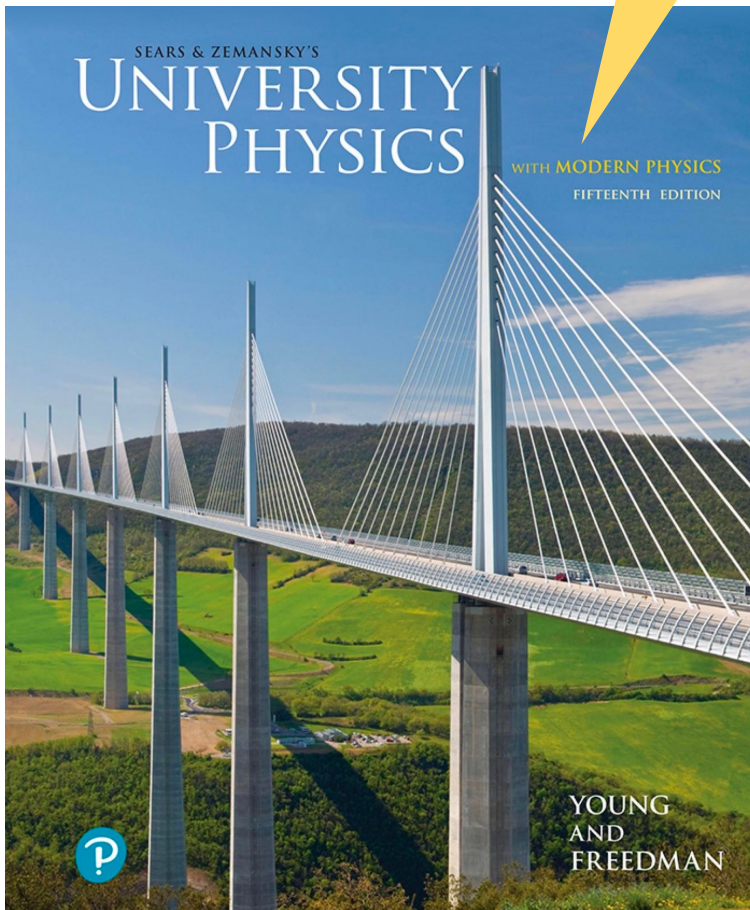




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**ACTIVATING UNIVERSITY PHYSICS:
MAKING PHYSICS LECTURES
COME ALIVE**

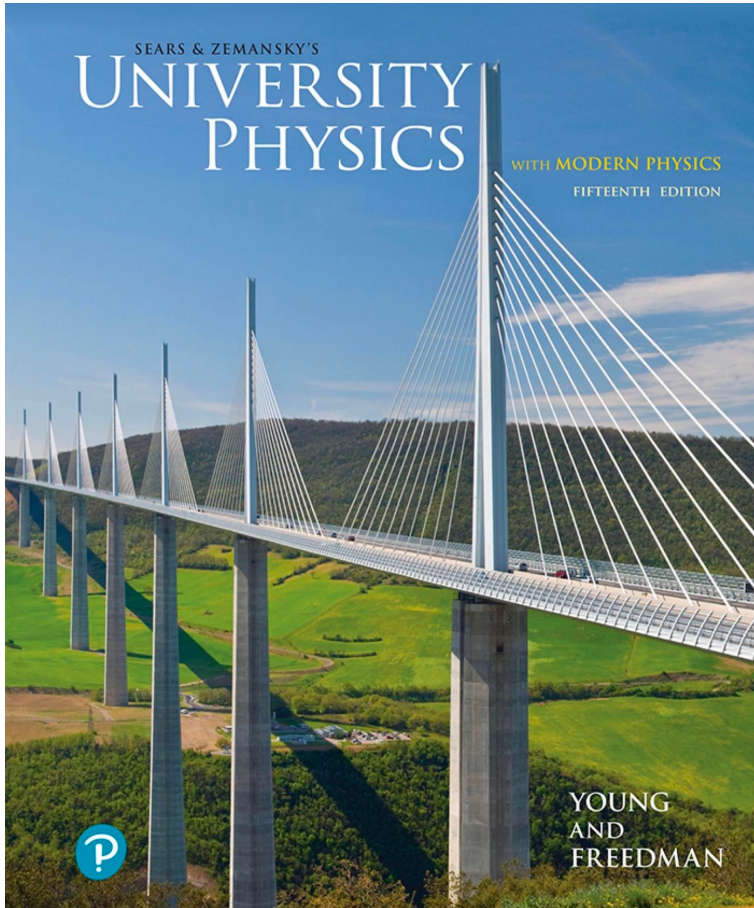


**ROGER FREEDMAN
AIRBOY@UCSB.EDU
10 MAY 2023**

**PLEASE FEEL FREE TO
ASK QUESTIONS DURING
THE WEBINAR!**

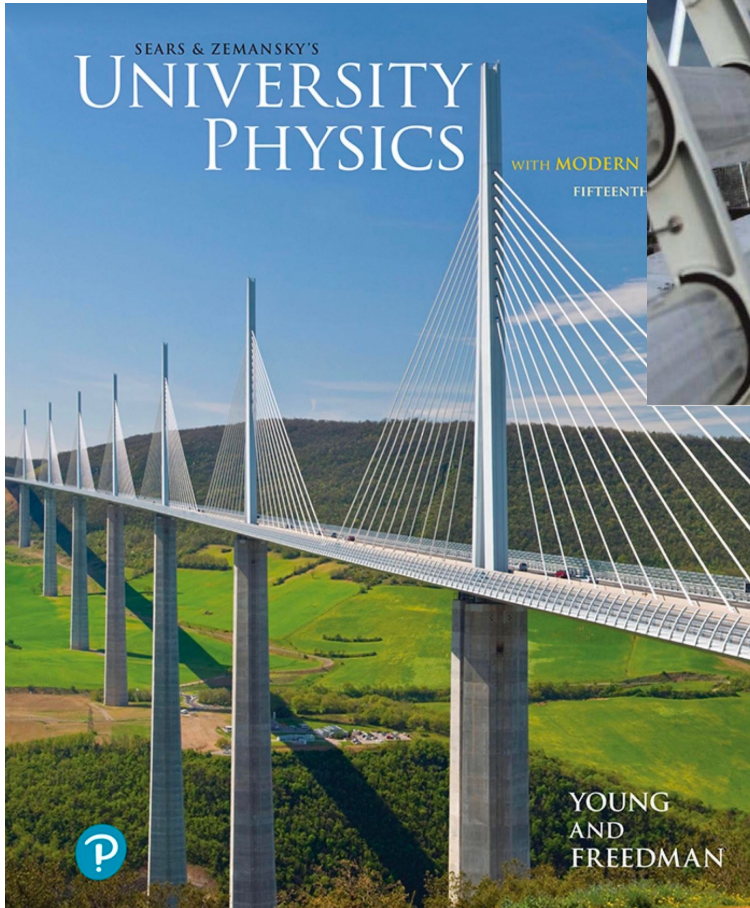


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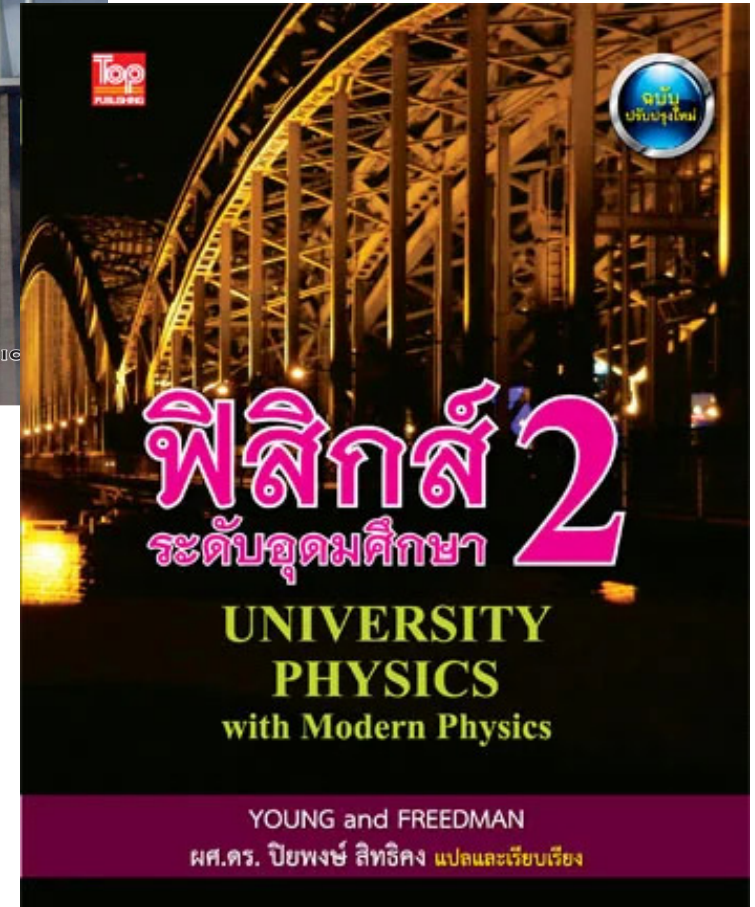
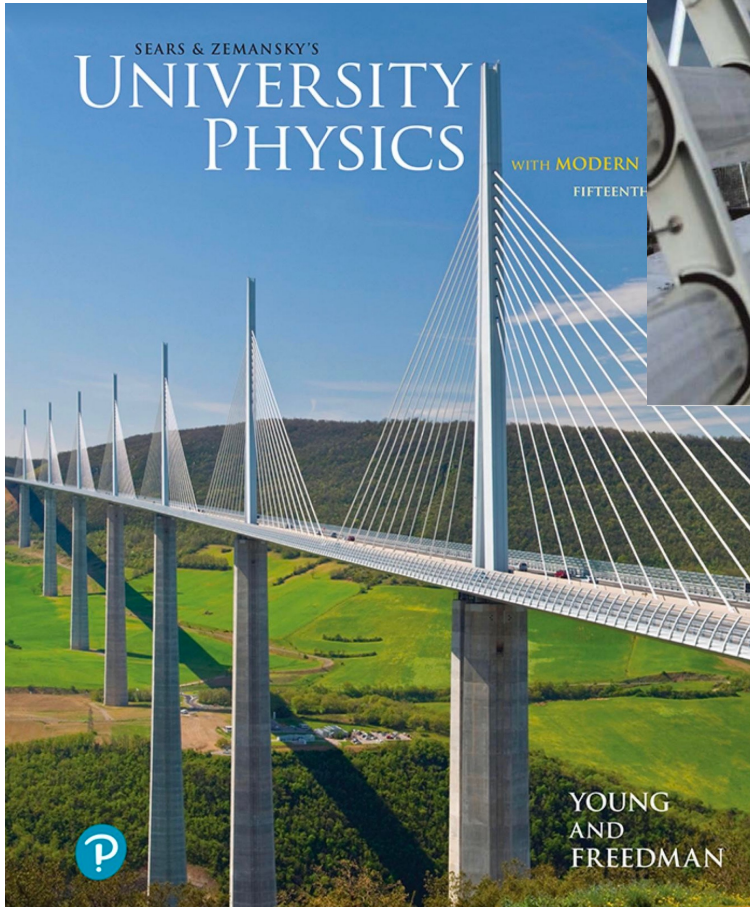


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I UNDERSTAND
THE CONCEPTS...



Pearson



I UNDERSTAND
THE **CONCEPTS...**

... I JUST CAN'T
DO THE **PROBLEMS!**

LECTURE 2023

TODAY'S LESSON : W_0 OR "WITTEN'S DOG"



NEUTRON ENCRUSTED
STEAMING HOT
DARK MATTER

$$e^- + p \rightarrow n + \nu$$
$$\Omega_\nu = \sum_{|i|=1}^{\infty} \left[\left(\frac{m_i}{93\text{eV}} \right)^2 + \frac{\langle \Omega_b W_0 \rangle}{(2+1)^4} \right]^2$$

"SUPERDIVERSYMMETRIC
STRING THEORY"

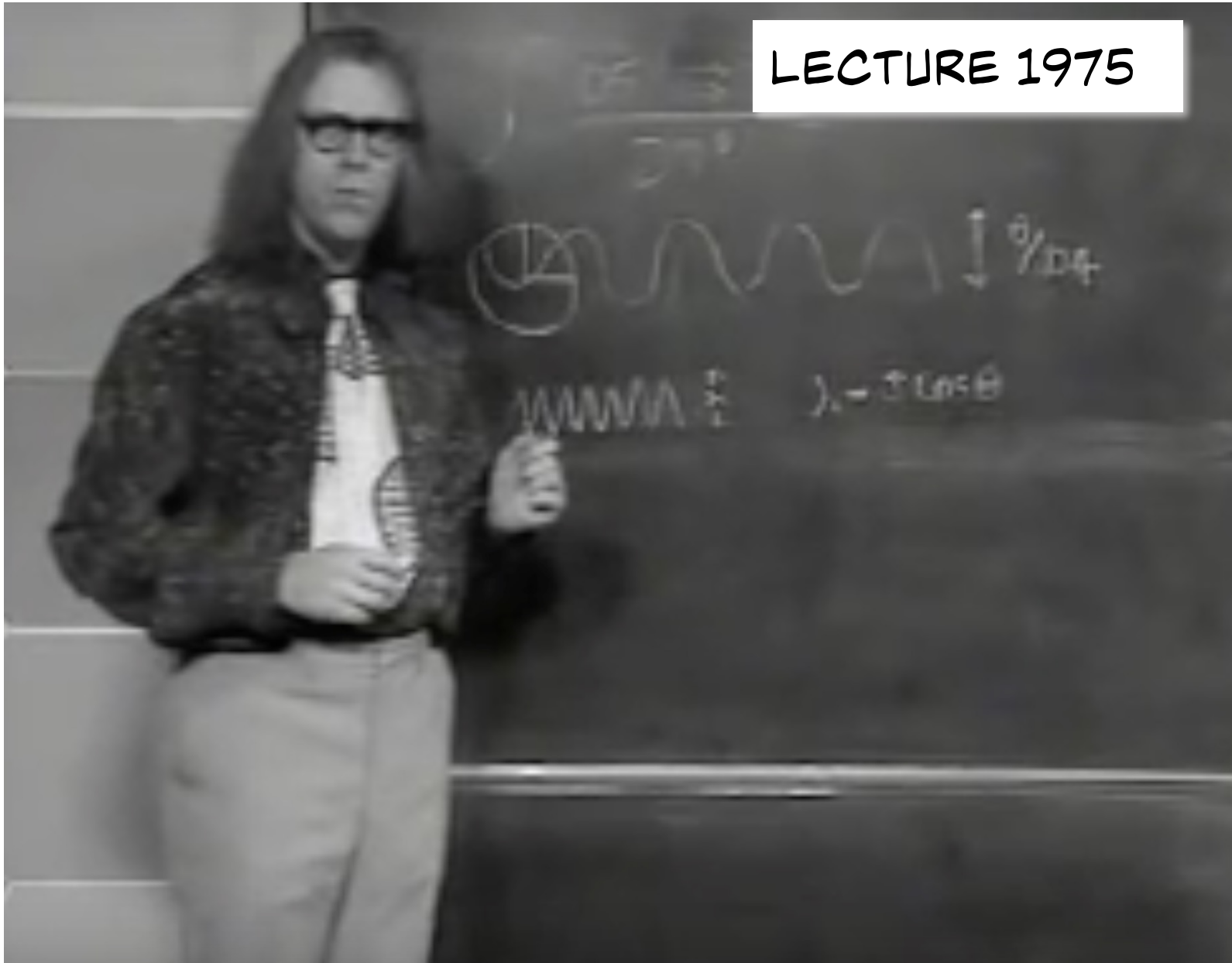


(FUTURAMA)



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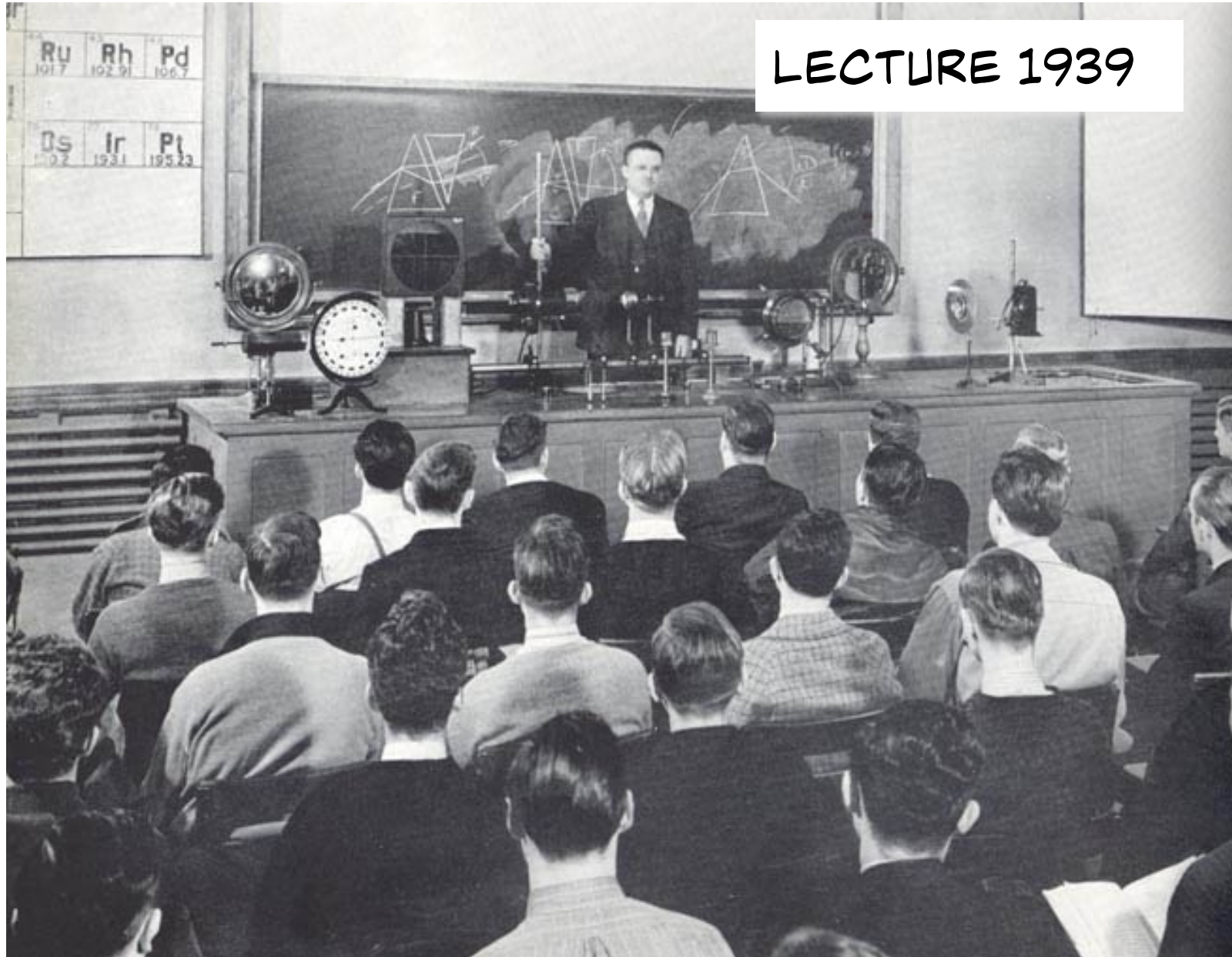
LECTURE 1975



