- worksheet: `positron.hep.upenn.edu/p8/files/ws03.pdf`
- Remember to check in with an instructor on your way out (if you leave early) or during the last 10 minutes of class (if you stay to the end), so that we can ask how today's work went for you. **End of day is fine for Canvas PDF upload.**
- I tried to keep groups mostly unchanged from last week, though **adds/drops required some rebalancing**.
- But your group of (2 or) 3 will share a table with a different group of (2 or) 3 each time. So your table number will change each day, but your group number will seldom change.
- Please write to me **in advance** if you need to miss class.
- Today's ws03 includes a hands-on exercise. Please watch for a space to open up at Table 9/10, and visit as a group, so that every group gets through it some time during today's class.
- I'll be away (UT Arlington) on Wednesday. Helping Ryan & Marija will be two of Phys8 2021's top students: Christina Cunningham & Sydney Goldstein. Same seating as today.

- before Wednesday's class meeting:
- Watch my day04 video (momentum), probably at $1.5\times$ or $2\times$ speed, since it is just under 2 hours long.
- I think if you do that, you will probably **not** need to **skim** Mazur chapter 04 (PDF on Canvas).
- If you like to read and don't like lectures, you can read the book and skip most of my videos. If you prefer lectures, you can watch the lecture videos and skip the reading. I originally wrote the lecture material assuming you did the reading first, but they're pretty self-contained. My lecture video PDF slides are at `positron.hep.upenn.edu/p8/files` with filenames `phys8_slides_*.pdf` eg `phys8_slides_04.pdf` for the video to watch before our "day04" class and worksheet ws04.
- So I'm pretty sure that you'll be able to choose either video or textbook reading to prepare for each class day.
- A concise summary of each chapter's key results is at `http://positron.hep.upenn.edu/p8/files/equations.pdf`

Reminder of ch03 key results

velocity is rate of change of position: $v_x = \frac{\mathrm{d}x}{\mathrm{d}t}$

acceleration is rate of change of velocity: $a_x = \frac{\mathrm{d}v_x}{\mathrm{d}t}$

If acceleration is **constant**, then:

$$v_{x,f} = v_{x,i} + a_x t$$

$$x_f = x_i + v_{x,i} t + \frac{1}{2} a_x t^2$$

$$v_{x,f}^2 = v_{x,i}^2 + 2a_x \left(x_f - x_i\right)$$

Important cases for which a_x is constant:

free fall: $a_x = -g$ (x axis points up)

inclined plane: $a_x = +g \sin\theta$ (x axis points downhill)

ch3 (acceleration)

