## Free Fall

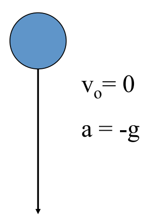
- All objects moving under the influence of gravity only are said to be in free fall
  - Free fall does not depend on the object's starting velocity, or how it got that velocity!
- All objects falling near the earth's surface fall with a constant acceleration
- The acceleration is called the acceleration due to gravity, and indicated by *g*

## Acceleration due to Gravity

- Symbolized by *g*
- $g = 9.8\ m/s^2$
- *g* is always directed downward
  - toward the center of the earth
- Ignoring air resistance and assuming *g* doesn't vary with altitude over short vertical distances, free fall is constantly accelerated motion

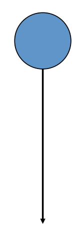
## Free Fall – an object dropped

- Initial velocity is zero
- Let up be positive
- Use the kinematic equations
  - Generally use y instead of x since vertical
- Acceleration is $-g = -9.80\ m/s^2$



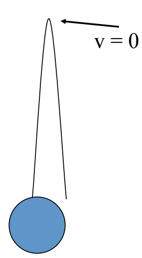

## Free Fall – an object thrown downward

- $a = -g = -9.80\ m/s^2$
- Initial velocity $\neq 0$
  - 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
- $a = -g = -9.80\ m/s^2$ everywhere in the motion

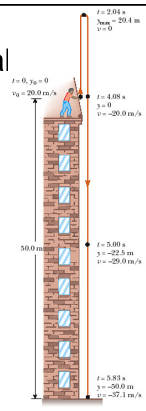



## Thrown upward, cont.

- The motion may be symmetrical
  - Then $t_{up} = t_{down}$
  - Then $v = -v_o$
- The motion may not be symmetrical
  - Break the motion into various parts
    - Generally up and down

## 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






## Example Problem

You drop a water balloon on your friend's head from the third-story window of your apartment building, 15.0 m from the ground.

- What is the water balloon's acceleration while it is in the air?
- How much time does it take for the water balloon to fall?
- How fast is it going as it hits your friend's head?
- How would these answers be different if, instead of dropping the water balloon, you tossed it straight upward with a speed of 5 m/s?

## Vector vs. Scalar Review

- All physical quantities encountered in this text will be either a scalar or a vector
- A **vector** quantity has both magnitude (size) and direction -> vel,, accel., disp.
- A **scalar** is completely specified by only a magnitude (size) -> time, speed, dist.

## Properties of Vectors

- Equality of Two Vectors
  - Two vectors are **equal** if they have the same magnitude and the same direction
- "Movement" of vectors in a diagram
  - Any vector can be moved parallel to itself without being affected

## More Properties of Vectors

- Negative Vectors
  - Two vectors are **negative** if they have the same magnitude but are 180° apart (opposite directions)
  - **A** = **-B**; **A** + (-**A**) = 0
- Resultant Vector
  - The **resultant** vector is the sum of a given set of vectors
  - **R** = **A** + **B**

## Adding Vectors

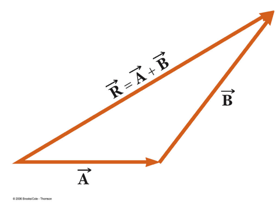
- When adding vectors, their directions must be taken into account
- Units must be the same
- Geometric Methods
  - Use scale drawings
- Algebraic Methods
  - More convenient

## Adding Vectors Geometrically (Tip-to-tail method)

- Choose a scale
- Draw the first vector with the appropriate length and in the direction specified, with respect to a coordinate system
- Draw the next vector with the appropriate length and in the direction specified, with respect to a coordinate system whose origin is the end of vector **A** and parallel to the coordinate system used for **A**

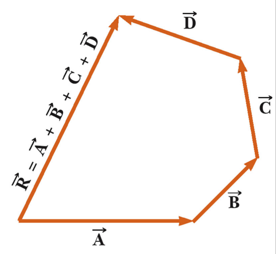
## Graphically Adding Vectors, cont.

- Continue drawing the vectors "tip-to-tail"
- The resultant is drawn from the origin of **A** to the end of the last vector
- Measure the length of and its angle
  - Use the scale factor to convert length to actual magnitude



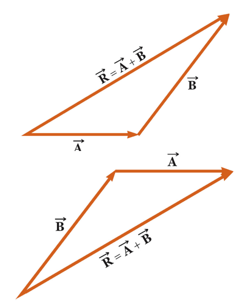

## Graphically Adding Vectors, cont.

- When you have many vectors, just keep repeating the process until all are included
- The resultant is still drawn from the origin of the first vector to the end of the last vector



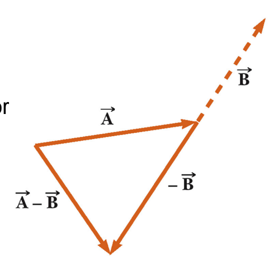

## Notes about Vector Addition

- Vectors obey the **Commutative Law of Addition**
  - The order in which the vectors are added does not affect the result
  - **A + B = B + A**



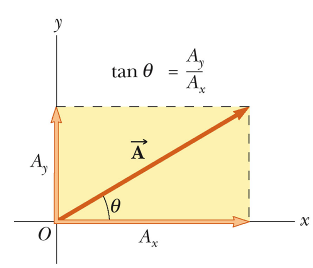

## Vector Subtraction

- Special case of vector addition
  - Add the negative of the subtracted vector
- **A** - **B** = **A** + (-**B**)
- Continue with standard vector addition procedure




## Components of a Vector

- A **component** is a projection of a vector along an axis
- It is useful to use **rectangular components**
  - These are the projections of the vector along the x- and y-axes



## Adding Vectors Algebraically

- Choose a coordinate system and sketch the vectors
- Find the x- and y-components of all the vectors
- Add all the x-components
  - This gives $R_x$, the x-component of the resultant:

$$R_x = \sum v_x$$

## Vectors Lecture-Tutorial

- Work with a partner or two
- Read directions and answer all questions carefully. Take time to understand it now!
- Come to a consensus answer you all agree on before moving on to the next question.
- If you get stuck, ask another group for help.
- If you get really stuck, raise your hand and I will come around.