(BBC)



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LECTURE 1939

(ILLINOIS INSTITUTE OF TECHNOLOGY)



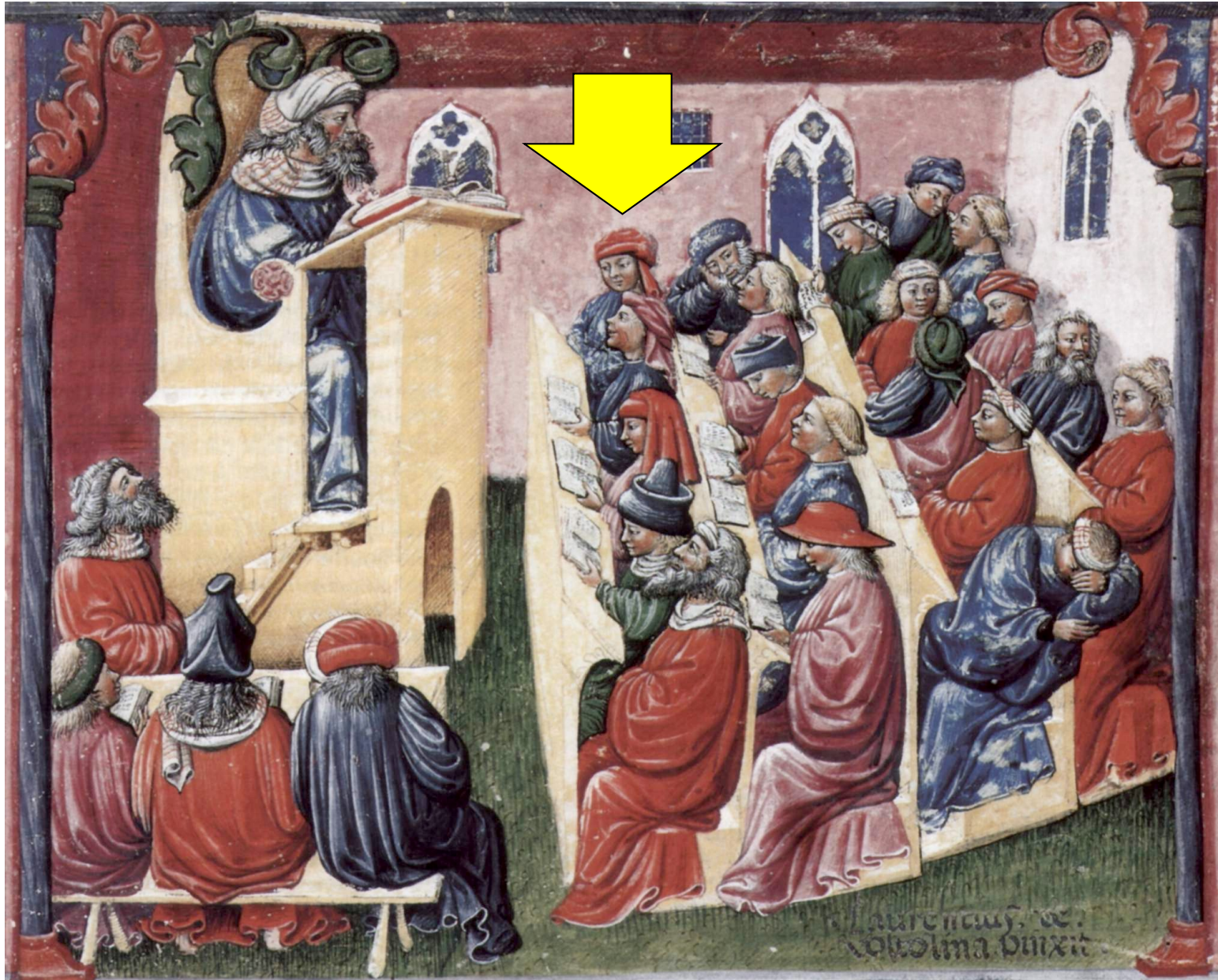
LECTURE 1375



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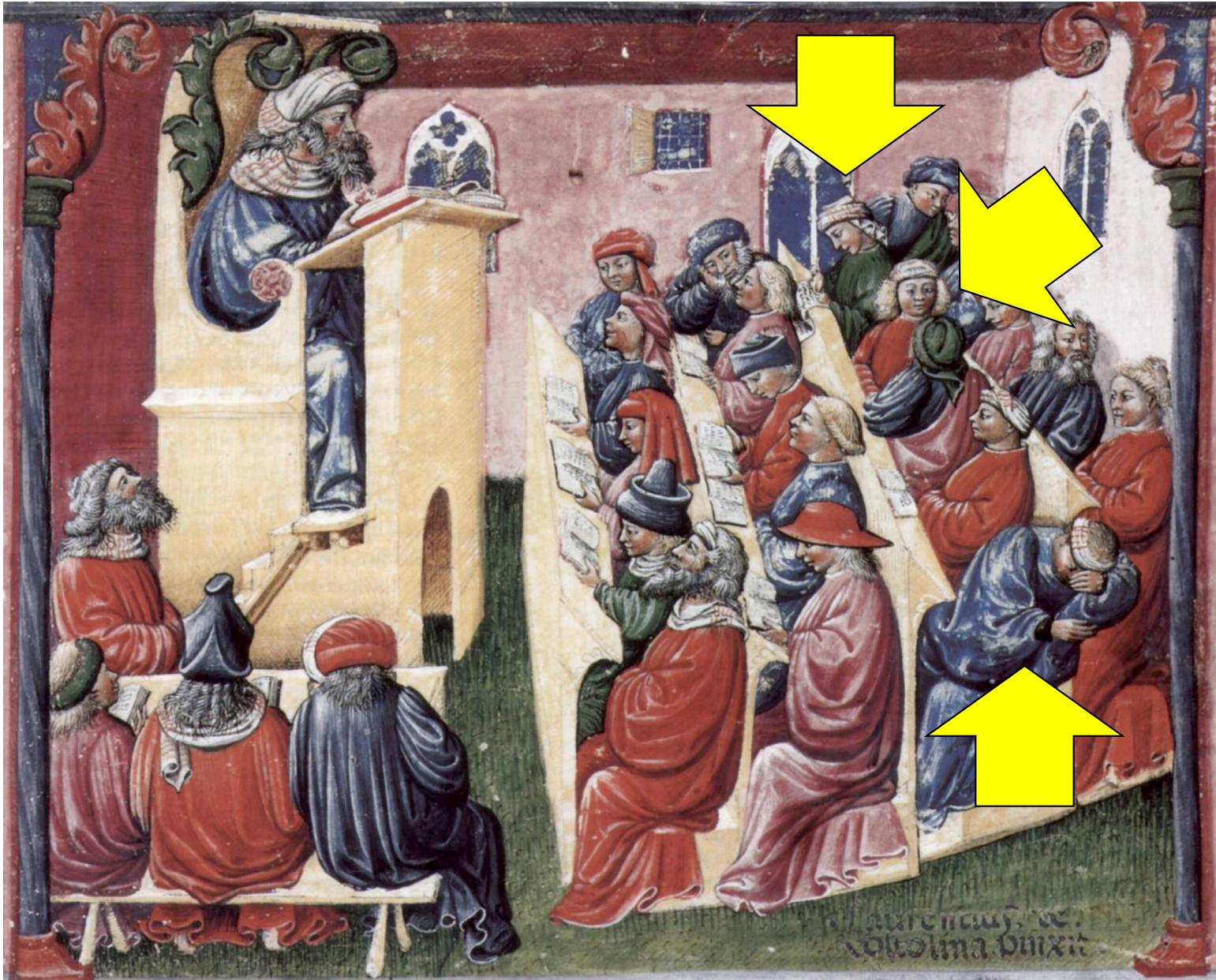
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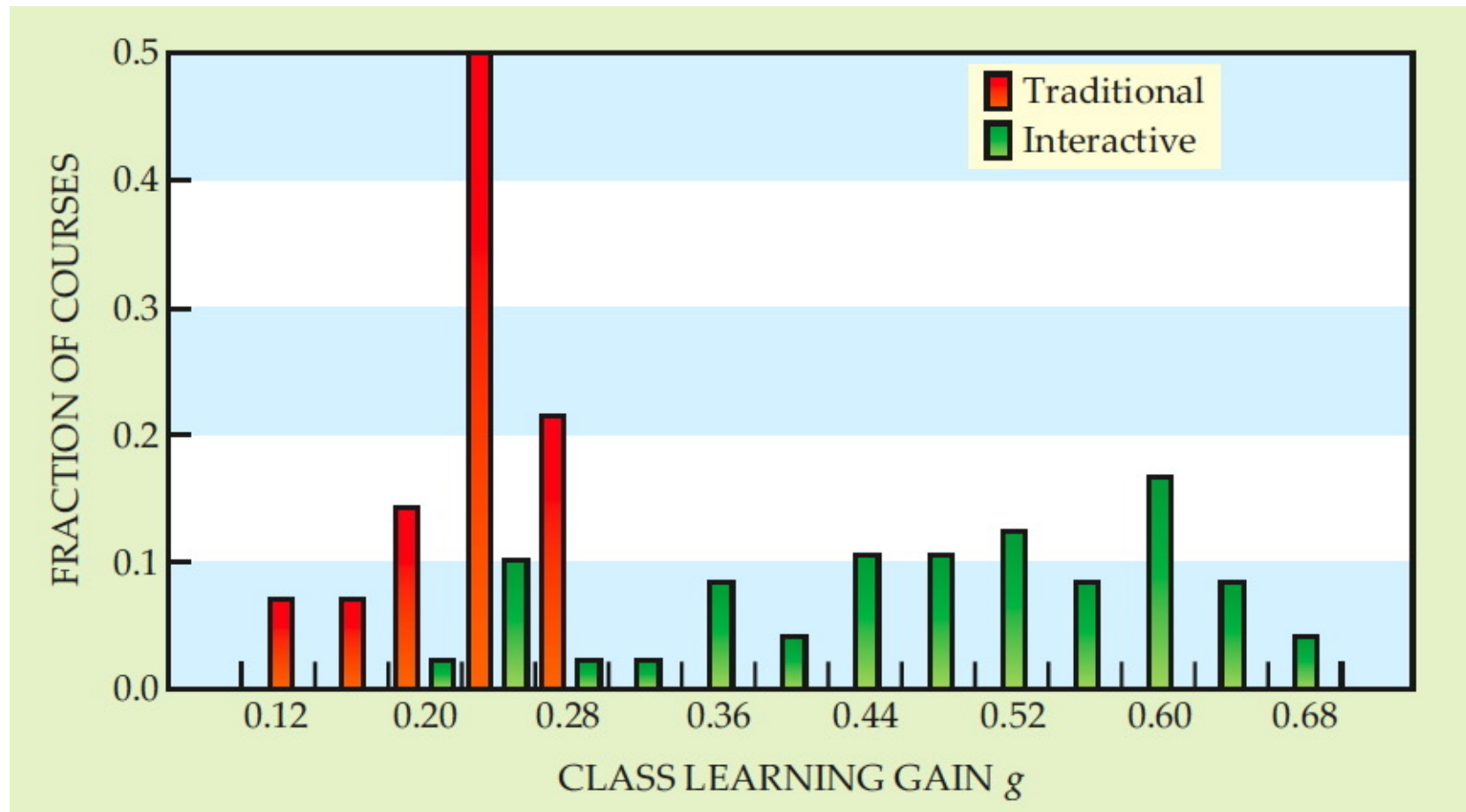
STUDENT LEARNING GAINS IN PHYSICS

CLASS LEARNING GAIN: $g = \frac{\langle \text{post-test}\% \rangle - \langle \text{pre-test}\% \rangle}{100 - \langle \text{pre-test}\% \rangle}$



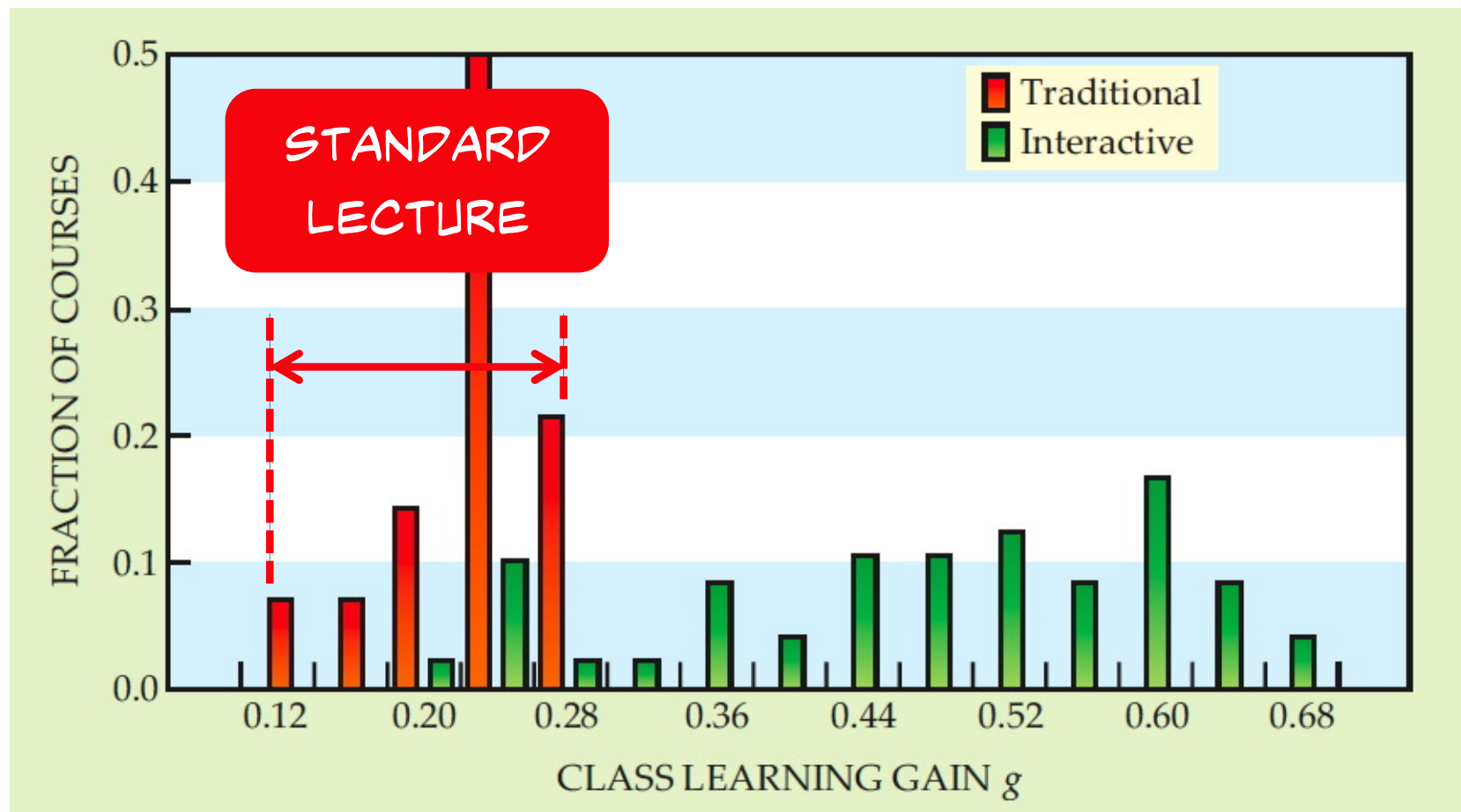
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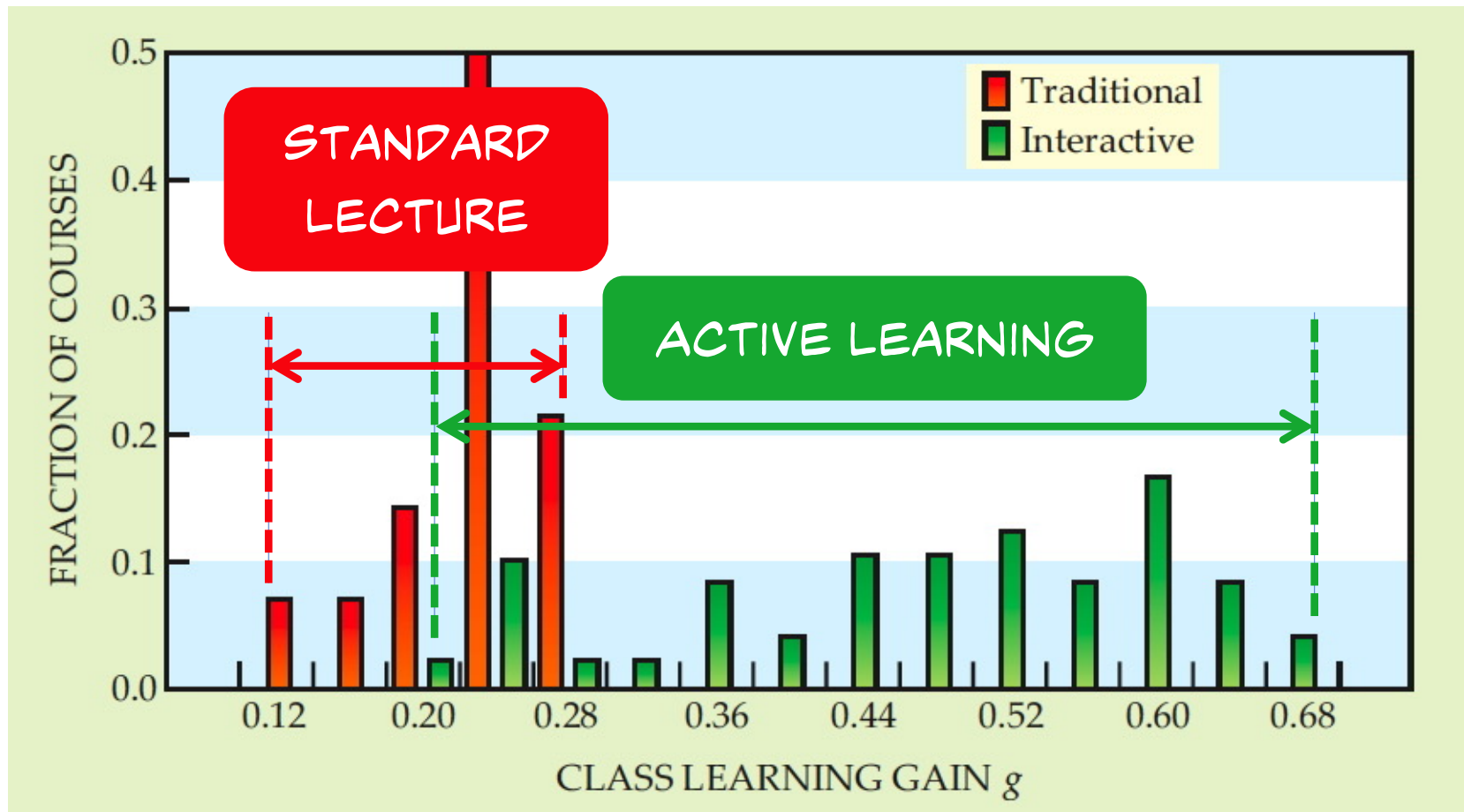
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WHAT IS ACTIVE LEARNING?



