An inquiry into science education, where the rubber meets the road

Richard Steinberg
School of Education and Department of Physics
City College of New York

Summer Scholars Program

- **Selective academic program serving rising 10th – 12th graders throughout NYC**
- **Most students attend specialized high schools**
- **Flexible curriculum; nine hours per week for 6 weeks; class size about 20**

Pretest question

Which of the following do you think best approximates the relative motion of the earth and the sun?

A. The sun goes around the earth

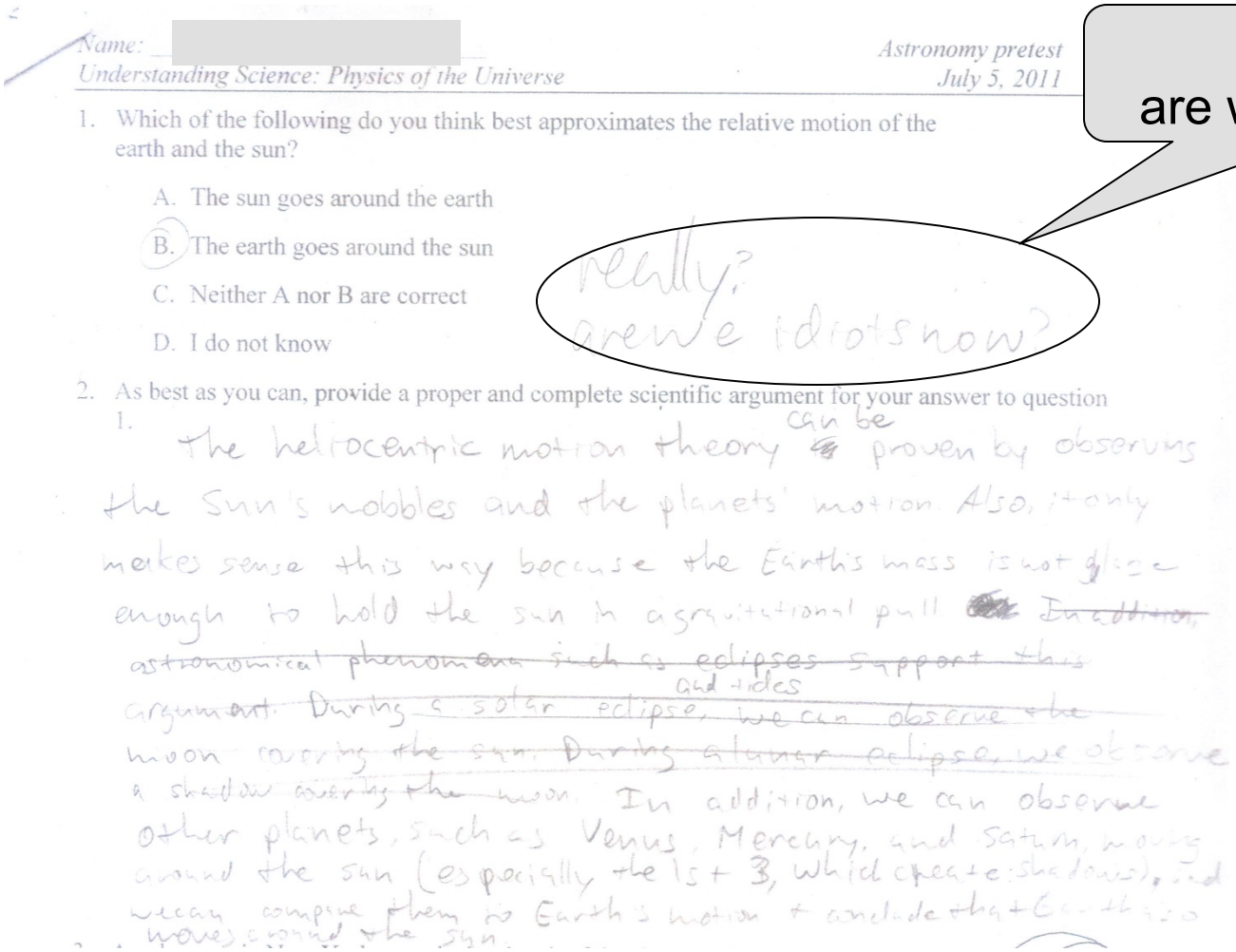
B. The earth goes around the sun

C. Neither A nor B are correct

D. I do not know

As best as you can, provide a proper and complete scientific argument for your answer.

