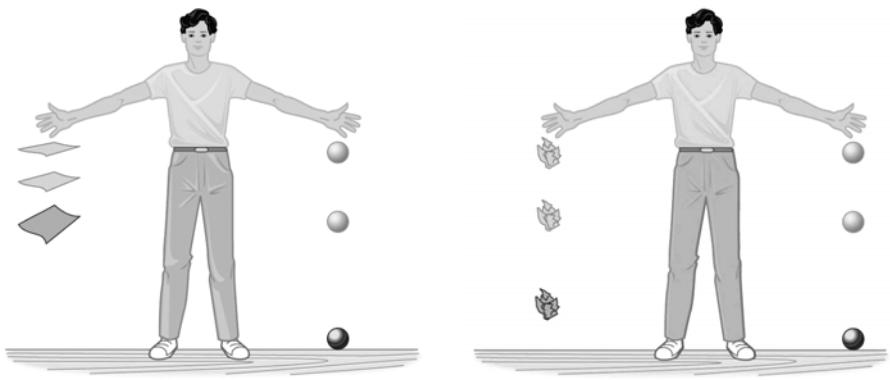
TABLE 2–5 Values of g at Different Locations on Earth (m/s^2)

Location	Latitude	g
North Pole	90° N	9.832
Oslo, Norway	60° N	9.819
Hong Kong	30° N	9.793
Quito, Ecuador	0°	9.780

If downward is designated as the ***+y*** direction, then $\vec{a}$ = +g; if upward is designated as the ***+y*** direction, then $\vec{a}$ = -g. (Note that ***g*** is ***always*** a positive number, but $\vec{a}$ may have either sign.)

Falling Objects in Air

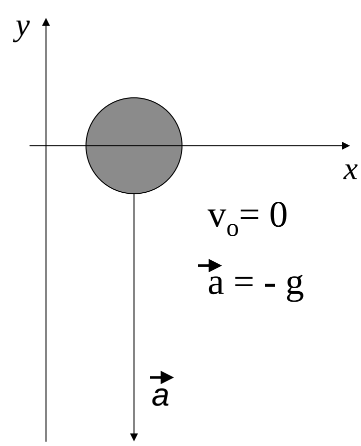
An object falling in air is subject to air resistance (and thus is not freely falling). Amount of air resistance depends on shape & size.



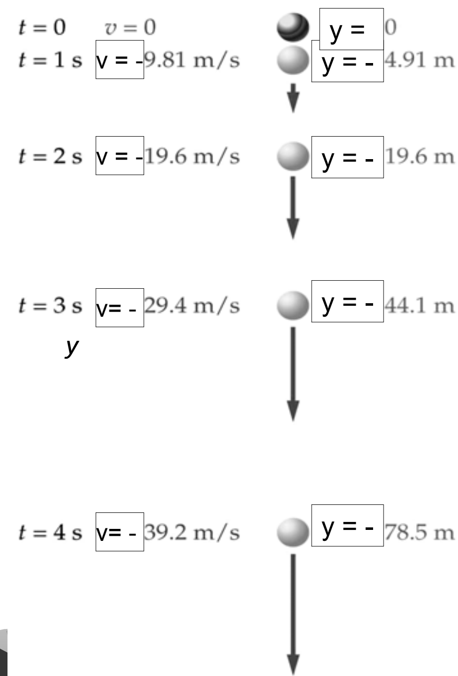
(a) (b)

Free Fall --Object Dropped

- Initial velocity is zero
- Frame: let up be positive
- Use the kinematic equations
  - Generally use y instead of x since vertical

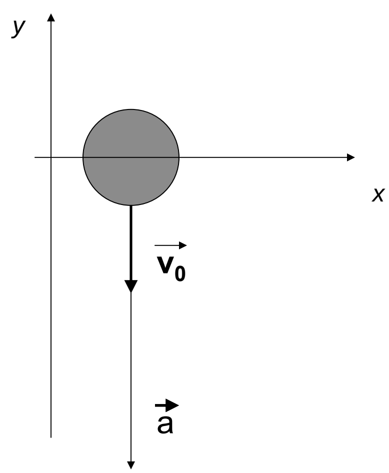


Free fall from rest:



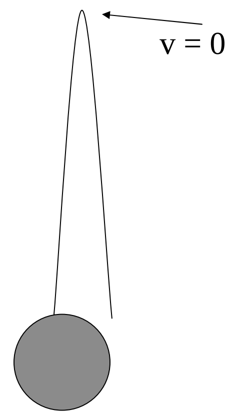
Free Fall --Object Thrown Downward

- $\vec{a}$ = - g
  - With upward being positive, acceleration will be negative, a = -9.8 m/s²
- Initial velocity ≠ 0
  - With upward being positive, initial velocity will be negative



Free Fall -- Object thrown upward

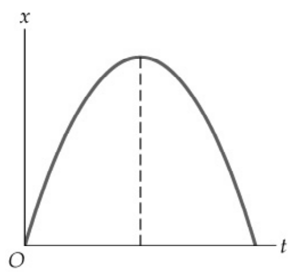
- Initial velocity is upward, so positive
- The instantaneous velocity at the maximum height is zero
- a = -g everywhere in the motion
- a is always downward, negative



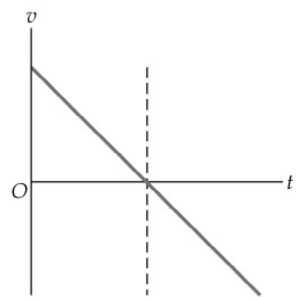
Thrown upward

- The motion may be “symmetrical” (object starts and ends at same height)
  - then $t_{up} = t_{down}$
  - then $v_f = -v_o$
- The motion may not be symmetrical
  - Break the motion into various parts
    - usually up part and down part

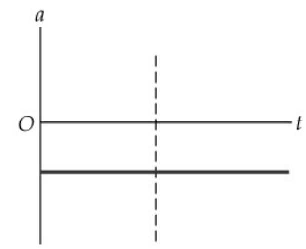
Graphical example: A ball is thrown upward from the ground level.



x = ball's height above the ground



Velocity is positive when the ball is moving upward

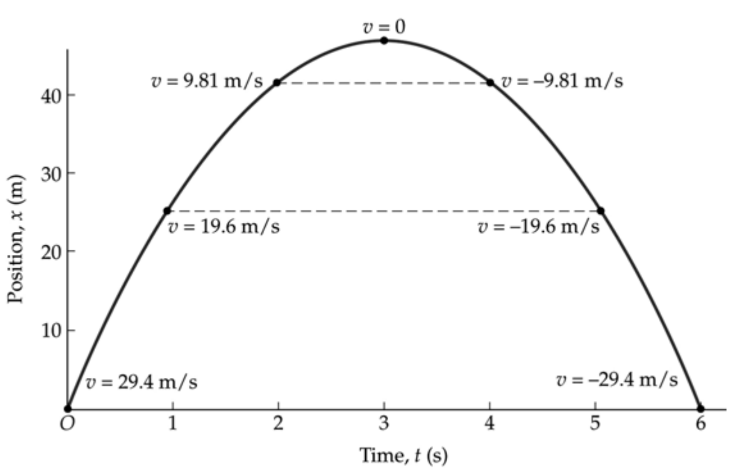


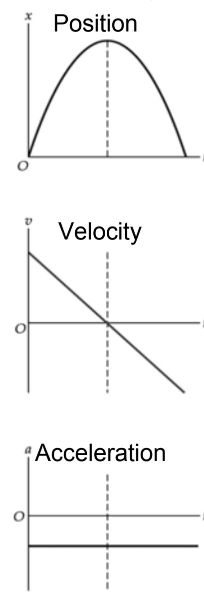
Why is acceleration negative?

Is there ever deceleration?

Object Thrown Upward (Symmetric)

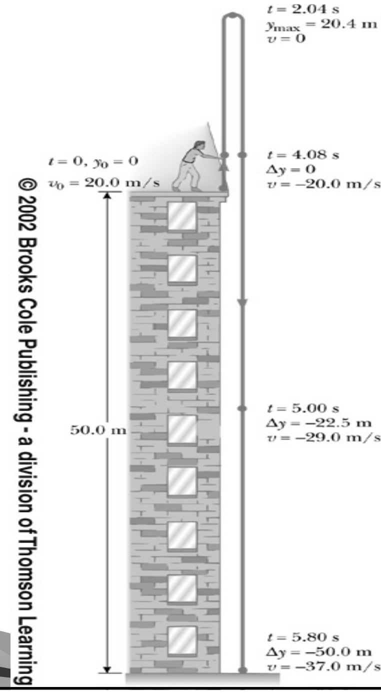
Position-time plot:





Non-symmetrical Free Fall

- Need to divide the motion into segments
- Possibilities include
  - Upward and downward portions
  - The symmetrical portion back to the release point and then the non-symmetrical portion



