# Problem solving: kinematics (II)

Physics 211
Syracuse University, Physics 211 Spring 2022
Walter Freeman

February 7, 2022

Announcements

- Homework 2 due date is **this Friday**
- Exam 1 is next Tuesday
  - No homework due next week
  - HW2 problems are similar to those on Exam 1
  - Recitation Friday is your group practice exam
  - If you must miss Friday, notify your TA in advance
    - Weekend: Exam review in the auditorium, Saturday, 5PM-8PM.
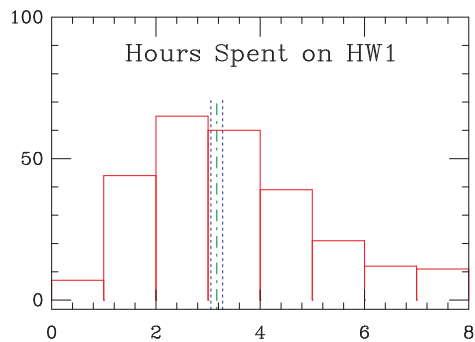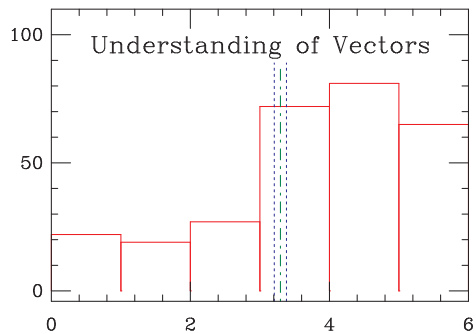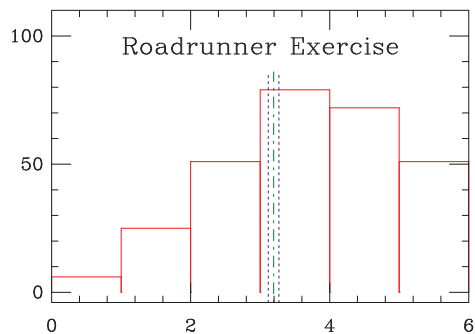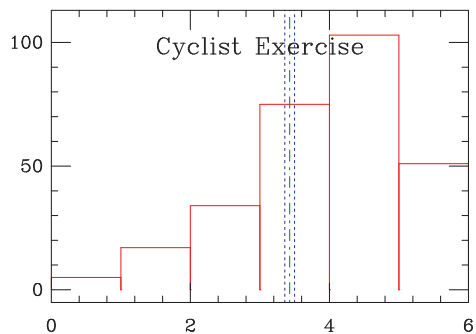
Makeup / study opportunities

We've arranged the following series of catchup/makeup/study sessions this week. All sessions will meet in the Clinic but may move to another room if need be.

- Tuesday 9:45-10:30 – I'll be in the Clinic helping with whatever people need.
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- Tuesday 5-6:30 – Mac and Kiersten:
  - General mathematics review
  - Review of vectors (for those who missed Friday's recitation)

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- Wednesday 3:00-4:30: Adil and Kiersten:
  - Catchup if you missed class due to COVID (focusing on beginning of semester)
  - Homework help
- Wednesday 4:30-5:30: I'll be in the Clinic.
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- Thursday 3:00-5:00: Adam P, Chris.
    - "How to Set Up Problems"
    - Homework help
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- Thursday 6:00-8:30 – AJ: "Bring Your Questions" – review of homework and recitation exercises by request

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- Friday all day: Group Exam Review. Not sure how something in the group exam worked? Come by to discuss!

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- You are allowed to bring one side of one page of notes that *you handwrite yourself* on Tuesday
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  - Your friend can't write it
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  - You can't print stuff from the internet
  - It won't help you as much anyway

Exam 1, promises

- There will be one problem where you need the quadratic formula
  - ... this means interpreting the two values it spits out
- There will be at least one instance where you need to interpret or sketch position, velocity, and acceleration graphs
- You will *not* need to compute derivatives or integrals algebraically
- The exam will be four problems, plus possibly a few short-answer questions

- Vectors: objects with direction and magnitude.
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  - Two representations:
  - Magnitude and direction (easiest to state, hardest to work with)
  - Components (easiest to work with)
  - Use trigonometry to go back and forth
- One more piece of notation about vectors...