Pretest responses



Name: [redacted]

Astronomy pretest
July 5, 2011

Understanding Science: Physics of the Universe

1. Which of the following do you think best approximates the relative motion of the earth and the sun?

   A. The sun goes around the earth

   B. The earth goes around the sun

   C. Neither A nor B are correct

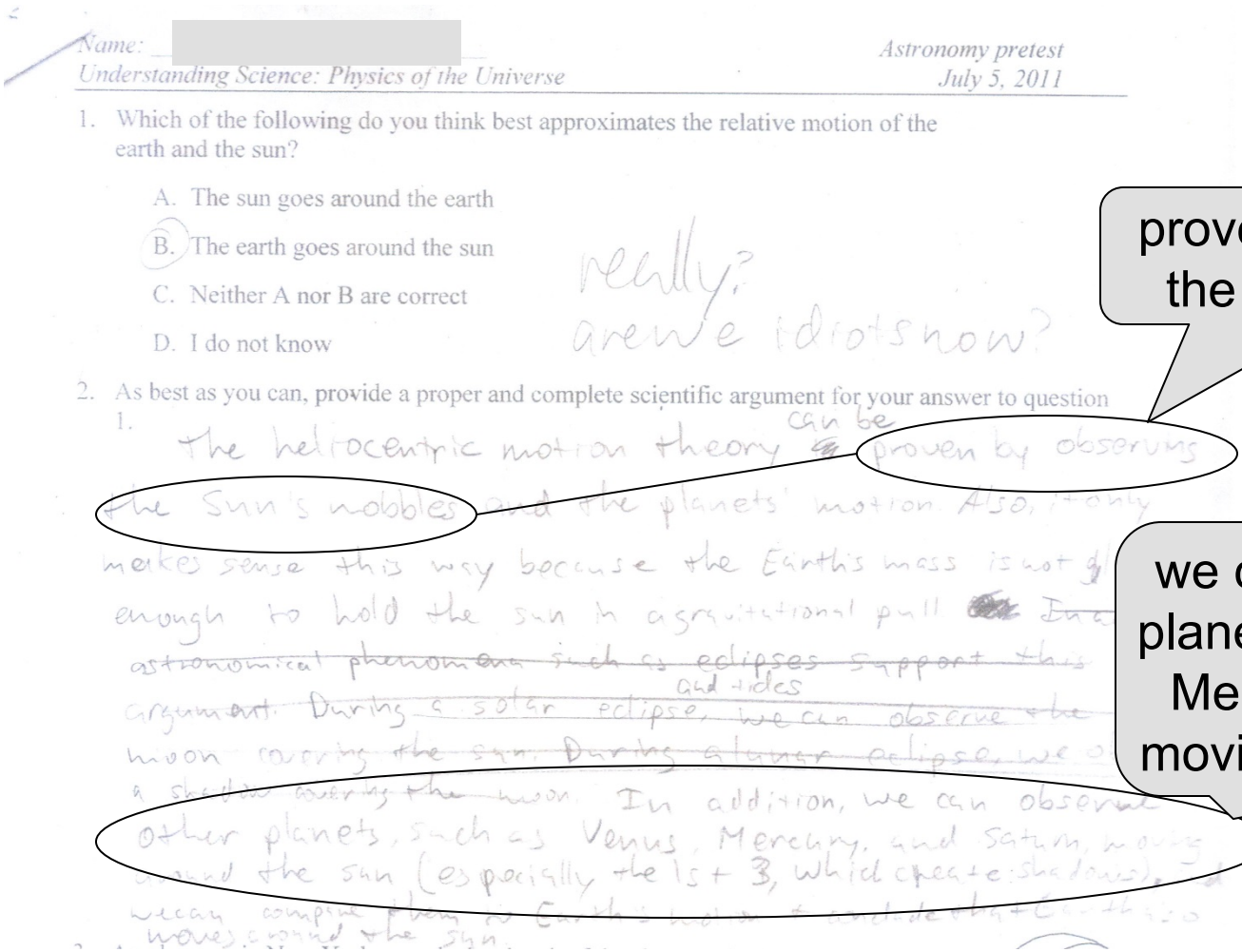
   D. I do not know

really?
are we idiots now?

2. As best as you can, provide a proper and complete scientific argument for your answer to question 1.

The heliocentric motion theory can be proven by observing the Sun's wobbles and the planets' motion. Also, it only makes sense this way because the Earth's mass is not large enough to hold the sun in a gravitational pull. ~~In addition, astronomical phenomena such as eclipses support this argument.~~ During a solar eclipse and tides, we can observe the moon covering the sun. ~~During a lunar eclipse, we observe a shadow covering the moon.~~ In addition, we can observe other planets, such as Venus, Mercury, and Saturn, moving around the sun (especially the 1st 3, which create shadows), and we can compare them to Earth's motion & conclude that Earth also moves around the sun.

Pretest responses



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Understanding Science: Physics of the Universe *July 5, 2011*

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proven by observing the sun's wobbles

we can observe other planets such as Venus, Mercury, and Saturn moving around the sun

Pretest responses

Student "reasoning"