ConcepTest 3

A person standing at the edge of a cliff throws one ball straight up and another ball straight down at the same initial speed. Neglecting air resistance, the ball to hit ground below the cliff with greater speed is the one initially thrown

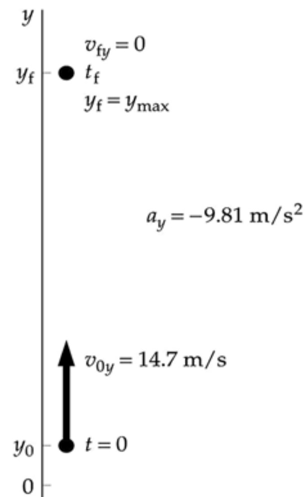
1. upward
2. downward
3. neither – they both hit at the same speed

Example: The Flying Cap

Upon graduation, a joyful student throws her cap straight up in the air with an initial speed of 14.7 m/s. (Neglect air resistance.)

What is acceleration of cap?

(a) When does cap reach its highest point?
(b) What is the distance to the highest point?
(c) Assuming the cap is caught at same height it was released, what is total time cap was in flight?



1. Draw the cap (as a dot) in its various positions.

2. (a) Use the time, velocity and acceleration relation.

$$v_x = v_{0x} + a_x \Delta t; \quad \Delta t = \frac{v_x - v_{0x}}{a_x} = \frac{(0\ \mathrm{m/s}) - (14.7\ \mathrm{m/s})}{-9.81\ \mathrm{m/s^2}} = 1.5\ \mathrm{s}$$

(b) Use average velocity: $\boldsymbol{v_{av}} = \boldsymbol{v_0}/2$ = 7.35 m/s;
$\Delta \boldsymbol{x} = \boldsymbol{v_{av}}\, \Delta \boldsymbol{t}$ = (7.35 m/s)(1.5 s) = 11.0 m

(c) Up time = down time, so total time is 3.0 s. (see text for a more complicated method.)

3. The answers have the right units and seem reasonable.

Fun QuickLab: Reaction time

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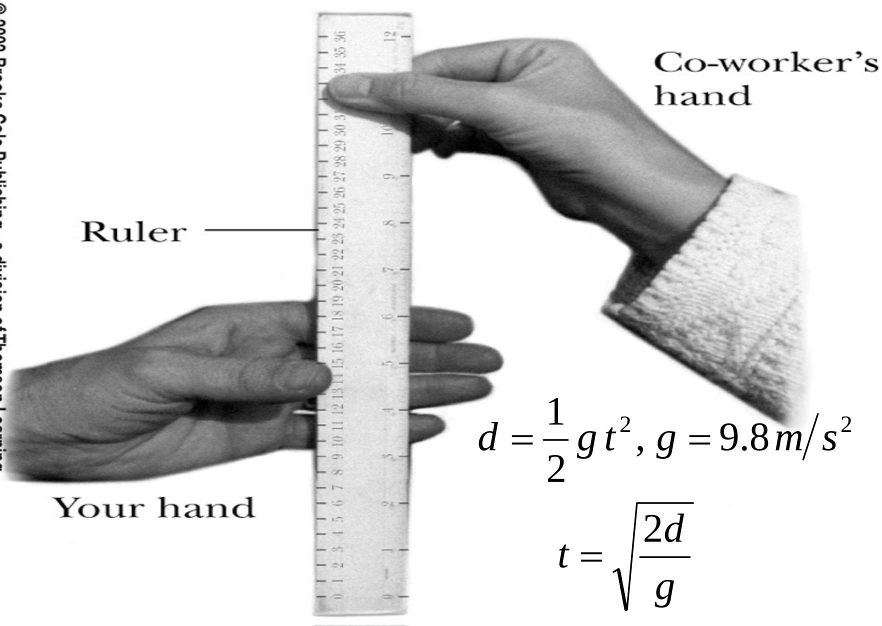


