What do you want your students to be able to do? Designing assessment questions to measure student learning

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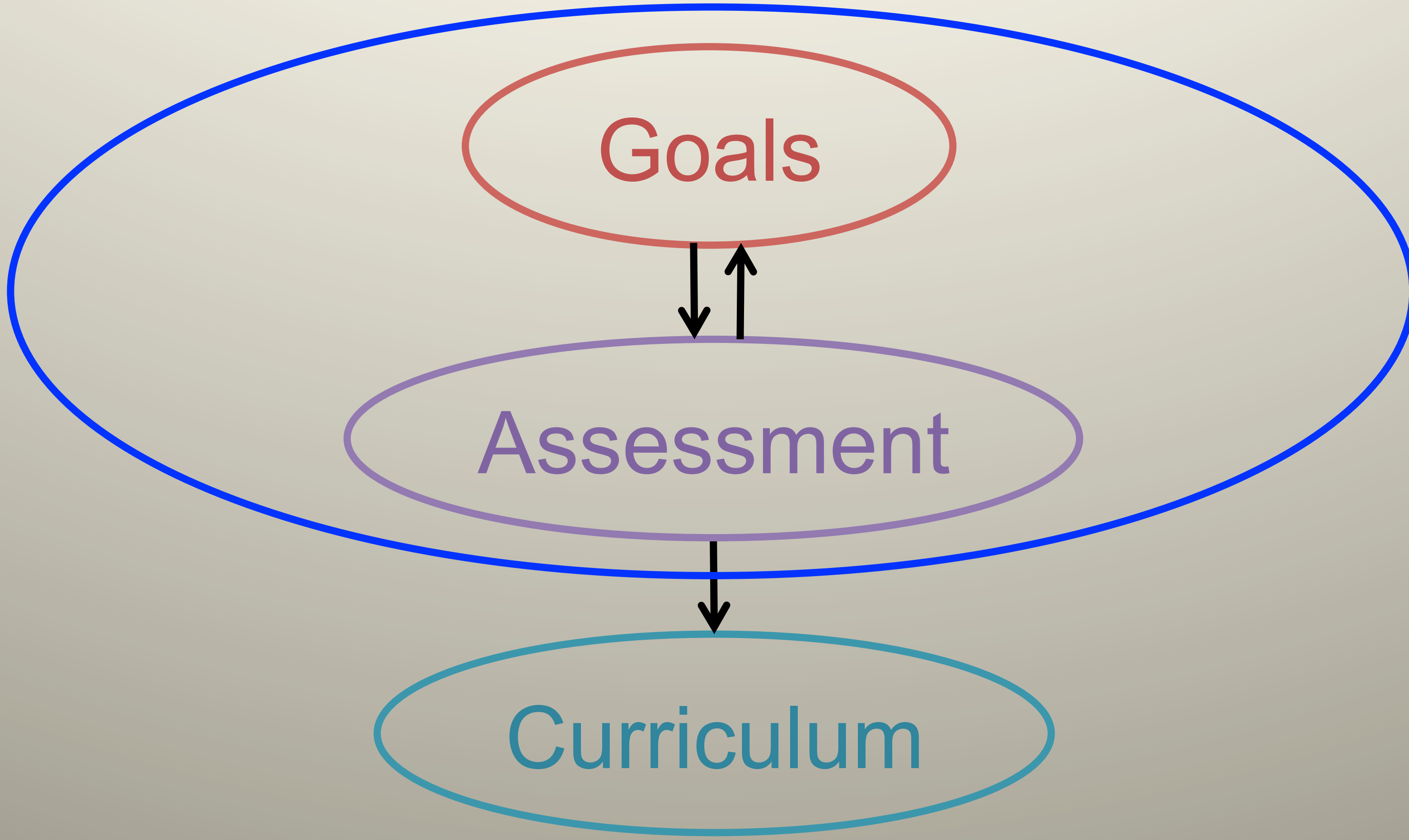
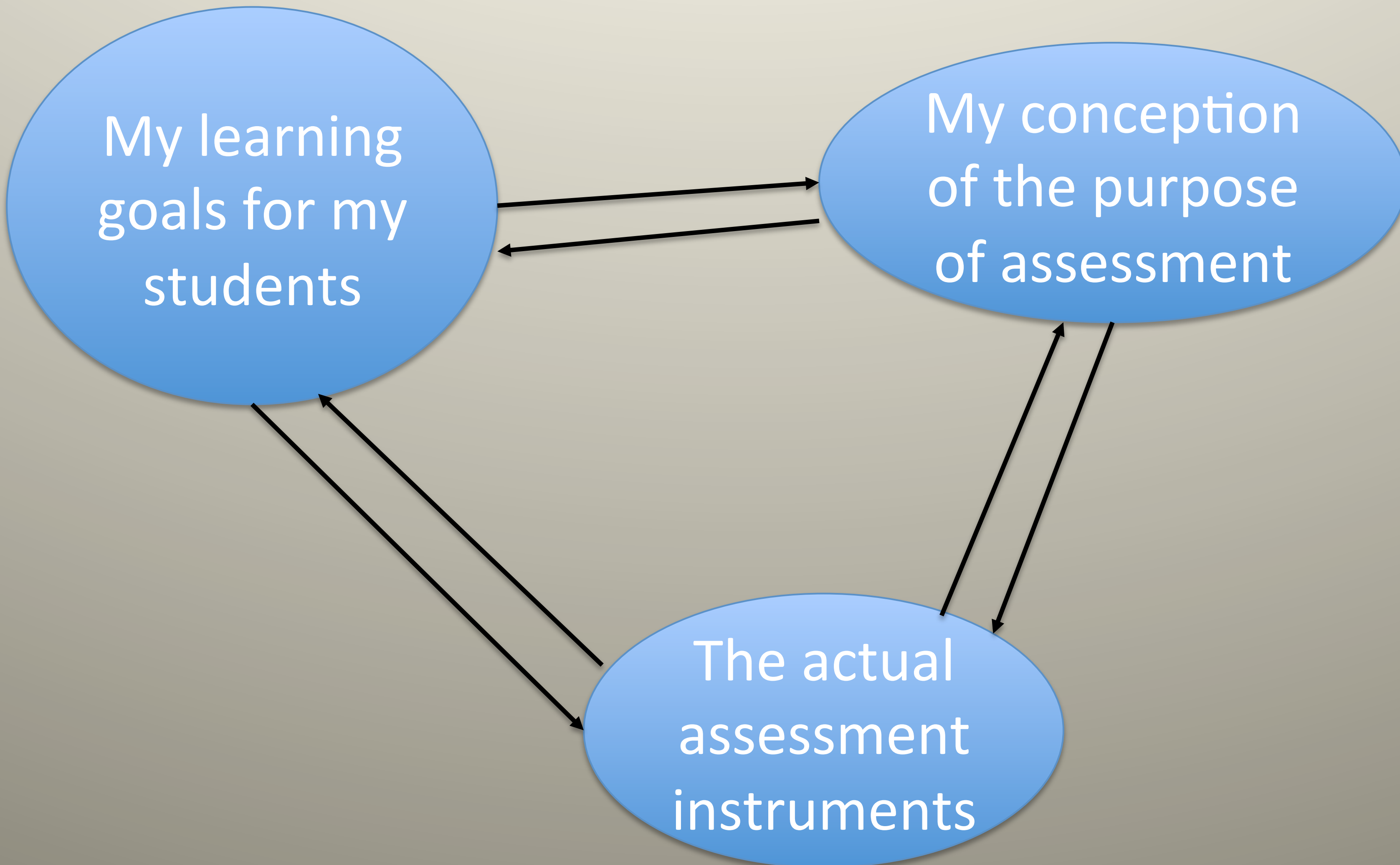
Assessment: There are no silver bullets