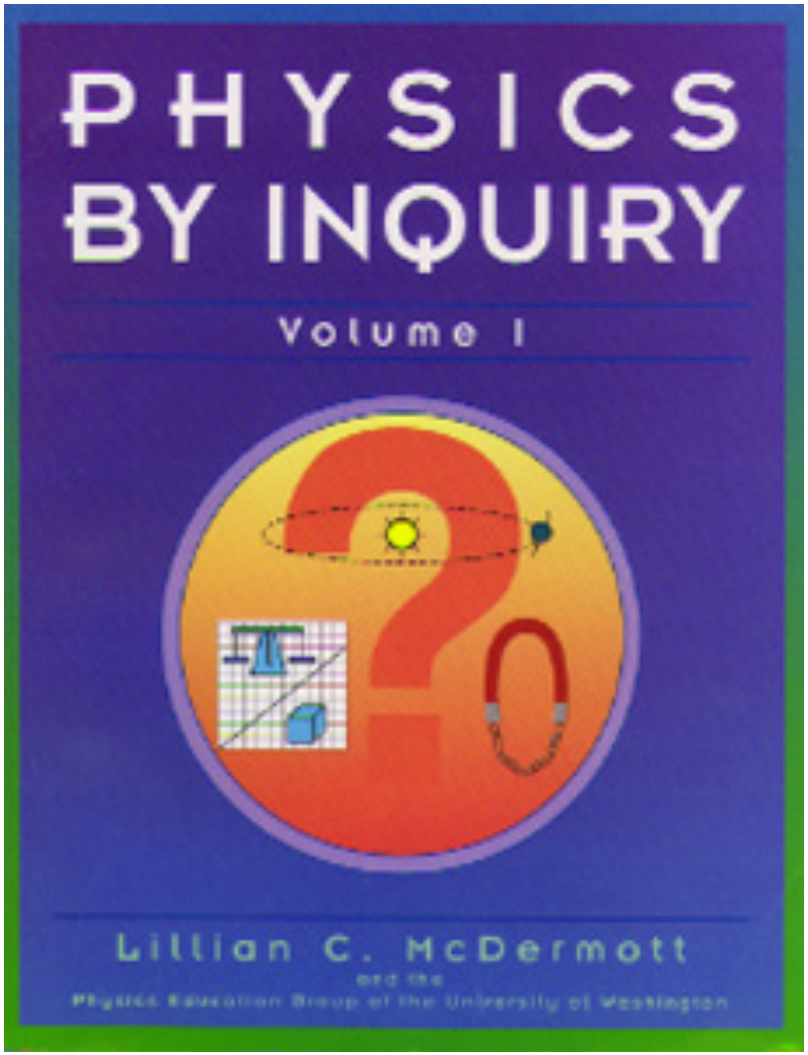
- "The earth goes around the sun because that's how we have different seasons. That is also how we have day and night as well as the different positions of the shadow."
- "The model of the universe is a heliocentric theory. This means that the sun is the center of the universe and all of the planets revolve around it."
- "During the scientific revolution, a theory was proved that …"

Pretest responses

Student "reasoning"

- "The sun is a planet of great size which is stationary at all times. If observed for the entire day the sun will move across the sky. Therefore one of the planets is moving. Since the sun remains in one place, earth must revolve around it."
- "I think the answer is B because we've been taught that since we were young. … the true answer is I do not know because I have not witnessed it myself."

Physics by Inquiry



Post-test question

Which of the following do you think best approximates the relative motion of the earth and the sun?

A. The sun goes around the earth

B. The earth goes around the sun

C. Neither A nor B are correct

D. I do not know

As best as you can, provide a proper and complete scientific argument for your answer.

Post-test responses

Choice D

- "If I work with a model where the earth stays and the sun goes around the earth I can account for the motion of earth and sun. If I work with a model where the sun stays and the earth goes around the sun I can account for the motion of the earth and sun, too."
- "I can account for the daily motions of the sun in 2 ways. …"
- "… Therefore I do not know which model is better. While the earth centered model can be more complicated than the sun centered model, if both are finely adjusted, both models can approximately show the relative motions of the earth and the sun. "

Post-test responses

Choice B

- "We observed that the sun moves across the sky. This can be explained by having the sun go around the earth or the sun still and the earth spinning. … The movements of the planets can be more easily explained by using the sun centered model and gravity so the earth going around the sun model is most likely correct."

- "I think B best approximates the relative motion of the earth and sun. Although both A and B account for the movement of the earth, sun, moon, and stars, B is much easier to explain the movement of the planets. Since it is observed that the distance between the earth and certain planets change over time, it would be difficult to incorporate this in a geocentric model."

Quantifying results

Pre/Post test rubric, explanations

1- Student's use of jargon, authority, circular reasoning, or irrelevant observations/experiments represents a significant part of their answer.