Unit vectors

In the "ordered pair" notation for vectors' components, you might write:

$$\vec{v} = (5, 3)$$

But this is clunky, if you're trying to write it as part of an algebraic statement.

Instead we introduce "unit vectors", vectors with length 1, in the x, y, and z directions.

$$\hat{i} = (1, 0, 0)$$
$$\hat{j} = (0, 1, 0)$$
$$\hat{k} = (0, 0, 1)$$

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- $\vec{v} = (5, 3)$: Ordered pair
- $\vec{v} = 5\hat{i} + 3\hat{j}$: Unit vectors
- Both give you the same information, but unit vectors can be easier algebraically
- They won't be essential for this class, but you should know the notation – other people use it quite a bit, and I use it once on your homework

A word on positive and negative acceleration, velocity, "speed", and displacement:

When you choose your origin, you choose one direction to be positive, and the other to be negative. (Here: right = positive.)

- An object with $x < 0$ just means it's left of the origin.
- An object with $v < 0$ means it's moving to the left.
- An object with $a < 0$ means:
  - A: it is moving to the left and gaining speed
  - B: it is moving to the right and slowing down
  - C: it is moving to the left and slowing down
  - D: it is moving to the right and gaining speed

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Do not confuse the sign of something with the sign of its derivative!

Last time

Acceleration, velocity, and position relationships are the same in 2D; they just apply independently for each component.

$$\vec{v}(t) = \vec{a}t + \vec{v}_0$$

$$\vec{s}(t) = \frac{1}{2}\vec{a}t^2 + \vec{v}_0 t + \vec{s}_0$$

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$$x(t) = \frac{1}{2}a_x t^2 + v_{x,0}t + x_0$$
$$y(t) = \frac{1}{2}a_y t^2 + v_{y,0}t + y_0$$

Working with variables

If you don't know the numerical value of a quantity yet, it's fine to leave it as a variable!

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Example from cannon problem:

$$x(t) = \frac{1}{2}a_x t^2 + {\color{red}v_{x,0}}t + x_0$$
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Example from cannon problem:

$$x(t) = v_{x,0}t$$
$$y(t) = -\frac{1}{2}gt^2 + v_{y,0}t$$

If you don't know the numerical value of a quantity yet, it's fine to leave it as a variable!

This is essential for solving many problems.

Example from cannon problem:

$$x(t) = v_0 \cos 45^o t$$

$$y(t) = -\frac{1}{2}gt^2 + v_0 \sin 45^o t$$

(I leave the rest to you for now...)

Problem solving: 2D kinematics, constant acceleration

- 0. Draw a cartoon of the situation, and choose a coordinate system
- 1. If you have vectors in the "angle and magnitude" form $(\vec{a}, \vec{v}, \vec{s})$, convert them to components
- 2. Write down the kinematics relations, separately for x and y
  - Many terms will usually be zero
  - Freefall: $a_x = 0$, $a_y = -g$ (with conventional choice of axes)
- 3. Understand what instant in time you want to know about: ask the right question
- 4. Put in what you know; solve for what you don't (using substitution, if necessary)
- 5. Think about the physical meaning of your solution

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- ⑤ 4. Put in what you know; solve for what you don't (using substitution, if necessary)
- ⑥ 5. Think about the physical meaning of your solution

"What instant in time do you know about?"

This is often the most difficult part of problems: it requires thought, not just math.

You throw a ball upward over a hole of height h. Your position is the origin, and up is positive.

What condition means "the ball has hit the ground"?

- A: $y = 0$
- B: $y = h$
- C: $y = -h$
- D: $v_y = 0$

You throw a ball upward off of a cliff of height h. The top of the cliff is the origin, and up is positive.