Backwards Design**



** Wiggins, Grant P., & McTighe, Jay. (2005). *Understanding by design* (2nd ed.). Virginia: ASCD.

A story of change through many iterations and much confusion



Learning goals try #1

~~I want my students to appreciate the beauty of Maxwell's~~ equations. unmeasurable

~~I want my students to understand Newton's laws.~~

Define "understand"…

~~I want my students to be able to solve problems involving~~ conservation of mechanical energy.

Too broad, unpack "solve a problem"

Assessing for Mastery

TEDxEastsidePrep - Dr. Tae - Can Skateboarding Save Our Schools?

http://www.youtube.com/watch?v=lHfo17ikSpY

It is all about performance!

Learning Goals

I want my students to acquire "high-level" scientific reasoning abilities. Students should be able to:

- Evaluate the reasonableness of an answer
- Represent physical processes with words, diagrams and mathematics
- Design an experiment to investigate a phenomenon or test a hypothesis
- Apply physics to real-world situations
- Be able to model a system, simplifying, deciding what can be ignored (making assumptions)
- Be able to learn about the world like a physicist.

"Traditional" Question

5. A boy throws a steel ball straight up. <u>Disregarding any effects of air resistance</u>, the force(s) acting on the ball until it returns to the ground is (are):

(A) its weight vertically downward along with a steadily decreasing upward force.
(B) a steadily decreasing upward force from the moment it leaves the hand until it reaches its highest point beyond which there is a steadily increasing downward force of gravity as the object gets closer to the earth.
(C) a constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point, after which there is only the constant downward force of gravity.
(D) a constant downward force of gravity only.
(E) none of the above, the ball falls back down to the earth simply because that is its natural action.

* Taken from the "Force Concept Inventory" – Hestenes, Wells, & Swackhammer

Experimental design

Your friend José claims that any object *always* moves in the direction of the net force exerted on it by other objects. Describe an experiment you could do [with a bowling ball and a rubber mallet] to show José that his rule is not *always* true.

Big learning goal: Be able to design an experiment that tests a hypothesis

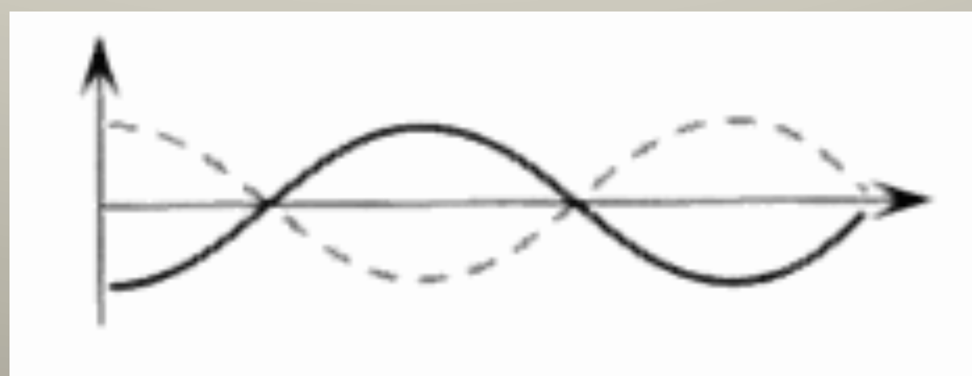
**Etkina, E., Van Heuvelen, A., White-Brahmia, S., Brookes, D. T., Gentile, M., Murthy, S., … Warren, A. (2006). Scientific abilities and their assessment. Physical Review Special Topics Physics Education Research, 2(2), 020103. http://doi.org/10.1103/PhysRevSTPER.2.020103

How do we grade this?

Item	Missng	Inadequate	Needs Improvement	Adequate
Is able to design a reliable experiment that tests the hypothesis (C2)		The experiment tests the hypothesis, but due to the nature of the design it is likely the data will lead to an incorrect judgment.	The experiment tests the hypothesis, but due to the nature of the design there is a moderate chance the data will lead to an inconclusive judgment.	The experiment tests the hypothesis and has a high likelihood of producing data that will lead to a conclusive judgment.
Is able to make a reasonable prediction based on a hypothesis (C3)		A prediction is made but it is identical to the hypothesis, OR Prediction is made based on a source unrelated to hypothesis being tested, or is completely inconsistent with hypothesis being tested, OR Prediction is unrelated to the context of the designed experiment.	Prediction follows from hypothesis but is flawed because * relevant experimental assumptions are not considered and/or * prediction is incomplete or somewhat inconsistent with hypothesis and/or * prediction is somewhat inconsistent with the experiment.	A prediction is made that * follows from hypothesis, * is distinct from the hypothesis, * accurately describes the expected outcome of the designed experiment, * incorporates relevant assumptions if needed.

