Critical Thinking in Physics and Astronomy Freshman Courses

Enhancing Analytical Skills for future Scientists and Engineers

Lih-Sin The
Department of Physics and Astronomy

- Critical thinking is the intellectual process of actively analyzing information, questioning assumptions, and forming well-reasoned arguments.

- It's about understanding concepts, applying them to solve problems, and evaluating the evidence to reach sound conclusions.

Course: PHYS1220 / Physics with Calculus I

Course Objectives:

- To give the successful student a working knowledge of mechanics and the skills necessary to solve basic mechanics problems with exercises in critical thinking using quantitative and qualitative analysis. Students are expected to have the skills to: ……..

… able to tie new concepts to those he/she already knew and apply them to new situations.

- In the Spring and Fall semesters, the courses are taught face-to-face with the grades depend on in-class quizzes, homework, mid-term exams, and final exam.

- Through critical thinking by analyzing the situation of the problems, creating strategies to solve them and practicing computational skills, students develop strong problem-solving skills.

- By the end, students hopefully will be well on their way to becoming critical thinkers and more successful students.

Online Discussion

Students will actively engage in Canvas online discussions designed to foster interpersonal connections and critical thinking skills. In the first discussion assignment, students are encouraged to introduce themselves, fostering community within the class.

In subsequent discussions, students are prompted to raise thought-provoking problems that stimulate curiosity about the chapter under consideration (30%).

Participation in these discussions is highly encouraged. Responding thoughtfully to their peers' posts worth 30%, and actively engaging in collaborative learning by proposing solutions or strategies to address presented problems worth 40%. By participating in discussions, students demonstrate their comprehension of the material and invite classmates to engage in collaborative problem-solving and idea exchange.

Solving physics problems is like participating in a sport

"**Physics is not a spectator sport**." It means that to understand physics it is not enough to simply read the textbook or hear in class. In physics class, students are expected to do problem solving and do experiments in a laboratory using the same sort of skills as a professional physicist.

The analogy : You cannot become a good athlete by simply watching sports on TV; you must practice on the field.

➔ practice solving problems.

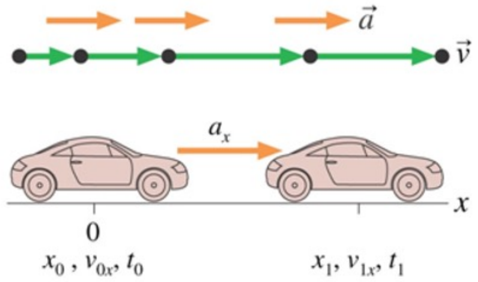
Solving Problems in Physics:

Translating **from words to symbols**

is the heart of problem solving in physics

A car starts from rest. After 2.0 seconds of constant acceleration of 2.0 m/s^2, how far does it go?

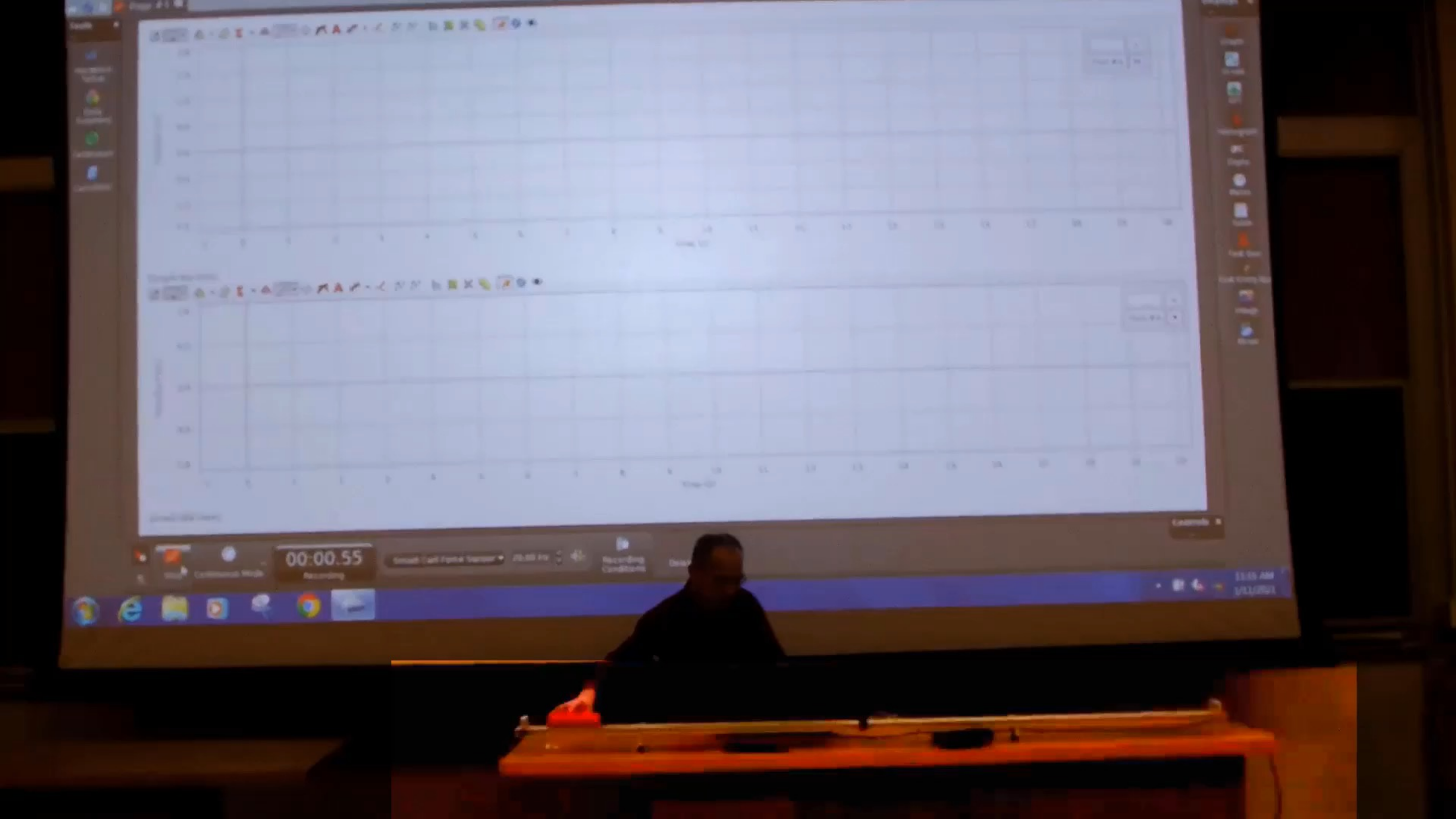
0. Interpret the statements of the problem.
1. Draw a motion diagram or a sketch of the situation of the problem.
2. Establish a coordinate system and labels.
3. List known quantities.



