‘Explain your reasoning’ boxes in Physics multiple choice questions

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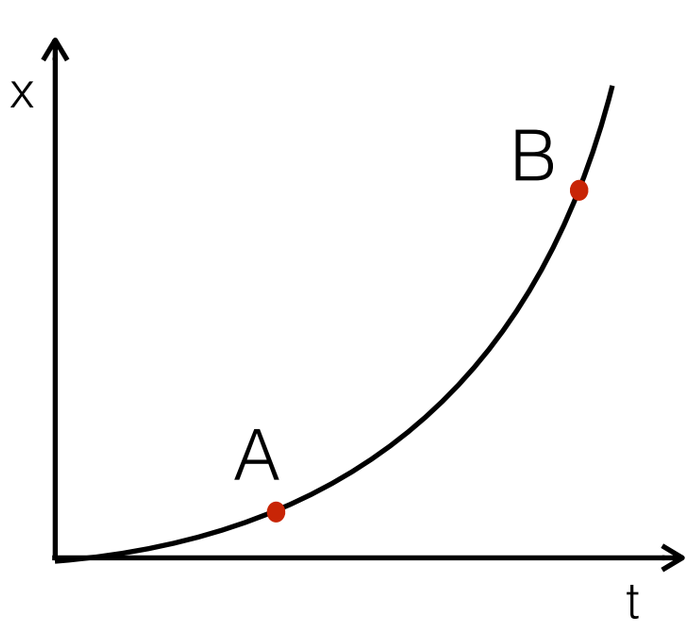
Outline

- Scientific Background & Motivation
- Goals
- Method
- Results
- Conclusion
- Further work
- Summary

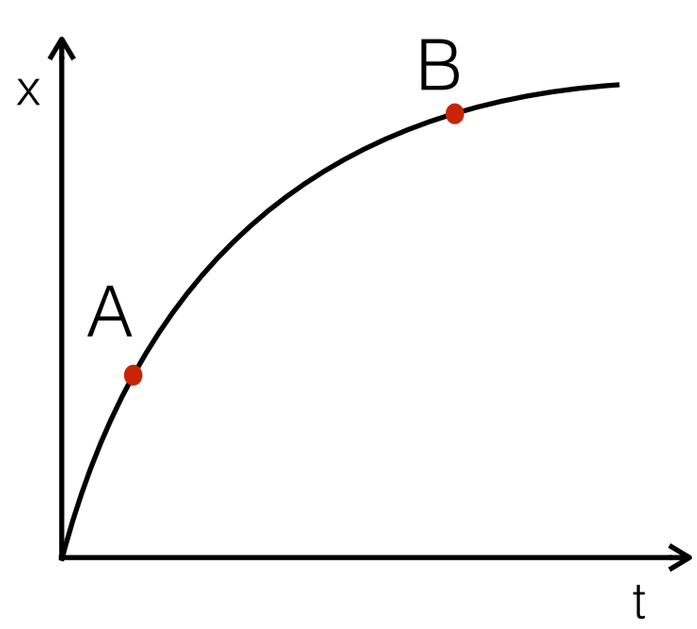
Scientific Background & Motivation

Andrew Heckler's Model:

At which point is the car moving faster?



(height and slope aligned, both are higher at B)



(height and slope conflicting, slope is smaller, height is larger at B)

Scientific Background & Motivation

- Andrew Heckler's model[1]:
  - Competition between relevant and irrelevant dimensions.
  - Relative processing time (Dual process theory).

- Does an 'explain your reasoning' box affect student responses in this framework?

[1] A. F. Heckler, Psychology of Learning and Motivation 55, 227 (2011).