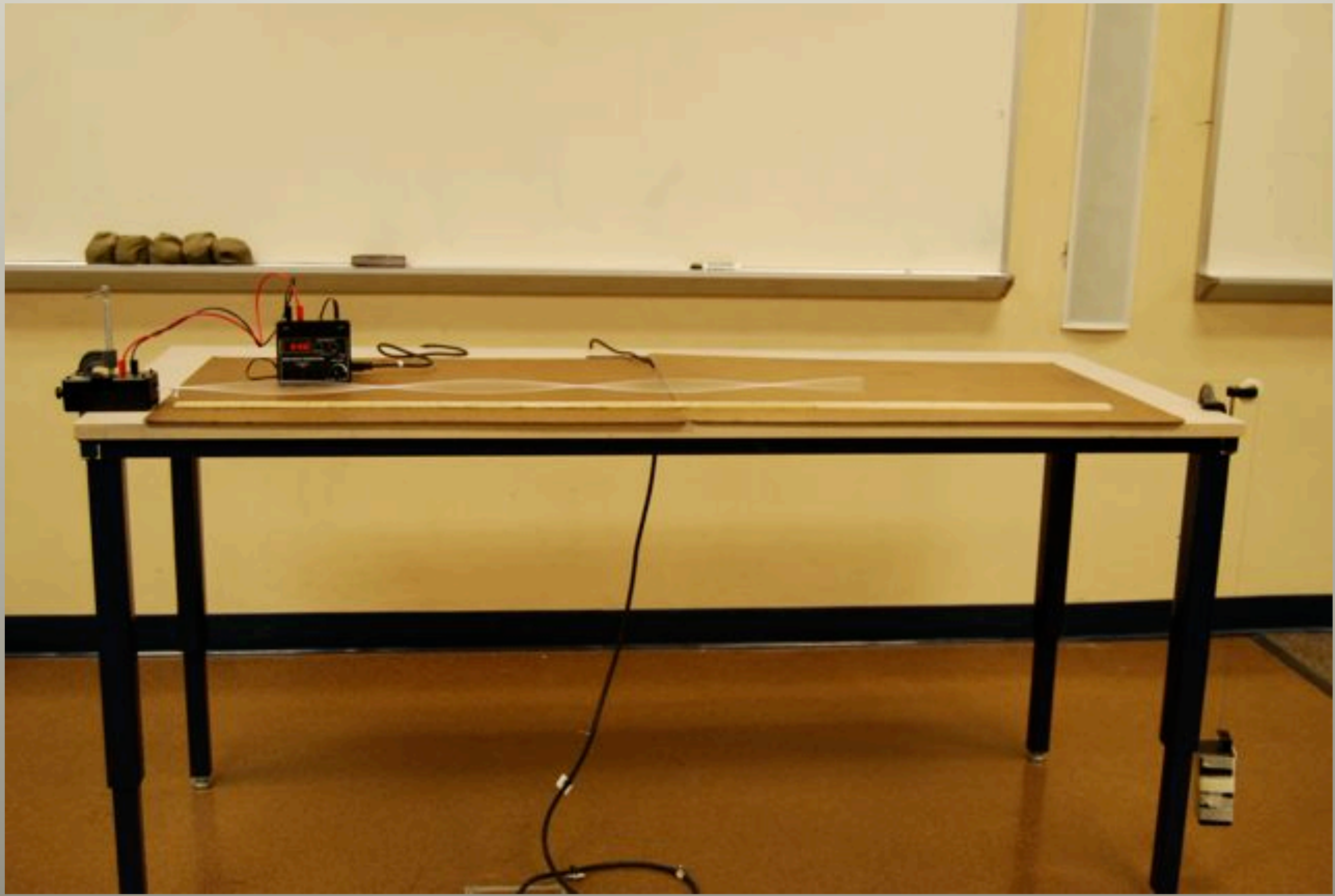
Traditional

Consider the standing wave pattern on a string shown in the diagram. If the string is 1.07 m long, has a mass of 12 g and is being driven by an oscillator vibrating at 48 Hz, what is the tension in the string?

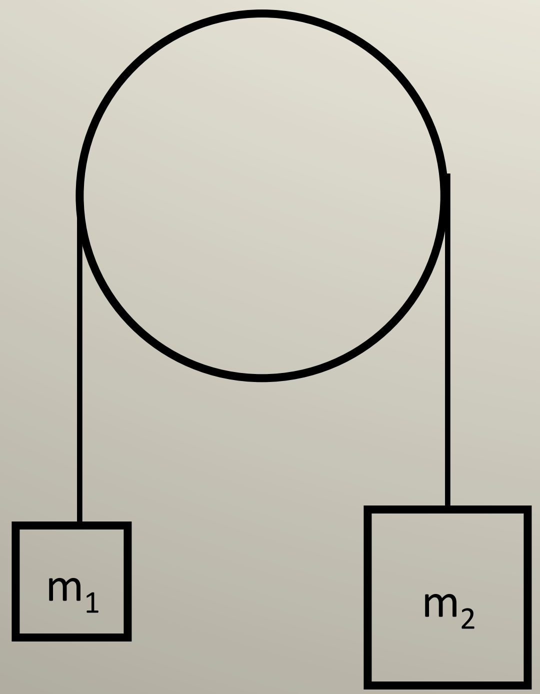


Re-envisioned

Using the set-up at the front of the class, decide what you need to measure, and measure it to find the mass of the hidden mass hanging off of the end of the string

