Clarity through Competence:
Supporting Physics Majors with Specifications Grading

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Introductory Physics for majors in physics and astronomy

(with calculus)

The mission purpose given to me by the Dept. Chair:

Improve the retention of students in our programs

Improve their academic preparation for upper-level physics courses

Improve their academic preparation for upper-level physics courses

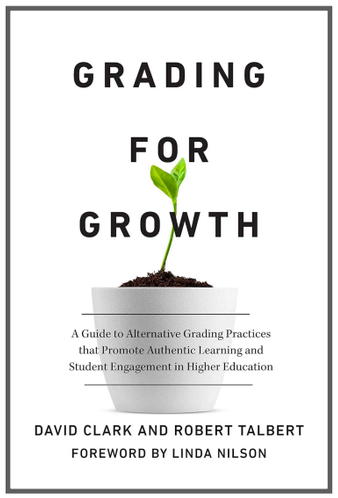
Learn the physics

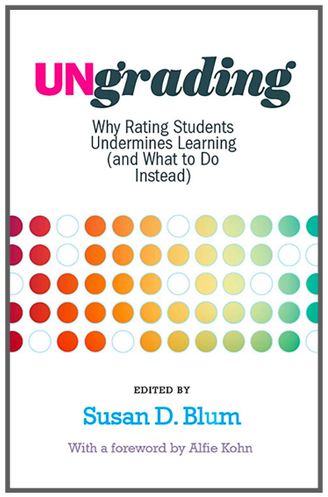
Develop the skills for ‘Professional Physics Work’

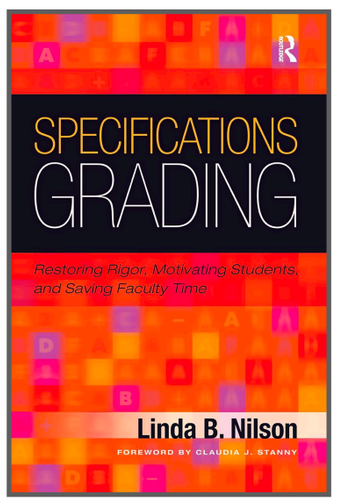
How can we assess *both* of these things?

How can we communicate *clearly* these goals to students?

