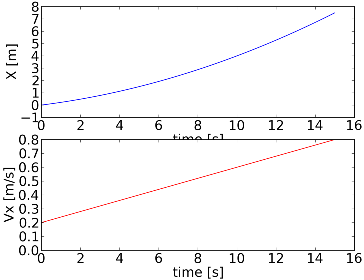
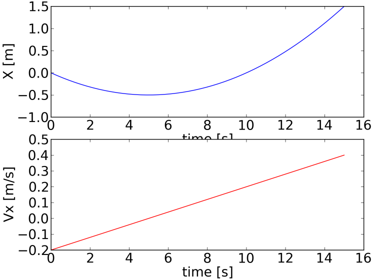
Physics 8 — Friday, September 6, 2019

- Turn in homework #1 at the start of class today.
- Most people report that HW1 took them somewhere in the range of 1–3 hours to complete. Maybe a bit more or less, depending on how long ago you most recently solved a lot of math problems.
- Also pick up homework #2 handout.
- Course www: `http://positron.hep.upenn.edu/physics8`
- Today, we will finish up Ch3 (acceleration) and start Ch4 (momentum), which you read for Wednesday.
- For Monday, read Ch5 (energy).
- You might have noticed that the solution for checkpoint 4.6 is wrong: they got it backwards. Also, for checkpoint 5.13, he wrote "yes" but he means "no."
- Someone asked an excellent question after class about the difference between scenarios (A) and (C) on the last question we discussed on Wednesday. Let's discuss that first.

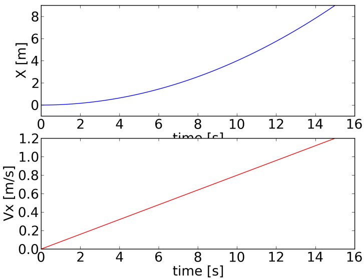
Which of the following shows the expected shapes of $x(t)$ [blue] and $v_x(t)$ [red] if I **shove** the cart gently downward from $x = 0\ \mathrm{m}$?



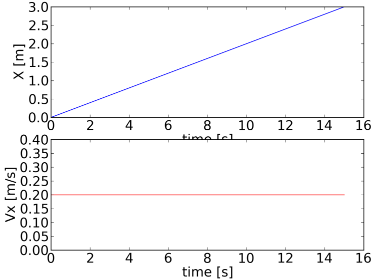
A



B

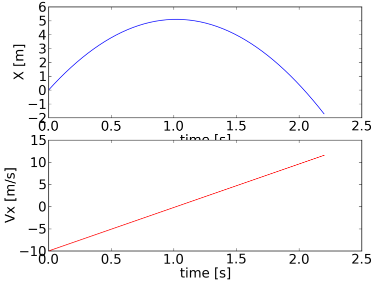


C

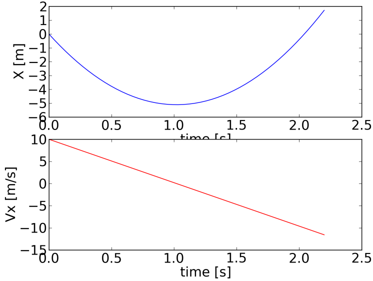


D

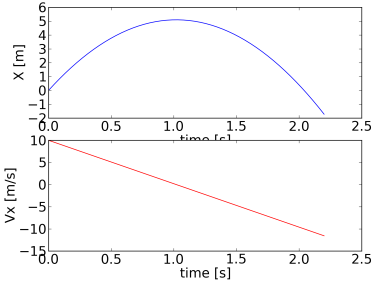
What are the expected shapes of $x(t)$ [blue] and $v_x(t)$ [red] for a **basketball tossed upward**, when the x axis points *upward*?



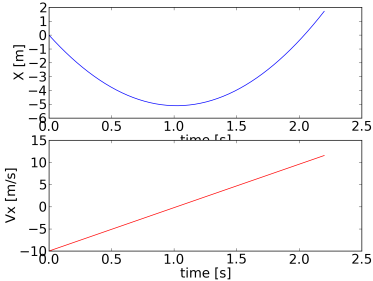
A



B



C



D

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

Ball thrown downward

If you stand up high and release an object with a downward shove, in the absence of air resistance, the motion (after release, but before hitting the ground) is best described by

(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

(Where we've defined the x axis to point *upward* here.)

I'm going to drop the basketball from a few meters in the air, and I'll let it bounce twice before I catch it. Working with one or two people next to you, draw a graph of $v_x(t)$ (velocity) and a graph of $a_x(t)$ (acceleration), spanning the time from release to catch. Let the x axis point upward. Don't worry about labeling the axes with numerical values, but do be clear about positive vs. zero vs. negative values.

Put your name(s) on your sheet of paper (one, two, or three people per sheet — whatever you prefer) and turn it in at the end of class. I'll give you credit for showing up and making the effort, not so much for correctness.

There will be a couple of other things for you to work out together in class today, so you'll probably need a full sheet of paper.