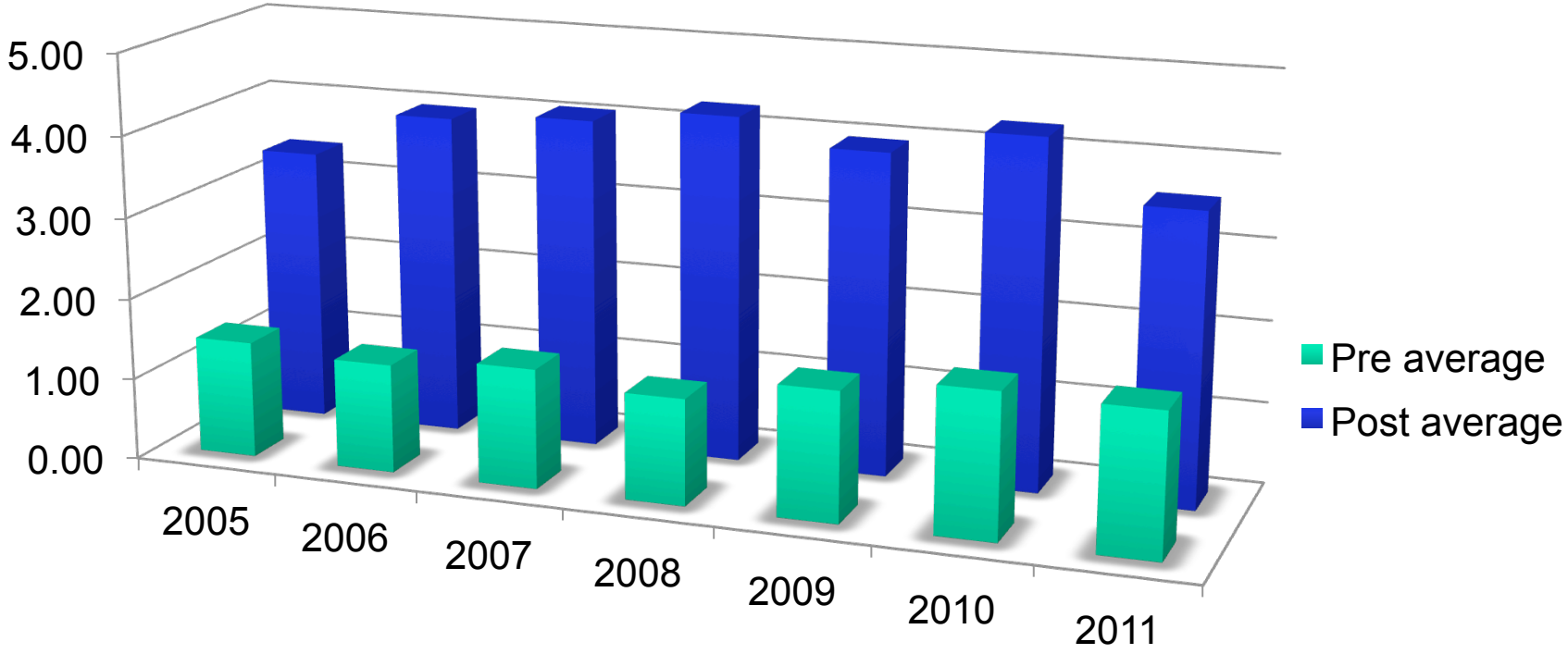
3- Student refers to relevant observation and experiments but part of explanation is erroneous or problematic.

5- Student cites observations/experiments distinguishing between 2 models and supports choice with proper explanation relevant to their answer.

"Probing student understanding of scientific thinking in the context of introductory astrophysics," R.N. Steinberg, S. Cormier, and A. Fernandez, *Phys. Rev. ST Phys. Educ. Res.* **5**, 020104 (2009).

Quantifying results

- ***N* = 139 (matched) over 7 year period**
  - » Pretest: Average score = 1.50
  - » Post-test: Average score = 3.92



An inquiry into science education, where the rubber meets the road

“In theory there is no difference between theory and practice. In practice there is.”

- Yogi Berra

An inquiry into science education, where the rubber meets the road

Perspectives entering sabbatical as a full time high school science teacher

- **Introductory college physics instructor**
- **Science education program director**
- **Teacher education program participant**

Qualitative observations

- **Introductory college physics instructor**
  - » Students have weak math, science, reasoning skills.
  - » Students have flawed approaches to learning physics.
- **Science education program director**
  - » Teacher candidates have varied strength in subject matter.
  - » Teacher candidates have an authoritarian perspective of science.
  - » Teacher candidates have a transmission approach to teaching science.

Qualitative observations

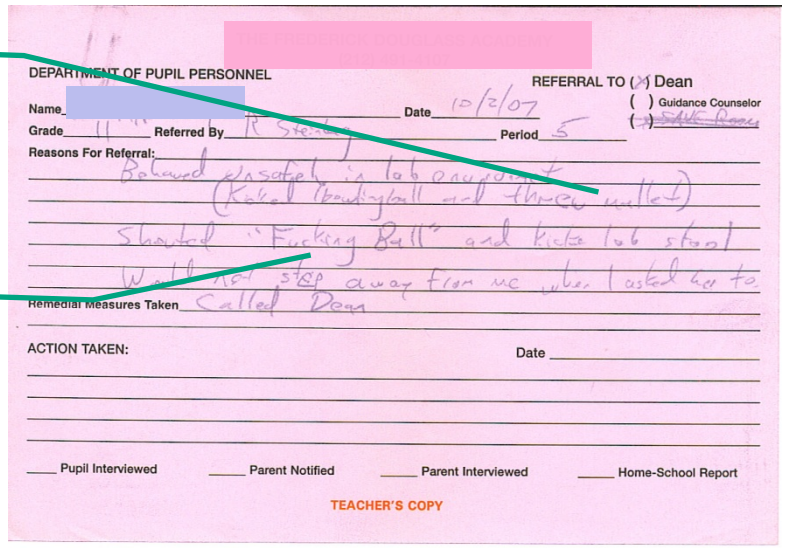
- **Teacher education program participant**
  - » Tell me what is going to help me tomorrow.
  - » What do I have to do to pass your class?
- **New York City High School Science Teacher**
  - » School administration emphasizes test results
  - » Teacher education classes tell me about “inquiry.”
  - » Content courses are varied but typically differ from both.
  - » The most important issue every day is classroom management.

