Physics 201, Lecture 3

Today's Topics

- Motion in One Dimension (chap 2)
  - One Dimensional Kinematics
  - Kinematics of Constant Acceleration
  - The Fun of Free Fall

- Expected from Preview:
  - Displacement, velocity, acceleration
  - Motion with constant acceleration
  - Free Fall

- Next Tuesday: Vectors

Review: Kinematical Quantities to Describe a Motion

Basic Quantities

- **Displacement (Δx):**
  change of position from $t_1 \rightarrow t_2$
- **Velocity (v):**
  rate of position change.
  - Average: $\Delta x/\Delta t$
  - Instantaneous: dx/dt
- **Acceleration (a):**
  rate of velocity change.
  - Average: $\Delta v/\Delta t$
  - Instantaneous : dv/dt

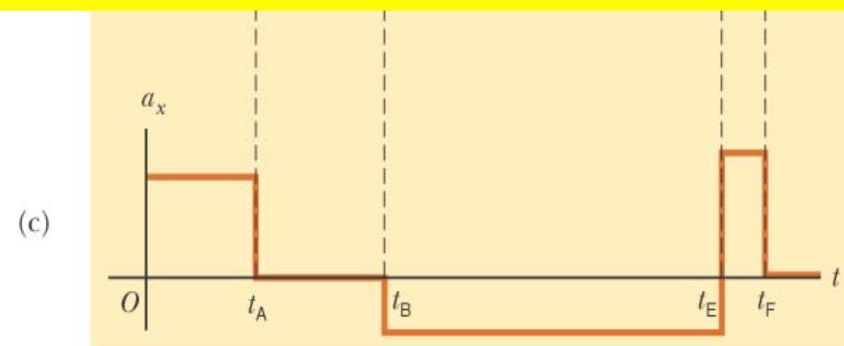
❖ Note the mathematical similarity in "**v** vs. **x**", and "**a** vs. **v**"

❖ speed $s=|v|$ is not the same as v.

Quick Quiz

What can you say about $t_B \rightarrow t_E$?

- The car must be going in negative direction (-x)
- The car must be speeding up.
- The car must be slowing down
- ➡ None of above is necessarily true



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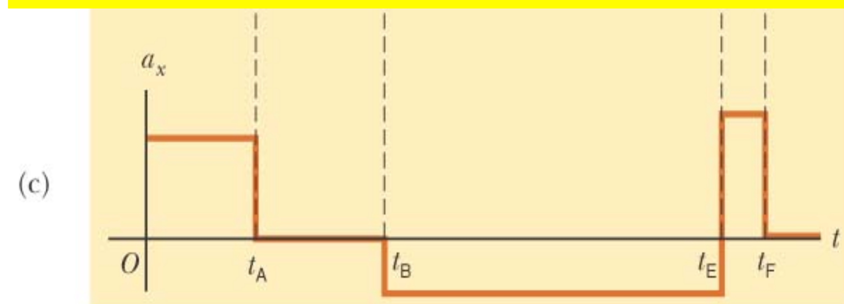
❖ Note the mathematical similarity in "v vs. x", and "a vs. v"

❖ speed s=|v| is not the same as v.

Quick Quiz

What is happening at time t_E ?

- The car is turning.
- The driver's foot must be moving from the gas paddle to the brake.
- The driver's foot must be moving from the brake to the gas paddle.
- The driver's foot is moving between the gas paddle and the brake. (either way possible).



A Tricky Word

- **Acceleration** shall be interpreted with a neutral sense
  - Positive acceleration does not necessarily mean speeding up.
  - Negative acceleration doe not necessarily mean slowing down

➔Direction is the key in the interpretation.