$$d = \frac{1}{2} g t^2, \; g = 9.8 \, m/s^2$$

$$t = \sqrt{\frac{2d}{g}}$$

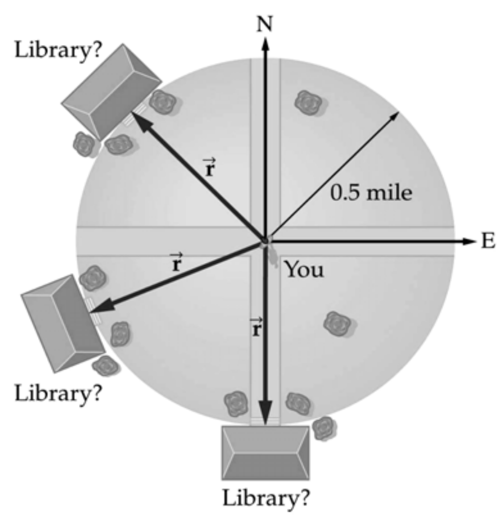
2-D Motion - Vectors

Scalar: number with units

Vector: quantity with magnitude and <u>direction</u>

How to get to the Library: you need to know how far ***and*** which way to go.

In 2-D, need more than + & - directions.

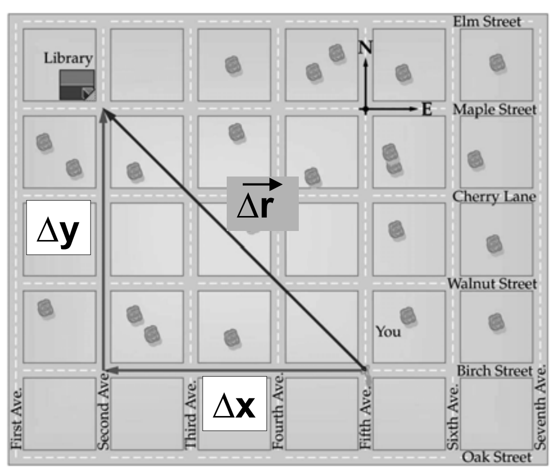


Vector Notation

- When handwritten, use an arrow:
- When printed, may be in bold print: **A**
- When dealing with just the magnitude of a vector in print, an italic letter may be used: *A*
- *Position vector usually written as* $\vec{\mathbf{r}}$
- Displacement vector $\Delta\vec{\mathbf{r}}$

The Components of a Vector

You may accomplish the displacement $\Delta\vec{r}$ by making a displacement Δx followed by a displacement Δy.



Δx is called the "x scalar component" of $\Delta\vec{r}$; Δy the "y scalar component"

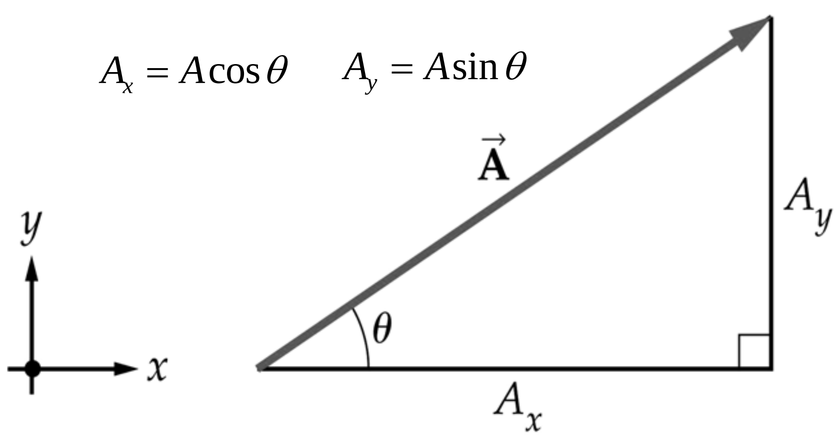
Vector Component Notation

- The x-component of a vector is usually written as A_x
- The y-component is A_y
- *For position vector* $\vec{\mathbf{r}}$ *we could write the x-component as* r_x *(textbook) or just x*
- The position vector y-component would be r_y or just y

The Components of a Vector

Components can be calculated from the size and direction angle of a vector, using trigonometry:

$$A_x = A\cos\theta \qquad A_y = A\sin\theta$$



More About Components of a Vector

- The previous equations are valid ***only if θ is measured with respect to the x-axis***
- The scalar components can be positive or negative and will have the same units as the original vector
- The x-component is the <u>projection</u> of vector along the x axis; the y-component the projection of the vector along y axis

Key Points of Lecture 4

Motion Examples with Acceleration
Force due to Earth Gravity, Newton's 2nd Law, Free Fall

Acceleration due to Gravity, g

Problems Involving Freely-Falling Objects

Vectors and Vector Components

- Before the next lecture, read <u>*Walker*</u> 3.3-3.6
- Homework Assignment #2c should be submitted by 11:00 PM on Friday, Sept. 11.