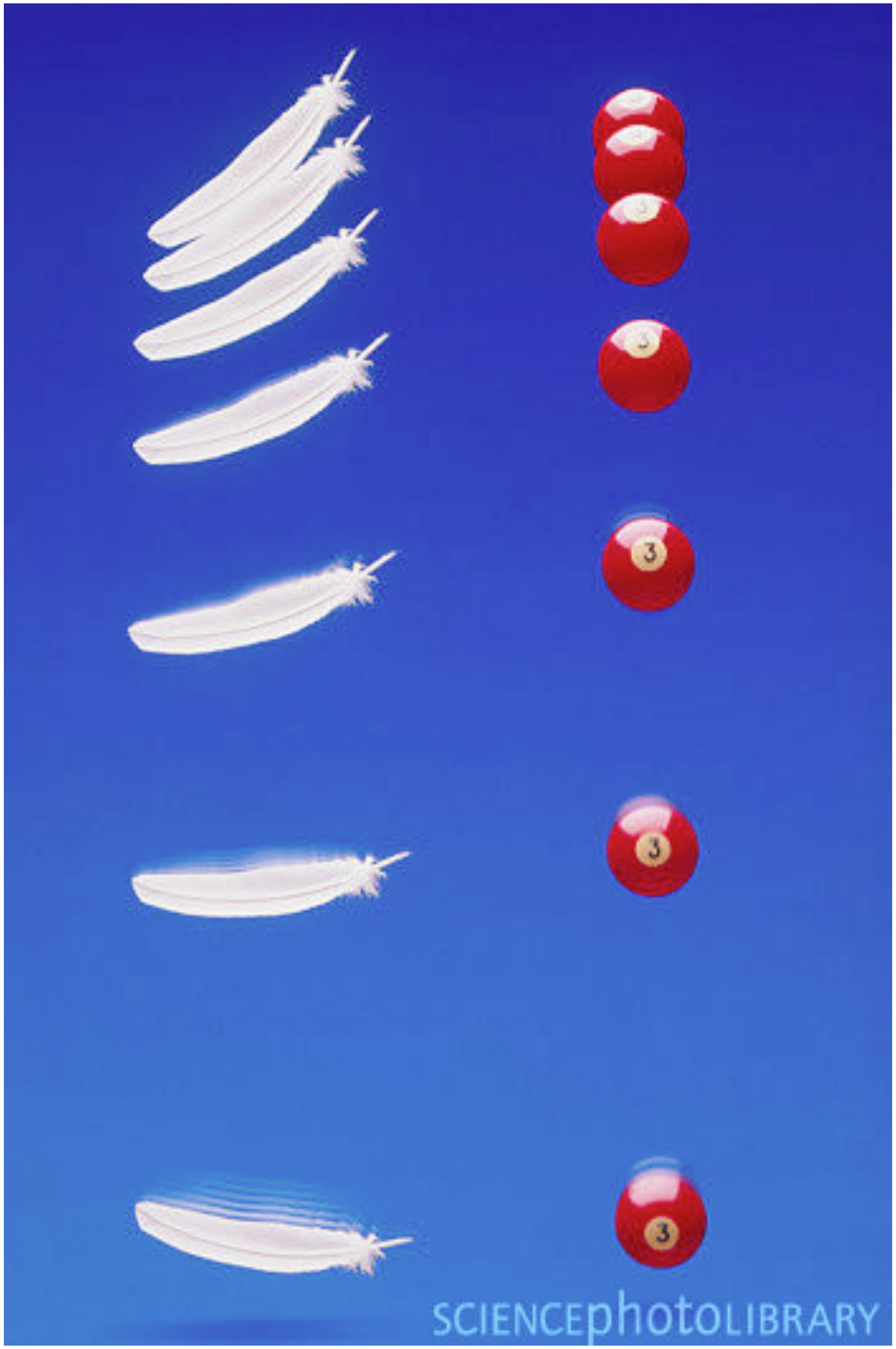


Welcome back to Physics 211

Lecture 2-2

- Last time:
  - Displacement, velocity, graphs
- Today:
  - Constant acceleration, free fall

Simplest case with non-zero acceleration

- Constant acceleration: $a = a_{av}$
- Can find simple equations for x(t), v(t) in this case