Goals

1. To confirm Heckler's model of relevant and irrelevant dimensions.

2. To quantify the effect of 'explain your reasoning' boxes on exam performance.

Method

1. Develop 4 questions each for the midterm and final exams of PHYS 100.

2. Half of students are asked to explain their reasoning.

3. Analyse the quantitative choice results to determine the characteristics of the effect of the treatment.

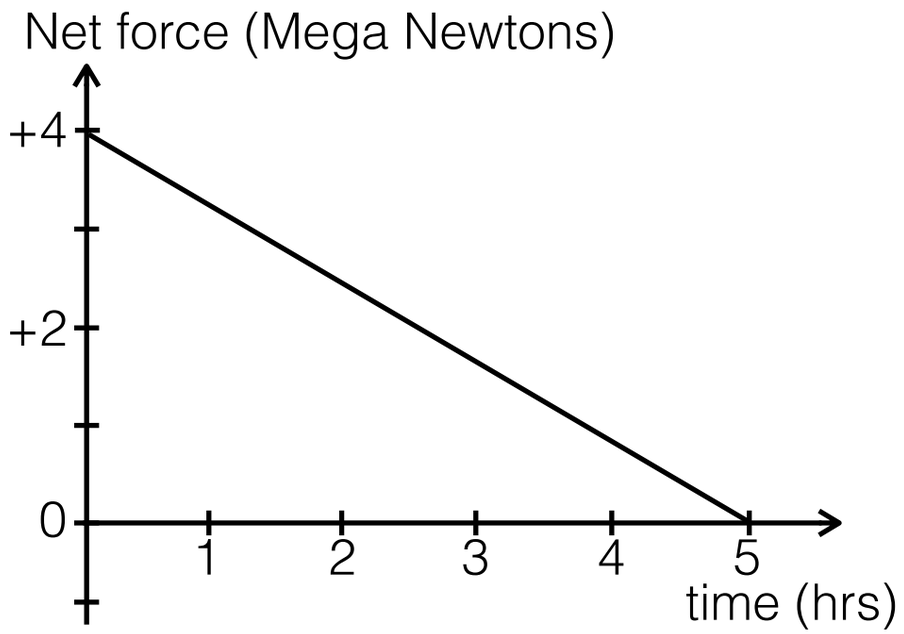
4. Transcribe student reasonings using a code that allows for further analysis.

Method

(Midterm)

[1.5 pts] The net force on a rocket is shown.
What happens to its speed?

A: Speed keeps increasing.
B: Speed keeps decreasing.
C: Speed remains constant.
D: Not enough information to decide.
E: First speeds up then slows down.



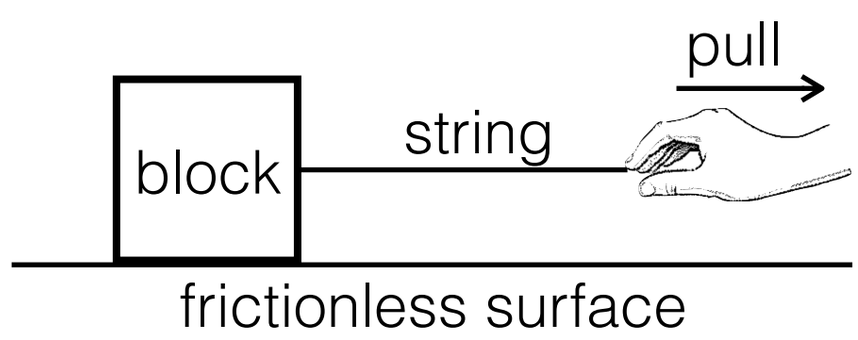
[0.5 pts] Please explain your reasoning in 1-2 sentences:

Method

(Final)

[1.5 pts] A student pulls a string attached to a block. He gradually decreases the force from F to F/2. What happens to the block's speed?

A: Speed keeps increasing.
B: Speed keeps decreasing.
C: Speed remains constant.
D: Not enough information to decide.



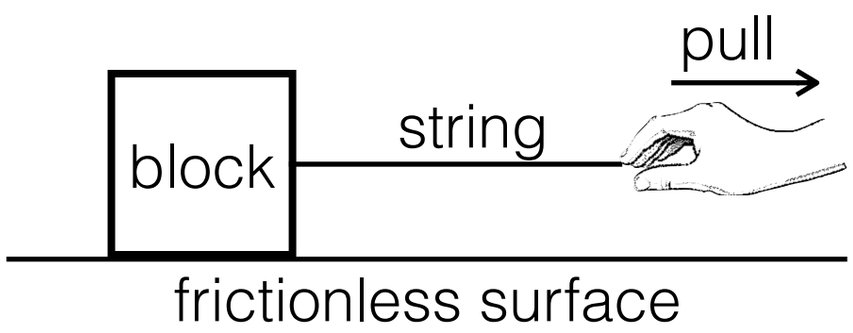
[0.5 pts] Please explain your reasoning in 1-2 sentences:

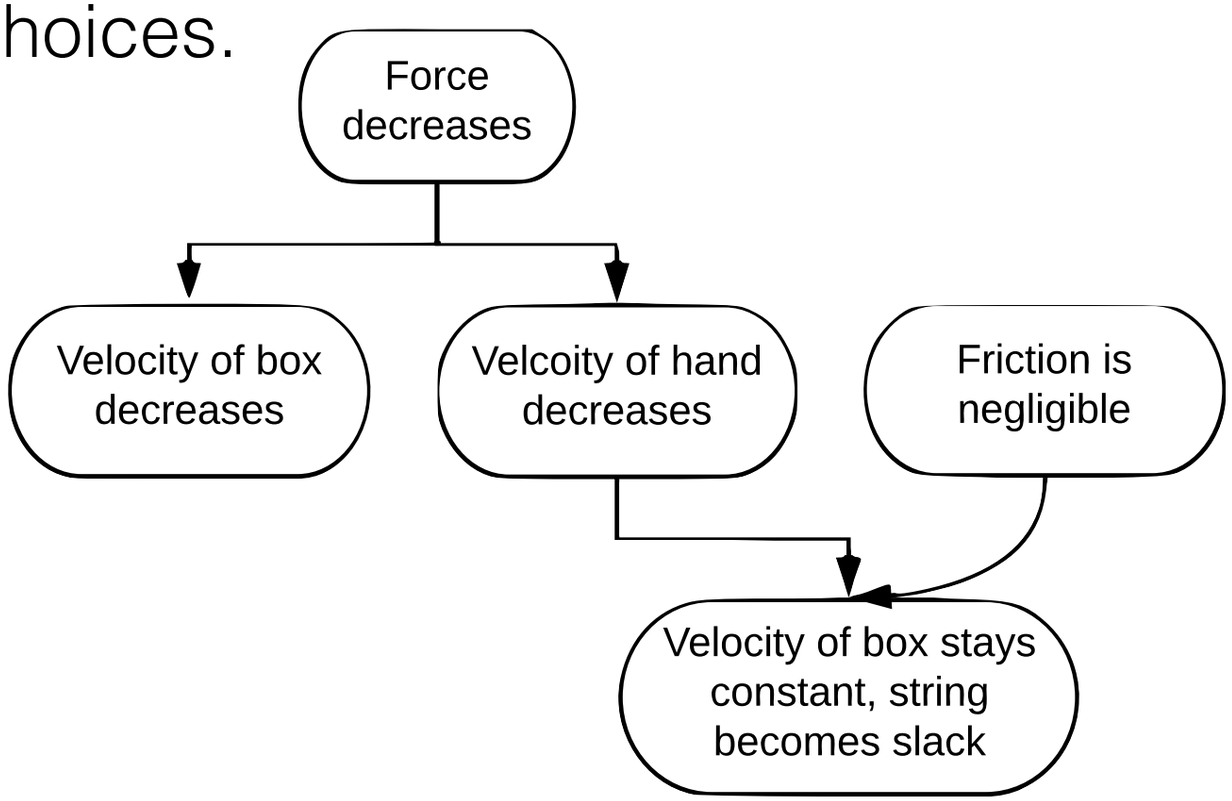
Results

From quantitative data: most common distractors follow Heckler's model predictions.

From reading responses to Block question and Rocket question:

- Block question: two irrelevant choices.





Results

- Reasonings for the same choice have high similarity.

- Reasonings for irrelevant choices follow Heckler's model predictions.

- Reasoning word count, detail and reiteration of answer choice are similar between choices.

Results

	Rocket question (Midterm)	Block question (Final)
Percentage correct	24% (control) 31% (treatment)	33% (control) 39% (treatment)
Percentage of incorrect choices corrected	8.52%	8.32%
Percentage of above accounted for by irrelevant choice decrease	15.5% (speed reduces)	159.8% (speed constant) –59.5% (speed reduces)
Percentage of correct choices with correct reasoning	86%	95%
Percentage of irrelevant choices with expected Heckler reasoning	80%	72.5%

