

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**”

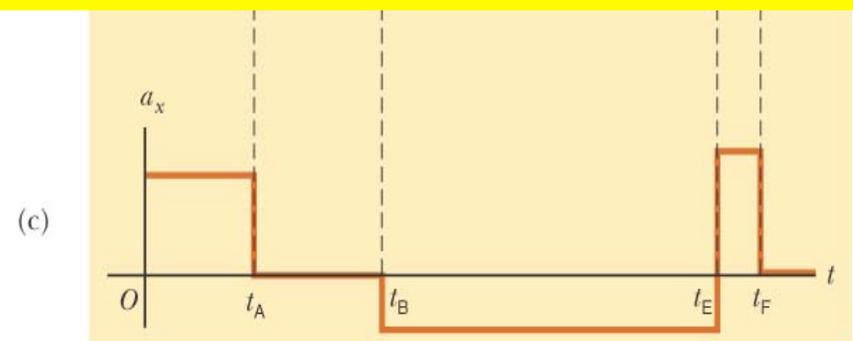
❖ speed $s=|v|$ is not the same as v .

x

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



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: $\Delta v/\Delta t$
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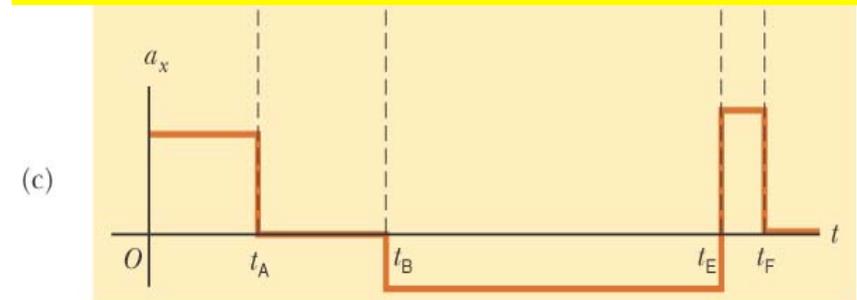
❖ Note the mathematical similarity in “**v** vs. **x**”, and “**a** vs. **v**”

❖ 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 $x(t)$:

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

□ Knowing velocity $v(t)$:

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

□ Knowing acceleration $a(t)$:

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

What about Distance?

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

Common 1-Dimensional Motions

□ Constant x :

▪ $x(t) = x_0, v(t) = 0, a(t) = 0$

□ 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)

$x_0 \equiv x(t=0)$

$v_0 \equiv v(t=0)$

□ 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

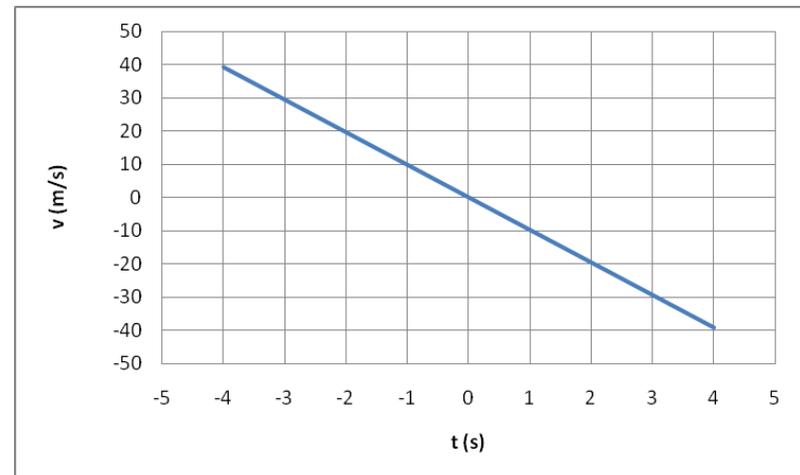
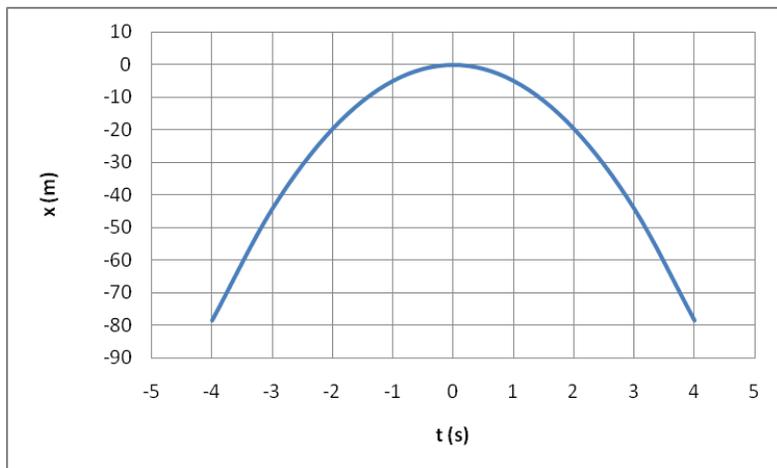
□ Assume $a = -9.80 \text{ m/s}^2$ at all time. It is known that at $t = 0 \text{ s}$, $x = x_0 = 0 \text{ m}$, and $v = v_0 = 0 \text{ m/s}$, what is v and x at $t = -4, -3, -2, -1, 1, 2, 3, 4 \text{ s}$?