$x_i = 0$ m	$x_f =$ __
$v_i = 0$ m/s	$v_f =$ __
$a_x = 2$ m/s^2	$\Delta t = 2.0$ s

4. List desired quantities.

$v_x = v_{0x} + a_x t$	(2.9)	Displacement Δx
$\Delta x = \frac{1}{2}(v_{0x} + v_x)t$	(2.10)	Acceleration a_x
$\Delta x = v_{0x}t + \frac{1}{2}a_x t^2$	(2.11)	Final velocity v_x
$\Delta x = v_x t - \frac{1}{2}a_x t^2$	(2.12)	Initial velocity v_{0x}
$v_x^2 = v_{0x}^2 + 2a_x \Delta x$	(2.13)	Final time t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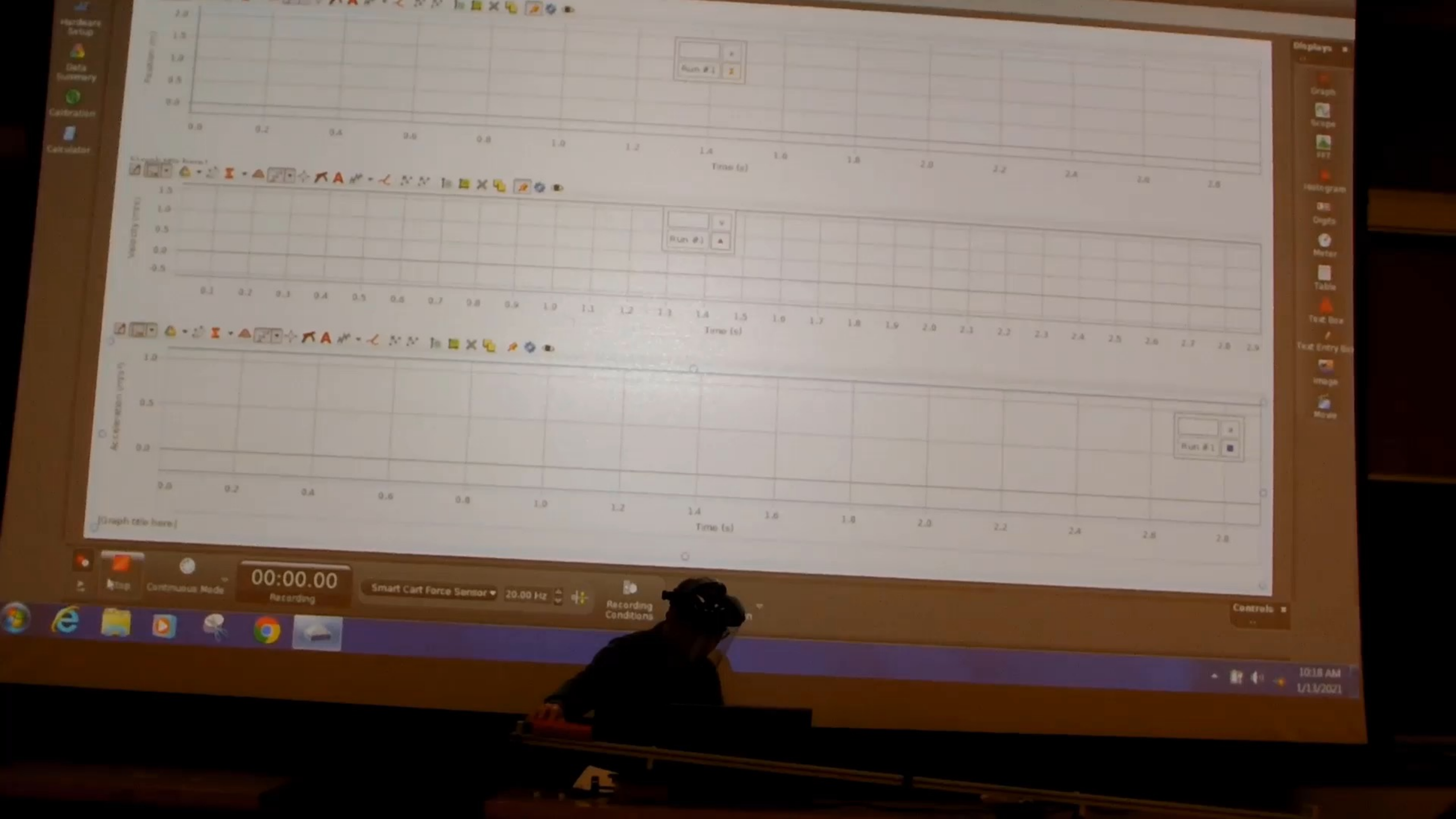
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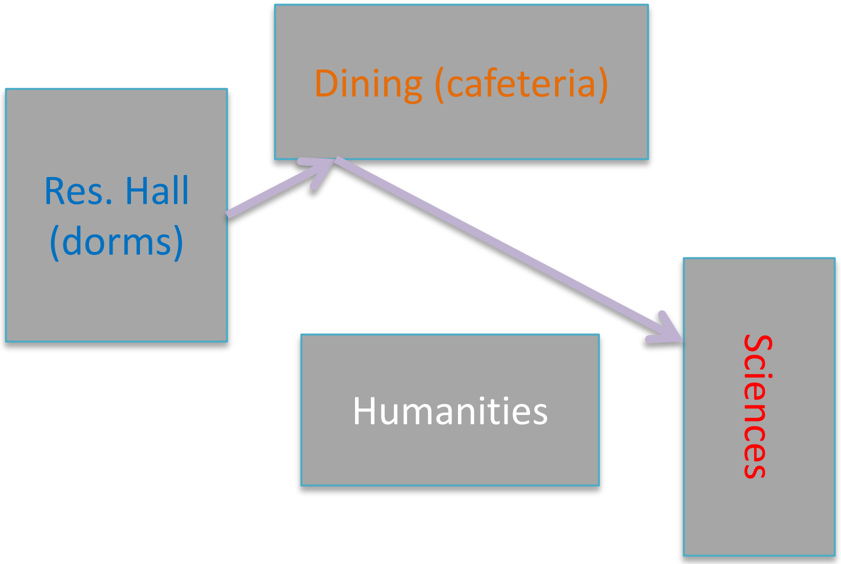
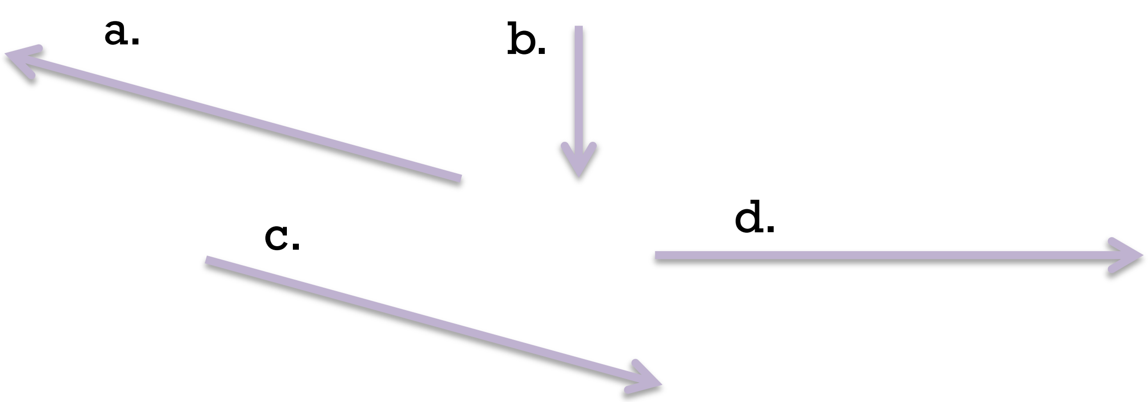
Take a walk.
Which choice is the resultant of the two trips?