Results

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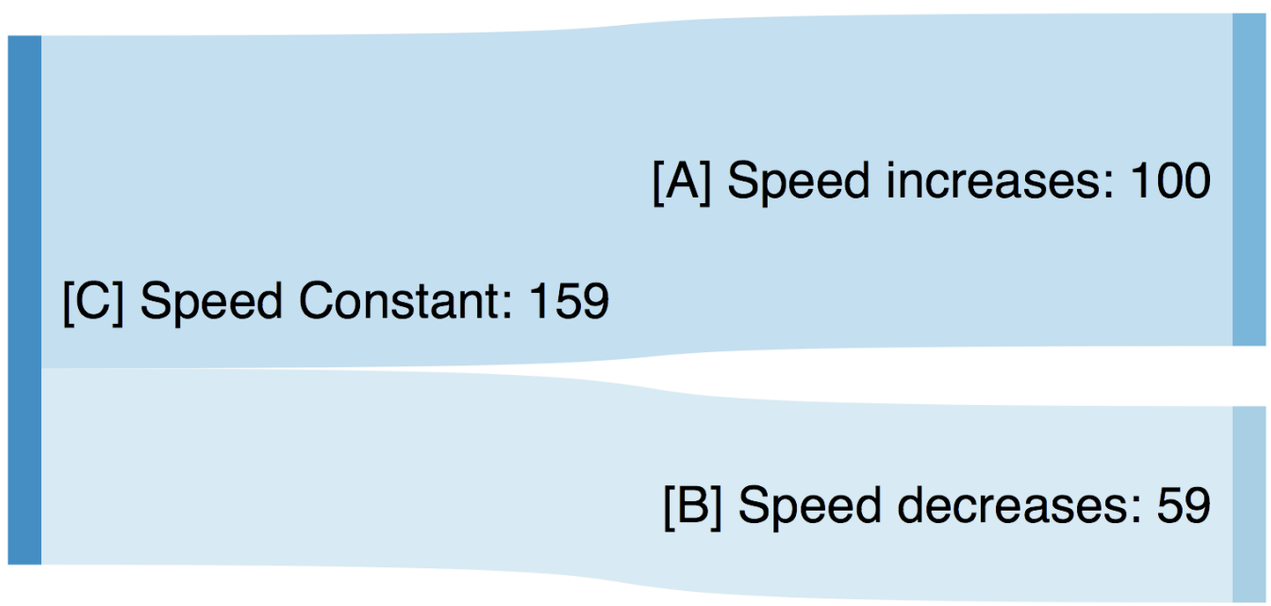