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

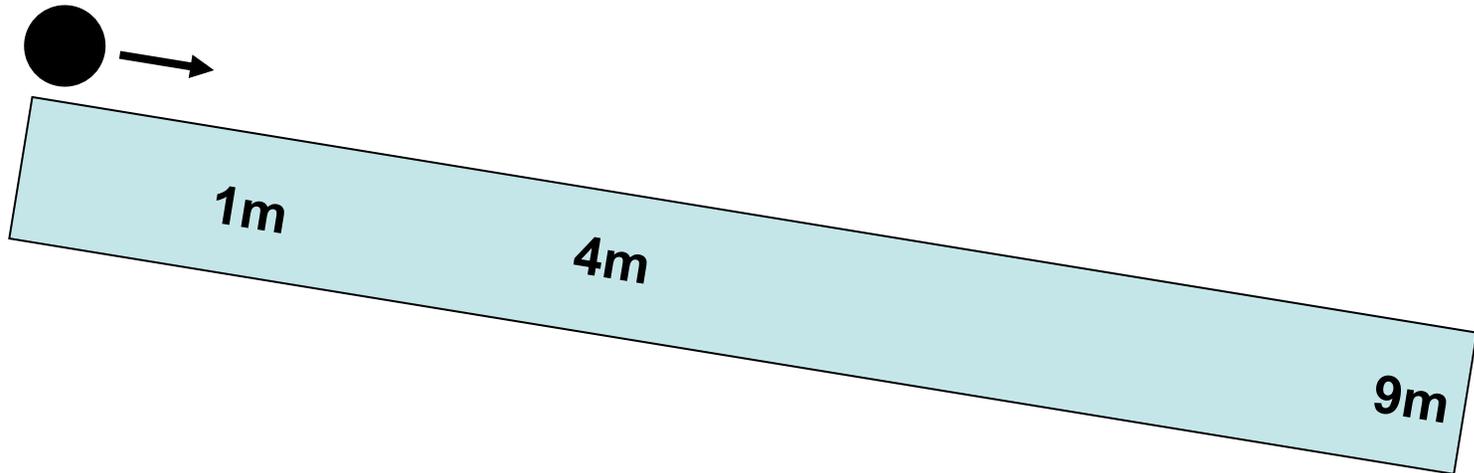
- Yes ←
- No

(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

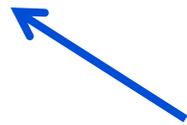


- at $t=0\text{s}$, ball released from rest
- at $t=1\text{s}$, ball passing 1m mark
- at $t=2\text{s}$, ball passing 4m mark
- at $t=3\text{s}$, ball passing 9m mark