Nicole walks from the dorms to the cafeteria, then from the cafeteria to the science building.



The segments of her walk add to give the vector representing her total travel.

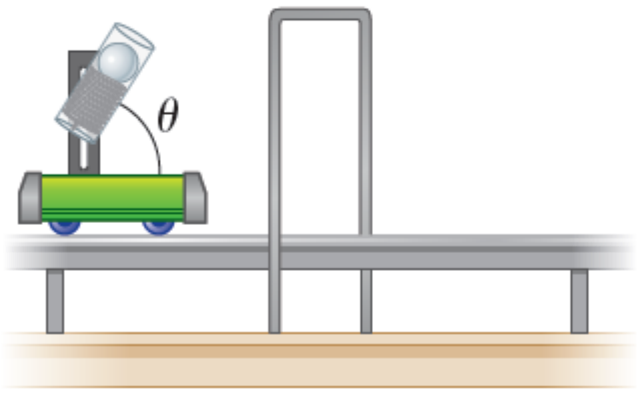
Use a graphical method to determine the best choice for her total displacement.



[Show the demo movie (3:24:7:07).]

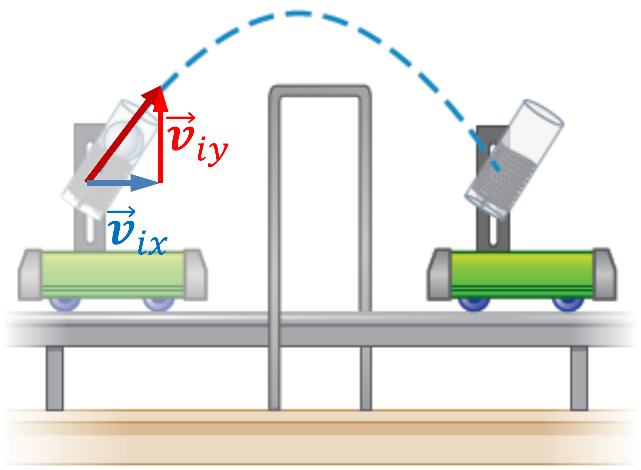
[Hippy Jump Tutorial]

What do we learn from the demonstration?



A.

The vertical height of the ball stays the same!!



B.