- Can still be used (loosely with caution):
  - Accelerating = Speeding up
  - Decelerating = Slowing down
  - Deceleration = rate of slowing down

Conversions amongst x(t), v(t), and a(t)

- **Knowing position x(t):**

$$v(t) = \frac{dx(t)}{dt} \qquad a(t) = \frac{dv(t)}{dt} = \frac{d^2x(t)}{dt^2}$$

- **Knowing velocity v(t):**

$$x(t) = x_{t=0} + \int_{t=0}^{t} v(t)dt, \qquad a(t) = \frac{dv(t)}{dt}$$

- **Knowing acceleration a(t):**

$$v(t) = v_{t=0} + \int_{t=0}^{t} a(t)dt, \qquad x(t) = x_{t=0} + v_{t=0}t + \int_{t=0}^{t} \left(\int_{t=0}^{t} a(t)dt \right) dt$$

What about Distance?

$$S(t) = \int_{t=0}^{t} |\, v(t) \,|\, dt$$

Common 1-Dimensional Motions

- **Constant x:**
  - $x(t) = x_0$, $v(t) = 0$, $a(t) = 0$

$x_0 \equiv x(t=0)$

- **Constant v:**
  - $v(t) = v_0$, $a(t) = 0$, $x(t) = x_0 + v_0 t$ (why? see board)

$x_0 \equiv x(t=0)$

- **Constant a:**
  - $a(t) = a_0$, $v(t) = v_0 + a_0 t$, $x(t) = x_0 + v_0 t + \frac{1}{2} a_0 t^2$ (why? see board)

$v_0 \equiv v(t=0)$

- **General case: x, v, a are all function of time**
  - Usually one needs calculus to convert among x, v, t

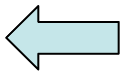
  → can be done but not in the scope of this course.

*** Please note: All parameters here (x, t, v, a) can be positive or negative depending on situation.**

Some Numerical Examples

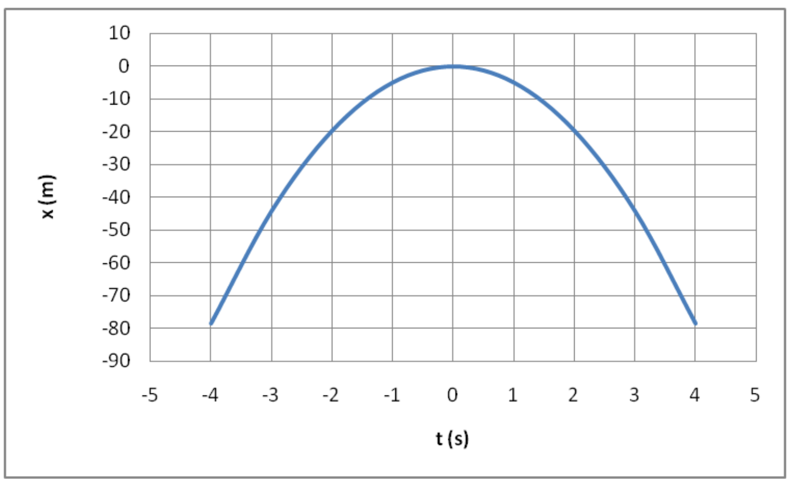
- **Assume a=-9.80 m/s^2 at all time. It is known that at t=0 s, x=x_0=0 m, and v=v_0=0m/s , what is v and x at t=-4, -3, -2, -1, 1, 2, 3, 4 s ?**

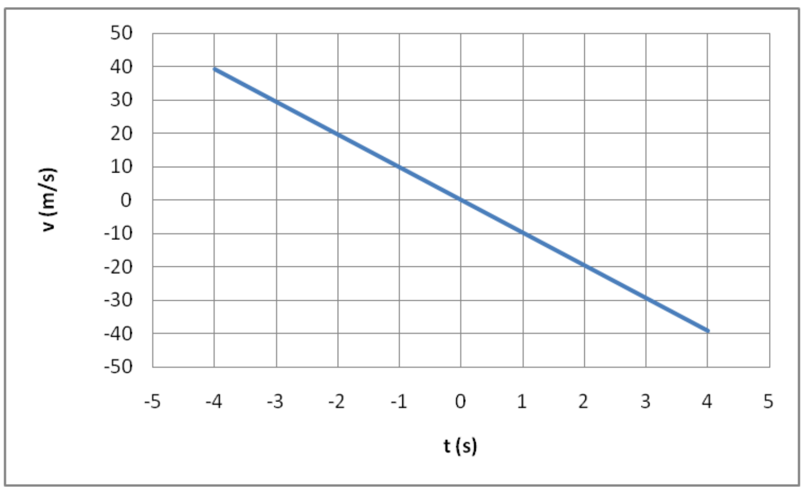
(Quick) Quiz 1: Wait! Can we do negative time?