→ $X(t) = a_0 t^2 / 2$ $a_0 = 2 \text{ m/s}^2$

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

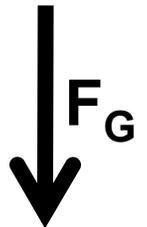
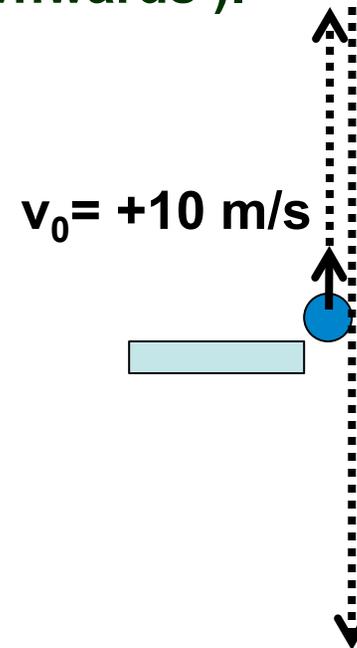
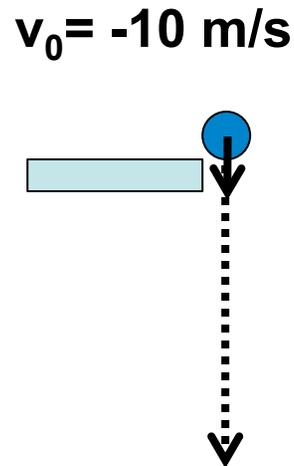
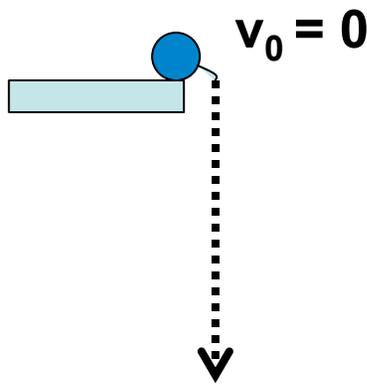
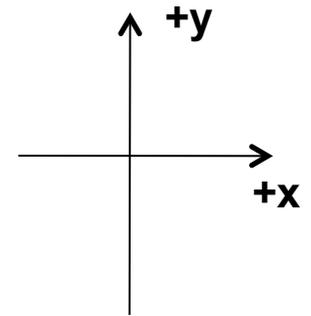
A typical car can have maximum deceleration of 8.0 m/s^2 (or $a = -8.0 \text{ m/s}^2$), If the car is moving at 60 mi/h ($= 97 \text{ km/h} = 26.9 \text{ m/s}$), What is the shortest braking distance (distance between the initial braking and full stop)?

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

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

1-Dimensional Free Fall

□ Free fall: motion under sole influence of gravitational force ($F_G = mg$, $g = 9.8 \text{ m/s}^2$, 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: $v_0=0$

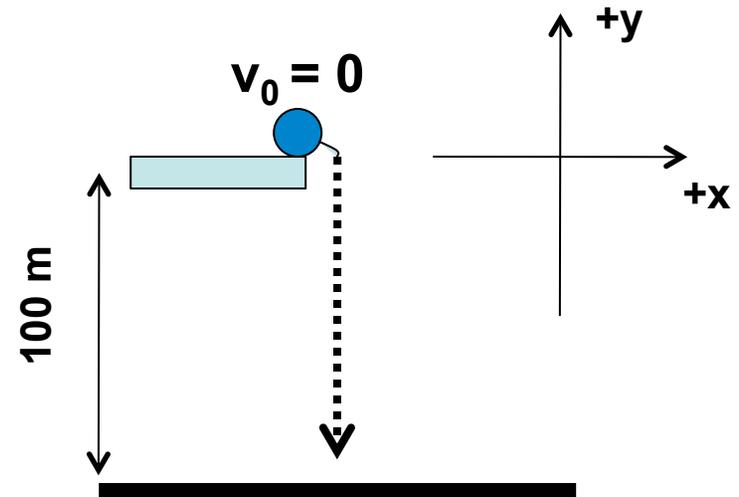
□ At $t=0$, a steel ball is falling from a platform at height of 100 m.