- A parabolic projectile **motion** can be composed out of two independent motions: a horizontal motion and a vertical motion.
- The horizontal motion is a motion with constant speed (acceleration $a_x = 0$).
- The vertical motion is a free-fall motion with an acceleration $a_y = -g$.
- **Relative Velocity**: the velocity of ball in the horizontal direction is the same as the velocity of the cart in the horizontal direction ➔ The velocity of the ball relative to the cart in horizontal direction is 0.
- The ball is always straight above the cart.

$$\vec{v}_{\text{peak}} = v_{ix}\,\hat{j} + 0\,\hat{j}$$

$$x_f = x_i + v_x \cdot t \qquad y_f = y_i + v_{iy} \cdot t - \frac{1}{2} g \cdot t^2$$

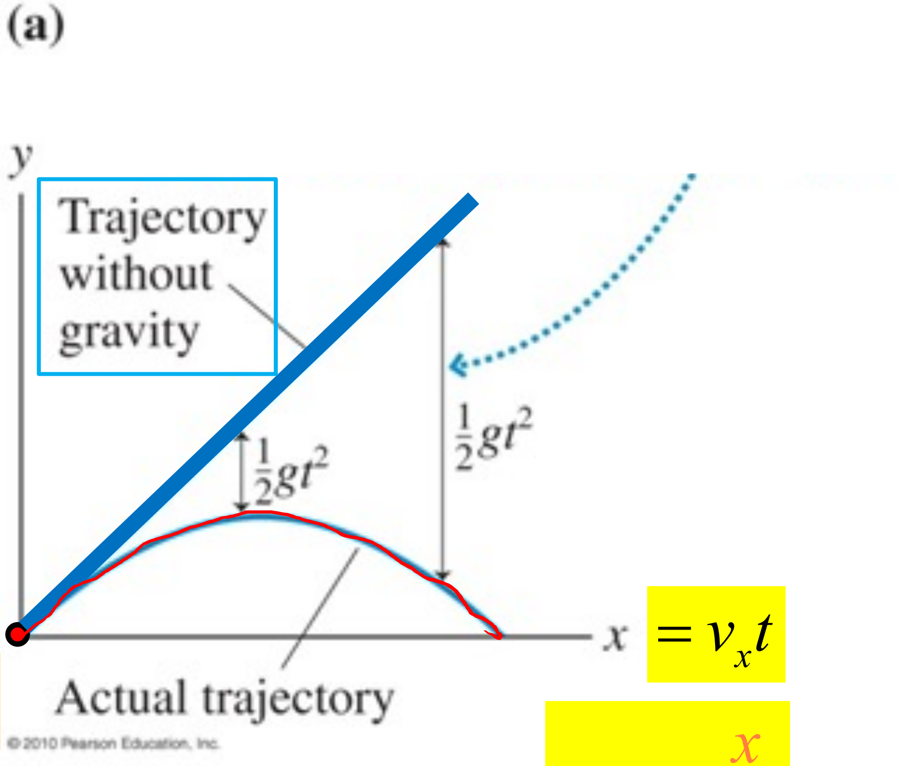
$$v_x = \text{constant} \qquad v_{fy} = v_{iy} - g \cdot t$$

Without gravity: $y_f = v_{iy} \cdot t = v_{iy} \cdot \frac{x}{v_x}$

With gravity: $y_f = v_{iy} \cdot t - \frac{1}{2} g \cdot t^2 = v_{iy} \cdot \frac{x}{v_x} - \frac{1}{2} g \left(\frac{x}{v_x}\right)^2$

The falling object: $y_f = y_0 \cdot t - \frac{1}{2} g \cdot t^2$

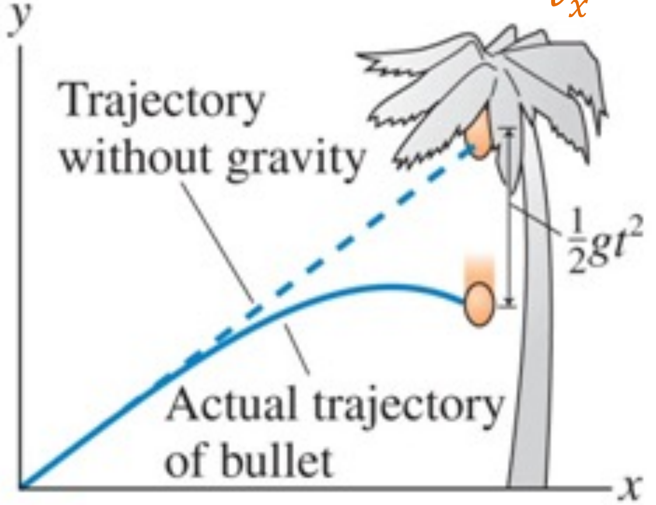
$y_0 = v_{iy} \cdot \frac{x}{v_x}$



$x_i = y_i = 0$

$= v_x t$

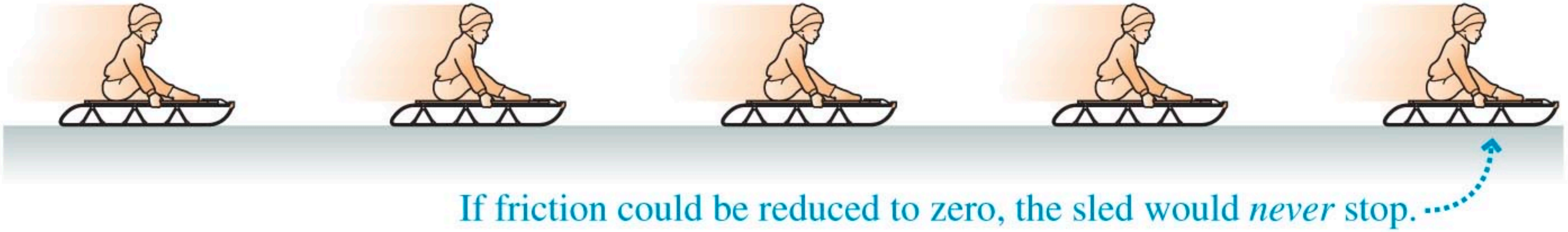
$\rightarrow t = \frac{x}{v_x}$



demo (00:00-01:45)

Newton's first law An object that is at rest will remain at rest, or an object that is moving will continue to move in a straight line with constant velocity, if and only if the net force acting on the object is zero.