Pearson

WHAT IS ACTIVE LEARNING?

*STUDENTS ARE ACTIVELY ENGAGED
DURING THE CLASS PERIOD*





Pearson

WHAT IS ACTIVE LEARNING?

STUDENTS ARE ACTIVELY ENGAGED
DURING THE CLASS PERIOD

- ANSWERING CONCEPTUAL QUESTIONS





WHAT IS ACTIVE LEARNING?

STUDENTS ARE ACTIVELY ENGAGED
DURING THE CLASS PERIOD

- ANSWERING CONCEPTUAL QUESTIONS
- PREDICTING THE RESULTS OF EXPERIMENTS

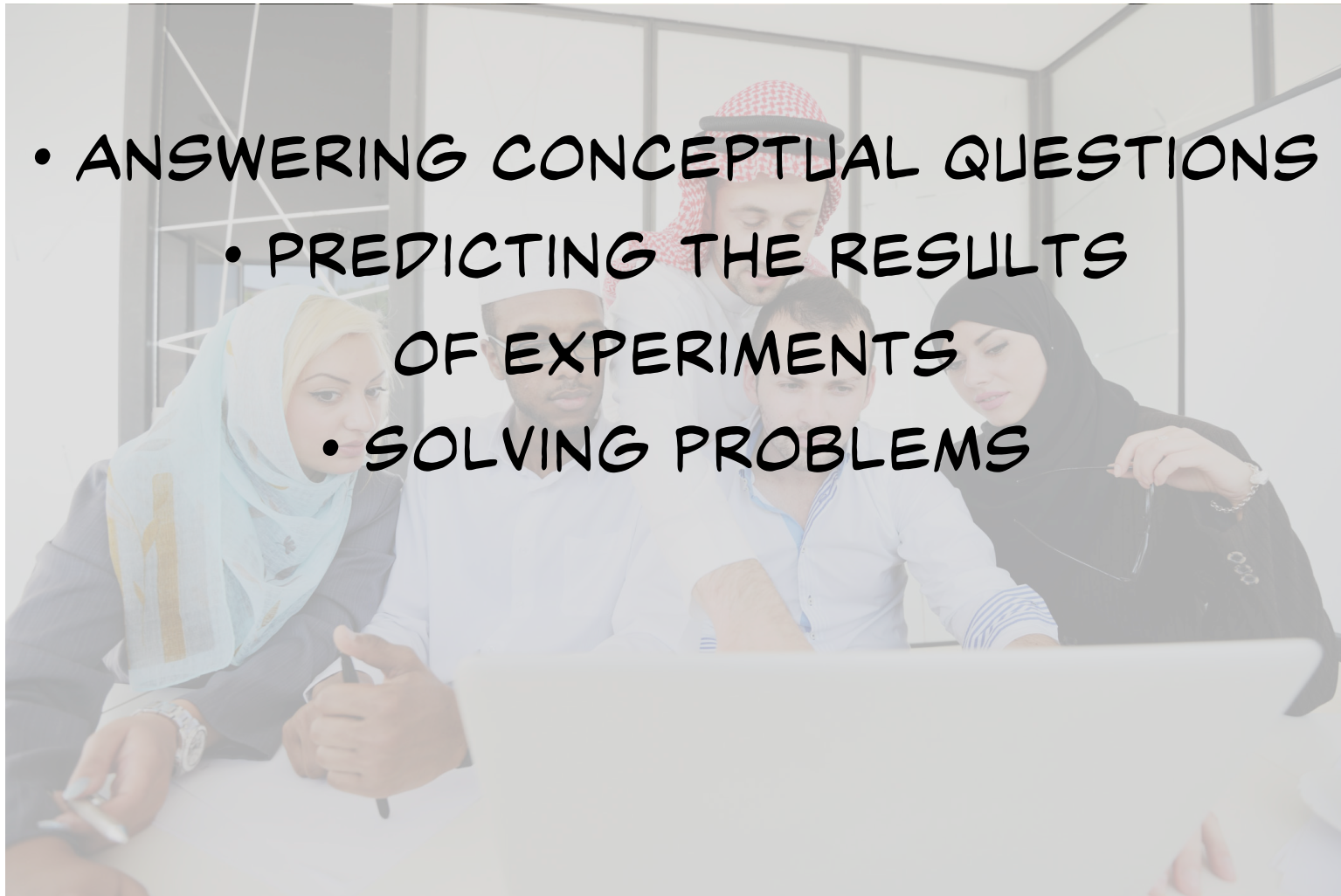




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STUDENTS ARE ACTIVELY ENGAGED
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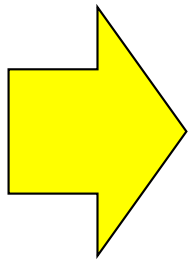
- ANSWERING CONCEPTUAL QUESTIONS
 - PREDICTING THE RESULTS OF EXPERIMENTS
 - SOLVING PROBLEMS



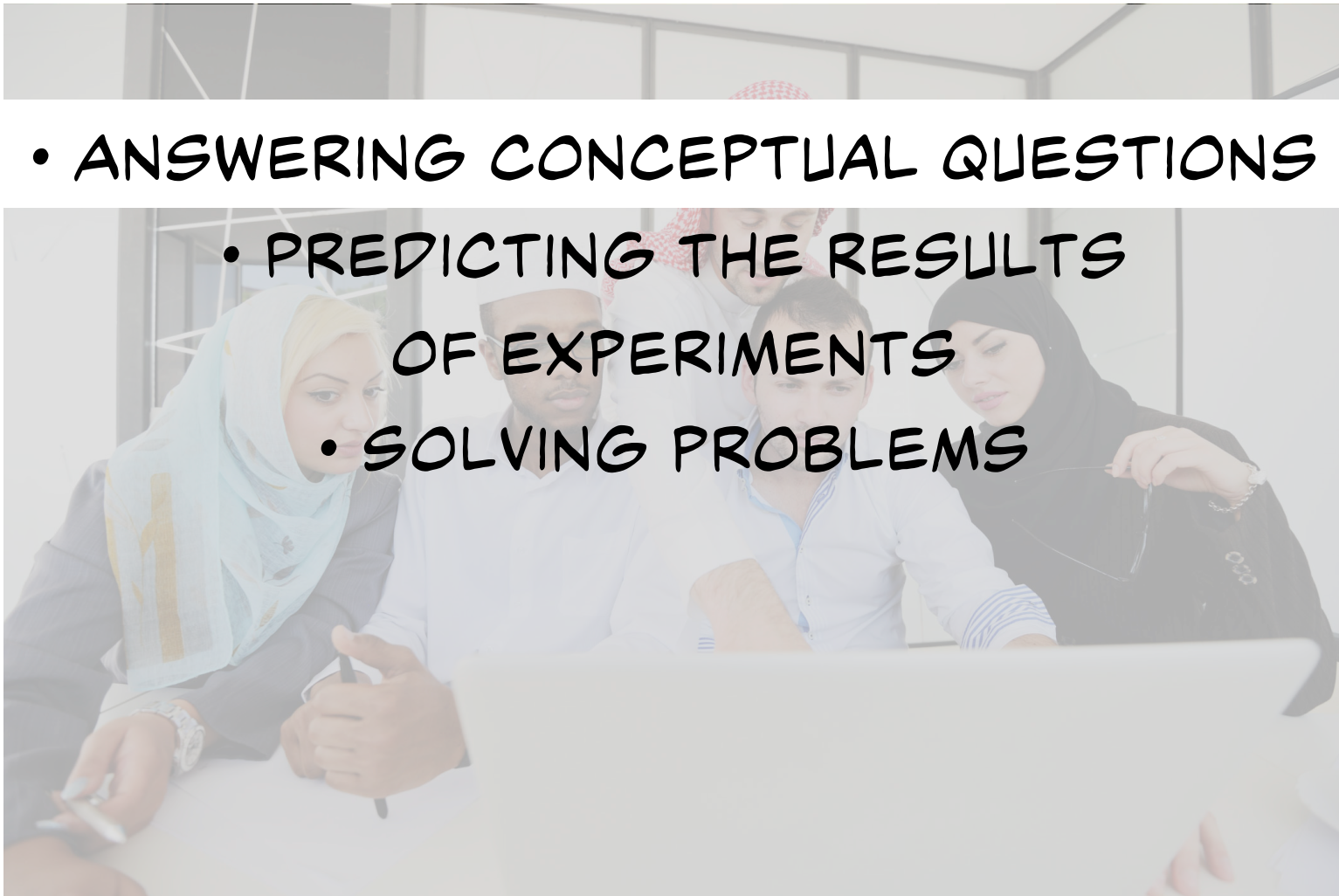


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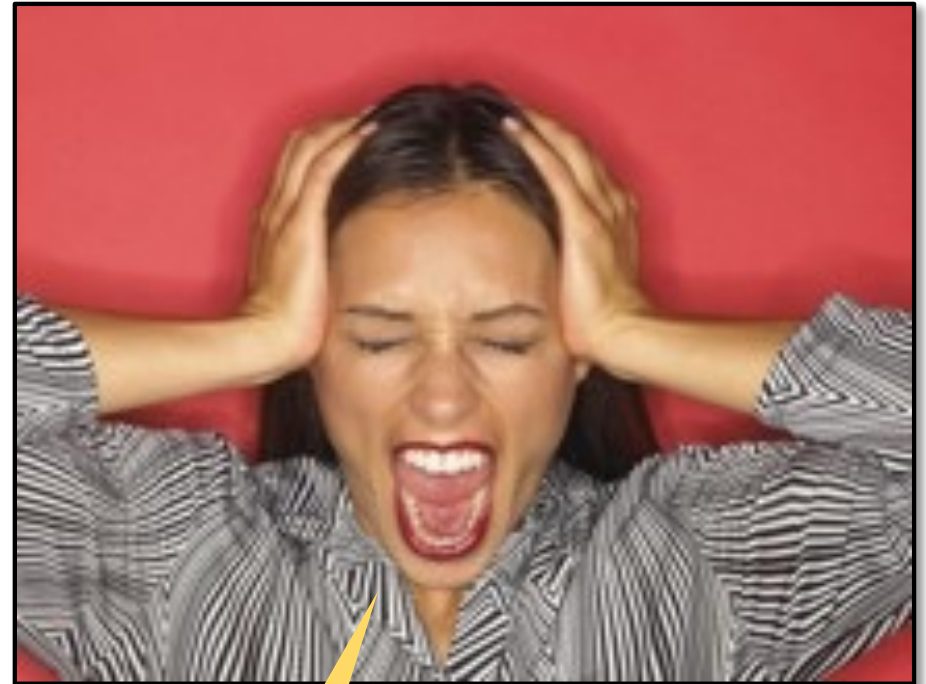


- ANSWERING CONCEPTUAL QUESTIONS
- PREDICTING THE RESULTS OF EXPERIMENTS
- SOLVING PROBLEMS





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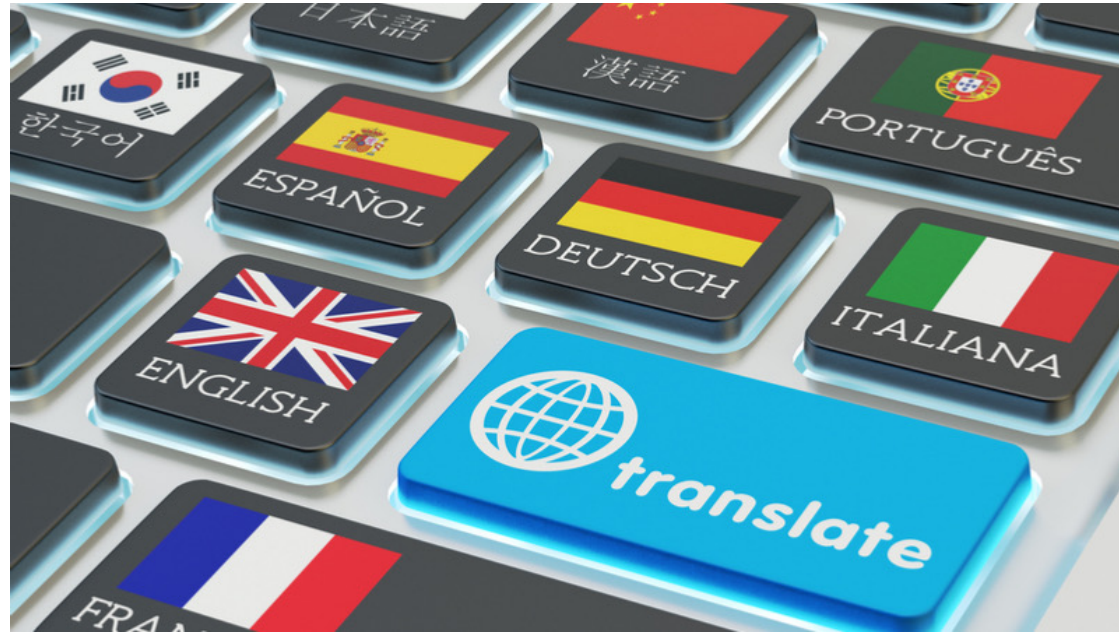


I UNDERSTAND
THE **CONCEPTS...**

... I JUST CAN'T
DO THE **PROBLEMS!**



Pearson



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Pearson



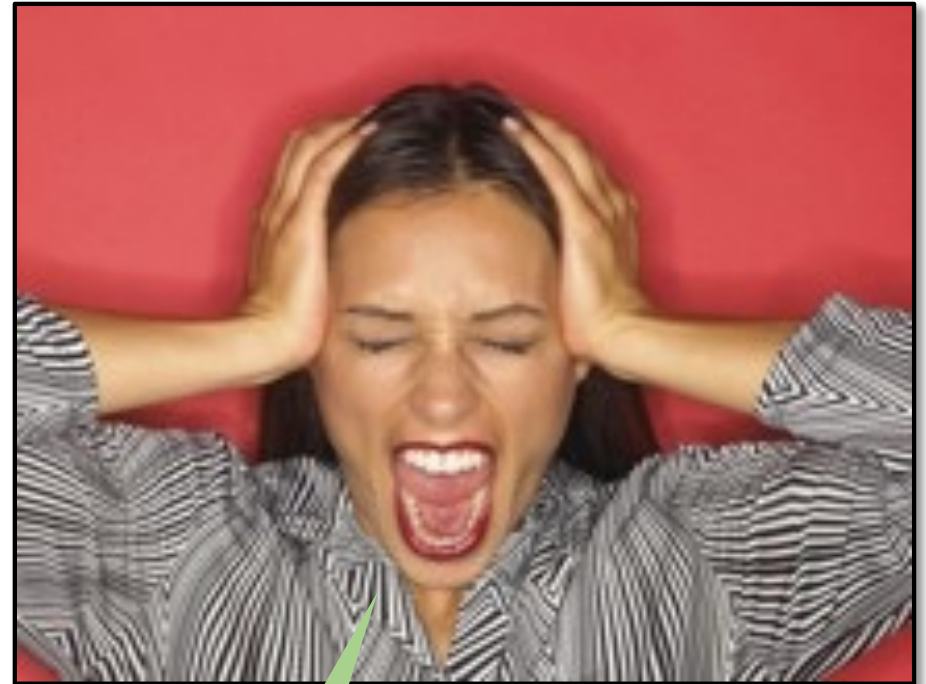
I CAN DO THE
PROBLEMS THAT ARE
JUST LIKE THOSE IN
THE BOOK...