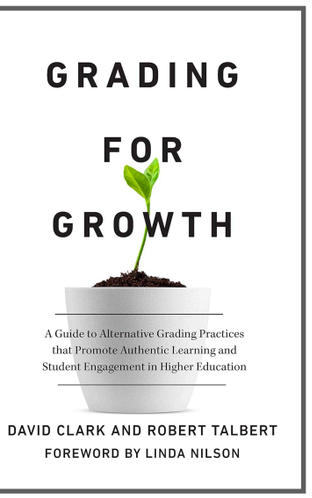
Just for context



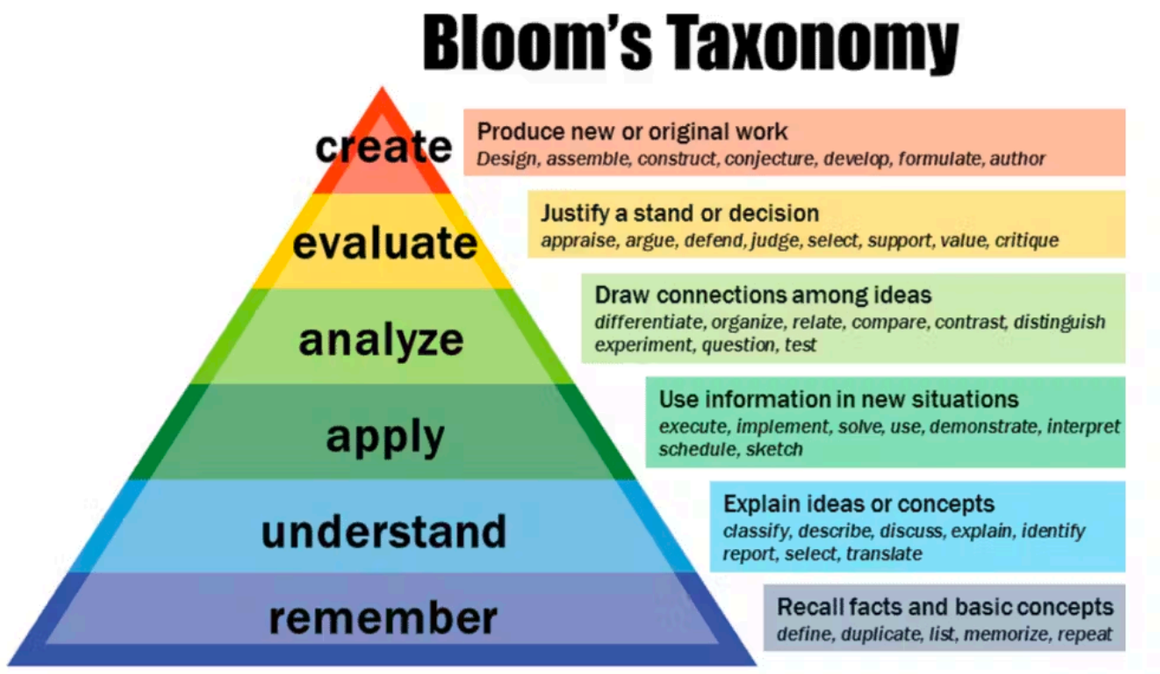


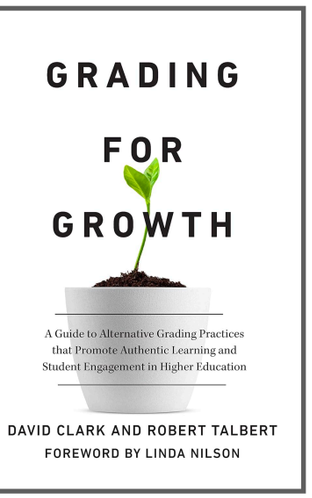


A	✦ Complete **All** (14) Core Learning Targets and ✦ Complete at least **5** Extra Learning Targets
B	✦ Complete **All** (14) Core Learning Targets and ✦ Complete at least **2** Extra Learning Targets
C	✦ Complete at least **12** Core Learning Targets
D	✦ Complete at least **9** Core Learning Targets (Because of the pre-requisites on LTs, this mean completing Core 1-9)
If you do not meet *all* of the criteria for any other grade, you will earn an F	


GRADING
FOR
GROWTH
A Guide to Alternative Grading Practices
that Promote Authentic Learning and
Student Engagement in Higher Education
DAVID CLARK AND ROBERT TALBERT
FOREWORD BY LINDA NILSON