- Yes 
- No

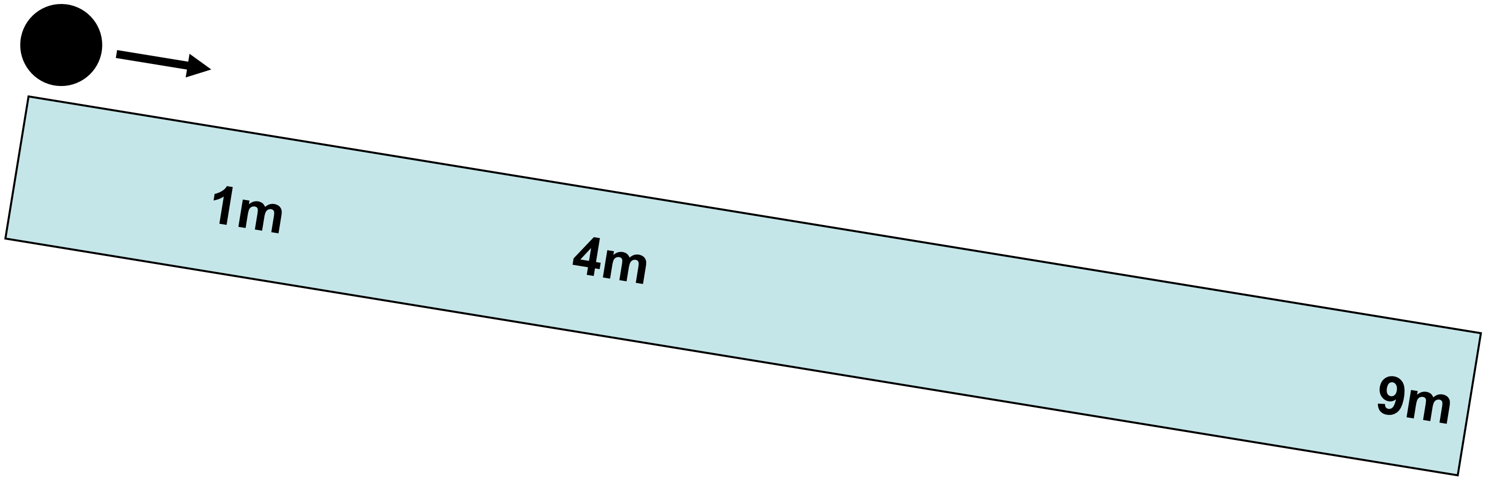
(see board for table results)

t	-4.0	-3.0	-2.0	-1.0	0	1.0	2.0	3.0	4.0	s
x	-78.4	-44.1	-19.6	-4.9	0	-4.9	-19.6	-44.1	-78.4	m
v	39.2	29.4	19.6	9.8	0	-9.8	-19.6	-29.4	-39.2	m/s
a	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	m/s^2





Demo: Ball on Acceleration Track



- at t=0s,ball released from rest
- at t=1s, ball passing 1m mark
- at t=2s, ball passing 4m mark
- at t=3s, ball passing 9m mark

➔ $X(t) = a_0 t^2/2 \quad a_0 = 2\ m/s^2$

Useful Formulas for Motion With Constant Acceleration

- $a(t) = a_0$
- $v(t) = v_0 + a_0 t$
- $v_{AV} = (v + v_0)/2$
- $x(t) = x_0 + v_0 t + \frac{1}{2} a_0 t^2$
- $v(t)^2 = v_0^2 + 2a(x - x_0)$ (why? see text)

Very useful formula:

- Braking distance
- Kinetic energy (a future topic)

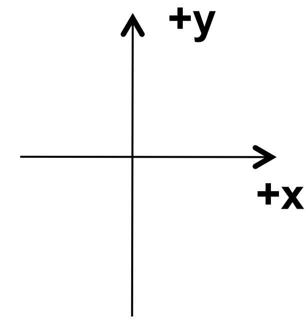
Quiz: Braking Distance

A typical car can have maximum deceleration of 8.0 m/s^2 (or a=-8.0 m/s^2), If the car is moving at 60 mi/h (=97 km/h = 26.9 m/s), What is the shortest braking distance (distance between the initial braking and full stop)?