Pearson



I CAN DO THE PROBLEMS THAT ARE JUST LIKE THOSE IN THE BOOK...



... BUT I DON'T UNDERSTAND THE CONCEPTS WELL ENOUGH TO DO ANYTHING ELSE!



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AN IN-CLASS TOOL
TO HELP STUDENTS
WITH CONCEPTUAL UNDERSTANDING:
CLICKER QUESTIONS

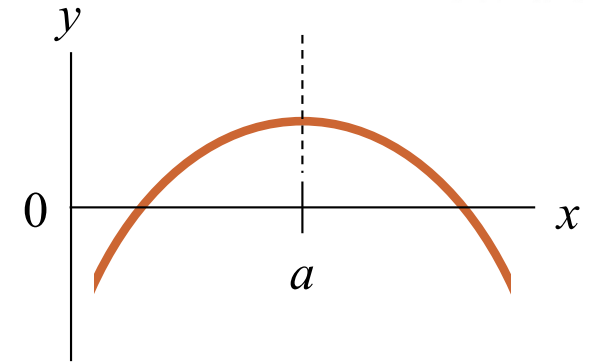
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QUESTION

A wave on a string is moving to the right. This graph of $y(x, t)$ versus coordinate x for a specific time t shows the shape of part of the string at that time.



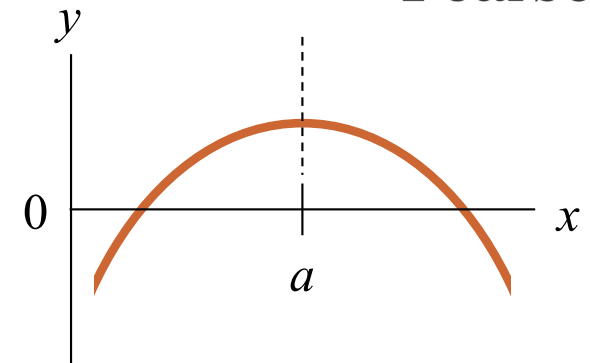
At this time, what is the *velocity* of a particle of the string at $x = a$?

- A. The velocity is upward.
- B. The velocity is downward.
- C. The velocity is zero.
- D. Either A. or B. is possible.
- E. Any of A., B., or C. is possible.



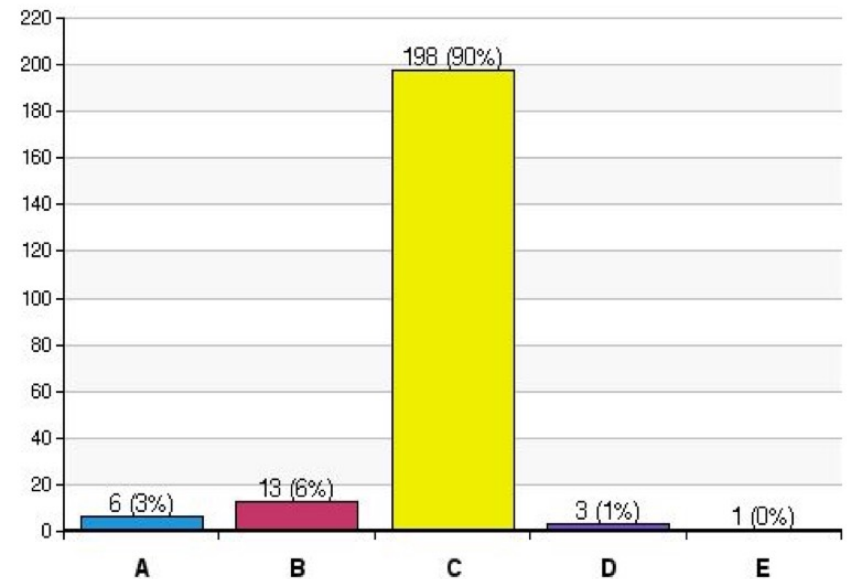
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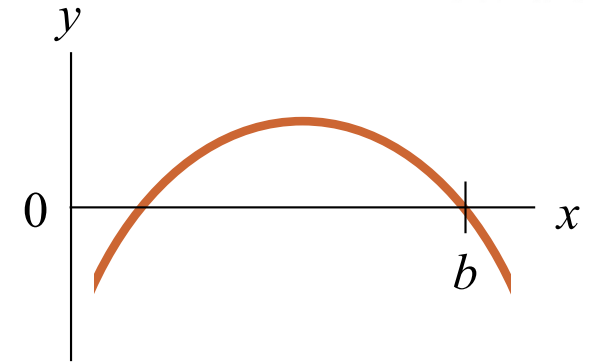
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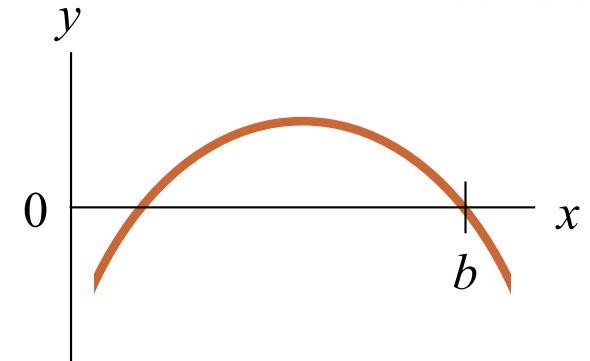
At this time, what is the *velocity* of a particle of the string at $x = b$?

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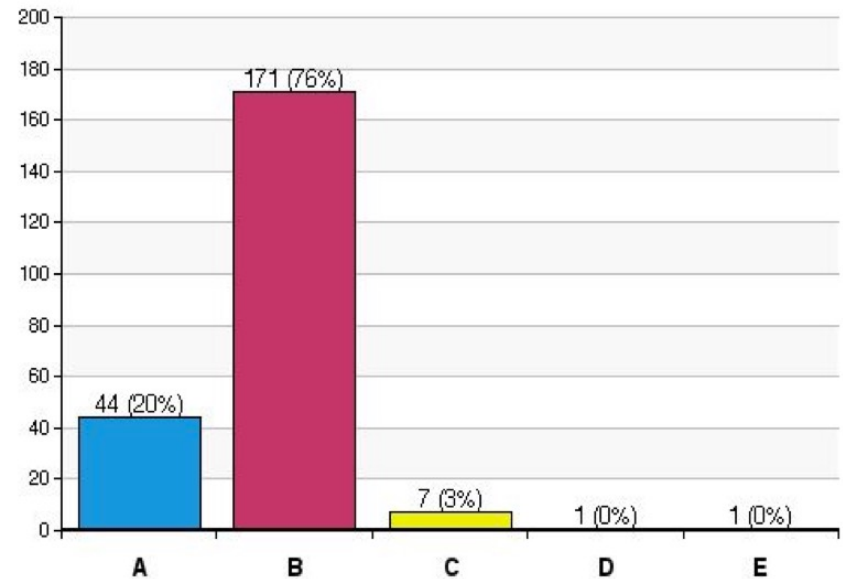
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A RANKING TASK

The figure shows three orbits of a spacecraft around the Earth:

A. circular orbit, radius

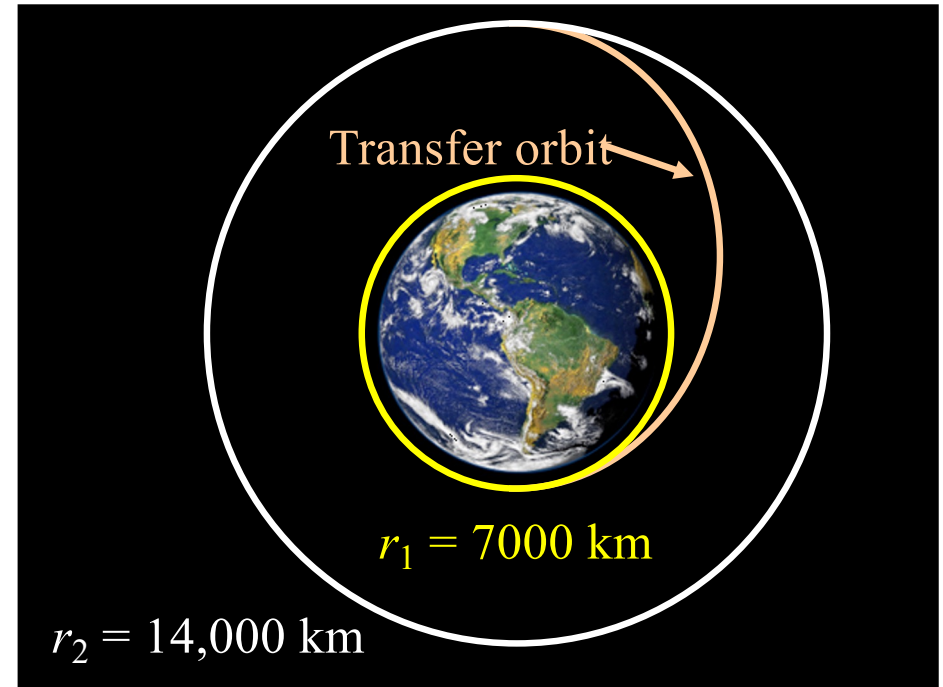
$$r_1 = 7000 \text{ km}$$

B. circular orbit, radius

$$r_2 = 14,000 \text{ km}$$

C. an elliptical transfer orbit between the orbits A and B

Rank these three orbits from *highest to lowest* angular momentum.



A RANKING TASK

ANSWER

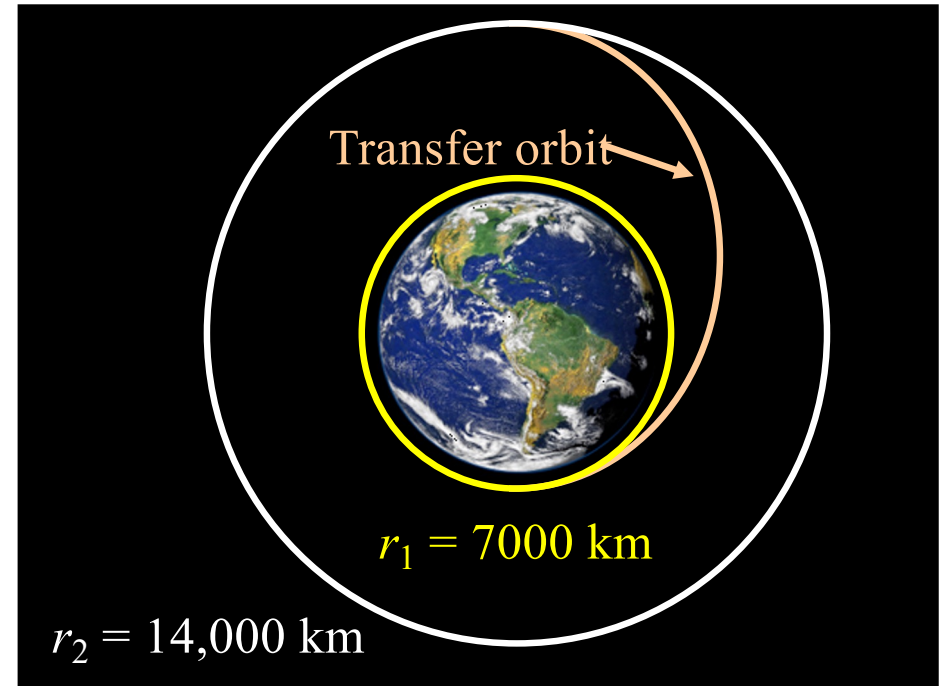
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B, C, A



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WHAT ACTIVE LEARNING PROVIDES





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WHAT ACTIVE LEARNING PROVIDES





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WHAT ACTIVE LEARNING PROVIDES





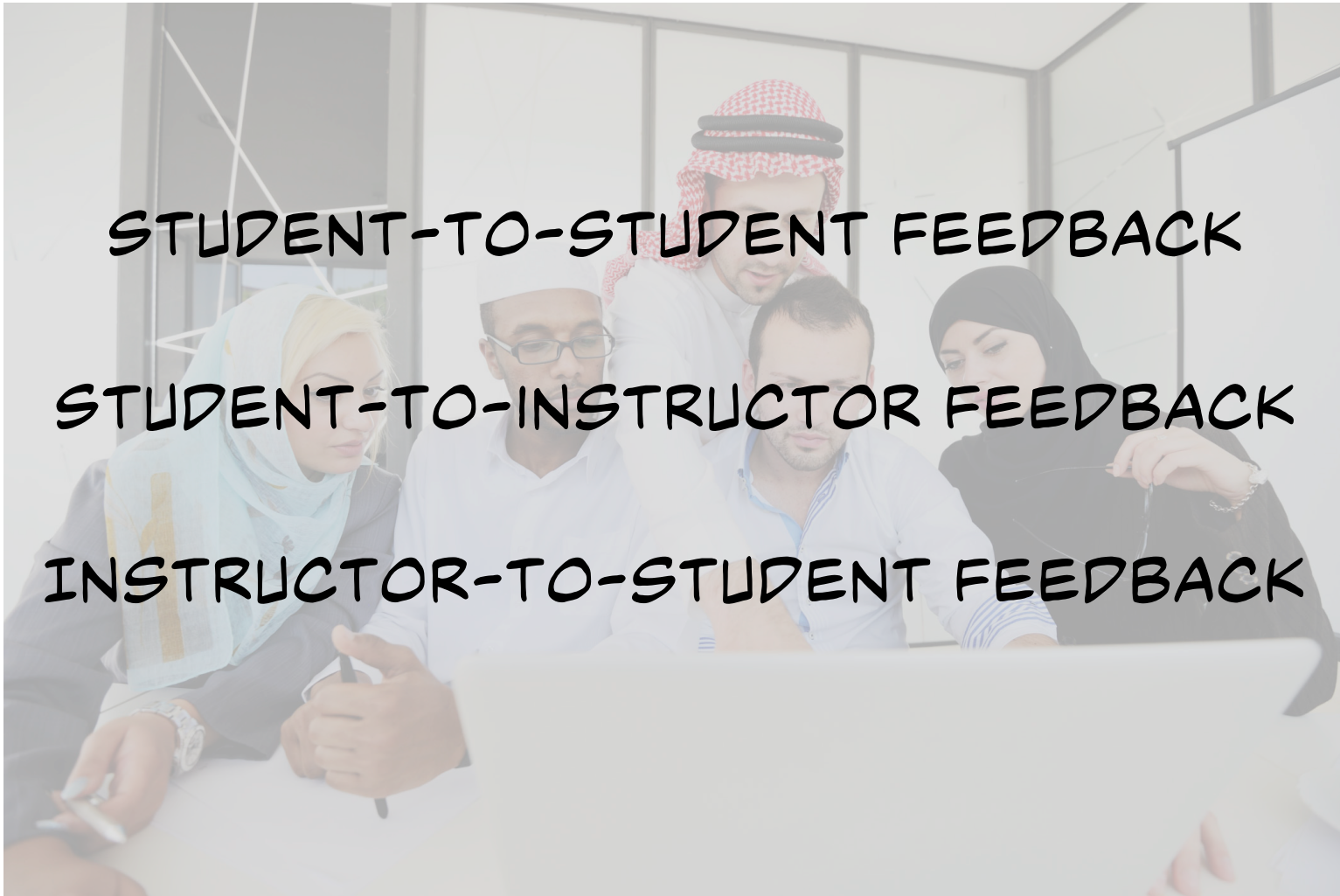
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WHAT ACTIVE LEARNING PROVIDES

STUDENT-TO-STUDENT FEEDBACK

STUDENT-TO-INSTRUCTOR FEEDBACK

INSTRUCTOR-TO-STUDENT FEEDBACK





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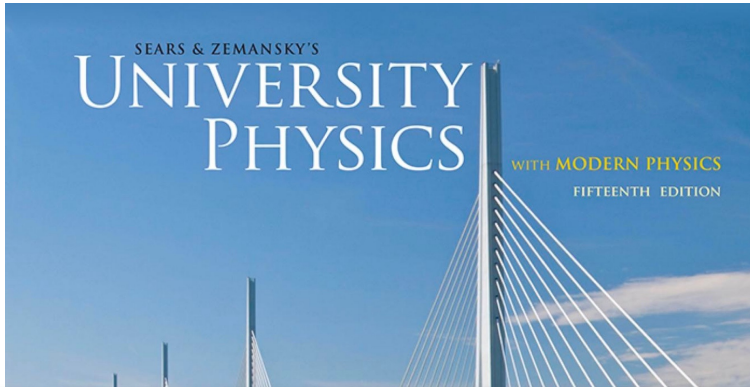
WHERE CAN CLICKER QUESTIONS (AND ANSWERS!) BE FOUND?





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WHERE CAN CLICKER QUESTIONS (AND ANSWERS!) BE FOUND?



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[Home](#) > [Resources by Chapter](#) > Chapter 2

Resources by Chapter

Chapter 2: Motion Along a Straight Line

Download instructor resources from the links below.

Lecture Outline and Text Elements

Chapter 2 Lecture and Text Elements

zip, 43.3 MB

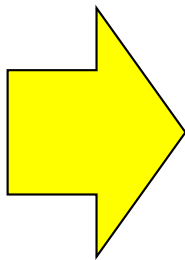
Download a .zip archive of chapter summary materials, end-of-chapter elements, figures and photos, key equations, problem-solving strategies, tables, chapter images in PowerPoint, and the accessible PowerPoint lecture outline for Chapter 2.