IN FEEDBACK LOOPS WE TRUST
CLEARLY DEFINED STANDARDS
HELPFUL FEEDBACK
MARKS INDICATE PROGRESS
REATTEMPTS WITHOUT PENALTY


Bloom's Taxonomy
create
Produce new or original work
Design, assemble, construct, conjecture, develop, formulate, author
evaluate
Justify a stand or decision
appraise, argue, defend, judge, select, support, value, critique
analyze
Draw connections among ideas
differentiate, organize, relate, compare, contrast, distinguish
experiment, question, test
apply
Use information in new situations
execute, implement, solve, use, demonstrate, interpret
schedule, sketch
understand
Explain ideas or concepts
classify, describe, discuss, explain, identify
report, select, translate
remember
Recall facts and basic concepts
define, duplicate, list, memorize, repeat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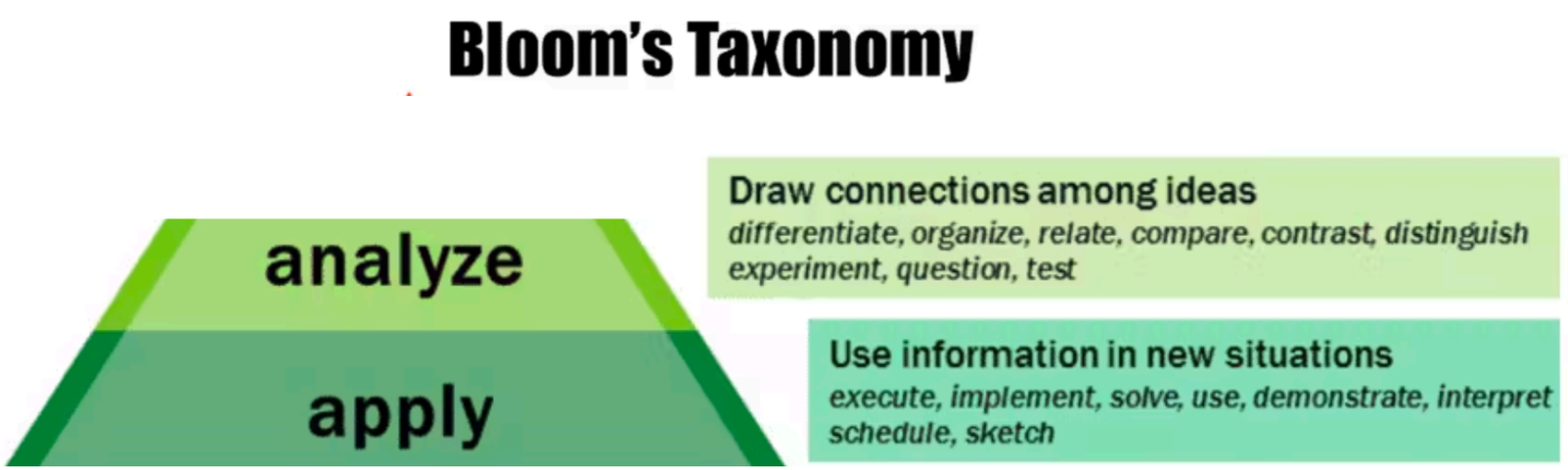

Bloom's Taxonomy
analyze
apply
Draw connections among ideas
differentiate, organize, relate, compare, contrast, distinguish
experiment, question, test
Use information in new situations
execute, implement, solve, use, demonstrate, interpret
schedule, sketch

Core Learning Targets

Block #1

1. I can **assess** whether an object has interacted.
2. I can **find** the future position of an object based on its average velocity or its momentum (relativistic or not).
3. I can use logical, non-quantitative but mathematical reasoning to **deduce** the direction of $\vec{p}_{\text{future}}$, $\overrightarrow{F}_{\text{net}}$ or $\vec{p}_{\text{now}}$, given the other two.

Block #2 (pre-requisite Block #1)

4. I can **estimate** the impact force in a sudden collision problem using order of magnitude estimation.
5. I can **predict** motion using the iterative method with a variable force (springs).
6. I can **solve** a kinematic problem with multiple unknowns.
7. I can **solve** a collision problem with conservation of momentum.

Block #3 (pre-requisite Block #2)

8. I can **find** the stiffness of an interatomic bond based on experimental data.
9. I can **solve** a “detective” problem with multiple unknowns, that requires considering more than one system, when the change in momentum is zero.

Block #4 (pre-requisite Block #3)

10. I can **solve** a problem using the energy principle, when the forces are constants with a point particle system.
11. I can **solve** a problem using the energy principle with a multi-object system and the concept of potential energy.
12. I can **solve** a rolling problem with the energy principle.
13. I can **calculate** the angular momentum of a system and the torque applied by a force to a system.
14. I can **solve** a statics problem with multiple unknowns using the momentum and angular momentum.

Extra Learning Targets

Extra Learning Targets (pre-requisite Core Block #3)

1. I can use the properties of a harmonic oscillator to analytically **predict** something about a mass-spring system.
2. I can **solve** a “detective” problem with multiple unknowns, that requires considering more than one system, when the change in momentum is not zero but unidirectional.
3. I can **solve** a “detective” problem with multiple unknowns, that requires one system, when the change in momentum is not zero and non-linear.
4. I can **calculate** the work done by a variable force with integration.
5. I can **relate** the graph of energies versus separation to determine the potential fate of the object.
6. I can **solve** a rotational collision problem.