➤ At what time it reaches ground?

$t=4.5\text{s}$ (see board)

➤ At what velocity it hits the ground?

$v_y = -44.3 \text{ m/s}$ (see board)



➤ What is its position at $t=1\text{s}$, 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 |

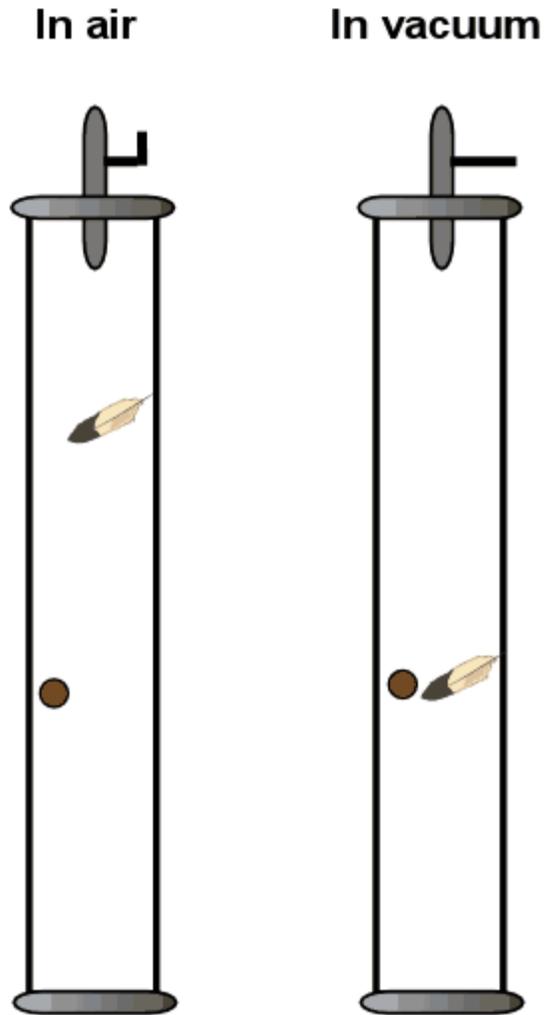
Quiz: Will the results change if feather in lieu of steel ball?

(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 $t=0$,

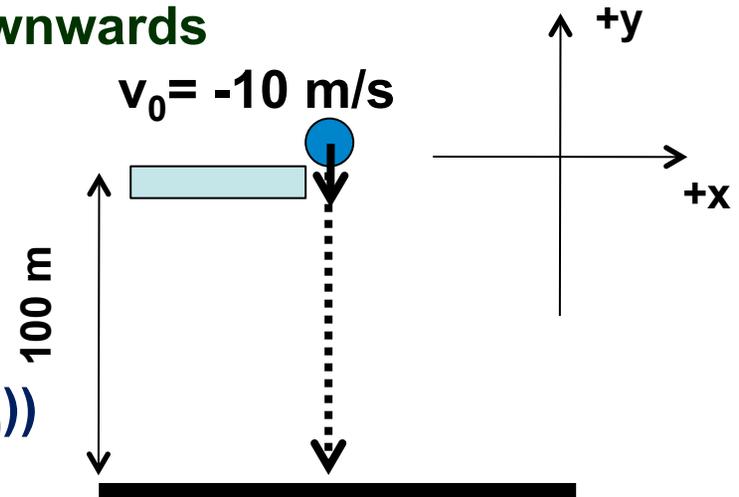
➤ At what velocity it hits the ground?

$v_y = -45.3$ 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?