Reminder

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: (write these on board)

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

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

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

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)

Q: If I stand $h = 20\,\mathrm{m}$ above the ground and release a steel ball from rest, how long does it take to reach the ground? (Hint: to avoid using a calculator, you can approximate $g \approx 10\ \mathrm{m/s^2}$.)

(A) 2.0 s

(B) 1.5 s

(C) 1.0 s

(D) 0.50 s

(E) 0.25 s

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

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

$$0 = h + 0 - \frac{1}{2} g t^2$$

Q: If I stand 20 m above the ground and release a steel ball from rest, what is its velocity at the instant just before it reaches the ground? (Use $g = 10 \text{ m/s}^2$ to simplify math.)

(A) 10 m/s, pointing downward
(B) 15 m/s, pointing downward
(C) 20 m/s, pointing downward
(D) 40 m/s, pointing downward
(E) 40 m/s, pointing upward

Q: If I stand 20 m above the ground and release a steel ball from rest, what is its velocity at the instant just before it reaches the ground? (Use $g = 10\ \mathrm{m/s^2}$ to simplify math.)

(A) 10 m/s, pointing downward
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If you already solved for t in the previous question then:

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If you already solved for t in the previous question then:

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

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$$v_{x,f} = 0 - gt$$

Or if you don't already know t then:

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

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Or if you don't already know t then:

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

$$v_{x,f}^2 = 0^2 + 2(-g)\,(0 - h)$$

Work on this together with 1 or 2 nearby people!

A box is at the lower end of a frictionless ramp of length $L = 10\ \mathrm{m}$ that makes a nonzero angle $\theta = 30^\circ$ with the horizontal. A worker wants to give the box a shove so that it just reaches the top of the ramp. How fast must the box be going immediately after the shove (assumed to be instantaneous) for it to reach its goal? Remember $\sin 30^\circ = \frac{1}{2}$ and use $g \approx 10\ \mathrm{m/s^2}$ to keep the math simple.

(A) 1.0 m/s

(B) 5.0 m/s

(C) 7.0 m/s

(D) 10 m/s

(E) 20 m/s

Put your group's name(s) on the sheet of paper you work this out on, and turn it in at the end for "in class" credit.

Reminder (on board): results derived from $\boxed{a_x = \mathrm{constant}}$.

Work on this together with 1 or 2 neighbors!

A box is at the lower end of a frictionless ramp of length $L = 10\ \mathrm{m}$ that makes a nonzero angle $\theta = 30^\circ$ with the horizontal. A worker wants to give the box a shove so that it just reaches the top of the ramp. She shoves the box, as we worked out on the previous page: the box's initial speed is 10 m/s. (Again, use $g \approx 10\ \mathrm{m/s^2}$ to keep the math simple.)

What is the box's speed when it is halfway up the ramp?

(A) 1.0 m/s

(B) 5.0 m/s

(C) 7.1 m/s

(D) 10.0 m/s

(E) 20.0 m/s

Chapter 4: momentum

- An object's momentum is $\vec{p} = m\vec{v}$ $\quad$ $p_x = mv_x$
- m is for "mass" a.k.a. "inertia." Mass plays two roles in physics: how strongly an object is attracted by gravity, and how difficult it is to change an object's velocity. We say "inertia" for now to focus on this latter aspect of mass. Inertia equals mass.
- Momentum is *conserved*: it can be transferred between interacting objects, but it cannot be created or destroyed.
- If the objects within a system have no interactions with the outside world ("isolated system"), then the momentum of that system is constant (cannot change).
- Imagine how it feels to throw a very heavy ball.
- Now imagine that you are standing on a sheet of ice!
- The difference is the *impulse* you get from the interaction between your shoes and the non-slippery floor.

For two carts colliding on a frictionless track, I can define "the system" to include just the two carts. Then $\boxed{\Delta\vec{p}_{\mathrm{system}} = \vec{0}}$ because the system is isolated (i.e. interactions with the outside are negligible).

Here are 7 different ways of saying the exact same thing:

$$\Delta\vec{p}_1 + \Delta\vec{p}_2 = \vec{0} \quad \text{(isolated system)}$$

$$\vec{p}_{1i} + \vec{p}_{2i} = \vec{p}_{1f} + \vec{p}_{2f}$$

$$p_{1x,i} + p_{2x,i} = p_{1x,f} + p_{2x,f}$$

$$m_1 \; \Delta v_{1x} \; + \; m_2 \; \Delta v_{2x} \; = \; 0$$

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

$$m_1 \; \Delta v_{1x} \; + \; m_2 \; \Delta v_{2x} \; = \; 0$$

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

Boxed equation is most useful for problem solving. Last equation is most useful for visual observation of collisions.

(For an isolated system of two objects)

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

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

Let's watch the collision between a cart of mass m and a cart of mass $3m$ that you considered after Tuesday night's reading.

Then let's watch the case where $m_1 = m_2$.

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