What condition means "the ball is at its highest point?"?

- A: $y = 0$
- B: $v_y = 0$
- C: $y = h$
- D: y is a maximum

A football player

A football player kicks the ball at 15 m/s at an angle of 30 degrees above the horizontal.

How can we frame the question "How far does the ball go?" in terms of our variables?

- A: What is x at the same time that v_x is zero?
- B: What is y at the same time that x is is zero?
- C: What is x at the same time that y is zero?
- D: What is x at the same time that v_y is zero?

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- How fast is it traveling at its highest point?
- How fast is it traveling when it strikes the ground?

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What is $v_{0,x}$?

A: $v_0 \cos \theta$
B: $v_0 \sin \theta$
C: $v_0 \tan \theta$
D: v_0

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What is $v_{0,y}$?

A: $v_0 \cos \theta$
B: $v_0 \sin \theta$
C: $v_0 \tan \theta$
D: v_0

- What changes if I put the football player up on a cliff?

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- What changes if they are kicking the ball up to someone on a cliff?

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- What changes if I want to know what velocity they need to kick the ball to midfield?

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- What changes if they are kicking the ball up to someone on a cliff?
- What changes if I want to know what velocity they need to kick the ball to midfield?
- What changes if I have air resistance?

A hiker throws a rock horizontally off of a $h = 100$ m tall cliff. If the rock strikes the ground $d = 30$ m away, how hard did she throw it? How fast was it going when it hit the ground? (Choose the origin at the base of the cliff, up/direction of throw as positive)

What is $v_{0,x}$ here?

A: 0
B: 10/3 m/s
C: You don't know *a priori*

What is $v_{0,y}$ here?

A: 0
B: 9.8 m/s
C: You don't know *a priori*

What is a_x here?

A: 0
B: -g
C: +g
D: You don't know *a priori*

What is a_y here?

A: 0
B: -g
C: +g
D: You don't know *a priori*

What is x_0 here?

A: 0
B: h
C: d
D: You don't know *a priori*

What is y_0 here?

A: 0
B: h
C: d
D: You don't know *a priori*

What question do you ask to find "how hard did she throw it?"

A: What value of $v_{x,0}$ makes it such that $x = d$ when $y = 0$?
B: What value of $v_{y,0}$ makes it such that $x = d$ when $y = h$?
C: What is the value of v_x when $y = 0$?
D: What is the magnitude of $\vec{v}$ when $y = 0$?
E: What is the magnitude of $\vec{v}_x$ when $y = h$?

What question do you ask to find "how fast is it going when it hits the ground?"

A: What is v_x at the time when $v_y = 0$?
B: What is v_x at the time when $y = 0$?
C: What is v_y at the time when $y = h$?
D: What is the magnitude of $\vec{v}$ when $y = 0$?
E: What is the magnitude of $\vec{v}$ when $y = h$?

What's the magnitude of $\vec{v}$?

A: $v\cos\theta$
B: $v\sin\theta$
C: $\tan^{-1}\frac{v_x}{v_y}$
A: $\sqrt{v_x^2 + v_y^2}$

Throwing a stone onto a slope

A hiker kicks a stone off of a mountain slope with an initial velocity of v_0 3 m/s horizontally. If the mountain has a slope of 45 degrees, how far down the slope does it land? (Choose the origin as the starting point.)

A: What is the magnitude of $\vec{s}$ when $x = y$?
B: What is the magnitude of $\vec{s}$ when $x = -y$?
C: What is the magnitude of $\vec{s}$ when $y = 0$?
D: What is y when $x = -y$?
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This is on your homework :) I won't give the answer here – this is for you to ponder!

A rocket is launched from rest on level ground. While its motor burns, it accelerates at 10 m/s at an angle 30 degrees below the vertical. After $\tau = 10$ s its motor burns out and it follows a ballistic trajectory until it hits the ground.

How far does it go?