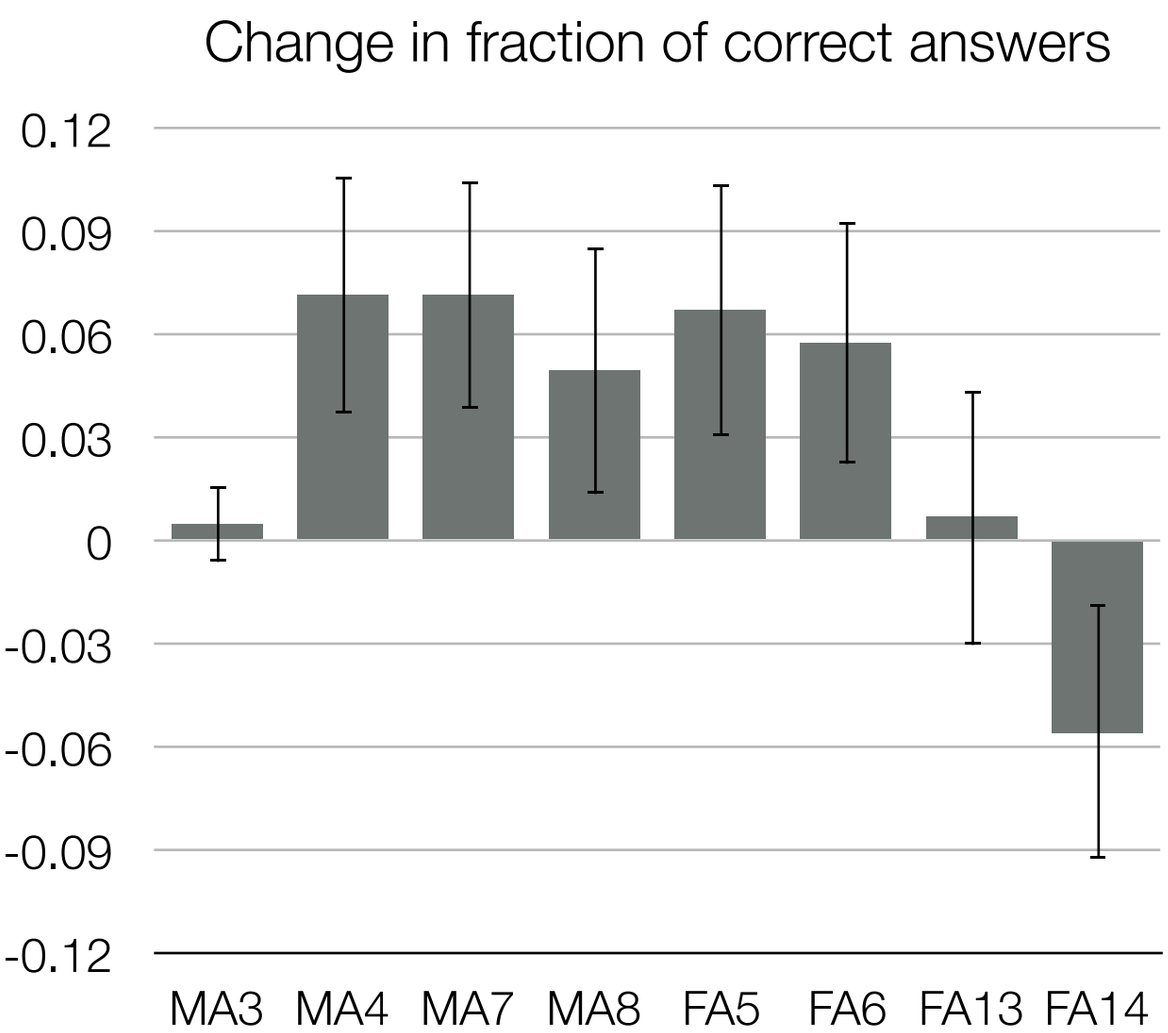
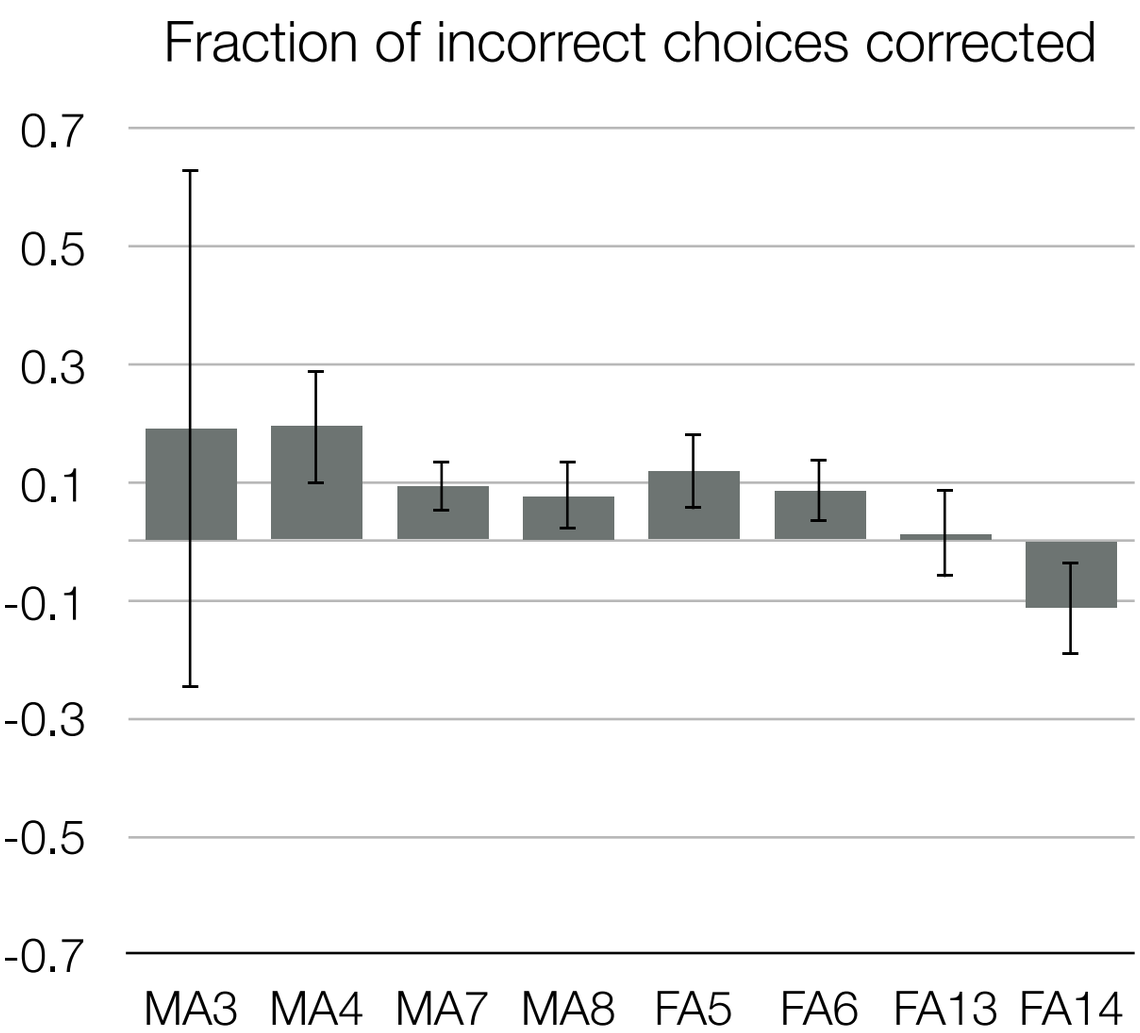