Chapter 2 Clicker Questions

pptx, 945 KB

Clicker questions in PowerPoint with alt text for accessibility.





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MASTERINGPHYSICS
INCLUDES EXTENSIVE
VIDEO CONTENT



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MASTERING PHYSICS INCLUDES EXTENSIVE VIDEO CONTENT

- VIDEO *TUTOR SOLUTIONS*
- VIDEO *TUTOR DEMONSTRATIONS*
- *CONCEPTUAL* VIDEOS
- VIDEO *LECTURES* BY PROF. MATT ANDERSON,
SAN DIEGO STATE UNIVERSITY



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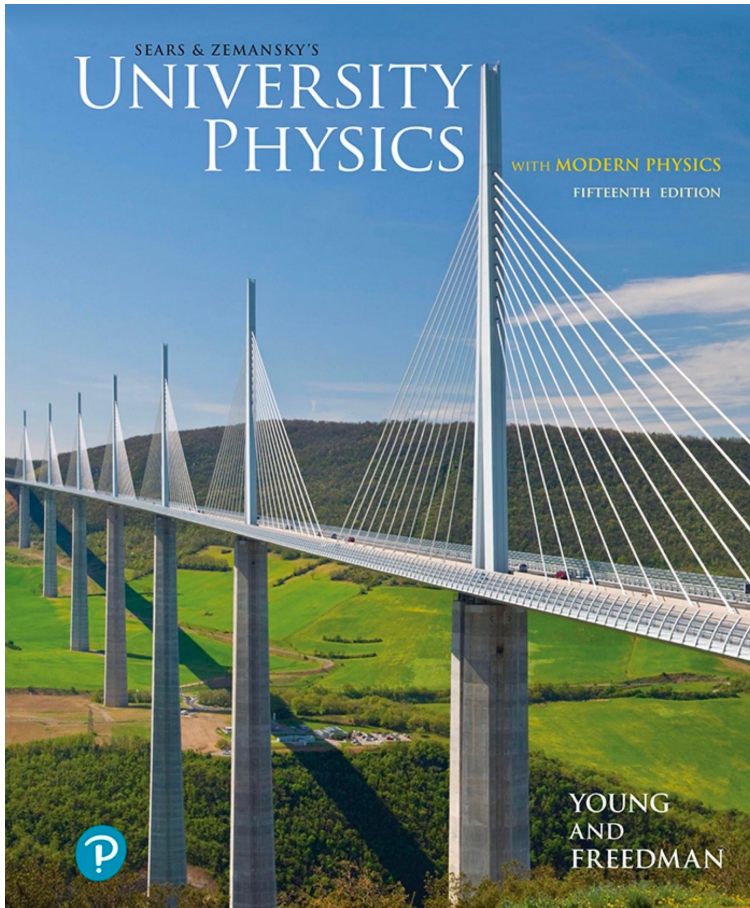
**IDEA: USE THESE TO
REPLACE PART OR ALL
OF YOUR OWN
LECTURES -- FREEING
UP CLASS TIME FOR
ACTIVE LEARNING!**

-- VIDEO **LECTURES** BY PROF. MATT ANDERSON,
SAN DIEGO STATE UNIVERSITY



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TEXTBOOK FEATURES DESIGNED TO HELP WITH STUDENT LEARNING





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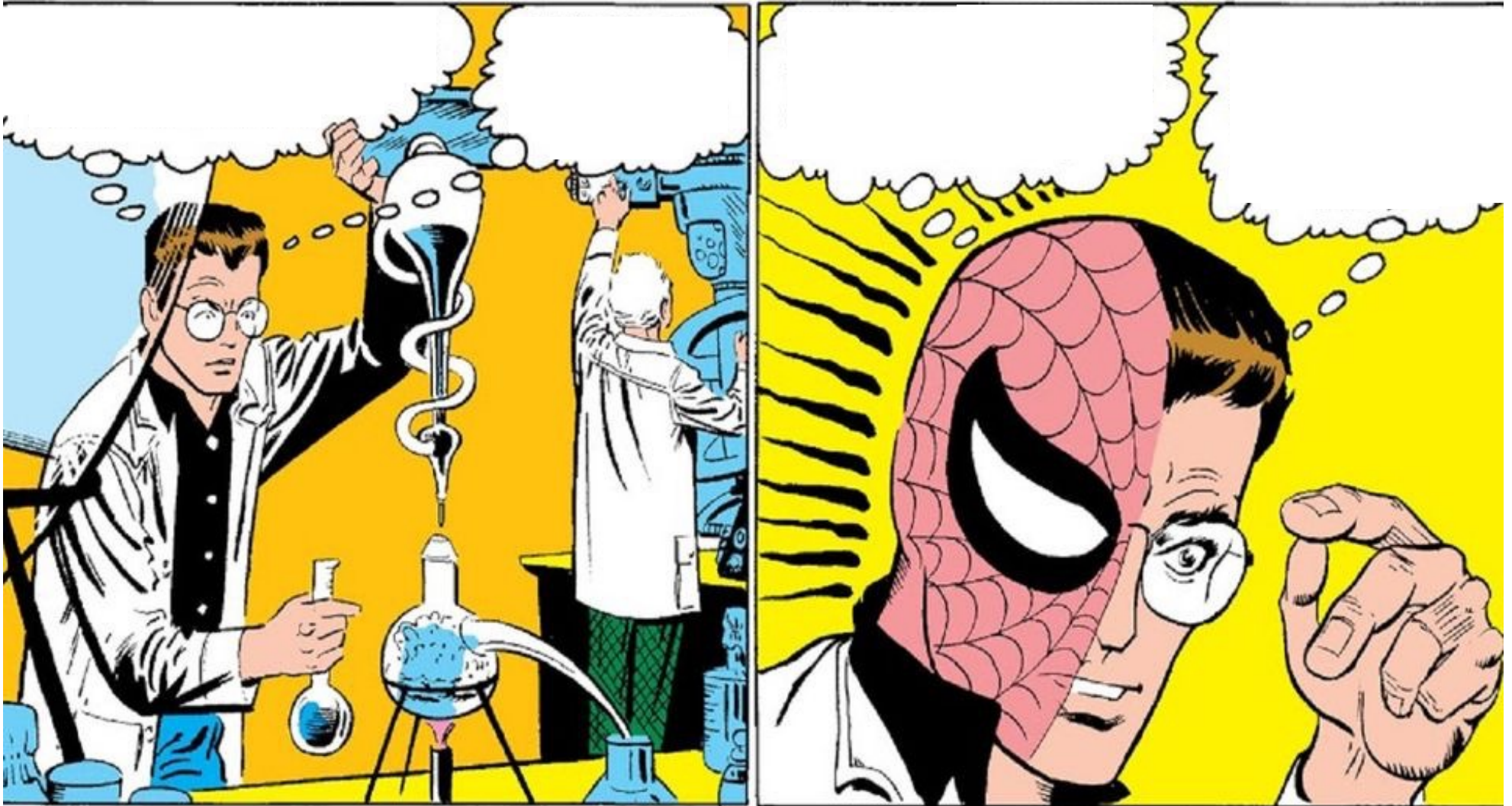
VISUAL AIDS TO LEARNING





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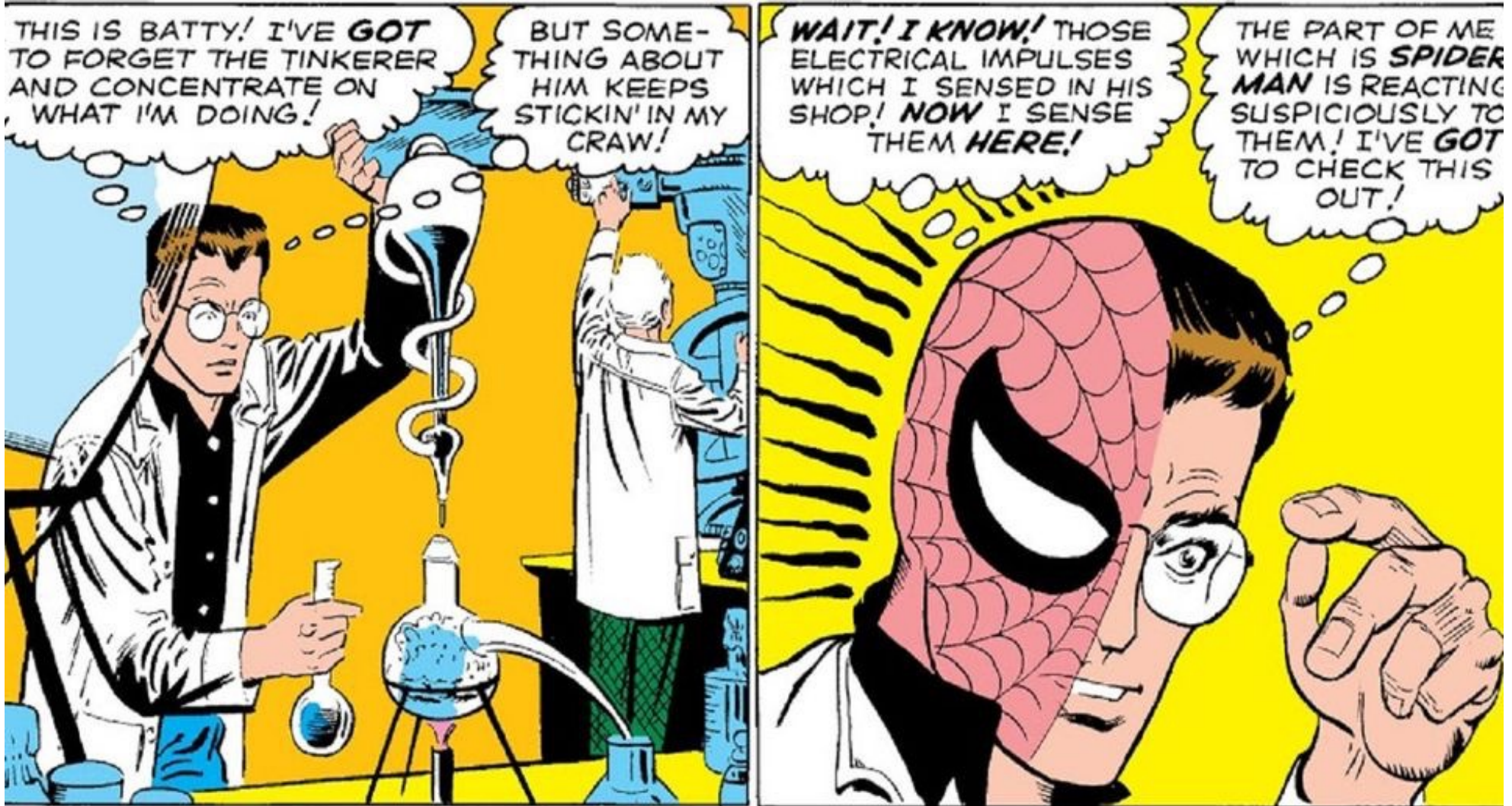
VISUAL AIDS TO LEARNING



THE AMAZING SPIDER-MAN #2, APRIL 1963 ©MARVEL



VISUAL AIDS TO LEARNING



THE AMAZING SPIDER-MAN #2, APRIL 1963 ©MARVEL



VISUAL AIDS TO LEARNING

A **KEY EQUATION** AS PRESENTED
IN MOST TEXTBOOKS

$$\vec{F}_{A \text{ on } B} = -\vec{F}_{B \text{ on } A} \quad (4.10)$$



VISUAL AIDS TO LEARNING

A **KEY EQUATION** AS PRESENTED
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$$\vec{F}_{A \text{ on } B} = -\vec{F}_{B \text{ on } A} \quad (4.10)$$

THE **SAME EQUATION** AS PRESENTED
IN **YOUNG & FREEDMAN**

Newton's third law:

When two objects
A and B exert forces
on each other ...

$$\vec{F}_{A \text{ on } B} = -\vec{F}_{B \text{ on } A}$$

... the two forces have
the same magnitude but
opposite directions.

(4.10)

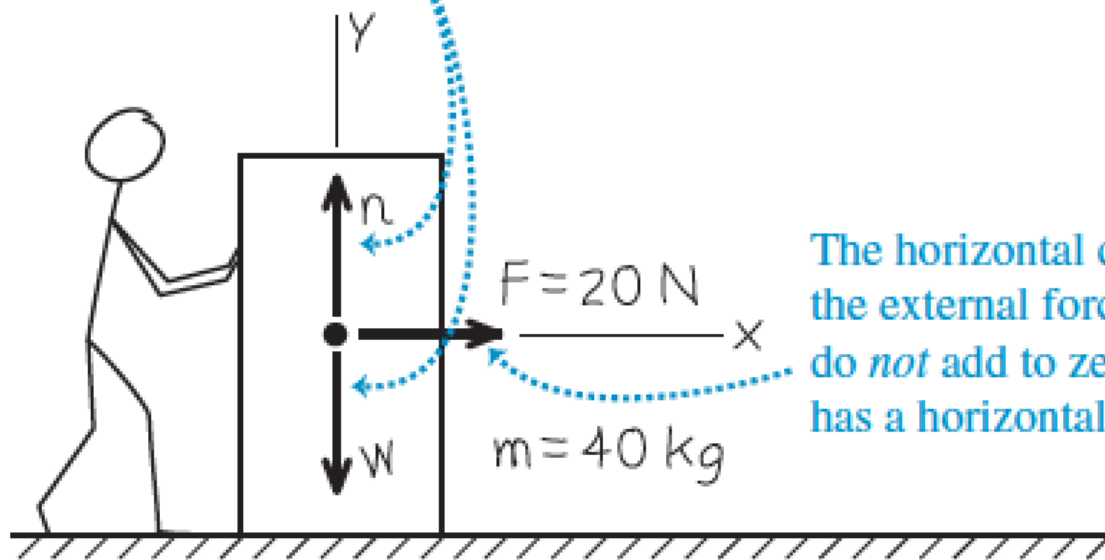
Note: The two forces act on different objects.

VISUAL AIDS TO LEARNING

MOST FIGURES ARE ALSO ANNOTATED

Figure 4.17 Our sketch for this problem.

The vertical components of the external forces on the box sum to zero, and the box has no vertical acceleration.



The horizontal components of the external forces on the box do *not* add to zero, so the box has a horizontal acceleration.



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PROBLEM-SOLVING GUIDANCE



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PROBLEM-SOLVING GUIDANCE

ISEE: IDENTIFY, SET UP, EXECUTE, EVALUATE



PROBLEM-SOLVING GUIDANCE

ISEE: IDENTIFY, SET UP, EXECUTE, EVALUATE

-- USED IN **PROBLEM-SOLVING STRATEGIES**

IN EVERY CHAPTER

PROBLEM-SOLVING STRATEGY 16.1 Sound Intensity

IDENTIFY *the relevant concepts:* The relationships between the intensity and amplitude of a sound wave are straightforward. Other quantities are involved in these relationships, however, so it's particularly important to decide which is your target variable.

SET UP *the problem* using the following steps:

1. Sort the physical quantities into categories. Wave properties include the displacement and pressure amplitudes A and p_{\max} . The frequency f can be determined from the angular frequency ω , the wave number k , or the wavelength λ . These quantities are related through the wave speed v , which is determined by properties of the medium (B and ρ for a liquid, and γ , T , and M for a gas).

2. List the given quantities and identify the target variables. Find relationships that take you where you want to go.

EXECUTE *the solution:* Use your selected equations to solve for the target variables. Express the temperature in kelvins (Celsius temperature plus 273.15) to calculate the speed of sound in a gas.

EVALUATE *your answer:* If possible, use an alternative relationship to check your results.



PROBLEM-SOLVING GUIDANCE

ISEE: IDENTIFY, SET UP, EXECUTE, EVALUATE

-- USED IN PROBLEM-SOLVING STRATEGIES

IN EVERY CHAPTER

-- USED IN ALL **WORKED EXAMPLES**

EXAMPLE 16.5 Intensity of a sound wave in air

WITH **✓** VARIATION PROBLEMS

Find the intensity of the sound wave in Example 16.1, with $p_{\max} = 3.0 \times 10^{-2}$ Pa. Assume the temperature is 20°C so that the density of air $\rho = 1.20$ kg/m³ and the speed of sound is $v = 344$ m/s.

IDENTIFY and SET UP Our target variable is the intensity I of the sound wave. We are given the pressure amplitude p_{\max} of the wave as well as the density ρ and wave speed v for the medium. We can determine I from p_{\max} , ρ , and v from Eq. (16.14).

EXECUTE From Eq. (16.14),

$$I = \frac{p_{\max}^2}{2\rho v} = \frac{(3.0 \times 10^{-2} \text{ Pa})^2}{2(1.20 \text{ kg/m}^3)(344 \text{ m/s})}$$
$$= 1.1 \times 10^{-6} \text{ J/(s} \cdot \text{m}^2) = 1.1 \times 10^{-6} \text{ W/m}^2$$

EVALUATE This seems like a very low intensity, but it is well within the range of sound intensities encountered on a daily basis. A very loud sound wave at the threshold of pain has a pressure amplitude of about 30 Pa and an intensity of about 1 W/m^2 . The pressure amplitude of the faintest sound wave that can be heard is about 3×10^{-5} Pa, and the corresponding intensity is about 10^{-12} W/m^2 . (Try these values of p_{\max} in Eq. (16.14) to check that the corresponding intensities are as we have stated.)

KEYCONCEPT The intensity (power per unit area) of a sound wave is proportional to the square of the pressure amplitude of the wave. The proportionality constant depends on the density of the medium and the speed of sound in the medium.