Interactions

Core 1

Momentum Principle

Core 2

Core 3

Applications:

Point Object system

- Sudden collision — Core 4
- Iterative method — Core 5
- Special analytical case: constant force
- Kinematic problem — Core 6

Multi-Object system

- Collision problems — Core 7

Extended objects

- Stiffness of interatomic bonds — Core 8
- Special analytical case: recall force (harmonic motion)
- Harmonic motion — Extra1

Force “detectives”

- When there is no change in momentum — Core 9
- When there is a change in momentum
  - Multi-system, unidirectional → Extra2
  - One-system, Non-linear → Extra3

Energy Principle

Point Object system

- Problems with constant forces — Core10
- Work done by a variable force by integration — Extra4

Multi-Object system

- Problems using potential energies — Core11
- Potential fate of objects interacting with a planet — Extra5

Extended objects

- Rolling problems — Core12

Angular momentum Principle

Core13

Extended objects

No change in angular momentum

- Statics problems — Core14

No external torque

- Rotational collisions — Extra6

First person

An action

Learning Target 9: I can solve a “force detective" problem with multiple unknowns, that requires considering more than one system, when the **change in momentum is zero**

Under which circumstances

Under which circumstances

Learning Target 10: I can **solve** a problem using the energy principle, when the forces are constants with a point particle system.

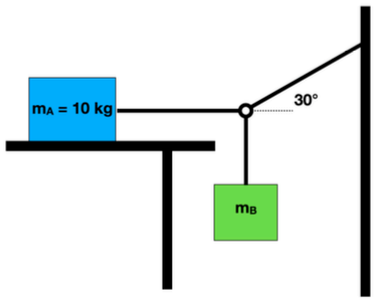
Learning Target Core 9: I can solve a "detective" problem with multiple unknowns, that requires considering more than one system, when the **change in momentum is zero**

Why this works: It’s a high-level task with clear constraints.
It’s not a "plug and chug" problem; it requires structural thinking.

Learning Target Core 9: I can solve a "detective" problem with multiple unknowns, that requires considering more than one system, when the **change in momentum is zero**

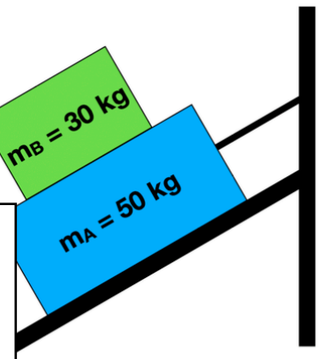
Learning Target Core 6 *I can solve a "detective" problem with multiple unknowns, that requires considering more than one system, when the change in momentum is zero*

A block rest on a table. The coefficient of static friction between the table and the block is 0.25. The block is connected by a rope to a ring of negligible mass, which is itself connected to a rope attached to a wall (making a 30◦ angle with the horizontal) and to a vertical rope from which another box is hangir is the maximum mass for the hanging box, so that the box on the table does not move? (Hint, I systems: the box on the table, the hanging box, and the ring holding the ropes.



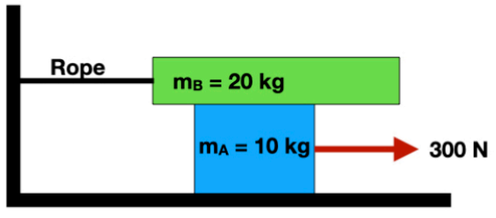
Learning Target Core 6 *I can solve a "detective" problem with multiple unknowns, that requires considering more than one system, when the change in momentum is zero*

Box A is sitting still on a ramp, which is inclined at 30° with respect to the horizontal. There is no friction between the ramp and Box A. Box A is attached to a wall by a rope of negligible mass. Block B sits on top of Block A and does not slide. Find the minimum coefficient of static friction between the two blocks, and the tension in the rope. Tilt your coordinate system so that the x-axis points up the ramp.