Results

- Effect of Treatment on fraction of correct answers





Conclusion

Goal 1: Confirm Heckler's model:

Conclusion: Heckler's model mostly explains the most popular incorrect choice.

Goal 2: Effect of 'explain your reasoning' box:

Conclusion: Results improved by ~8%.
Migration of choices from incorrect to correct upon treatment is partly explained by Heckler's model.

Further work

- Perform quantitative analyses for the 6 other questions.

- Selectively transcribe more questions to inform the interpretation of the quantitative analyses.

- Suggestion: Replace ‘explain your reasoning’ box with multiple choice question.

Summary

- Experiment explored the relation of dual process theory to Heckler's model of relevant and irrelevant dimensions in Physics multiple choice questions.

- Promising but insufficient support was found for the predictive power of Heckler's model pertaining to the effect of 'explain your reasoning' boxes.

Acknowledgements

- Dr Joss Ives
- Dr Jared Stang
- Dr Rob Kiefl

Appendix - FA5

A5 [1.5 pts]. Two vehicles of mass M and $2M$ are moving the *same direction* and with the *same speed* on a highway. Both drivers apply their brakes at the same time and both vehicles begin sliding. If the coefficient of kinetic friction μ_k between the tires and the road is the same for both vehicles, which vehicle stops first?

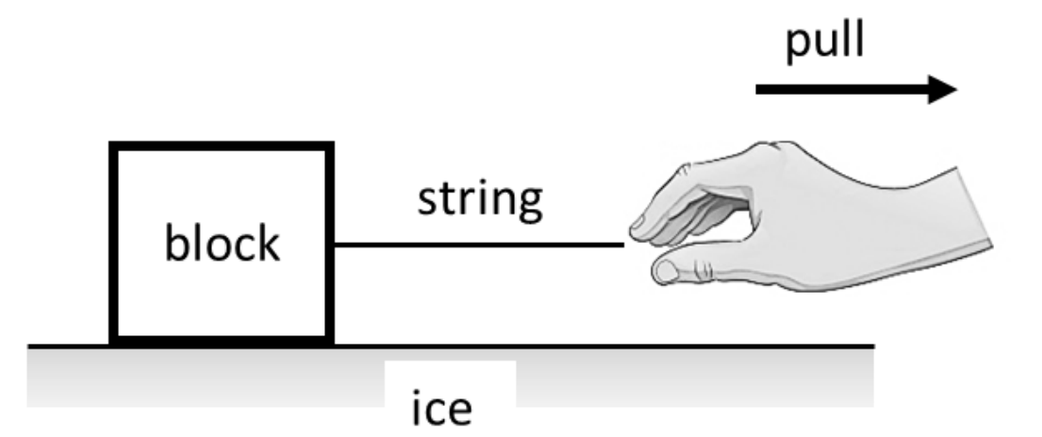
Ⓐ The less massive vehicle
Ⓑ The more massive vehicle
Ⓒ Both stop at the same time
Ⓓ Not enough information to determine

[0.5 pts] Please explain your reasoning for the above in 1-2 sentences.

Appendix - FA6

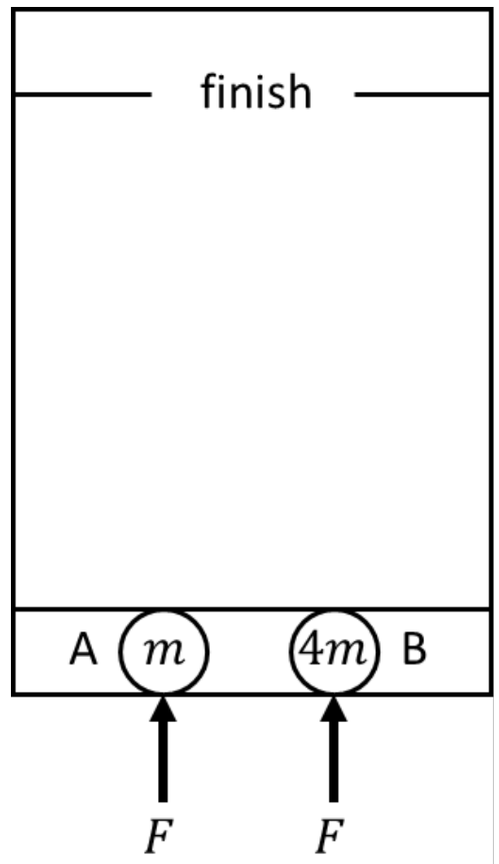
A6 [2 pts]. A student pulls a block, initially at rest at x = 0.0 m, a distance of 80 cm across a smooth, level ice surface. Assume friction is negligible. As the block covers the first 40 cm, the student exerts a constant force of magnitude F. As the block moves between the 40 cm and 80 cm marks, the student continuously decreases the magnitude of the force from F to F/2. Describe the motion of the block between 40 cm and 80 cm.

Ⓐ The block moves at constant speed
Ⓑ The block speeds up
Ⓒ The block slows down
Ⓓ Not enough information to determine



Appendix - FA13

A13 [2 pts]. The diagram below depicts two pucks on a frictionless table. Puck B is four times as massive as puck A. Starting from rest, the pucks are pushed across the table by two <u>equal</u> forces. Which puck has the greater kinetic energy upon reaching the finish line?