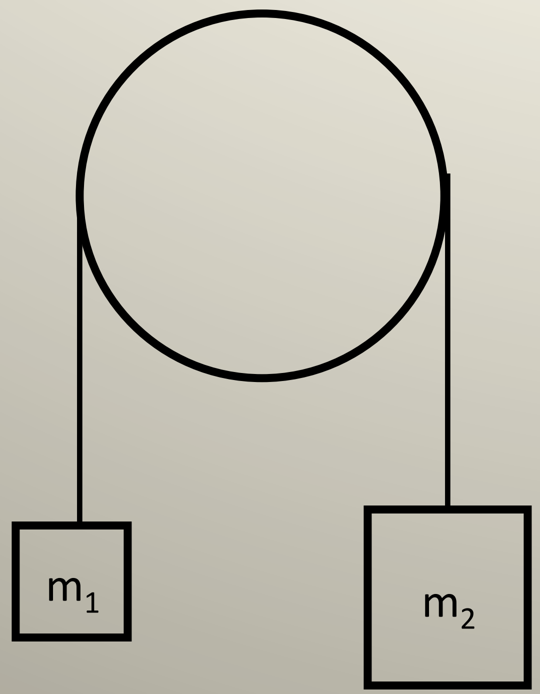


Traditional



Two blocks, mass m_1, and m_2 hang over a light, frictionless pulley from a string of negligible mass. Find the acceleration of the system.

Re-envisioned



Two blocks, mass m_1, and m_2 hang over a light, frictionless pulley from a string of negligible mass. Find the acceleration of the system. Your friend Juan proposes the following solution for the acceleration:

$$a = \frac{m_1 + m_2}{m_1 - m_2} g$$

Is this correct or not? Evaluate Juan's solution using one or more limiting cases.

Open-ended

In the barber shop or hairdresser, there is a large mirror on the wall for each station. Once the haircut is finished, the barber/hairdresser has a little mirror that he/she uses to allow the customer to see the back of his/her head. Should the barber/ hairdresser i) have the customer face the large mirror on the wall and use the small hand held mirror behind his/her head, or ii) have the customer face away from the wall and hold the small mirror in front of them? Justify your reasoning with ray diagrams.

Student Response

And I know this class is challenging because…if there's anything that requires you to reason beyond any human possibility is the exam. With [the] exam you go into it and you know it but you don't know that you know it. But you know it and the best example was the last exam, Exam No 2, with the barber shop thing. I didn't know that I knew that question and I literally reasoned it out and I got full points on that question. I got full points on that question. I never – I even left it. I was like, "I think that's right but I'm not even sure because I just reasoned it out but I hope that that's right."

And when I found I got full points I was like, "Wow." Because I remember I even told during the exam, I was like, "You threw this out of nowhere. I don't know where this came from but this is weird." And I realized that I was able to reason it out. That to me was the biggest accomplishment I've had in this class. [While I was working on the question I said to myself] "You know what? I'm gonna take it step by step. I'm gonna do the analyzing we normally did with the mirrors and just figure it out and work through it." And it worked. And to see that it worked, it completely – it made everything worthwhile.

Recapitulation

Learning Goals

Content focus → Process focus

purpose of assessment

Get the right answer → Demonstrate mastery

Assessment activities

Traditional problems →

- Open-ended
- Multiple possibilities
- Experimental design
- Target specific abilities
- Creativity

Part 2: Putting it into action

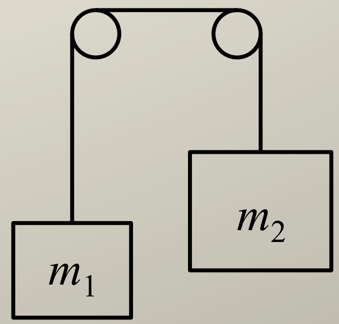
- Students need multiple opportunities to demonstrate masterful performance.
- Assessment must be formative.
- Assessment needs to be adaptive (not everyone is in my class to get an A and become a practicing physicist.)
- Assessment needs to be more frequent with lower stakes.
- Grading needs to be fast and easy.