Challenges of inquiry-oriented physics

- **Classroom management**

threw mallet

"f#*%ing ball"


DEPARTMENT OF PUPIL PERSONNEL

REFERRAL TO (X) Dean
( ) Guidance Counselor

Name_____ Date 10/2/07

Grade 11 Referred By R Stevens Period 5

Reasons For Referral:

Remedial Measures Taken Called Dean

ACTION TAKEN: Date

___ Pupil Interviewed ___ Parent Notified ___ Parent Interviewed ___ Home-School Report

TEACHER'S COPY

Challenges of inquiry-oriented physics

- **Classroom management**
- **Student approaches / epistemologies**
  - » "Is that on the Regents?"
  - » The average of 36 and 38 is 57
  - » Q: Find T_f of 50g Zn block (T_i = 71°C) placed in 200g of water (T_i = 10°C).
    A: 3°C
  - » Solution to *5x = 80* is *x = 75*

Challenges of inquiry-oriented physics

- **Classroom management**
- **Student approaches / epistemologies**
  - » “A car moves with a constant velocity of 9.5 m/s. What is the velocity of the car?” … “I could not do this one because I did not know which formula to use.”

Challenges of inquiry-oriented physics

- **Classroom management**
- **Student approaches / epistemologies**
- **Emphasis on standardized short-answer exams**
  - » Regents question:
    - The tau neutrino, the muon neutrino, and the electron neutrino are all:”

      a. leptons b. baryons c. hadrons d. mesons
    - 82% answered correctly (*N* = *38*)

Contrasting worksheets

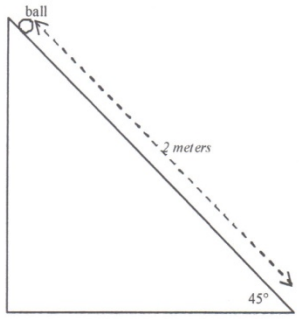
- **Use your reference sheet to answer the following questions. Show all work including the equation and substitution with units.**
- **In answering the following questions, do NOT use your reference sheets. Answer the questions how you would have answered them had you never taken a physics class. Explain how you determined your answers.**

Contrasting worksheets

1. Equilibrium exists on an object where three forces are acting on it. If one of the forces is a 7.0N force north and another force is a 3.0N force south, what is the magnitude and direction of the third force?

2. On planet X the weight of a 3.0kg rock is 24 pounds. What is the weight of a 6.0kg rock on planet X?

3. A 0.5 kg ball starts from rest and rolls 2.0 meters down a hill which makes an angle of 45° with respect to the horizontal. (See figure at right.) Is the time it takes the ball to cover the first meter greater than, less than, or equal to the time it takes to cover the second meter?

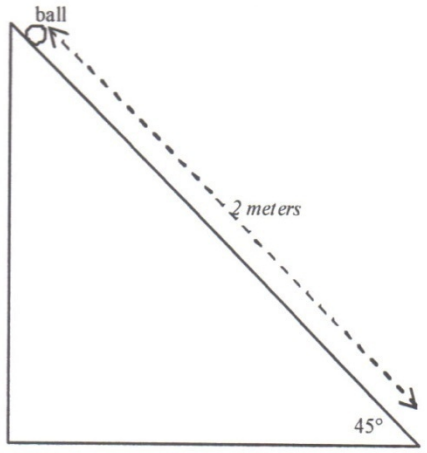


Contrasting worksheets

3. A 0.5 kg ball starts from rest and rolls 2.0 meters down a hill which makes an angle of 45° with respect to the horizontal. (See figure at right.) Is the time it takes the ball to cover the first meter greater than, less than, or equal to the time it takes to cover the second meter?

$\Delta x =$

IDK



7. A truck starting from rest accelerates at a rate of 5 miles per hour each second for 4 seconds. What is the final velocity of the truck?

$\frac{5 \text{ miles}}{1 \text{ hr}}$

5 miles = (1500 m)(5) = 7500 meters

1 mile = 1500 m

$V_F a = 7500 \text{ m/s} \times 4 \text{ s}$

$a = 30{,}000 \text{ m/s}^2$

$V_F = 0(4s) + 30{,}000 \text{ m/s}^2(4s)$

~~$V_F = 0 +$~~

$V_F = 120{,}000 \text{ m/s}$

Contrasting worksheets

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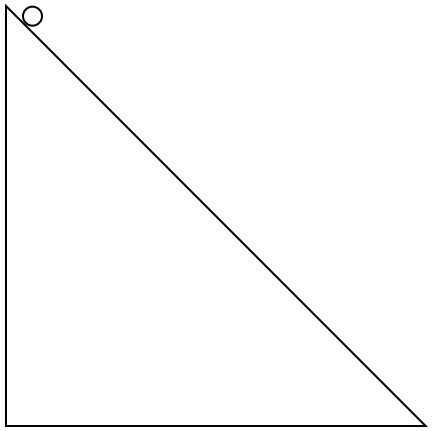


Contrasting worksheets

- **Is the time it takes the ball to cover the first meter greater than, less than, or equal to the time it takes to cover the second meter?**
  - » Reference tables: 47% correct (*N=43*)

3. A 0.5 kg ball starts from rest and rolls 2.0 meters down a hill which makes an angle of 45° with respect to the horizontal. (See figure at right.) Is the time it takes the ball to cover the first meter greater than, less than, or equal to the time it takes to cover the second meter?