PROBLEM-SOLVING GUIDANCE

ISEE: IDENTIFY, SET UP, EXECUTE, EVALUATE

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PROBLEM-SOLVING GUIDANCE

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PROBLEM-SOLVING GUIDANCE

-- **KEY CONCEPT** CALLED OUT EXPLICITLY IN ALL EXAMPLES

EXAMPLE 16.5 Intensity of a sound wave in air

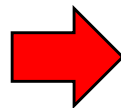
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IDENTIFY and SET UP Our target variable is the intensity I of the sound wave. We are given the pressure amplitude p_{\max} of the wave as well as the density ρ and wave speed v for the medium. We can determine I from p_{\max} , ρ , and v from Eq. (16.14).

EXECUTE From Eq. (16.14),

$$I = \frac{p_{\max}^2}{2\rho v} = \frac{(3.0 \times 10^{-2} \text{ Pa})^2}{2(1.20 \text{ kg/m}^3)(344 \text{ m/s})}$$
$$= 1.1 \times 10^{-6} \text{ J/(s} \cdot \text{m}^2) = 1.1 \times 10^{-6} \text{ W/m}^2$$



EVALUATE This seems like a very low intensity, but it is well within the range of sound intensities encountered on a daily basis. A very loud sound wave at the threshold of pain has a pressure amplitude of about 30 Pa and an intensity of about 1 W/m^2 . The pressure amplitude of the faintest sound wave that can be heard is about 3×10^{-5} Pa, and the corresponding intensity is about 10^{-12} W/m^2 . (Try these values of p_{\max} in Eq. (16.14) to check that the corresponding intensities are as we have stated.)

KEYCONCEPT The intensity (power per unit area) of a sound wave is proportional to the square of the pressure amplitude of the wave. The proportionality constant depends on the density of the medium and the speed of sound in the medium.

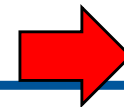


PROBLEM-SOLVING GUIDANCE

-- **KEY CONCEPT** CALLED OUT EXPLICITLY IN
ALL EXAMPLES

-- THREE EXAMPLES PER CHAPTER HAVE
ASSOCIATED **VARIATION PROBLEMS**

EXAMPLE 16.5 Intensity of a sound wave in air



WITH **VARIATION PROBLEMS**

Find the intensity of the sound wave in Example 16.1, with $p_{\max} = 3.0 \times 10^{-2}$ Pa. Assume the temperature is 20°C so that the density of air is $\rho = 1.20 \text{ kg/m}^3$ and the speed of sound is $v = 344 \text{ m/s}$.

IDENTIFY and SET UP Our target variable is the intensity I of the sound wave. We are given the pressure amplitude p_{\max} of the wave as well as the density ρ and wave speed v for the medium. We can determine I from p_{\max} , ρ , and v from Eq. (16.14).

EXECUTE From Eq. (16.14),

$$I = \frac{p_{\max}^2}{2\rho v} = \frac{(3.0 \times 10^{-2} \text{ Pa})^2}{2(1.20 \text{ kg/m}^3)(344 \text{ m/s})}$$
$$= 1.1 \times 10^{-6} \text{ J/(s} \cdot \text{m}^2) = 1.1 \times 10^{-6} \text{ W/m}^2$$

EVALUATE This seems like a very low intensity, but it is well within the range of sound intensities encountered on a daily basis. A very loud sound wave at the threshold of pain has a pressure amplitude of about 30 Pa and an intensity of about 1 W/m^2 . The pressure amplitude of the faintest sound wave that can be heard is about 3×10^{-5} Pa, and the corresponding intensity is about 10^{-12} W/m^2 . (Try these values of p_{\max} in Eq. (16.14) to check that the corresponding intensities are as we have stated.)

KEYCONCEPT The intensity (power per unit area) of a sound wave is proportional to the square of the pressure amplitude of the wave. The proportionality constant depends on the density of the medium and the speed of sound in the medium.



PROBLEM-SOLVING GUIDANCE

-- **KEY CONCEPT** CALLED OUT EXPLICITLY IN
ALL EXAMPLES

-- THREE EXAMPLES PER CHAPTER HAVE
ASSOCIATED **VARIATION PROBLEMS**

GUIDED PRACTICE

For assi

KEY EXAMPLE **VARIATION PROBLEMS**

Be sure to review **EXAMPLES 16.5, 16.6, 16.7, 16.8, and 16.9** (Section 16.3) before attempting these problems.

VP16.9.1 A 256 Hz sound wave in air (density 1.20 kg/m^3 , speed of sound 344 m/s) has intensity $5.50 \times 10^{-8} \text{ W/m}^2$. (a) What is the wave's pressure amplitude? (b) If the intensity remains the same but the frequency is doubled to 512 Hz, how does this affect the pressure amplitude?

VP16.9.2 At a certain distance from a fire alarm, the sound intensity level is 85.0 dB. (a) What is the intensity of this sound? (b) How many times greater is the intensity of this sound than that of a 67.0 dB sound?

VP16.9.3 A lion can produce a roar with a sound intensity level of 114 dB at a distance of 1.00 m. What is the sound intensity level at a distance of (a) 4.00 m and (b) 16.0 m from the lion? Assume that intensity obeys the inverse-square law.

VP16.9.4 The sound intensity level inside a typical modern airliner in flight is 66.0 dB. The air in the cabin has density 0.920 kg/m^3 (less than in the atmosphere at sea level) and speed of sound 344 m/s. (a) What is the pressure amplitude of this sound? (b) If the pressure amplitude were increased by a factor of 10.0, what would the new sound intensity level be?

(ANSWERS TO THE
VARIATION PROBLEMS
ARE PROVIDED AT THE
END OF THE CHAPTER)



PROBLEM-SOLVING GUIDANCE

-- **BRIDGING PROBLEM** IN EACH CHAPTER

HELPS TRANSITION TO END-OF-CHAPTER PROBLEMS
(ANSWER PROVIDED AT END OF CHAPTER)

BRIDGING PROBLEM Loudspeaker Interference

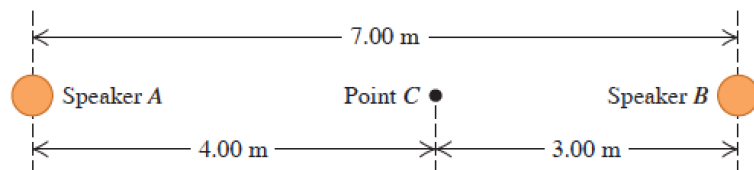
Loudspeakers *A* and *B* are 7.00 m apart and vibrate in phase at 172 Hz. They radiate sound uniformly in all directions. Their acoustic power outputs are 8.00×10^{-4} W and 6.00×10^{-5} W, respectively. The air temperature is 20°C. (a) Determine the difference in phase of the two signals at a point *C* along the line joining *A* and *B*, 3.00 m from *B* and 4.00 m from *A* (Fig. 16.39). (b) Determine the intensity and sound intensity level at *C* from speaker *A* alone (with *B* turned off) and from speaker *B* alone (with *A* turned off). (c) Determine the intensity and sound intensity level at *C* from both speakers together.

SOLUTION GUIDE

IDENTIFY and SET UP

1. Choose the equations that relate power, distance from the source, intensity, pressure amplitude, and sound intensity level.

Figure 16.39 The situation for this problem.



2. Decide how you'll determine the phase difference in part (a). Once you have found the phase difference, how can you use it to find the amplitude of the combined wave at *C* due to both sources?
3. List the unknown quantities for each part of the problem and identify your target variables.

EXECUTE

4. Determine the phase difference at point *C*.
5. Find the intensity, sound intensity level, and pressure amplitude at *C* due to each speaker alone.
6. Use your results from steps 4 and 5 to find the pressure amplitude at *C* due to both loudspeakers together.
7. Use your result from step 6 to find the intensity and sound intensity level at *C* due to both loudspeakers together.

EVALUATE

8. How do your results from part (c) for intensity and sound intensity level at *C* compare to those from part (b)? Does this make sense?
9. What result would you have gotten in part (c) if you had (incorrectly) combined the *intensities* from *A* and *B* directly, rather than (correctly) combining the *pressure amplitudes* as you did in step 6?



Pearson

CONFRONTING MISCONCEPTIONS



Pearson

CONFRONTING MISCONCEPTIONS

-- CAUTION PARAGRAPHS IN EVERY CHAPTER



CONFRONTING MISCONCEPTIONS

- CAUTION PARAGRAPHS IN EVERY CHAPTER
- POINT OUT COMMON POINTS OF CONFUSION

CAUTION Wave velocity vs. particle velocity Remember that the velocity of the wave as a whole is *not* the same as the particle velocity. While the wave continues to move in the direction of propagation, individual particles in the wave medium merely slosh back and forth, as shown in Fig. 16.1. Furthermore, the maximum speed of a particle of the medium can be very different from the wave speed. |



CONFRONTING MISCONCEPTIONS

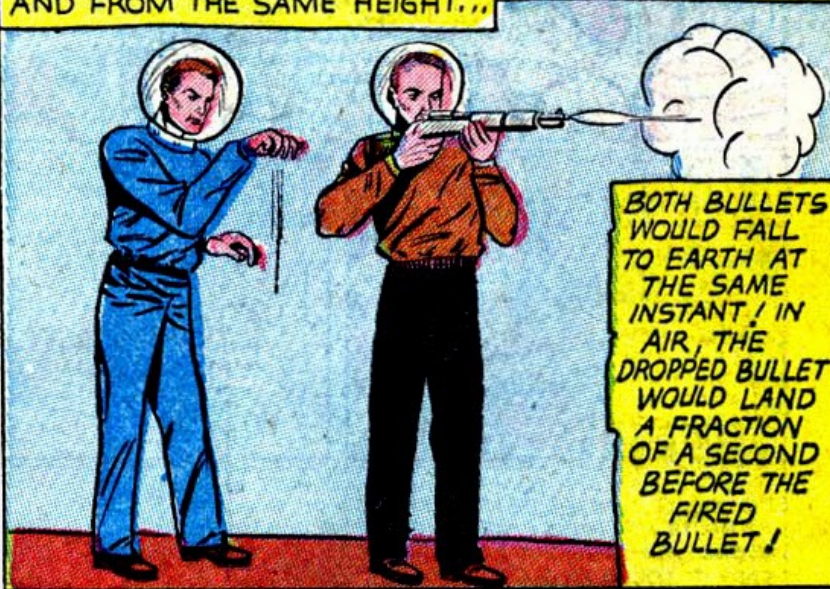
- CAUTION PARAGRAPHS IN EVERY CHAPTER
- POINT OUT COMMON POINTS OF CONFUSION
- POINT OUT COMMON PRECONCEPTIONS
ABOUT PHYSICS

CAUTION Any particle following a curved path is accelerating. When a particle is moving in a curved path, it always has nonzero acceleration, even when it moves with constant speed. This conclusion is contrary to the everyday use of the word “acceleration” to mean that speed is increasing. The more precise definition given in Eq. (3.9) shows that there is a nonzero acceleration whenever the velocity vector changes in *any* way, whether there is a change of speed, direction, or both. |

CONFRONTING MISCONCEPTIONS

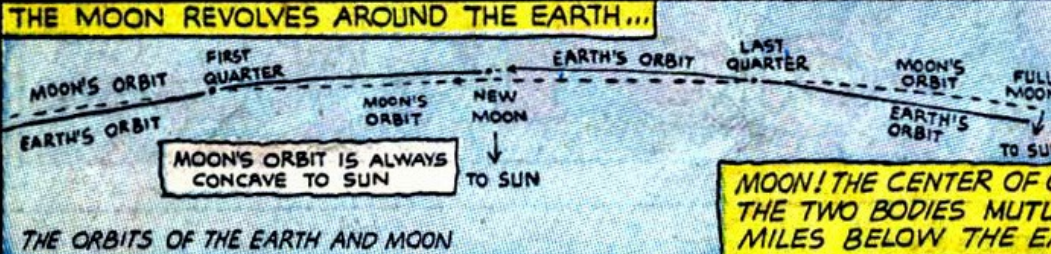
SCIENCE
says you're
WRONG
if you
BELIEVE THAT

IN A VACUUM, A BULLET THAT IS DROPPED FROM A HAND WILL STRIKE THE GROUND SOONER THAN ONE FIRED FROM A RIFLE HELD PARALLEL TO THE GROUND AND FROM THE SAME HEIGHT...



BOTH BULLETS WOULD FALL TO EARTH AT THE SAME INSTANT! IN AIR, THE DROPPED BULLET WOULD LAND A FRACTION OF A SECOND BEFORE THE FIRED BULLET!

THE MOON REVOLVES AROUND THE EARTH...



MOON'S ORBIT IS ALWAYS CONCAVE TO SUN

THE ORBITS OF THE EARTH AND MOON

IT IS ONLY PARTIALLY TRUE THAT THE MOON REVOLVES AROUND THE EARTH, FOR AT THE SAME TIME THE EARTH REVOLVES AROUND THE MOON! THE CENTER OF GRAVITY AROUND WHICH THE TWO BODIES MUTUALLY REVOLVE IS 1000 MILES BELOW THE EARTH'S SURFACE!



CONFRONTING MISCONCEPTIONS



STRANGE ADVENTURES #119
AUGUST 1960
©DC



MYSTERY IN SPACE #70
SEPTEMBER 1961
©DC



Pearson

A NEW COMIC BOOK FOR PHYSICS

JUANELE AND FREEDMAN'S
**PHYSICS
COMICS** AND STORIES





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A NEW COMIC BOOK FOR PHYSICS



COLLABORATOR AND ARTIST:

JUANELE

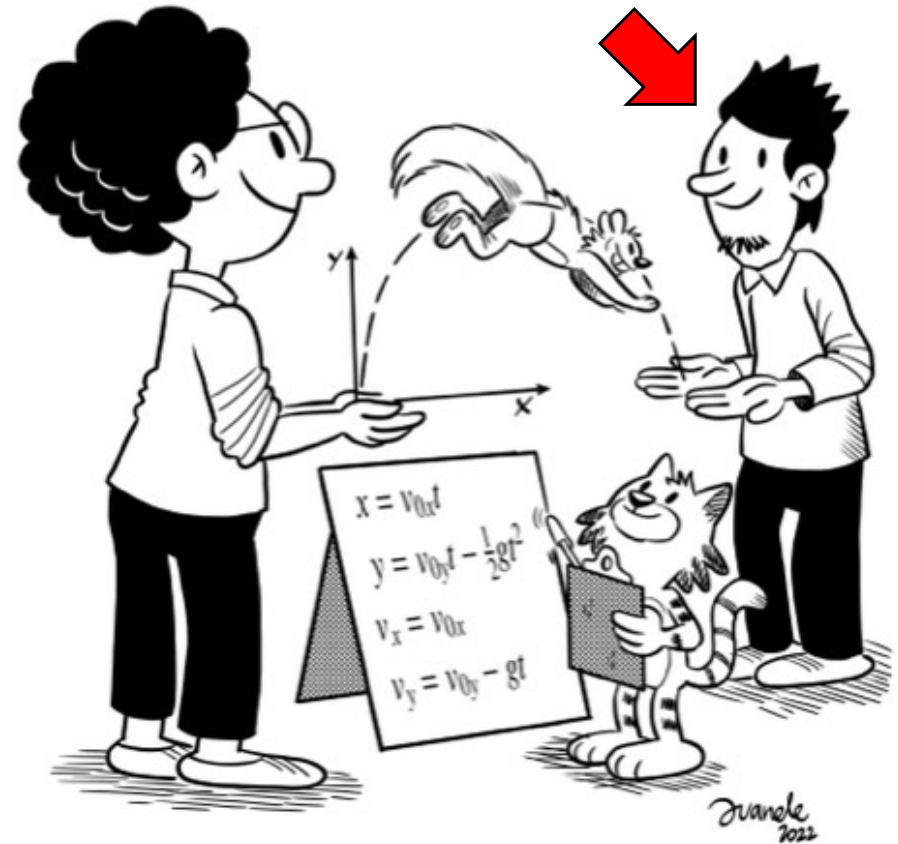
(DR. JUAN MANUEL RAMÍREZ DE ARELLANO)





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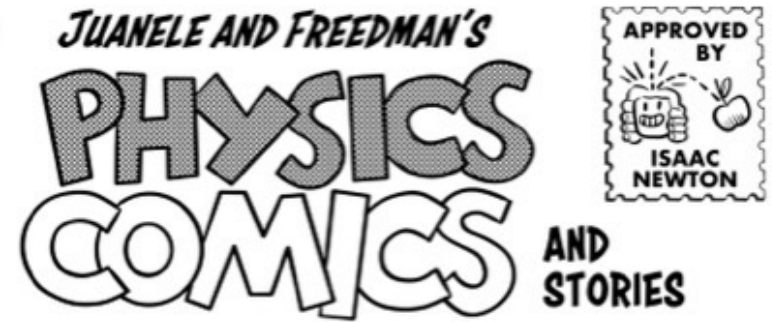
A NEW COMIC BOOK FOR PHYSICS