First implementation

- Grade everything pass/fail: Nilson, L. B. (2015). Specifications Grading. Sterling, Virginia: Stylus Publishing, LLC.
- An exam every 2 weeks.
- 2 levels of question: “Core” and “Advanced”
- Create 3 versions of each question (allowing for 2 additional retries)
- Grades awarded by number of “core” and “advanced” students pass.

A core question

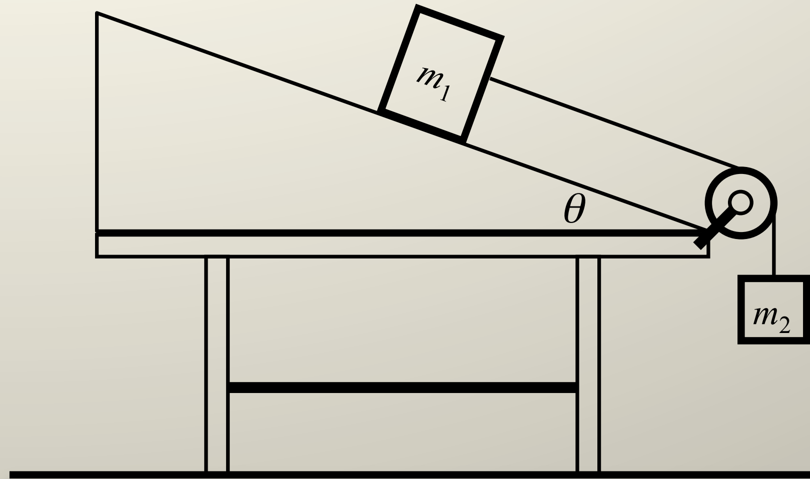
Your friend Juan is presented with the following problem:
Two blocks, masses m_1 = 3 kg and m_2 = 5kg, hang over light frictionless pulleys from a string of negligible mass. Find the acceleration of the system. After some calculating, Juan comes up an acceleration of 16m/s^2 for the system.
WITHOUT solving the problem from scratch, is Juan's solution reasonable or not? Use your knowledge of physics to construct a clear argument why his solution is reasonable or not reasonable.



Rubric Item	Criteria for adequate performance	P/F
Clarity	Student explains using appropriate physics ideas. Explanation is clear, sufficiently detailed, easy to follow, and shows understanding.	
Is able to evaluate the reasonableness of a result.	Evaluates reasonableness of a solution with a argument that appeals to the physical reasonableness of the situation	

An advanced question

Guarang tries to solve the following problem: A pair of blocks (masses are m_1 and m_2) are connected by a light rope that runs over a frictionless pulley as shown in the figure. There is friction (coefficient of kinetic friction = μ_k) between m_1 and the slope. The slope has an angle θ as shown in the figure. Find the acceleration of the 2-block system. After some work, Guarang comes up with the following solution: $a = \dfrac{m_2 g - \mu_k m_1 g \cos\theta}{m_1 + m_2}$



Evaluate Guarang's solution using **two** (2) distinct special, limiting, or known cases.

	Rubric Item	Criteria for adequate performance	P/F
Case 1	**Clarity**	Student explains using appropriate physics ideas. Explanation is clear, sufficiently detailed, easy to follow, and shows understanding.	
	Is able to evaluate the reasonableness of a result.	Evaluates reasonableness of a solution with a special/limiting/known case and all the steps of the reasoning process are present.	
Case 2	**Clarity**	Student explains using appropriate physics ideas. Explanation is clear, sufficiently detailed, easy to follow, and shows understanding.	
	Is able to evaluate the reasonableness of a result.	Evaluates reasonableness of a solution with a special/limiting/known case and all the steps of the reasoning process are present.	

The n-1 rule:

On a question with *n* rubric items, if you have *n*-1 passes, (i.e., one fail), you can come to office hours and demonstrate competency through a quick oral exam, turning an overall “F” can be turned into an overall “P”.

Second implementation

- Much the same as the first, but with slight modifications:
- Implemented a points system: core pass = 4 points, advanced pass = 9 points.
- Points accumulated for passing homework and labs.
- Group exams on alternate weeks (everyone in group gets same # of points).

Does it work?