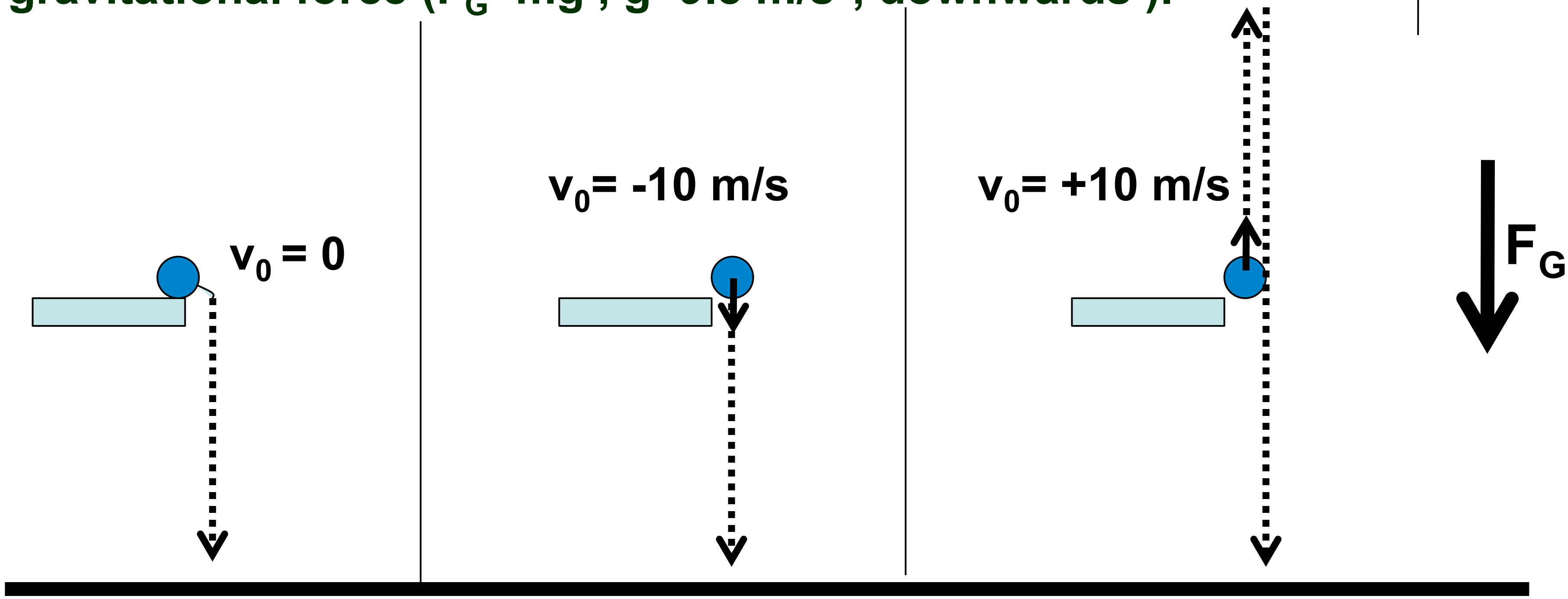
A: 45 m, B: 4.5m, C: not enough information.

$x - x_0 = -(v_0^2 - 0^2)/(2a) = -26.9^2 / (-2 \times 8.0) = 45$ m (Drive safely!)