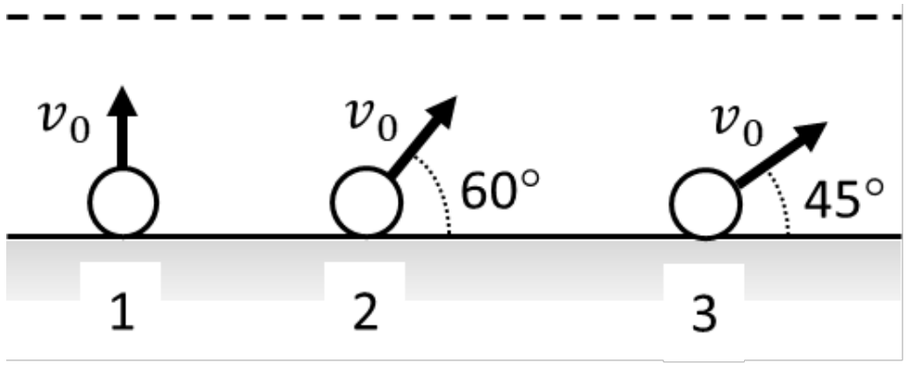


Ⓐ Puck A
Ⓑ Puck B
Ⓒ They both have the same amount of kinetic energy
Ⓓ Not enough information to determine

Appendix - FA14

A14 [1.5 pts]. Three balls are launched from the same horizontal level with identical speeds $|\overrightarrow{v_0}|$ as shown below. Ball (1) is launched vertically upward, ball (2) at an angle of 60°, and ball (3) at an angle of 45°. All three balls have sufficient speed to reach the dashed line. Which ball is moving fastest (has the largest speed) at the level of the dashed horizontal line?

Ⓐ Ball 1
Ⓑ Ball 2
Ⓒ Ball 3
Ⓓ They all have the same speed
Ⓔ Not enough information to determine



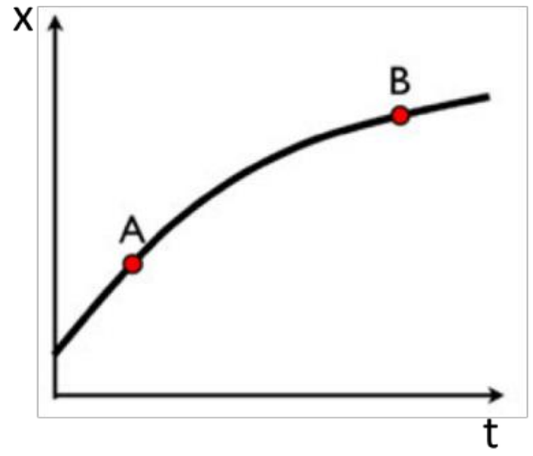
[0.5 pts] Please explain your reasoning for the above in 1-2 sentences.

Grader only ⓪ ◯

Appendix - MA3

A3 [1.5 pts]. A position-time graph for a car is shown. At which time is the car moving faster?

Ⓐ t_A
Ⓑ t_B
Ⓒ The speed is the same at t_A and t_B



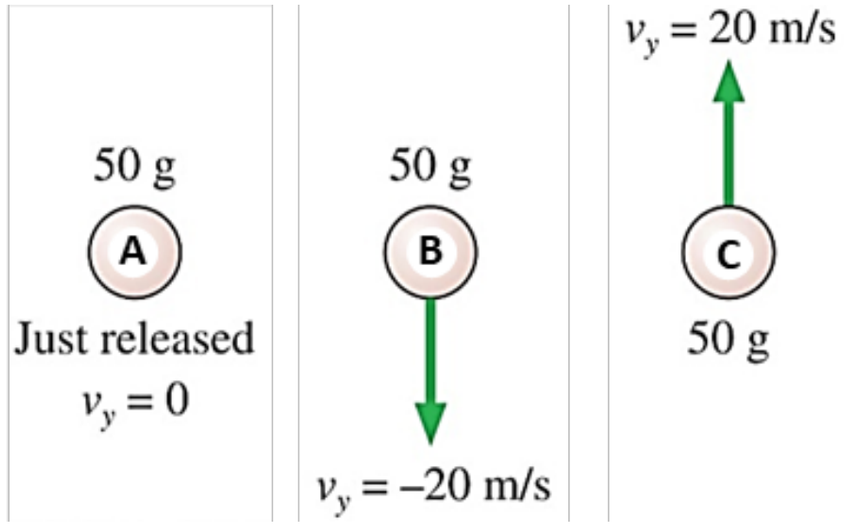
[0.5 pts] Please explain your reasoning for the above in 1-2 sentences.

Grader only Ⓞ Ⓘ

Appendix - MA4

A4 [2 pts]. Three balls move through the air as shown. The balls move under the influence of gravity, and air resistance can be ignored. For which ball is the *magnitude* of the *net force* acting on the ball the largest?