(c) Frictionless surface

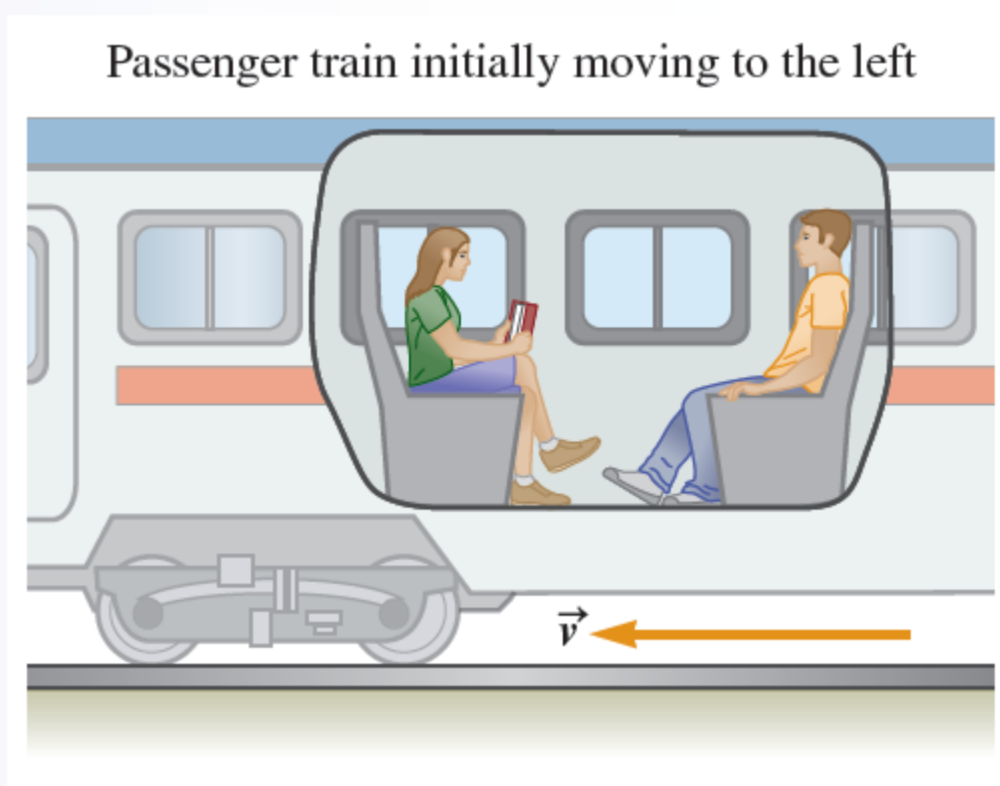


- The property of a body to remain at rest or to remain in motion with constant velocity is called **inertia**.

- However, ***to change a motion*** (from rest to a certain velocity or change the velocity of the object), **a force** (push or pull) **is required**.

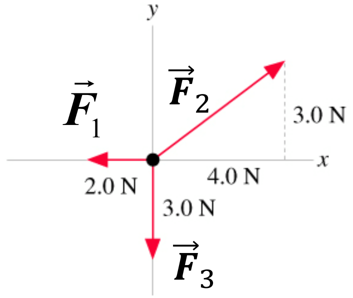
The magician demo (00:55-01:00)

Newton's First Law



More injuries to passengers who were standing or facing forward

➔ Wear a seat belt!



Complete information about Forces

$$F_{\text{net},\,x} = F_{1x} + F_{2x} + F_{3x}$$
$$F_{\text{net},\,y} = F_{1y} + F_{2y} + F_{3y}$$

→

$$a_x = \frac{F_{\text{net},\,x}}{m}$$
$$a_y = \frac{F_{\text{net},\,y}}{m}$$

→

Use the kinematic Eqs. to determine either x_f, y_f, v_{fx}, v_{fy}

Force ↔ ***a*** ↔ *Motion* $(x_{f,} v_{f,} \Delta t)$

$$F_{1x} + F_{2x} + F_{3x} = F_{\text{net},\,x}$$
$$F_{1y} + F_{2y} + F_{3y} = F_{\text{net},\,x}$$