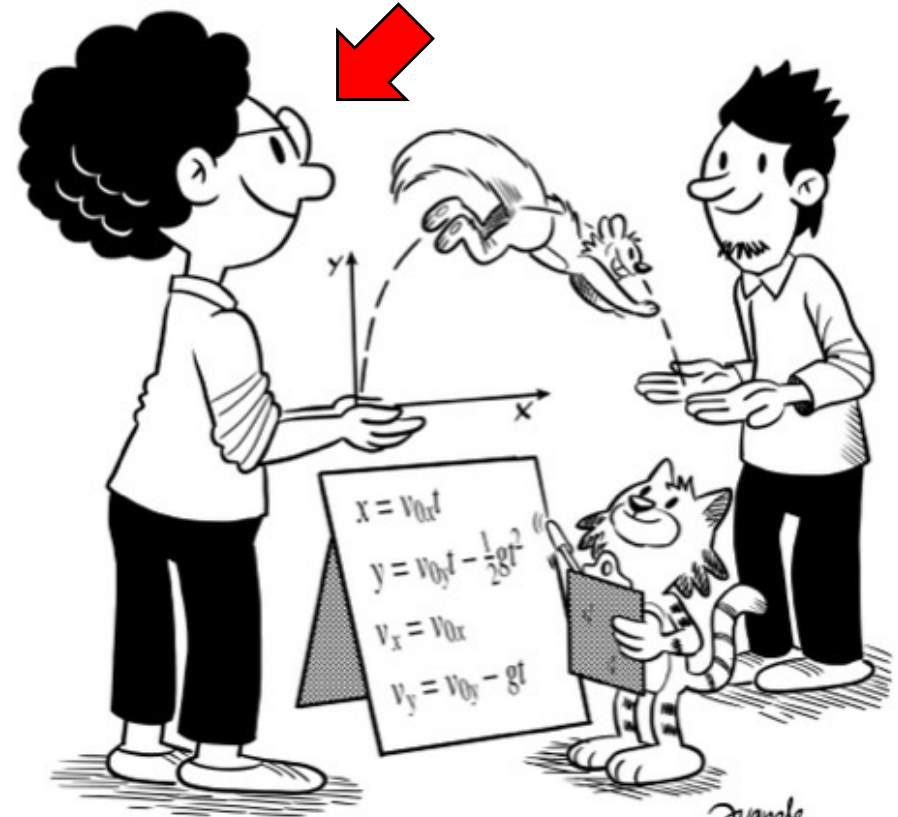
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A NEW COMIC BOOK FOR PHYSICS



ALONZO

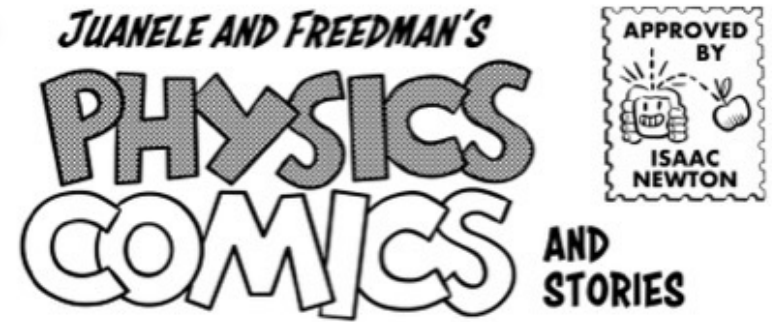
ELENA





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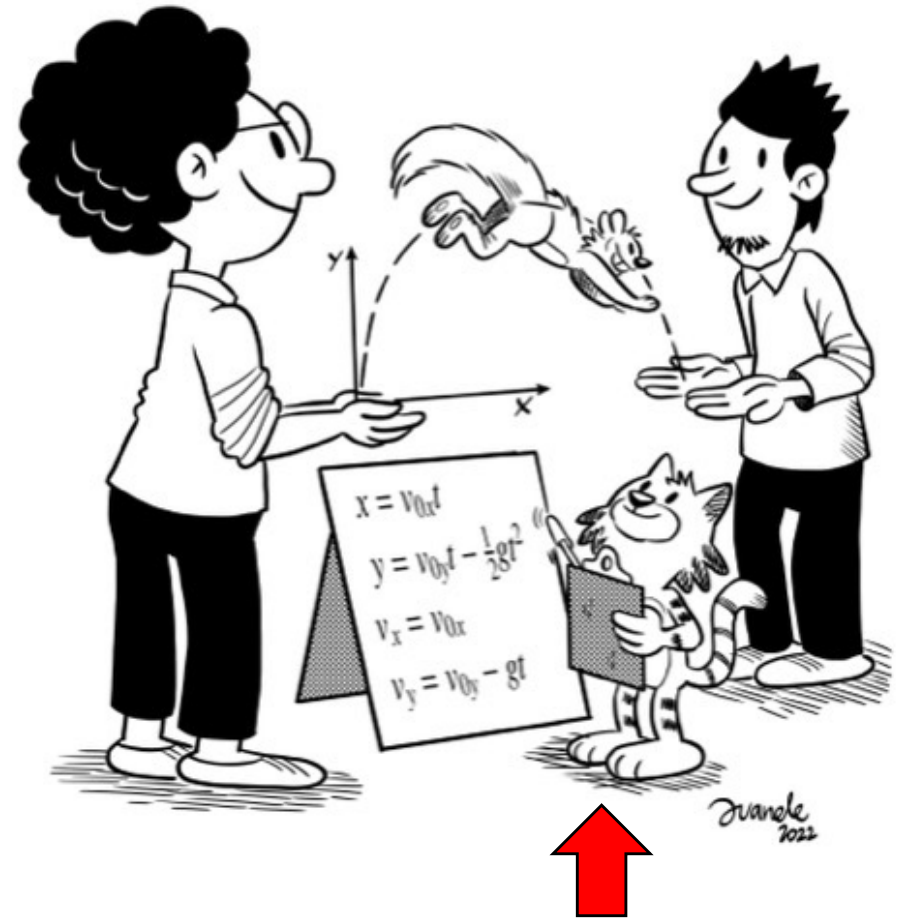


ALONZO

ELENA



KEPLER THE CAT





Pearson

A NEW COMIC BOOK FOR PHYSICS

JUANELE AND FREEDMAN'S
**PHYSICS
COMICS**



AND
STORIES



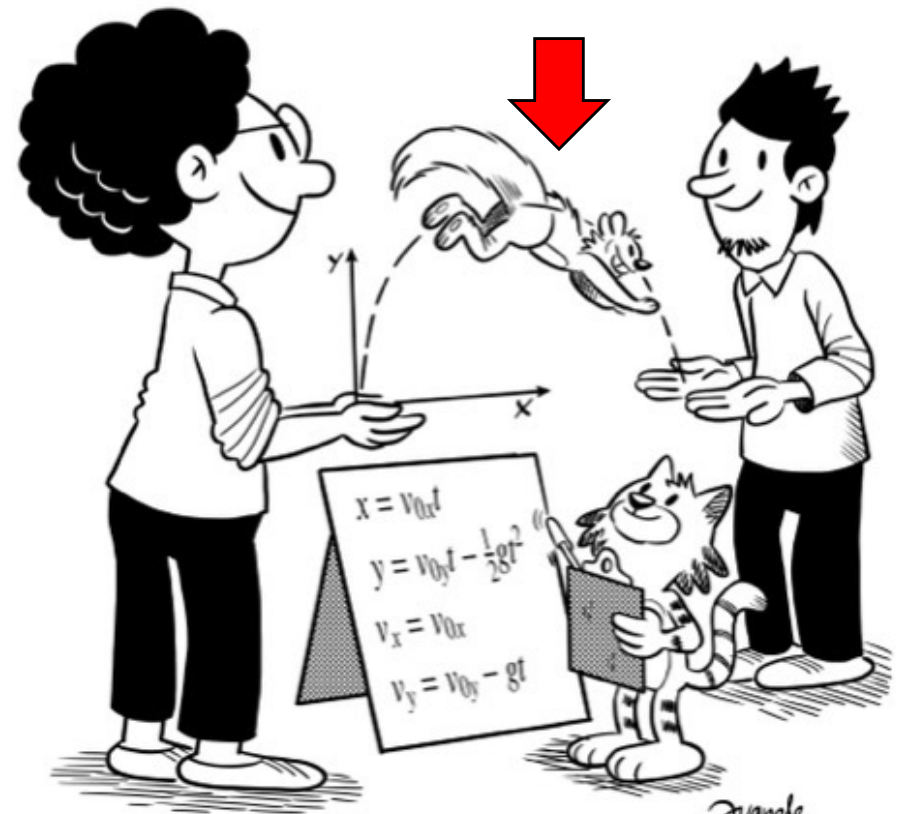
ALONZO

ELENA



KEPLER THE CAT

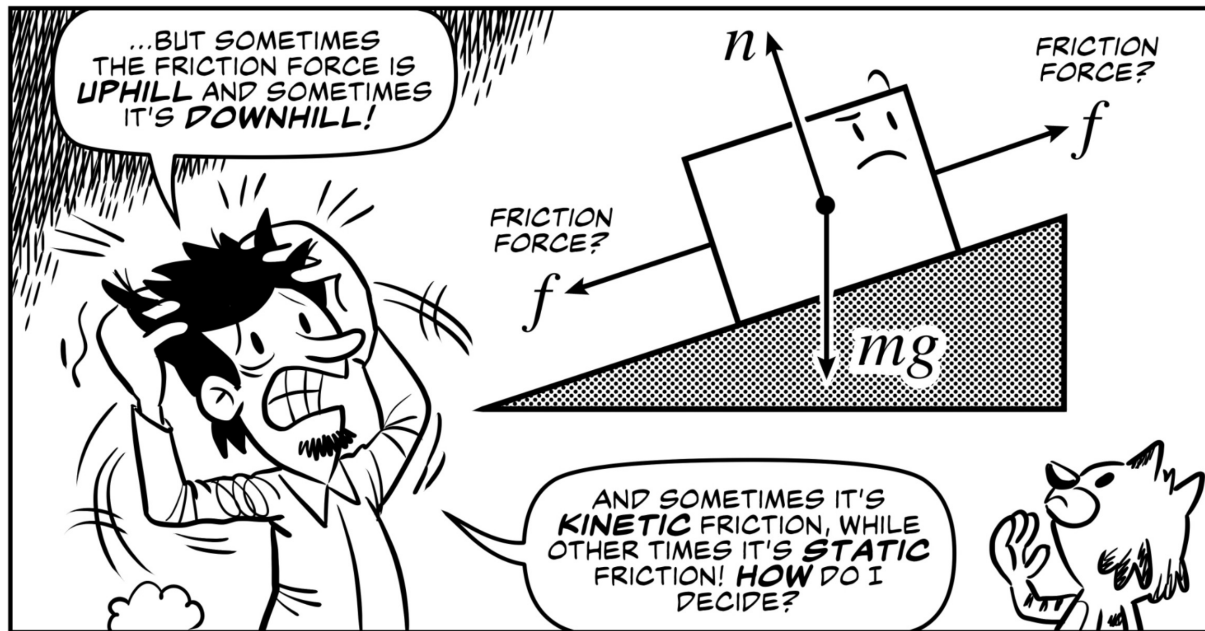
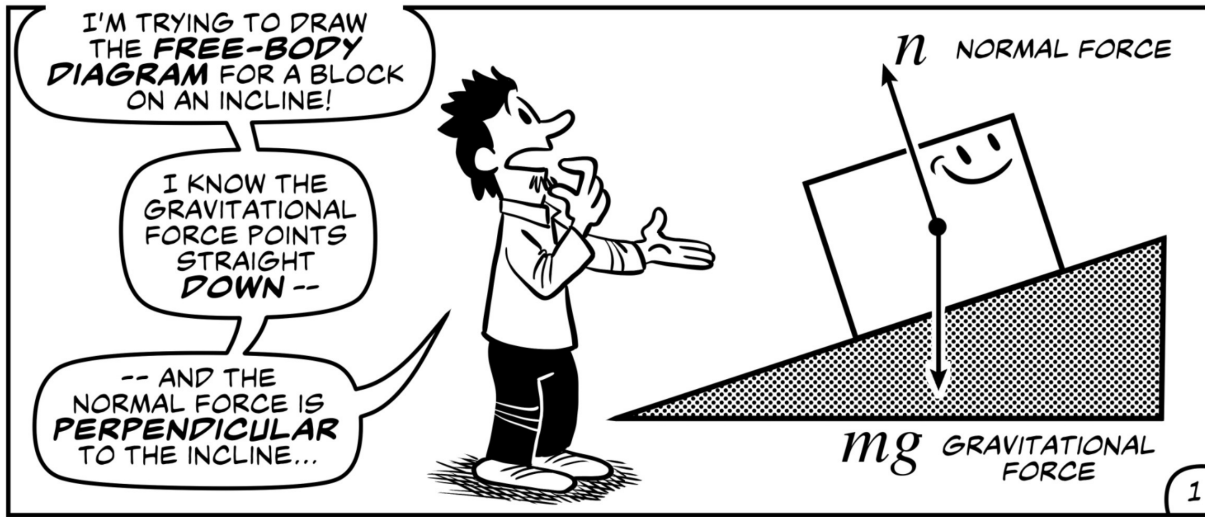
THE SQUIRREL



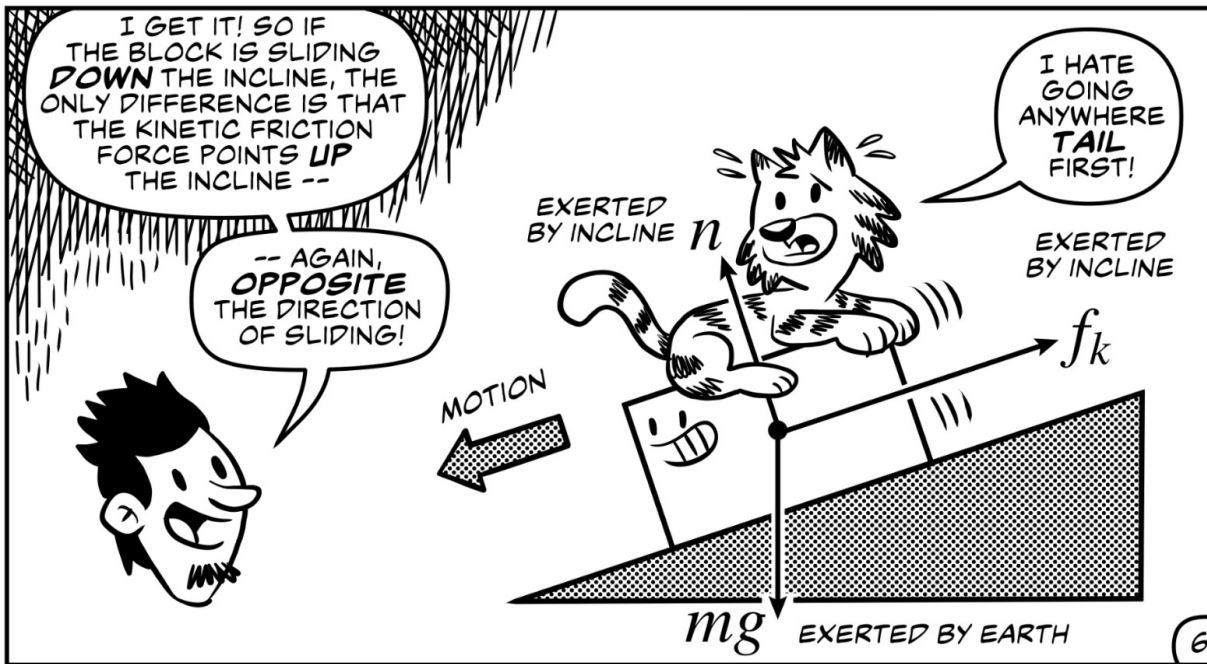
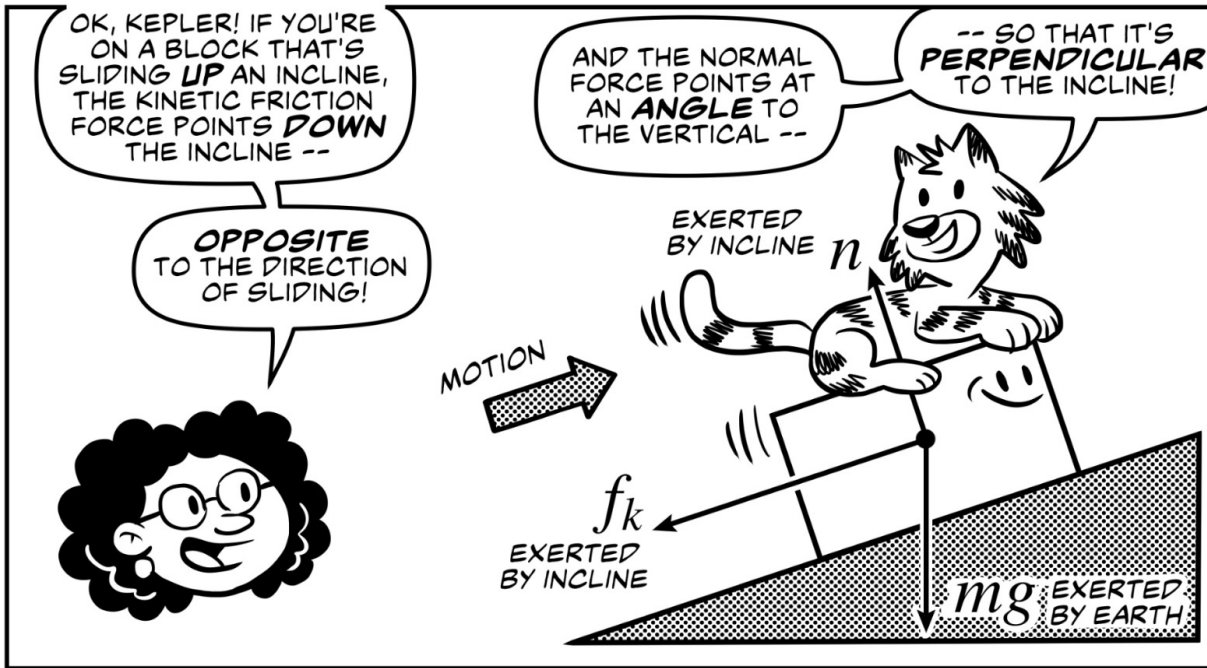
Juanele
2022