1-Dimensional Free Fall



- ❑ **Free fall: motion under sole influence of gravitational force (F_G=mg , g=9.8 m/s^2, downwards).**

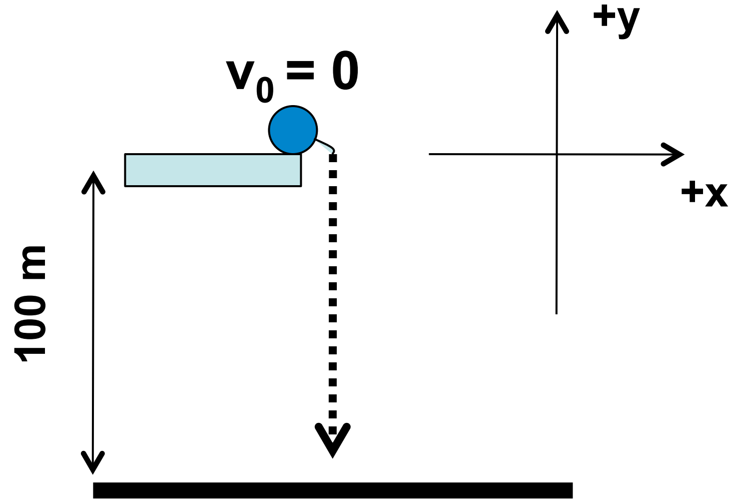


Facts on Free Fall

On Earth surface, if no air resistance, all "free fall" objects, regardless of shape, size, weight, initial velocity, speed, etc. , are subject to the same downwards acceleration of 9.8 m/s^2. (Why: will explain in Lecture 7)

1-Dimensional Free Fall: $v_0=0$

- ❑ At t=0, a steel ball is falling from a platform at height of 100 m.
  - At what time it reaches ground?
    t=4.5s (see board)
  - At what velocity it hits the ground?
    v_y= -44.3 m/s (see board)



- What is its position at t=1s, 2s?
  (we have done this before !, remember?)

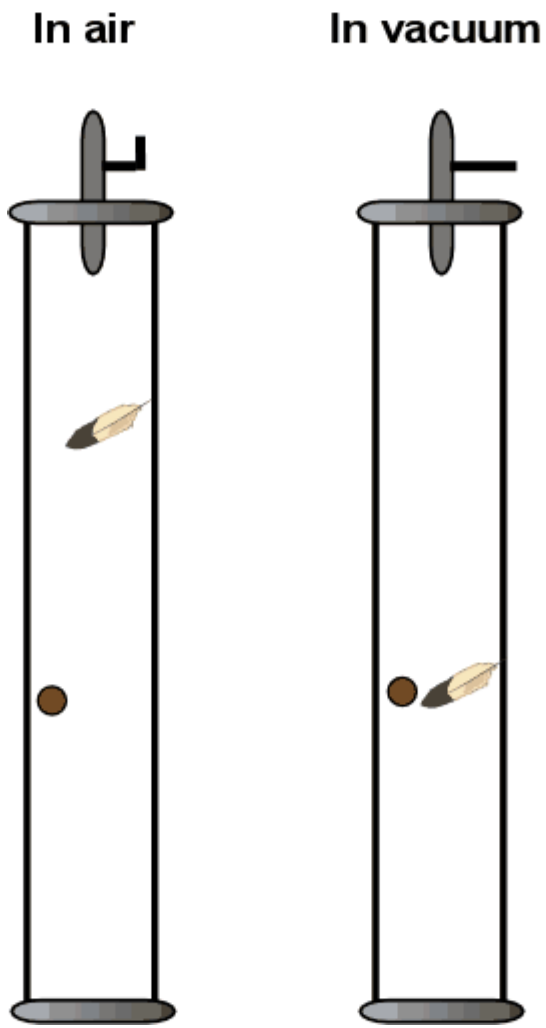
t	0	1.0	2.0	3.0	4.0	s
y	0	-4.9	-19.6	-44.1	-78.4	m
v	0	-9.8	-19.6	-29.4	-39.2	m/s
a	-9.8	-9.8	-9.8	-9.8	-9.8	m/s^2