$$T - mg = ma_y$$

←

$$F_{\text{net},\,x} = ma_x$$
$$F_{\text{net},\,y} = ma_y$$

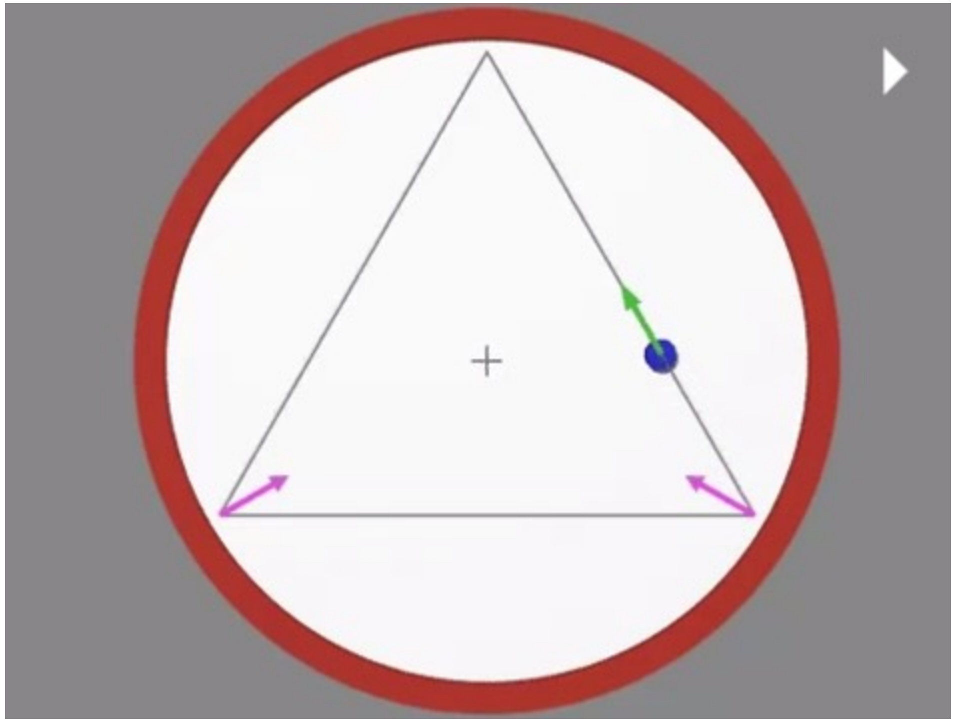
←

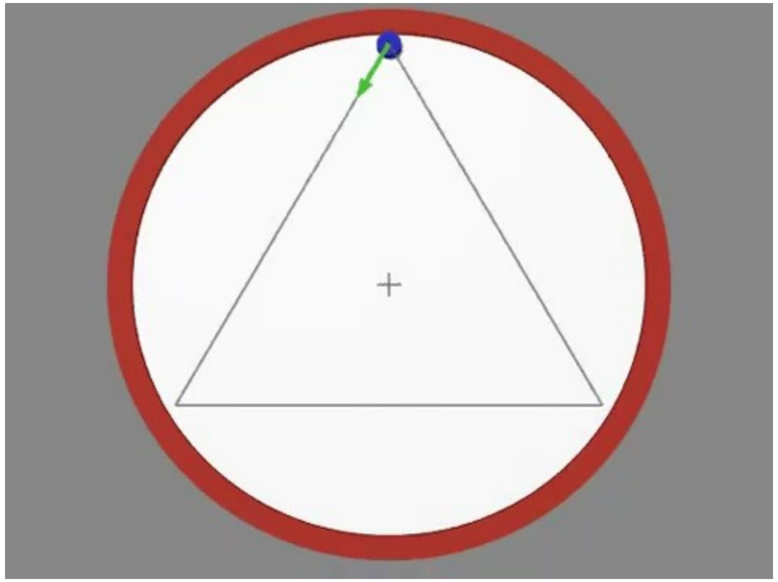
Complete information of x, y, v_x, v_y

↓

determine a_x, a_y using the kinematic eqs.

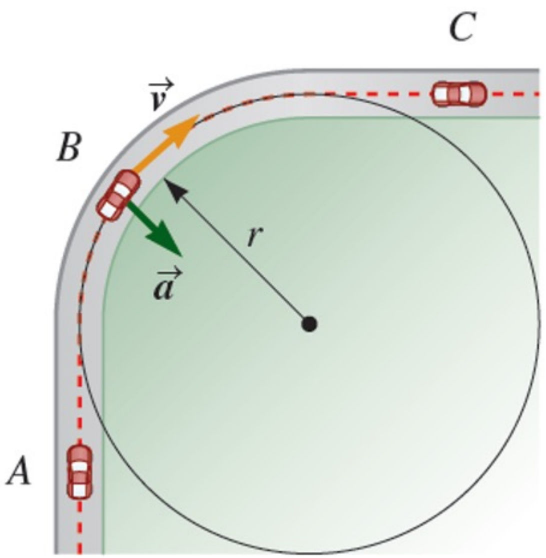
Show www.youtube.com/watch?v=fSfVVz0eIis

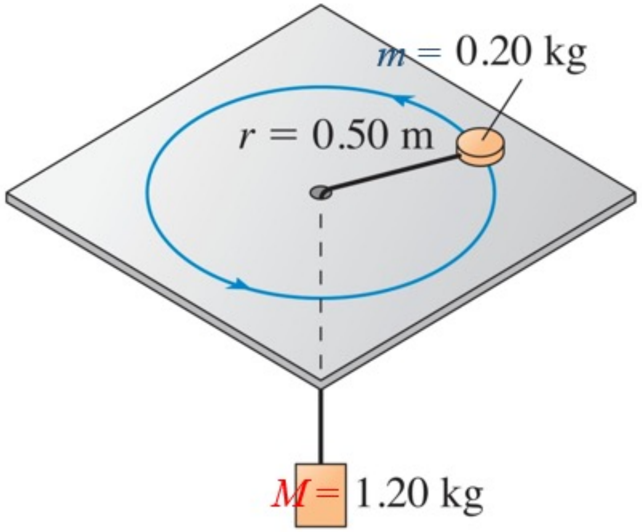


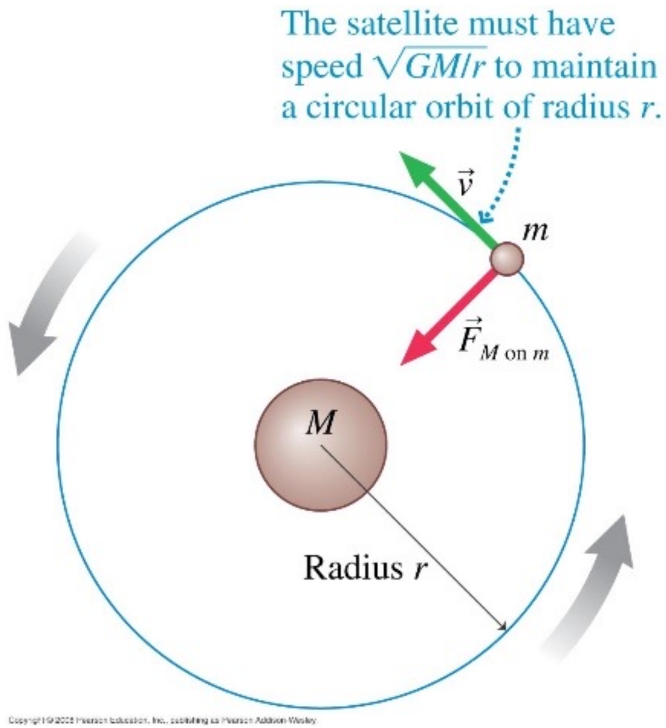


When the ball bounces off the surface, it experiences a normal force directed in the direction of the ***arrow*** (acceleration's direction).