1^{st} constant acceleration equation

- From definition of a_{av}: $a_{av} = \Delta v/\Delta t$

$$\text{Let } a_{av} = a,\ \Delta t = t,\ \Delta v = v - v_0$$

Calculate v as a function of a, t, and v_0

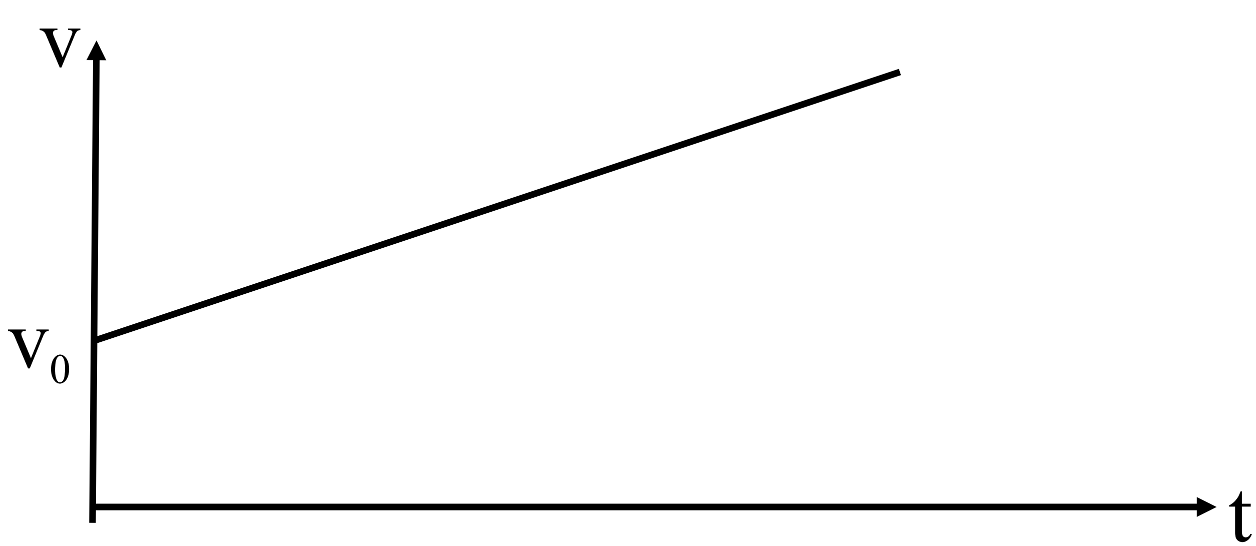
1^{st} constant acceleration equation

- From definition of a_{av}: $a_{av} = \Delta v/\Delta t$

Let $a_{av} = a$, $\Delta t = t$, $\Delta v = v - v_0$

Find: $v = v_0 + at$

*equation of straight line in v(t) plot

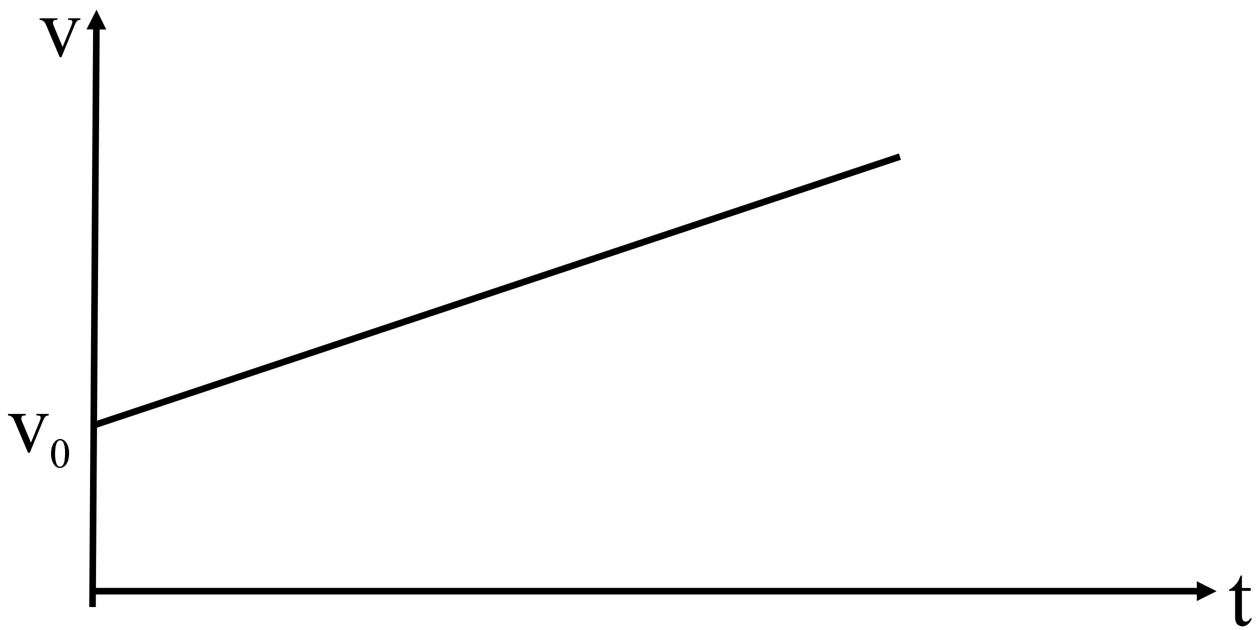


2^{nd} const. acceleration equation

- Notice: graph makes it clear that

$$v_{av}=(1/2)(v + v_0)$$

$$x - x_0 = (1/2)(v + v_0)t$$



3^{rd} constant acceleration equation

- Using 1^{st} constant acceleration equation

$$v = v_0 + at$$

insert into relation between x, t, and v_{av} :