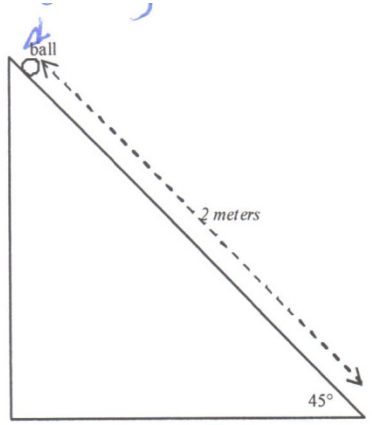
0.5kg
the time
is equal.

$v = \frac{d}{t}$

$(t)\ 0.5kg = \frac{2m}{xt}$

$\frac{.5kg\,t}{.5kg} = \frac{2m}{0.5kg}$

$t = 4\ m/kg$



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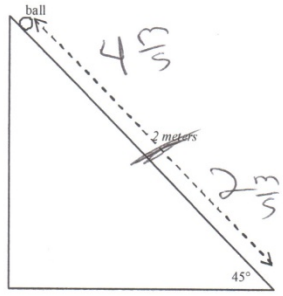

$v_i = 0$
$d = 1$
$v_f = ?$

$v_i = 0$
$d = 2$
$v_f = ?$

greater

$v_f^2 = 0^2 + 2(9.81)(1)$
$\sqrt{v_f^2} = \sqrt{19.62}$
$v_f = 4.429 \frac{m}{s}$

$v_f^2 = 0^2 + 2(9.81)2$
$\sqrt{v_f^2} = \sqrt{39.24}$
$v_f = 6.264 \frac{m}{s}$
$6 - 4 = 2 \frac{m}{s}$

Contrasting worksheets

- **Is the time it takes the ball to cover the first meter greater than, less than, or equal to the time it takes to cover the second meter?**
  - » Reference tables: 47% correct (*N*=43)
  - » No reference tables: 44% correct (*N*=32)

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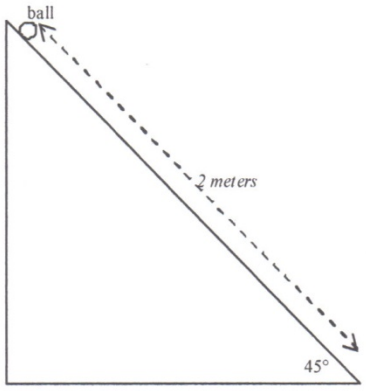
Greater time, because the longer it rolls the more speed it picks up.



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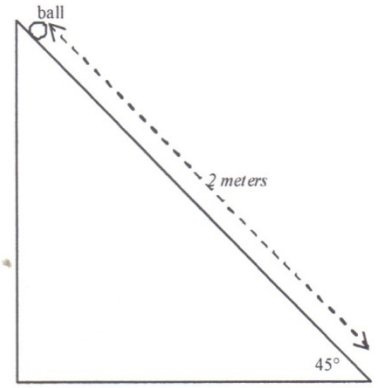
By the time the ball gets to the second half of the meters it would already be moving faste so it would cover the second meter quicker



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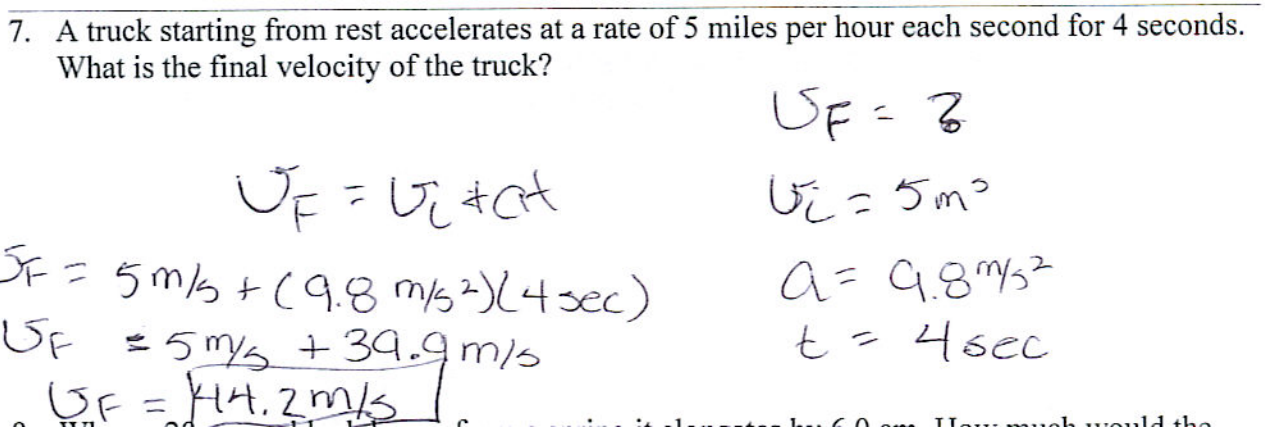

7. A truck starting from rest accelerates at a rate of 5 miles per hour each second for 4 seconds. What is the final velocity of the truck?