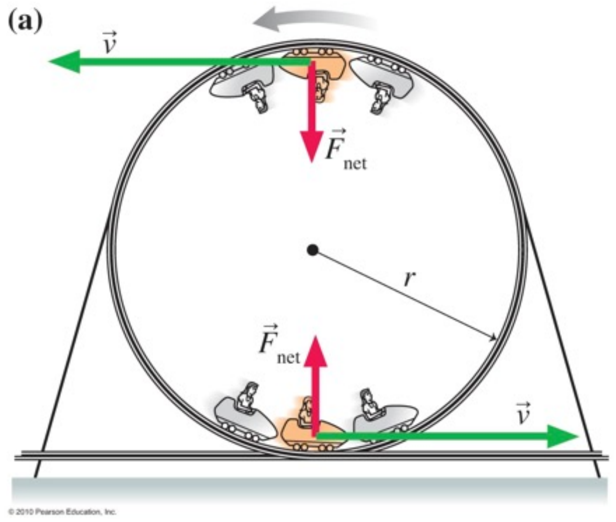
For an object to move in a circular motion, there must be a force pushing it to the center of the circle continuously (01:10-03:00).

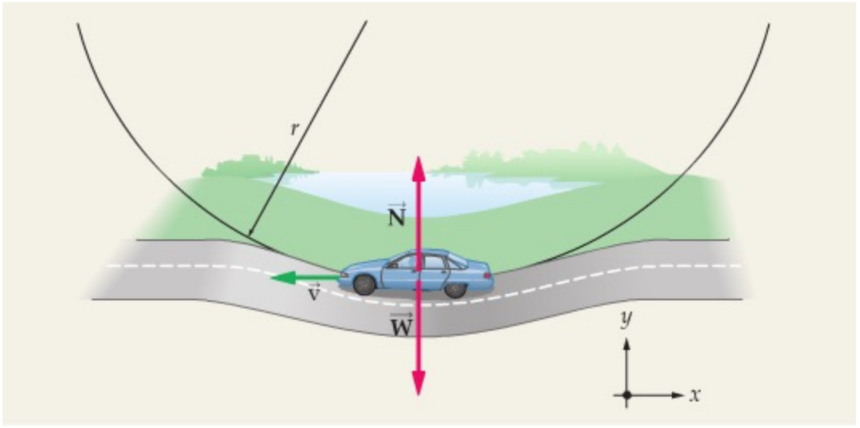


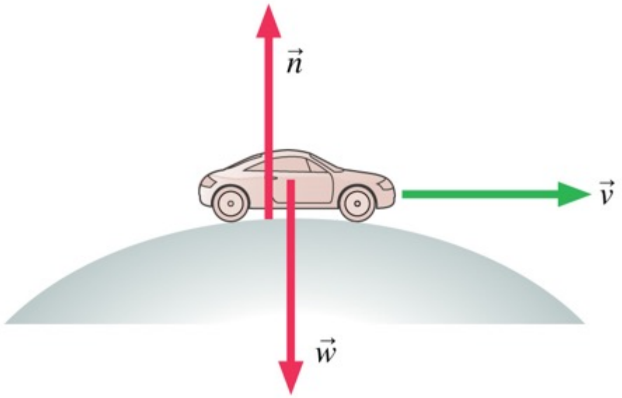




$$F_{\text{net in the direction to the center of the circle}} = m\frac{v^2}{r}$$





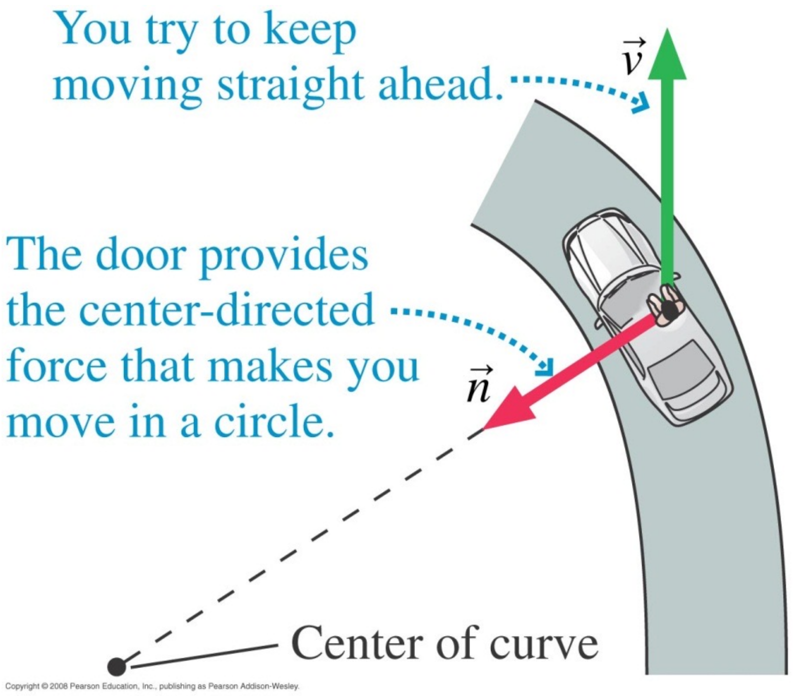


Centrifugal Force

If the car you are in turns a corner quickly, you feel "thrown" against the door.