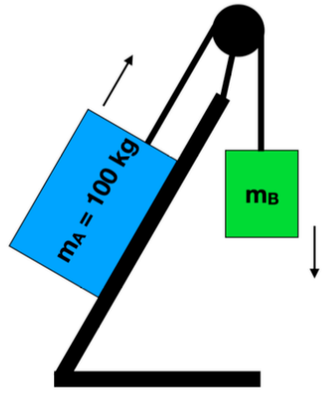
Learning Target Core 6 *I can solve a "detective" problem with multiple unknowns, that requires considering more than one system, when the change in momentum is zero*

On a table, a block of mass $m_B = 20$ kg is placed on top of another block of mass $m_A = 10$ kg. The top block is attached to the wall on the left by a rope. The mass of the rope is very small, and the rope is horizontal. There is friction between the bottom block and the table, as well as between t The coefficients of friction are the same between all surfaces. You pull on the bottom block 300 N. The block moves to the right with a constant velocity. Solve for the tension in the ro



Learning Target Core 6 *I can solve a "detective" problem with multiple unknowns, that requires considering more than one system, when the change in momentum is zero*

Box A (100 kg) is placed on a ramp, which is inclined at 60° with respect to the horizontal. The coefficient of kinetic friction between the ramp and Box A is 0.6 and the coefficient of static friction is 0.7. Box A is attached by rope of negligible mass to Block B. The rope passes over a pulley (the black circle on the diagram) and Block B is hanging on the other side of the ramp. If Block B is **moving downward at *constant speed***, what is the mass of Block B?



Learning Target Core 9: I can solve a "detective" problem with multiple unknowns, that requires considering more than one system, when the **change in momentum is zero**

Transparency: Including the rubric with the assignment, not just after it's graded.

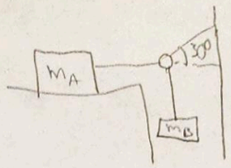
The Language of Growth: Moving the conversation from "How many points do I need?" to "What do I need to demonstrate?"

Raise the bar: the rubric can include more than "getting an answer"

Physics	
	11. I defined the systems.
	12. I correctly listed all of the interactions and drew them on a free-body diagram.
	13. I wrote a vector expression for each force.
	14. I correctly determined the change in momentum.
	15. I correctly identified and clearly marked reciprocal forces, as needed.
	16. I correctly identified and clearly marked equal tension interactions for mass-less ropes, as needed.
	17. I proved that the problem can be solved and provided a plan for "doing the math".
	18. I mathematically solved for the unknown quantity the problem was asking for, unless the question said not to do so.

What I am expecting Professional Physics Work to 'look like' ?

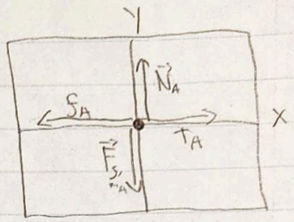
$k_s = 0.25$
$m_A = 10 k_s$



(1)

Core 6

System 1: Box A



Forces at a Distance

object	magnitude	direction
Earth (gravity)	$m_A g$	$\langle 0,-1,0 \rangle$ ✓

Contact Forces

object	magnitude	direction
Table (normal)	N_A	$\langle 0,+1,0 \rangle$ ✓
Table (friction)	$\mu_s N_A$	$\langle -1,0,0 \rangle$ ✓
Rope A (tension)	T_A	$\langle +1,0,0 \rangle$ ✓

Momentum Principle

	$d\vec{p}/dt$	=	$\vec{F}_{net}$	
x	0	=	$T_A - \mu_s N_A$ ✓	(1)
y	0	=	$N_A - m_A g$ ✓	(2)
z	0	=	0	

Other Systems On Next Pages →

Work

- Because the ropes being used are of a negligible mass, the tensions are ~~reciprocal~~ the same on both ends of the rope.
- To solve for the maximum mass of the hanging box (m_B), we will set the static friction of the table on box A to it's max value. ✓
- The problem can be solved because there are 5 equations and unknowns

Plan

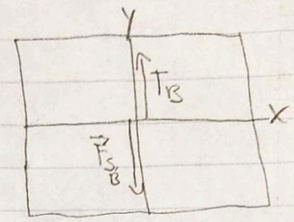
1) Use eq (2) to solve for N_A
2) Use eq (1) to solve for T_A
3) Use eq (4) to solve for T_C
4) Use eq (5) to solve for T_B
5) Use eq (3) to solve for m_B

Cont →

(2)

Core 6 - Cont.