$$v_x = \frac{dx}{dt} \qquad a_x = \frac{dv_x}{dt}$$

if a_x is constant then

$$v_{xf} = v_{xi} + a_x t$$

$$x_f = x_i + v_{xi} t + \frac{1}{2} a_x t^2$$

$$v_{xf}^2 = v_{xi}^2 + 2a_x (x_f - x_i)$$

free-fall

↑ x

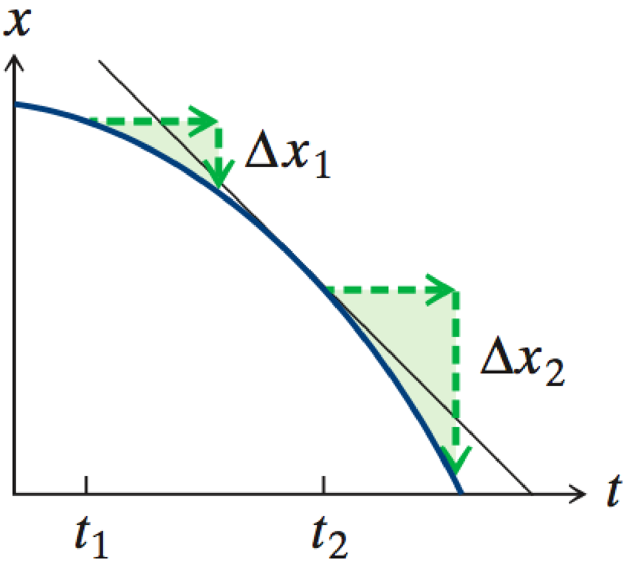
$a_x = -g$

inclined plane

↘ x

$a_x = +g \sin\theta$

At time t_2 in the position-vs-time graph below, the object is



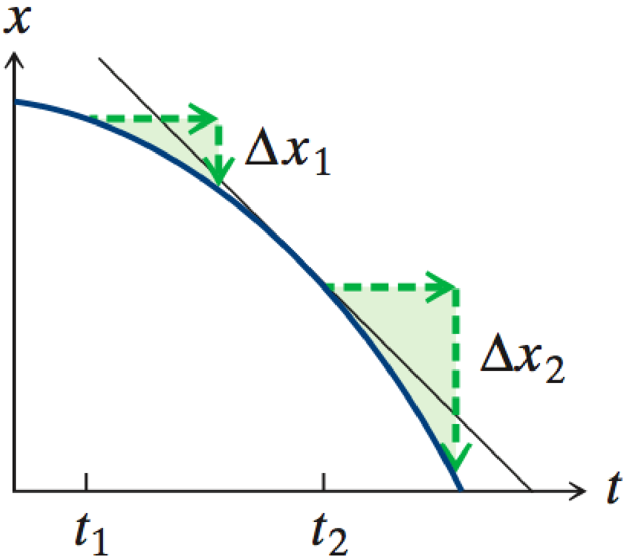
(A) not moving

(B) moving at constant speed

(C) speeding up

(D) slowing down

At time t_2 in the position-vs-time graph below, is v_x (the x component of velocity) is



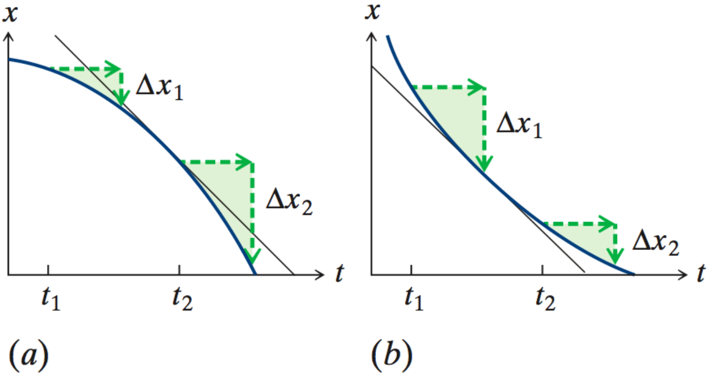
(A) zero

(B) not changing

(C) increasing

(D) decreasing

The x component of acceleration in these two graphs is



(A) positive in (a), negative in (b)

(B) negative in (a), positive in (b)

(C) negative in both (a) and (b)

(D) positive in both (a) and (b)

(E) zero in both (a) and (b)

I toss a basketball upward and watch it travel up and back. We define the x axis to point *upward*. At the top of its trajectory (where it turns around), v_x is

(A) positive

(B) negative

(C) zero

(D) infinite

(E) undefined

I toss a basketball upward and watch it travel up and back. We define the x axis to point *upward*. At the top of its trajectory (where it turns around), a_x is

(A) positive

(B) negative

(C) zero

(D) infinite

(E) undefined

Basketball tossed upward

What are the values of v_x and a_x at the top of the basketball's trajectory (assuming that the x axis points upward)?

(A) $v_x < 0$, $a_x = -9.8\ \mathrm{m/s^2}$

(B) $v_x < 0$, $a_x = 0$

(C) $v_x = 0$, $a_x = -9.8\ \mathrm{m/s^2}$

(D) $v_x = 0$, $a_x = 0$

(E) $v_x = 0$, a_x is undefined

A variation on a worksheet problem

A rock dropped from the top of a building travels 21.5 m in the last second before it hits the ground. Assume that air resistance is negligible. (The worksheet will probably ask, "How tall is the building?") Which of the following statements is true? (Let x-axis point upward.)

(A) The rock's average velocity $v_{x,\mathrm{av}}$ during the last 1.0 s of its fall is $-21.5\ \mathrm{m/s}$.

(B) The rock's instantaneous velocity v_x one second before it hits the ground is $-21.5\ \mathrm{m/s}$.

(C) The rock's instantaneous velocity v_x at the instant just before it hits the ground is $-21.5\ \mathrm{m/s}$.

(D) Statements (A), (B), (C) are all true.

(E) Statements (A), (B), (C) are all false.

A rock dropped from the top of a building travels 21.5 m in the last second before it hits the ground. Assume that air resistance is negligible. (Worksheet will probably ask, "How tall is the building?") At the instant just before hitting the ground, the rock's **speed** is

(A) 21.5 $\mathrm{m/s}$

(B) -21.5 $\mathrm{m/s}$

(C) Somewhat faster than 21.5 $\mathrm{m/s}$

(D) Somewhat slower than 21.5 $\mathrm{m/s}$

(E) We don't have enough information to decide.

A rock dropped from the top of a building travels 21.5 m in the last second before it hits the ground. Assume that air resistance is negligible. (Worksheet will probably ask, "How tall is the building?") Let the building height be h. Let the total time the rock falls be t. Which is a true statement about the problem?