$$x - x_0 = v_{av}t = (1/2)(v + v_0)t$$

$$(\text{set } \Delta t = t, \text{ i.e. take } t_0 = 0)$$

Solve for x.

3^{rd} constant acceleration equation

- Using 1^{st} constant acceleration equation

$$v = v_0 + at$$

insert into relation between x, t, and v_{av} :

$$x - x_0 = v_{av}t = (1/2)(v + v_0)t$$

(set $\Delta t = t$, i.e. take $t_0 = 0$)

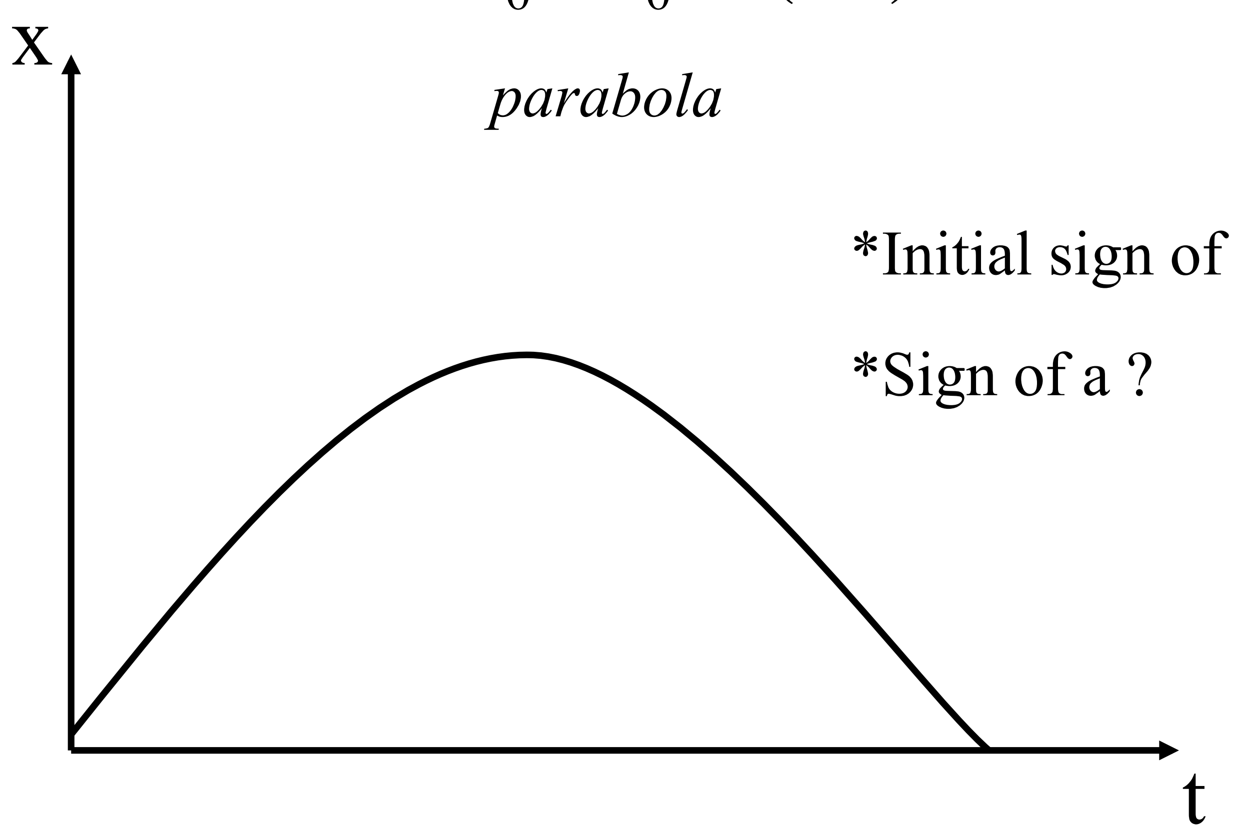
yields: $$x - x_0 = (1/2)(2v_0 + at)t$$

or: $$x = x_0 + v_0 t + (1/2)at^2$$

x(t) graph- constant acceleration

$$x = x_0 + v_0 t + (1/2)at^2$$

parabola



*Initial sign of v ?