System 2: Box B



Forces at a distance

object	magnitude	direction
Earth (gravity)	$m_B g$	$\langle 0,-1,0 \rangle$ ✓

Contact Forces

object	magnitude	direction
Rope B (tension)	T_B	$\langle 0,+1,0 \rangle$ ✓

Momentum principle

	$d\vec{p}/dt$	=	F_{net}	
x	0	=	0	
y	0	=	$T_B - m_B g$	(3) ✓
z	0	=	0	

Work Cont

1) $N_A = m_A g$
$= 10 k_g \cdot 9.8 \frac{m}{s^2}$
$= 98 N$ ✓

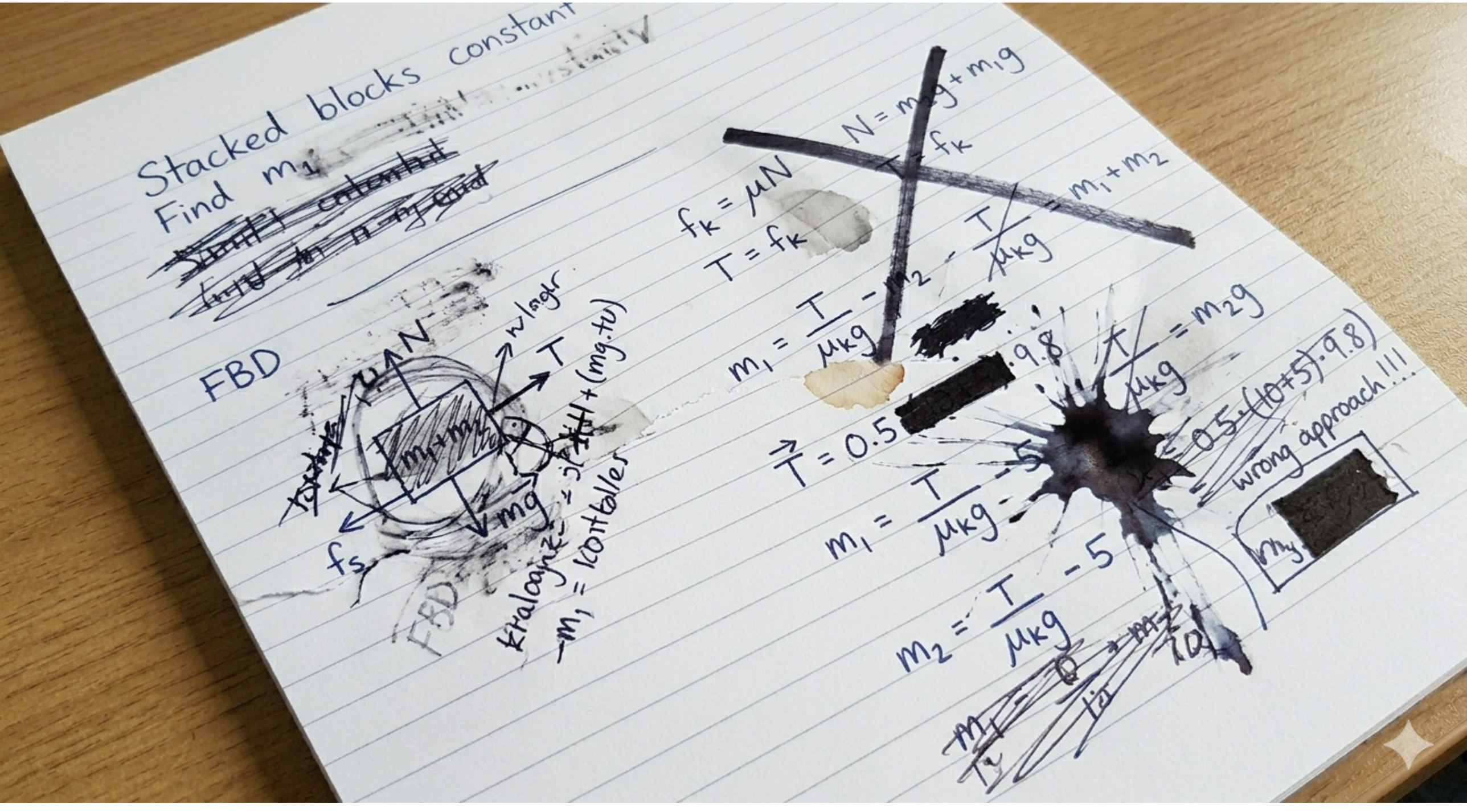
2) $T_A = \mu_s N_A$
$= 0.25 \cdot 98 N$
$= 24.5 N$ ✓