(A) $h - \frac{1}{2}gt^2 = 0$

(B) $0 - gt = -21.5\ \mathrm{m/s}$

(C) $h - \frac{1}{2}g[t - 1.0\ \mathrm{s}]^2 = 21.5\ \mathrm{m}$

(D) $0 - g[t - 1.0\ \mathrm{s}] = -21.5\ \mathrm{m/s}$

(E) (A) and (B) are both true.

(F) (A) and (C) are both true.

(G) (A), (B), (C), and (D) are all true.

(H) (A), (B), (C), and (D) are all false.

Key results from upcoming Chapter 4 (momentum):

Momentum $\boxed{\vec{p} = m\vec{v}}$. Constant for *isolated* system: no external pushes or pulls (next week we'll say "forces"). Conservation of momentum in isolated two-body collision implies

$$m_1 v_{1x,i} + m_2 v_{2x,i} = m_1 v_{1x,f} + m_2 v_{2x,f}$$

which then implies (for isolated system, two-body collision)

$$\frac{\Delta v_{1x}}{\Delta v_{2x}} = -\frac{m_2}{m_1}$$

If system is not isolated, we introduce a concept called "impulse" meaning the transfer of momentum into a system from outside the system, due to objects inside the system interacting with objects outside the system. You will rarely use impulse, other than to consider whether or not it is nonzero.

1*. At the unused tables (9,10), we have placed several copies of today's hands-on activity. The materials are a rubber "super" ball, an orange/white striped meter stick, and a vise to hold the meter stick upright. From roughly a meter above the table, release the ball from rest, let it bounce twice, and catch it some time after its second bounce. (I usually like to catch it near its peak height.) If possible, to aid your graphing, use one teammate's smartphone to film a slow-motion video, with the orange/white striped meter stick in the background. Sketch a graph of $x(t)$, of $v_x(t)$, and of $a_x(t)$. Ask us or your neighbors for help or advice where needed, and compare with your neighbors' results! Expressing and labeling key features in a clear way is more important than drawing a perfect graph.

Optional: If you have extra time, try uploading your video to the "video analysis" web app

`https://www.physics.upenn.edu/undergraduate/undergraduate-physics-labs/loggerpro`

and use Video Analysis to analyze your slo-mo video. If you do this, either show or email the results to Bill (`ashmansk@hep.upenn.edu`) for **extra credit**.

2. (§3.5) You start your car from rest and accelerate at a constant rate, heading east (toward the Jersey Shore). Your speed is 26.8 m/s after 23.5 s. (a) What is your acceleration? (State both magnitude and direction.) (b) How far do you travel during these 23.5 s?

3. (§3.6) An astronaut finds herself on the planet Mars, whose acceleration due to gravity she wishes to verify. To find this acceleration, she drops a rock, which falls 2.55 m in 1.17 s. What is the magnitude of acceleration due to gravity, as determined by this astronaut?

4. (§3.6) With what minimum speed must a ball be thrown straight up in order to reach a height of 13.5 m above the launch position? How many seconds does the ball take to reach this height? (Neglect air resistance.)

5*. (§3.6) On a top-secret mission, an espionage agent prepares to drop a flash-memory stick from a bridge railing 33.8 m to the deck of a speedboat approaching on the river. Channel markers are spaced regularly along the river (with one of them just below the drop position), and the boat is passing them at the rate of 1 marker every 0.875 s. How many markers away should the boat be when the agent drops the film?

6*. (§3.7) A woman steps outside one winter day to go to work. Her icy driveway is 13.5 m long from top to mailbox, and it slopes downward at 6.0° from the horizontal. She sets her briefcase on the ice at the top while opening the garage, and it slides down the driveway. (a) What is its acceleration? (b) How many seconds does it take to get halfway to the mailbox? (c) How many seconds (after setting it down) until it reaches the mailbox? (d) What is its speed at the instant it reaches the mailbox?

7*. A piece of roof ballast (stone) that falls (effectively, is released from rest) from the top of a building travels 12.8 m in the last second before it hits the ground. How high is the building? (This is **very** tricky, but we discussed it at length in the video lecture.)

Rubric: 4 points per problem: 2 for effort, 2 for correctness.

- 4 points = correct or very nearly correct
- 3 points = minor mistake
- 2 points = major mistake
- 1 point = you haven't convinced us that you put in much effort to try to solve the problem
- 0 points = nothing or very little of substance written down
- For some problems (such as today's hands-on bridge model), it may be unreasonable for us to look for "correctness," so instead all 4 points will be for effort.
- 4 additional overall points for presenting your work clearly, with adequate reasoning. So if n is the number of problems, the total points will usually be $4n + 4$.