$v_F = ?$

$v_F = v_i + at$

$v_i = 5\ m/s$

$v_F = 5\ m/s + (9.8\ m/s^2)(4\ sec)$

$a = 9.8\ m/s^2$

$v_F = 5\ m/s + 39.9\ m/s$

$t = 4\ sec$

$v_F = 44.2\ m/s$

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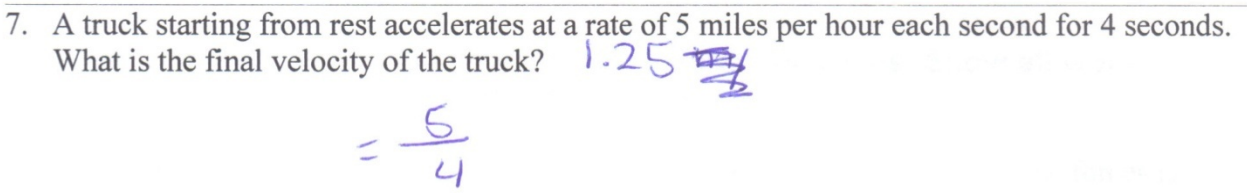

7. A truck starting from rest accelerates at a rate of 5 miles per hour each second for 4 seconds. What is the final velocity of the truck? 1.25 5/4 = 5/4

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For each second I would add 5 and my answer would be 20

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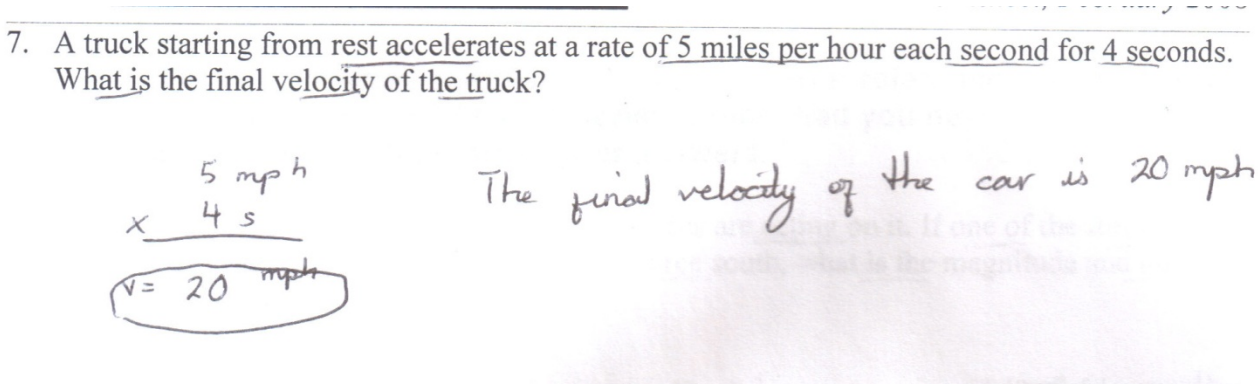

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5 mph
x 4 s
v = 20 mph

The final velocity of the car is 20 mph

Things that work / matter

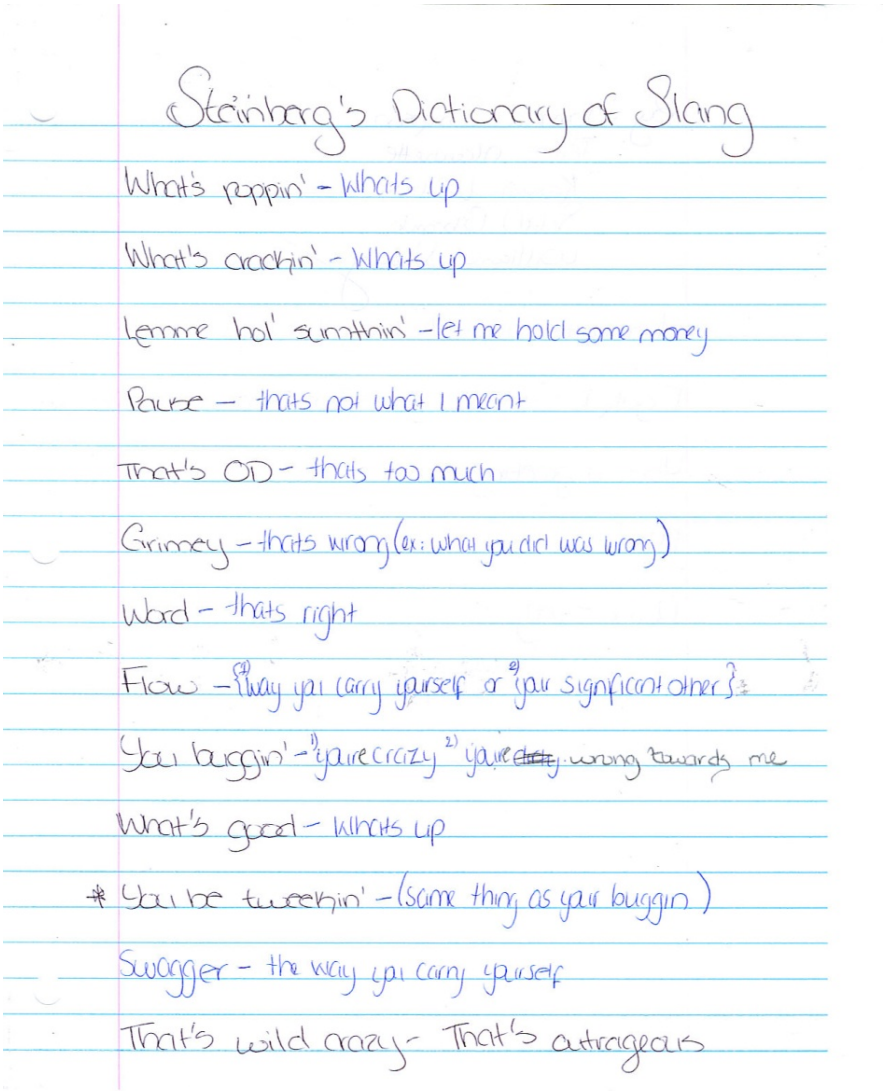
- Mr. Diaz's life science class
- Ms. O'Brien's history class
- Aaron's enthusiasm
- Scotch tape experiment
- Phet Simulations