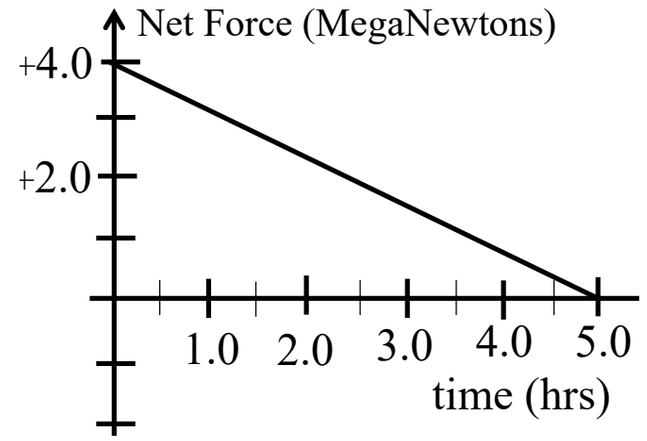
Ⓐ Ball A
Ⓑ Ball B
Ⓒ Ball C
Ⓓ The magnitude of the net force is largest and equal for B and C.
Ⓔ The magnitude of the net force is the same for all three balls.



Appendix - MA7

A7 [1.5 pts]. A rocket is launched straight up, and the *net force* (in MegaNewtons = millions of Newtons) on the rocket as a function of time is shown in this graph. The rocket travels straight up, with up being defined as the positive direction.

During the time interval from t = 2 hours to t = 3 hours, what happens to the speed of the rocket?



Ⓐ The rocket is speeding up the whole time
Ⓑ The rocket is slowing down the whole time.
Ⓒ The rocket is moving with a constant speed the whole time.
Ⓓ The rocket is speeding up at first, and then it slows down.
Ⓔ There is not enough information given to decide.

[0.5 pts] Please explain your reasoning for the above in 1-2 sentences.

Grader only ⓪ ①

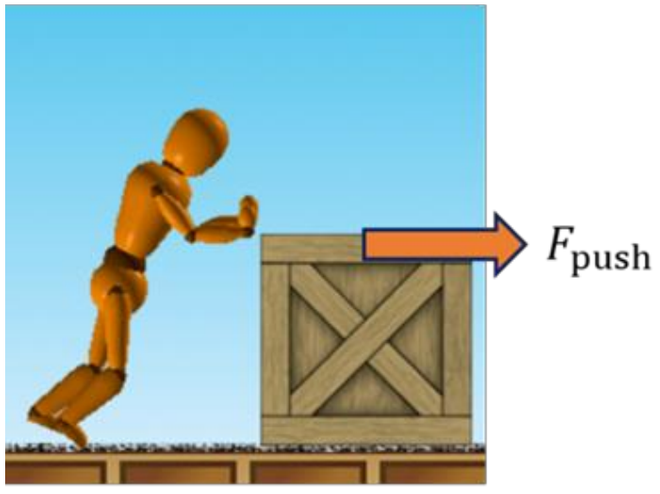
Appendix - MA8

A8 [2 pts]. Consider the following situations. In both situations, the person is pushing on the boxes with the same pushing force, F_{push}. The boxes are ***at rest*** in both situations and the total mass of the boxes in situation 2 is twice as large as in situation 1. Compare the magnitude of the friction forces, f_s, in the two situations.

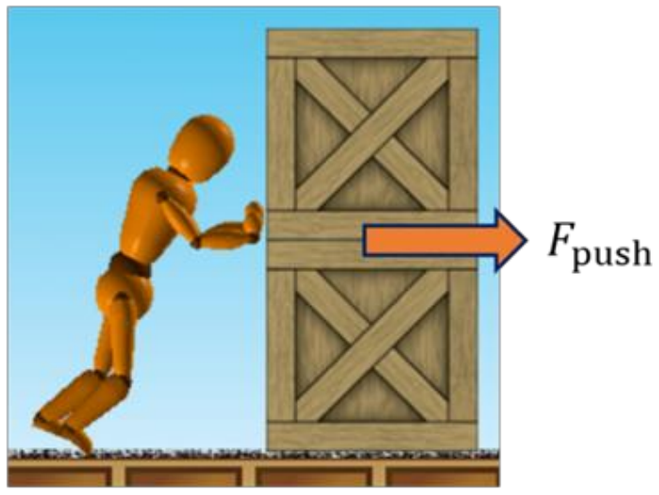
Ⓐ $f_{s1} = f_{s2}$

Ⓑ $f_{s1} > f_{s2}$

Ⓒ $f_{s1} < f_{s2}$



Situation 1



Situation 2