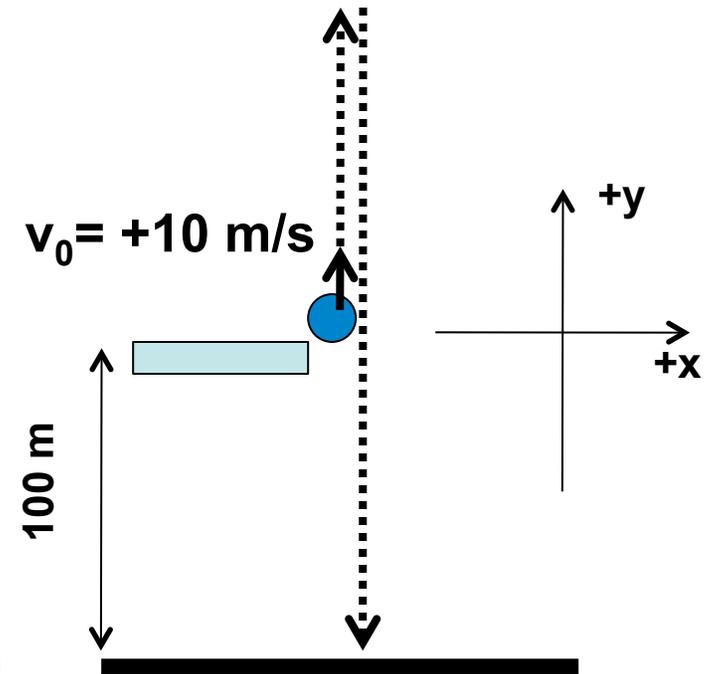
$v_y = -45.3$ m/s (use: $v(t)^2 = v_0^2 + 2a(y-y_0)$)

➤ At what time it hits the ground?

$t = 5.6$ s (use: $v(t) = v_0 + a_0t \rightarrow t = (v(t) - v_0)/a_0$)

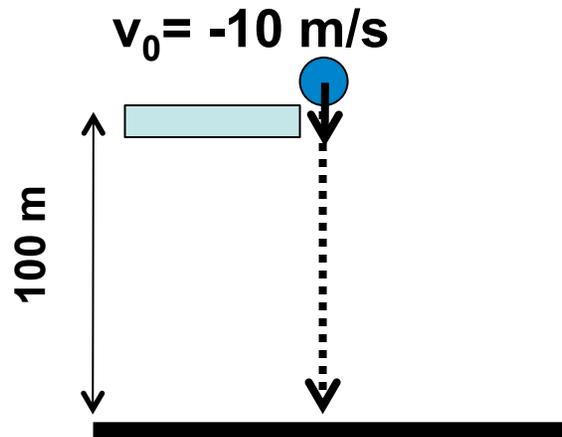
➤ During the flight the ball will fall back to platform level once, at what time this happen? ($t = 2.0$ s, use $x(t) = x_0 + v_0t + \frac{1}{2} a_0t^2$),
at what velocity is it at when this happens? ($v_y = -10$ m/s, DIY please)

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

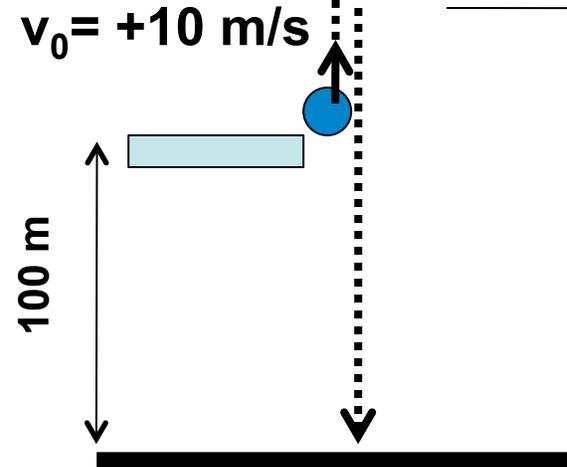


End-Of-Lecture Quizzes

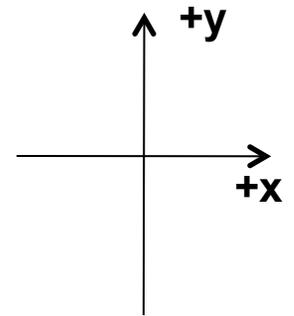
- Considering these two cases:



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.