3) $T_C \cos 30 = T_A$
$T_C = \frac{T_A}{\cos 30} = \frac{24.5 N}{0.87}$
$= 28.2 N$ ✓

4) $T_B = T_C \sin 30°$
$= 28.2 N \cdot \sin 30°$ ✓
$= 14.1 N$

5) $m_B g = T_B$
$m_B = \frac{T_B}{g}$
$= \frac{14.1 N}{9.8 \frac{m}{s^2}}$ ✓
$= 1.44 k_g$

What I am expecting Professional Physics Work to 'look like' ?



What I am expecting Professional Physics Work to 'look like' ?

How can we express this?

Writing like a Physicist: Treating the solution as a technical document, not just a scratchpad.

Satisfactory does not mean perfect: They are not experts just yet! We need to distinguishing between a student being "messy" and a student being "wrong."

For each of your learning standards / grading rubric:
What is essential, and what is just busy-work?

Learning Target Core 9: I can solve a "detective" problem with multiple unknowns, that requires considering more than one system, when the **change in momentum is zero**

Rubric

General	
	1. I created a symbol for all the known and unknown quantities relevant to the problem.
	2. I clearly identified which quantity I am looking for.
	3. I wrote the solution in logical sections so that the logical progression is easy to follow.
	4. I included units each time I wrote down a numerical value.
	5. I included $\rightarrow$ for every vector symbols.
	6. I used proper vector notation when writing a vector in components.
	7. I included a sketch of the situation with a coordinate system.
	8. I used clear and concise language to explain the steps of my analysis.
Math	
	9. I used correct vectorial and algebra manipulations.
	10. I used correct unit algebra.
Physics	
	11. I defined the systems.
	12. I correctly listed all of the interactions and drew then on a free-body diagram.
	13. I wrote a vector expression for each force.
	14. I correctly determined the change in momentum.
	15. I correctly identified and clearly marked reciprocal forces, as needed.
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Helping students get there: provide clarity

Item	Professional (Pass)	Unsatisfactory (Revise)
Vector Notation	All vector quantities are denoted with an arrow, and are never equated to scalars.	Treating vectors as scalars. Incorrect notation makes an equation invalid. The lack of vector notation makes it ambiguous whether a quantity is a scalar, a magnitude, or a component
Logic Flow	Clear “Story”, logic is self-evident to a peer	Random equations in a "cloud."
Grammar	Spelling or grammar errors allowed as long as the textual meaning of the sentence is still accurate.	The written text is illegible or nonsensical.

In conclusion, my challenge to you

Pick one homework/exam question.

Verbalize the standard/goal this question is addressing with an action verb and a set of constraints.

Think about what are the essential components of satisfactory work that student can use to demonstrate competence.

Think also about what are not an essential components of satisfactory work at this moment, and think of examples to give students!

Useful resources:

- Grading for Growth blog: https://gradingforgrowth.com/

- alternativegrading.slack.com (there is a Physics channel)

- Blog of Robert Talbert https://rtalbert.org/ (Mathematics Dept. at Grand Valley State University

Who I would like to thank for making whole courses available
on https://github.com/RobertTalbert