The "force" that seems to push an object to the outside of a circle is called the *centrifugal force*.

It describes your experience *relative to a noninertial reference frame*, **but there really is no such force.!!!**

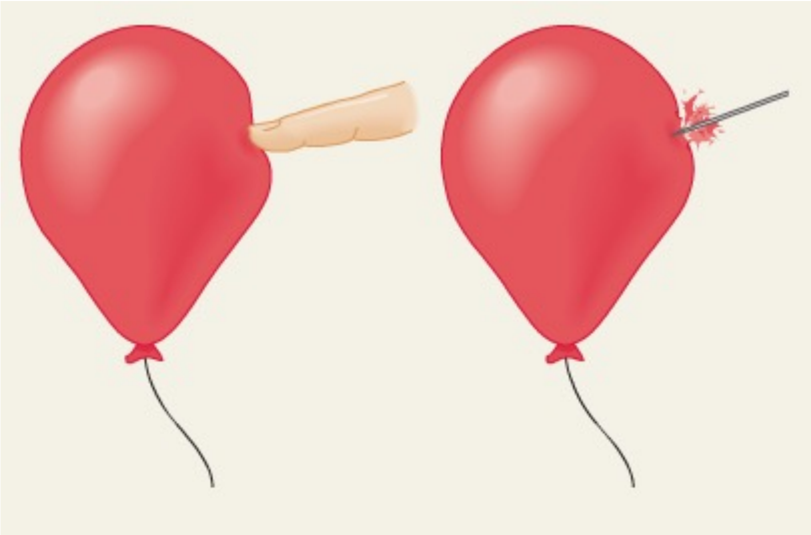


Popping a Balloon

Find the pressure exerted on the skin of a balloon if you press with a force of 2.1 N using (a) your finger or (b) a needle.

Assume the area of your fingertip is 1.0×10^{-4} m^2 and the area of the needle tip is 2.5×10^{-7} m^2. The balloon pops with a pressure of 3.0×10^{5} N/m^2.

$$p \equiv \frac{F}{A}$$



Pressure exerted by the finger:

$$p = \frac{F}{A} = \frac{2.1 \text{ N}}{1.0 \times 10^{-4} \text{ m}^2} = 2.1 \times 10^{4} \text{ N/m}^2$$

Pressure exerted by the needle:

$$p = \frac{F}{A} = \frac{2.1 \text{ N}}{2.5 \times 10^{-7} \text{ m}^2} = 8.4 \times 10^{6} \text{ N/m}^2$$

http://www.nytimes.com/video/science/100000004045543/how-ballooons-pop.html

On a Frozen Lake

You are walking out on a frozen lake, and you begin to hear the ice cracking beneath you. What is your best strategy for getting off the ice safely?

a) stand absolutely still and don't move a muscle
b) jump up and down to lessen your contact time with the ice
c) try to leap in one bound to the bank of the lake
d) shuffle your feet (without lifting them) to move toward shore
e) lie down flat on the ice and crawl toward shore

Course: ASTR1020 / Stellar Astronomy

Course Description:

- This course is a study of stars, galaxies, and the universe.
- It is a descriptive survey of the universe beyond the solar system, emphasizing basic physical concepts and galactic and extragalactic objects.

- This course is a course for non-science majors, but it applies mathematics.
- It requires students to understand the application of scientific methods throughout the course for 3 hours of the General Education Natural Science competencies requirement.

- The class usually has ~110 students.
- Assign homework, Quizzes, and exams are multiple-choice questions.
- So how do the students practice to express their line of reasoning?

- Discussion assignments where students express their line of thought.

The Assignment: “Does It Make Sense?” Chapter-22 Discussion Cases.

1. Two stars that look very different must be made of different kinds of elements.
2. In a hypothetical universe that contains only low-mass stars, we could not find elements heavier than carbon.
3. The atoms in our bodies are made of ”star stuff”.
4. Stars that look red-hot have hotter surfaces than stars that look blue.
5. Some of the stars on the main sequence of the H-R diagram are not converting hydrogen into helium.
6. The smallest, hottest stars are plotted in the lower left-hand portion of the H-R diagram.
7. Stars that begin their lives with the most mass live longer than less massive stars because it takes them a lot longer to use up their hydrogen fuel.
8. Star clusters with lots of bright, blue stars are generally younger than clusters that don’t have any such stars.
9. All giants, supergiants, and white dwarfs were once main-sequence stars.
10. Most of the stars in the sky are more massive than the Sun.
11. Globular clusters generally contain lots of white dwarfs.
12. If the Sun had been born as a high-mass star some 4.5 billion years ago, rather than as a low-mass star, the planet Jupiter would probably have Earth-like conditions today, while Earth would be hot like Venus.
13. After hydrogen fusion stops in a low-mass star, its core cools off until the star becomes a red giant.

Discussion Assignment

Tasks:

- Each student chooses a topic of Canvas discussion from about 10-15 cases given by the instructor, then
  1. Post the whole statement of the chosen discussion. (20 pts)
  2. Write a judgment on whether the statement makes sense or not. (30 pts)
  3. Write clearly the reasons for your judgment based on what we learn in this chapter:
     - Tie the concepts learned in this chapter to the case statement (30 pts)
     - Write in a clear manner and correct grammar with a good flow of reasoning (20 pts)
- After posting the task above, each student should peer-review and grade anonymously two posts selected randomly by Canvas LMS using the criteria above and the discussion rubric shown below. The score of the assignment is the average of the scores given by the two anonymous reviewers.