Pearson



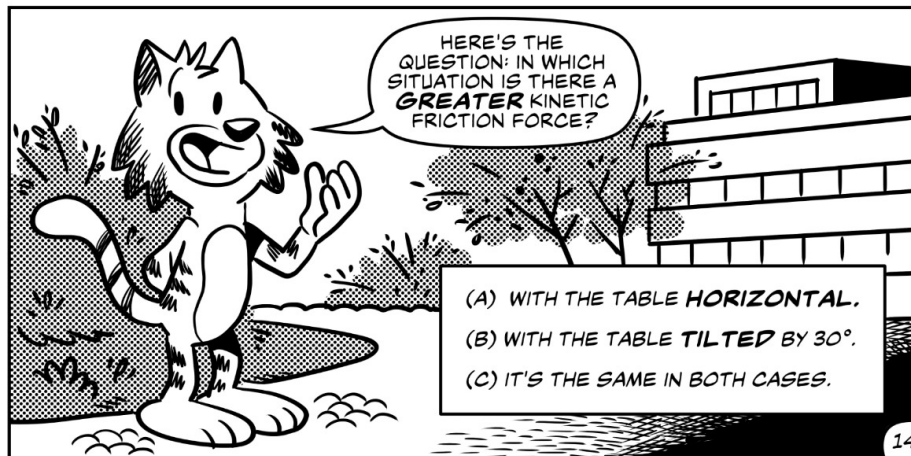
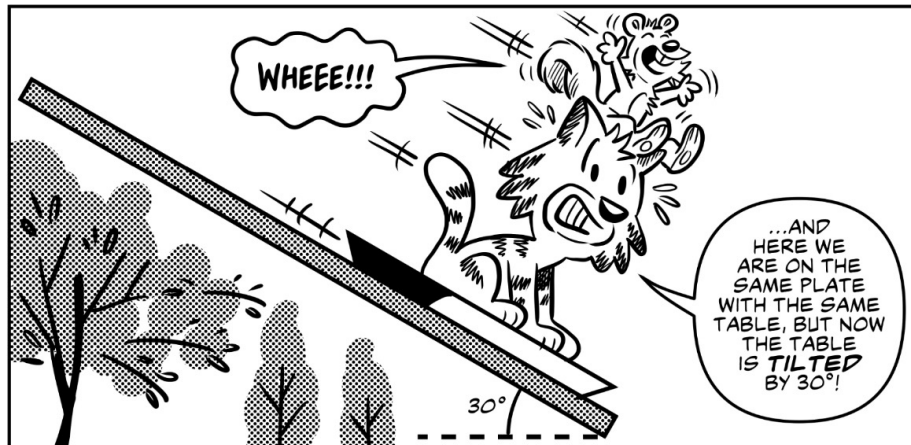
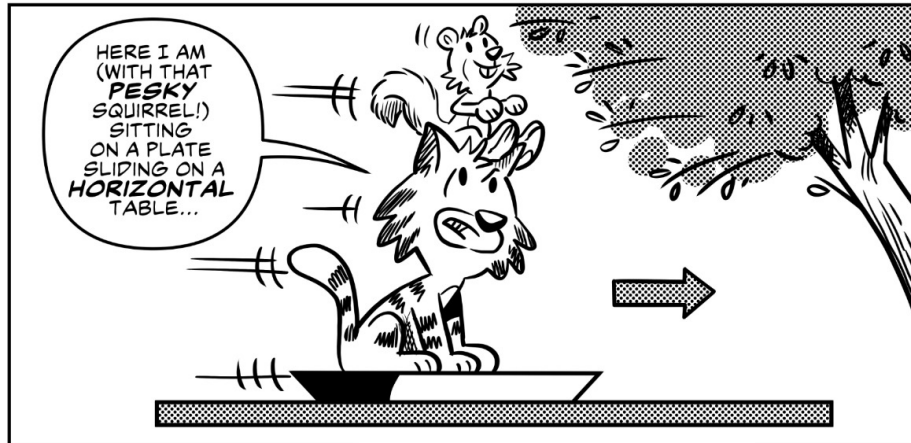
ALONZO
HAS THE SAME
DIFFICULTIES
WITH PHYSICS
AS MANY TYPICAL
STUDENTS



ELENA
PROVIDES ALONZO
WITH STUDENT-
TO-STUDENT
GUIDANCE
(WITH COMIC
RELIEF FROM
KEPLER)



TEST YOURSELF with **KEPLER** THE CAT



KEPLER
CHECKS FOR
CONCEPTUAL
UNDERSTANDING



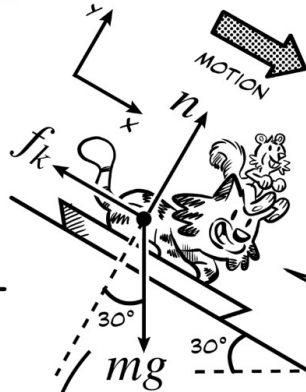
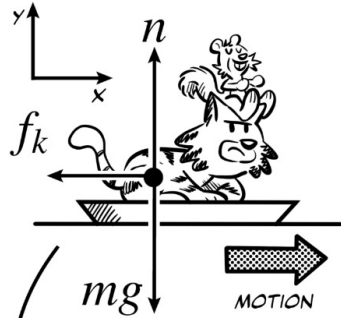
ANSWER



(A) THE MAGNITUDE OF THE KINETIC FRICTION IS GIVEN BY $f_k = \mu_k n$

THE COEFFICIENT OF KINETIC FRICTION μ_k IS THE SAME IN BOTH SITUATIONS --

-- BUT THE NORMAL FORCE n IS GREATER IN THE HORIZONTAL CASE!



TO SEE THIS, DRAW THE FREE-BODY DIAGRAMS FOR BOTH SITUATIONS.

CHOOSE THE X-AXIS TO BE IN THE DIRECTION OF MOTION AND THE Y-AXIS PERPENDICULAR TO THE TABLE...



...THEN WRITE NEWTON'S SECOND LAW IN COMPONENT FORM.

THERE'S NO ACCELERATION PERPENDICULAR TO THE TABLE, SO THE NET FORCE IN THE Y-DIRECTION IS ZERO.

HORIZONTAL TABLE

TILTED TABLE

① $\sum F_x = -f_k = ma_x$

① $\sum F_x = mg \sin 30^\circ - f_k = ma_x$

② $\sum F_y = n - mg = 0$

② $\sum F_y = n - mg \cos 30^\circ$

SOLVE THE EQUATION $\sum F_y = 0$ FOR THE NORMAL FORCE n

THEN FIND $f_k = \mu_k n$



FROM EQUATION ② WE HAVE:

$n = mg$

so $f_k = \mu_k mg$

HORIZONTAL TABLE

FROM EQUATION ② WE HAVE:

$n = mg \cos 30^\circ = 0.866mg$

so $f_k = 0.866 \mu_k mg$

TILTED TABLE

YOU'LL SEE THAT THE KINETIC FRICTION IS GREATER IN THE HORIZONTAL CASE --

-- AND ONLY 0.866 AS MUCH WHEN THE TABLE IS TILTED BY 30°!



THERE ARE TWO REASONS WHY THE PLATE HAS AN EASIER TIME SLIDING ON THE TILTED TABLE:

FRICTION IS LESS, AND GRAVITY HELPS!

KEPLER
CHECKS FOR
CONCEPTUAL
UNDERSTANDING
... AND PROVIDES
GUIDANCE WITH
ASSISTANCE
FROM
THE SQUIRREL



**SOLVING PROBLEMS
LIKE THE EXPERTS DO:**

KINETIC AND STATIC FRICTION

AND NOW WE
HAVE ALL THE TOOLS
WE NEED TO SOLVE
PROBLEMS INVOLVING
FRICTION!

I'M
READY,
LET'S
GO!

OK ALONZO!
HERE WE ARE
AT REST ON THE
TILTED TABLE
AGAIN.

HERE'S SOME
(POTENTIALLY)
USEFUL INFO:

Mass of Kepler: 4.00 kg
Mass of squirrel: 0.60 kg
Mass of plate: 0.50 kg
Coefficients of friction:
 $\mu_k = 0.400$
 $\mu_s = 0.600$

CAN YOU
**CALCULATE THE
MAXIMUM ANGLE**
THAT THE TABLE CAN
HAVE FROM THE
HORIZONTAL THAT
WILL KEEP US FROM
SLIDING?

θ

**THE ENTIRE
CAST PROVIDES
GUIDANCE
WITH SOLVING
PHYSICS
PROBLEMS**



Pearson

**THE ENTIRE
CAST PROVIDES
GUIDANCE
WITH SOLVING
PHYSICS
PROBLEMS
...INCLUDING
STEP-BY-STEP
HELP!**

NOW I JUST HAVE TO DO A LITTLE ALGEBRA TO SOLVE FOR THE MAXIMUM ANGLE θ TO PREVENT SLIDING...

...AND YOU CAN SEE THAT THIS ANGLE IS JUST THE ARCTANGENT OF μ_s , THE COEFFICIENT OF STATIC FRICTION!

AND SINCE $\mu_s = 0.600$ YOU CAN TILT THE TABLE UP TO 31.0° WITHOUT MAKING US SLIDE!

SOLVE ① FOR f_{smax} :

$$f_{smax} = mg \sin \theta$$

SOLVE ② FOR n :

$$n = mg \cos \theta$$

SUBSTITUTE f_{smax} AND n INTO ③ :

$$mg \sin \theta = \mu_s mg \cos \theta$$

CANCEL THE mg FACTORS:

$$\sin \theta = \mu_s \cos \theta$$

so $\mu_s = \frac{\sin \theta}{\cos \theta} = \tan \theta$

SOLVE FOR θ :

$$\theta = \arctan \mu_s$$

SINCE $\mu_s = 0.600$,

$$\theta = \arctan 0.600 = 31.0^\circ$$

The cartoon shows a man in a white shirt and black pants explaining the problem to a woman with curly hair and glasses. They are standing next to a table tilted at an angle. A cat is sitting on the table, and a smaller cat is sitting on the table next to it. The man is pointing at the table with a dashed line. The woman is pointing at the man. The background shows some rocks and a tree.

SLIDING DOWNHILL

$$a_x = (9.80 \frac{m}{s^2}) \times (\sin 35.0^\circ - (0.400) \cos 35.0^\circ) = +2.41 \frac{m}{s^2}$$



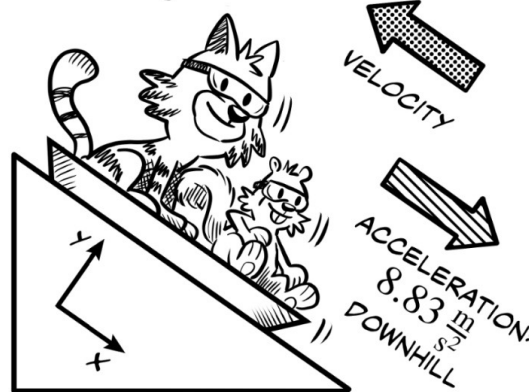
FOR THE **DOWNHILL** CASE, THE ACCELERATION IS **POSITIVE** -- THAT IS, IT POINTS DOWNHILL.

SO AS THE PLATE SLIDES DOWNHILL, IT **GAINS SPEED** BECAUSE THE VELOCITY AND ACCELERATION ARE IN THE **SAME** DIRECTION.



SLIDING UPHILL

$$a_x = (9.80 \frac{m}{s^2}) \times (\sin 35.0^\circ + (0.400) \cos 35.0^\circ) = +8.83 \frac{m}{s^2}$$



FOR THE **UPHILL** CASE THE ACCELERATION IS **ALSO POSITIVE** -- THAT IS, DOWNHILL -- BUT IS **EVEN GREATER** THAN IN THE DOWNHILL CASE.

THAT'S BECAUSE IN THIS CASE BOTH GRAVITY **AND** KINETIC FRICTION PULL THE PLATE DOWNHILL!

AND BECAUSE THE ACCELERATION IS OPPOSITE TO THE VELOCITY,

THE PLATE **LOSES SPEED** AS IT MOVES UPHILL!



ELENA AND KEPLER
 DEMONSTRATE
 THAT PROBLEM-SOLVING DOESN'T
 END WITH FINDING
 A NUMBER OR
 FORMULA
 ... YOU MUST ALSO
 INTERPRET
 THE ANSWER!



Pearson

RESOLVER PROBLEMAS COMO LOS EXPERTOS:

FRICCIÓN CINÉTICA Y ESTÁTICA

¡YA TENEMOS TODAS LAS HERRAMIENTAS QUE NECESITAMOS PARA RESOLVER PROBLEMAS CON FRICCIÓN!

¡ESTOY LISTO! ¡VAMOS!

¡BIEN, ALONZO! ESTAMOS OTRA VEZ EN REPOSO EN LA MESA INCLINADA.

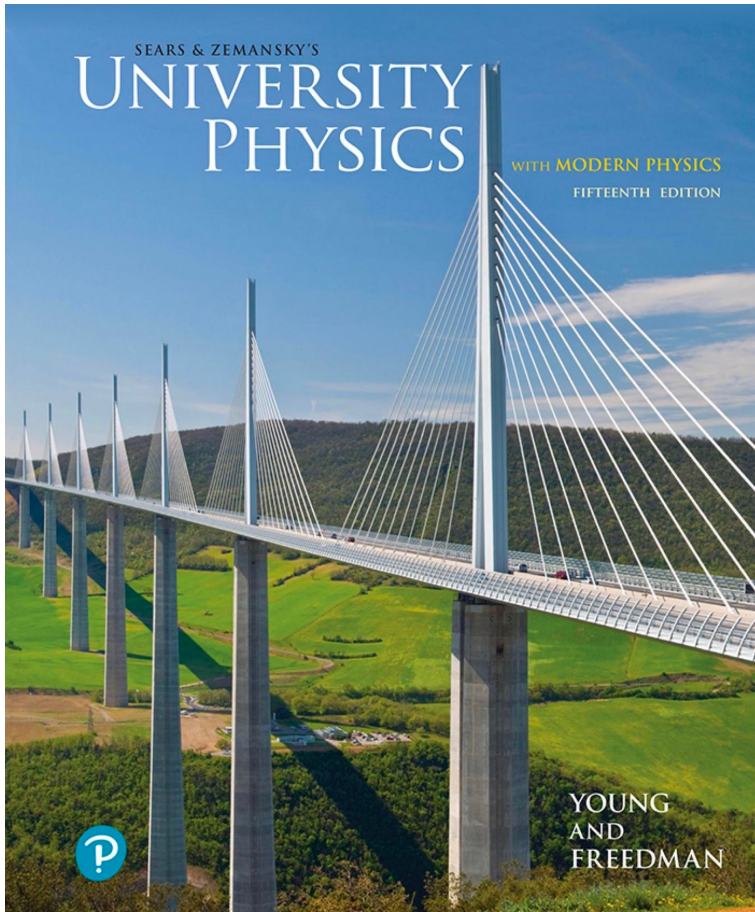
AQUÍ HAY INFORMACIÓN (POTENCIALMENTE) ÚTIL:

Masa de Kepler: 4.00 kg
Masa de la ardilla: 0.60 kg
Masa del plato: 0.50 kg
Coeficientes de fricción:
 $\mu_k = 0.400$
 $\mu_s = 0.600$

¿PUEDES CALCULAR EL ÁNGULO MÁXIMO DESDE LA HORIZONTAL QUE PUEDE TENER LA MESA, EVITANDO QUE NOS DESLICEMOS?

θ

EACH CHAPTER OF
THE COMIC BOOK
WILL ALSO BE
AVAILABLE IN
SPANISH



ROGER FREEDMAN
AIRBOY@UCSB.EDU

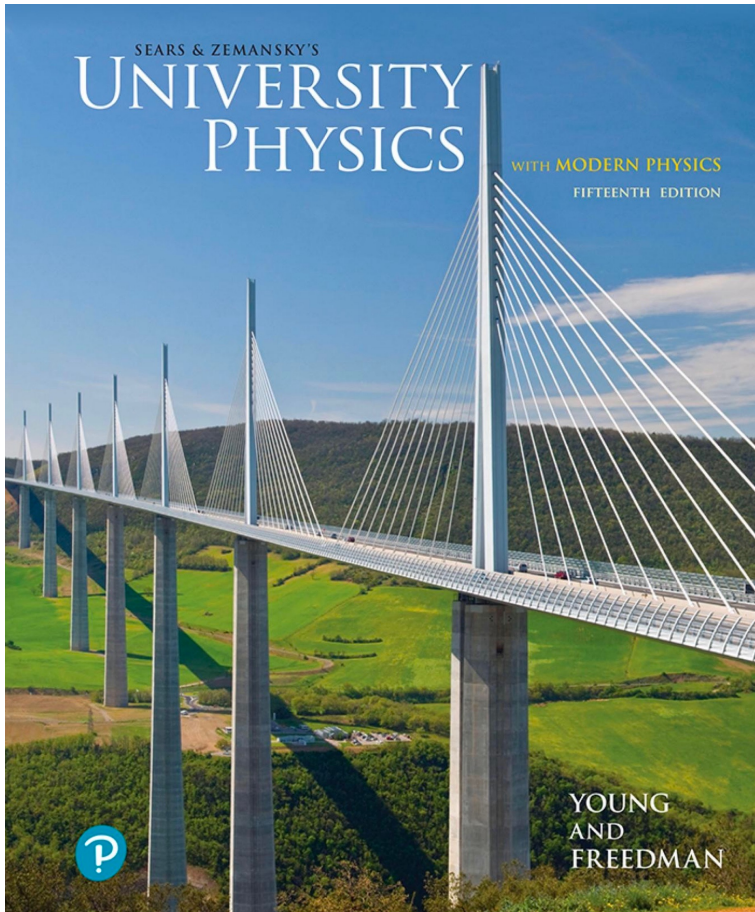


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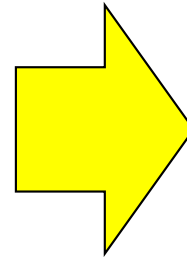
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AIRBOY@UCSB.EDU



LINKS TO INFO ABOUT
ACTIVE LEARNING, A SAMPLE
CHAPTER OF THE COMIC BOOK,
CHATGPT, AND MUCH MORE!



bit.ly/42EozWY