*Sign of a ?

4^{th} constant acceleration equation

- Can also get an equation independent of t
- Substitute $t = (v - v_0)/a$ into

$$x - x_0 = (1/2)(v + v_0)t$$

4^{th} constant acceleration equation

- Can also get an equation independent of t
- Substitute $t = (v - v_0)/a$ into

$$x - x_0 = (1/2)(v + v_0)t$$

we get: $$2a(x - x_0) = v^2 - v_0^2$$

or: $$v^2 = v_0^2 + 2a(x - x_0)$$

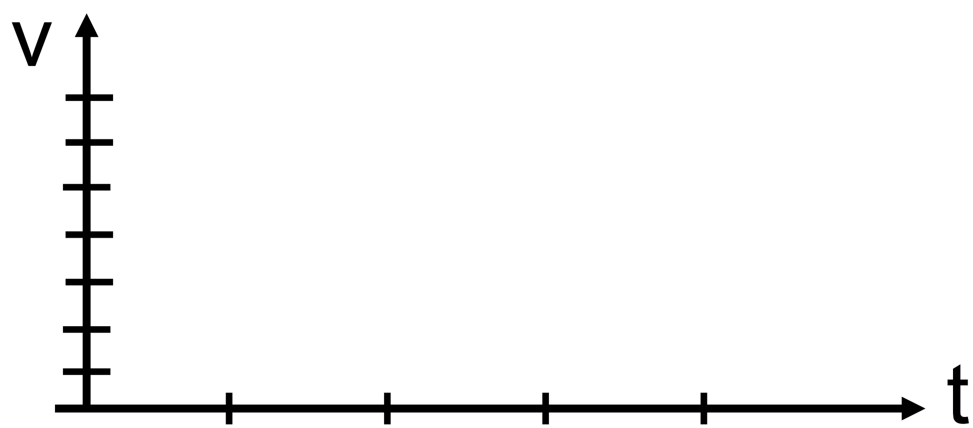
Clicker 2-2.1: An object moves with constant acceleration, starting from rest at t = 0 s. In the first four seconds, it travels 10 cm.

What will be the displacement of the object in the following four seconds (*i.e.* between t = 4 s and t = 8 s)?

1. 10 cm
2. 20 cm
3. 30 cm
4. 40 cm

Rolling disk demo

- Compute average velocity for each section of motion (between marks)
- Measure time taken (metronome)



Motion with **constant** acceleration:

$$v = v_0 + at$$

$$v_{av} = (^1/_2)\,(v_0 + v)$$

$$x = x_0 + v_0 t + (^1/_2)\,a\,t^2$$

$$v^2 = v_0^2 + 2a\,(x - x_0)$$

*where x_0, v_0 refer to time = 0 s ;

x, v to time *t*

Freely Falling Bodies:

- Near the surface of the earth, neglecting air resistance and the earth's rotation, <u>all</u> objects experience the same downward acceleration due to their gravitational attraction with the earth:

$$g = 9.8 \text{ m/s}^2$$

  - Near = height small relative to radius of earth

Example of constant acceleration:

- ***Free fall demo***
- Compare time taken by feather and billiard ball to fall to the ground from the same height
- Influence of air in room?

Sample problem

- A brick is dropped (zero initial speed) from the roof of a building. The brick strikes the ground in 2.50 s. Ignore air resistance, so the brick is in free fall.
  - How tall, in meters, is the building?
  - What is the magnitude of the brick's velocity just before it reaches the ground?
  - Sketch a(t), v(t), and y(t) for the motion of the brick.

Motion in more than 1 dimension

- Have seen that 1D kinematics is written in terms of quantities with a magnitude and a sign

- Examples of 1D **vectors**

- To extend to $d > 1$, we need a more general definition of vector

Reading assignment

- Vectors Ch 3.1-3.4

Vectors: basic properties

- are used to denote quantities that have magnitude *and* direction
- can be added and subtracted
- can be multiplied or divided by a number
- can be manipulated **graphically** (*i.e.,* by drawing them out) or algebraically (by considering components)

Vectors: examples and properties

- Some <u>vectors</u> we will encounter:
  position, velocity, force

- Vectors commonly denoted by boldface letters, *or* sometimes arrow on top

- Magnitude of **A** is written |**A**|, *or* no boldface and no absolute value signs

- Some quantities which are <u>not</u> vectors:
  temperature, pressure, volume ….

Drawing a vector

- A vector is represented graphically by a line with an arrow on one end.
- Length of line gives the **magnitude** of the vector.
- Orientation of line and sense of arrow give the **direction** of the vector.
- Location of vector in space does not matter -- two vectors with the same magnitude and direction are equivalent, independent of their location