Things that work / matter

- **Miguel: "*Special aptitude in the field*"**
- **Carlos and Linda: Period 9**
- **Basketball team game**
- **Joan and Pedro: Parent teacher night**

Things that work / matter

- **My third section of Regents Physics**



Steinberg's Dictionary of Slang

What's poppin' - Whats up

What's crackin' - Whats up

Lemme hol' sumthin' - let me hold some money

Pause - thats not what I meant

That's OD - thats too much

Grimey - thats wrong (ex: what you did was wrong)

Word - thats right

Flow - {1) way you carry yourself or 2) your significant other}

You buggin' - 1) you're crazy 2) you're ~~crazy~~ wrong towards me

What's good - Whats up

* You be tweekin' - (same thing as your buggin)

Swagger - the way you carry yourself

That's wild crazy - That's outrageous

Things that work / matter

***Physics by Inquiry*, Astronomy**

- ***Summer Scholars Program rubric scores***
  - » N=139 (matched)
  - » Pretest: Average score = 1.50
  - » Post-test: Average score = 3.92
- ***Public high school results***
  - » N=35 students (19 took pretest, 9 took post-test)
  - » Pretest: Average score = 1.05
  - » Post-test: Average score = 3.44

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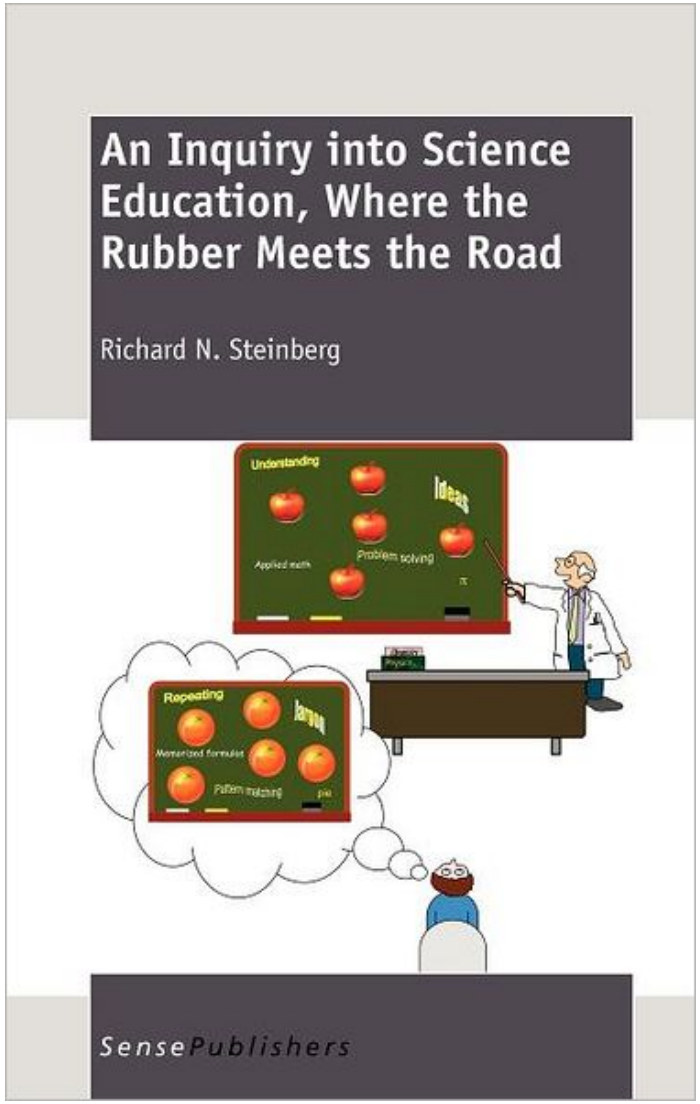

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www.sci.ccny.cuny.edu/~rstein/