Quiz: Will the results change if feather in lieu of steel ball? (ignore air friction): Yes / No

see demo

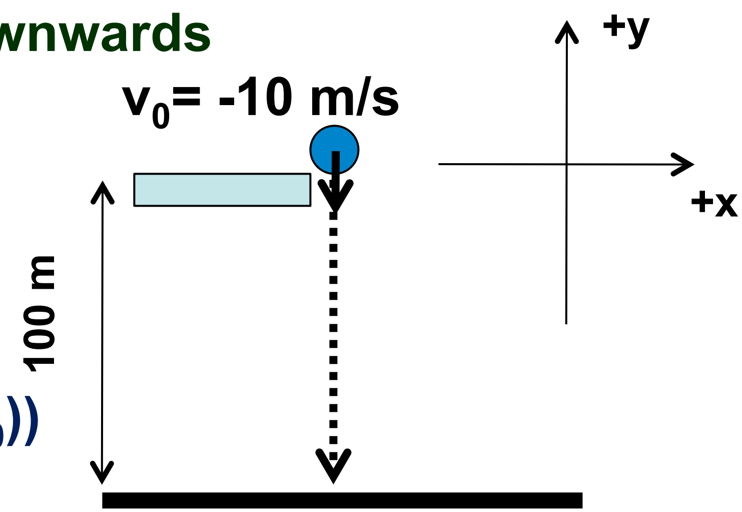
Demo: Free Fall

- Coin and feather, which falls faster?



1-Dimensional Free Fall: Throwing Down

- Now this time, the ball is thrown downwards with v_0=-10 m/s at t=0,



- At what velocity it hits the ground?

  v_y=- 45.3 m/s (use: $v(t)^2 = v_0^2 + 2a(y-y_0)$)

- At what time it hits the ground?

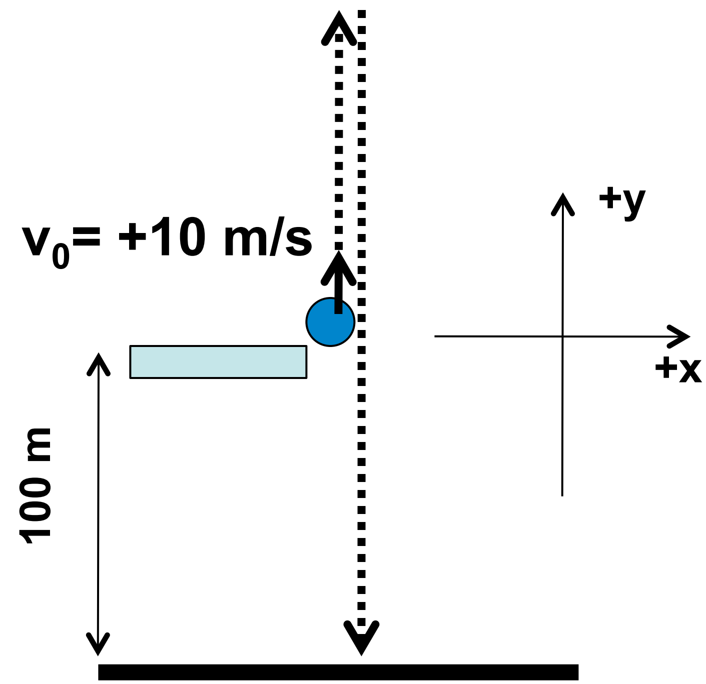
  t= 3.6 s (use: $v(t) = v_0 + a_0 t \rightarrow t=(v(t)-v_0)/a_0$)

- Again, can you calculate its position at any time ?

  (After lecture exercise.)

1-Dimensional Free Fall: Throwing Up

- what if the ball is thrown up with v_0=+10 m/s at t=0,



- At what velocity it hits the ground?
  v_y=- 45.3 m/s (use: $v(t)^2 = v_0^2 + 2a(y-y_0)$)

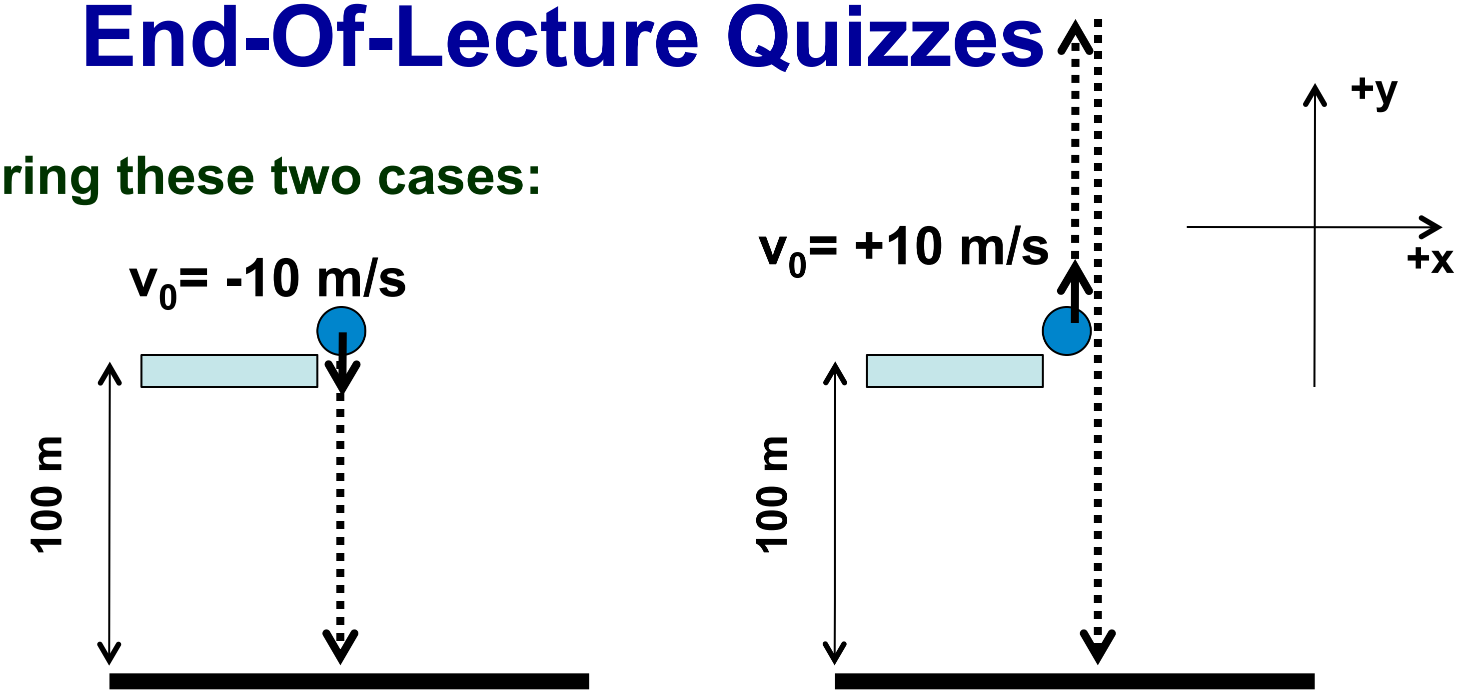
- At what time it hits the ground?
  t= 5.6 s (use: $v(t) = v_0 + a_0 t \rightarrow t=(v(t)-v_0)/a_0$)

- During the flight the ball will fall back to platform level once, at what time this happen? (t=2.0s, use $x(t) = x_0+v_0t + ½ a_0t^2$) ,
  at what velocity is it at when this happens ? (v_y=-10 m/s, DIY please)

- Again, can you calculate its position at any time ?
  (After lecture exercise.)

End-Of-Lecture Quizzes

- Considering these two cases:



A: Throwing down

B: Throwing up

- Which takes longer to hit the ground?
  - A, B, Same

- In which case the ball hits the ground with higher speed?
  - A, B, same

College of Engineering
Policies On Final Exam Rescheduling

- **Regulation 9 Student responsibility for scheduling:**

" Each student is responsible for arranging a course list that will permit satisfactory progress towards degree requirements and a class schedule that (a) avoids class and final exam scheduling conflicts, (b) avoids an excessively demanding final exam schedule, and (c) verifies registration in chosen classes."

- **Regulation 25 Final exam rescheduling:**

" A student may be permitted to take an examination at other than the regularly scheduled time only with permission of the instructor. Permission will be granted only for illness or other unusual and substantiated cause beyond the student's control. (See also Regulation 9)."

(http://www.engr.wisc.edu/current/coe-enrollment-regulations.html)

➔ We do NOT have flexibility to accommodate direct conflict, 3-exam/24-hrs, etc.