



Concept inventories in physics: Multiple choice or free text?

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What is a concept inventory?

- A concept inventory is an instrument designed to assess students' conceptual understanding, usually with the aim of measuring the learning gain that has occurred across a class as a result of a particular piece of teaching¹.
- Most concept inventories consist of a series of multiple-choice questions, each with one correct answer and a number of incorrect answers, known as distractors, based on common student misconceptions.
- Concept inventories do not usually give feedback to students, rather just informing professors of their class's conceptual understanding.
- The Force Concept Inventory (FCI)² was one of the earliest concept inventories and remains widely used.

A large truck breaks down out on the road and receives a push back into town by a small compact car as shown in the figure below.



15. While the car, still pushing the truck, is speeding up to get up to cruising speed:
- (A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
 - (B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
 - (C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
 - (D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
 - (E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

Figure: Here and throughout the presentation, most figures show questions from the Force Concept Inventory (source: https://www.talkphysics.org/wp-content/uploads/2015/07/fci-rv95_1.pdf)

Concerns about the use of multiple-choice questions

- Students can guess the answer.
- Students can work backwards from the distractors to work out which is correct.
- The distractors suggest options a student may not have thought of.
- The answer a student might want to give may not be one of those provided.^{3,4}

So, do multiple-choice concept inventories tell us the truth about our students' conceptual understanding?⁵

18. The figure below shows a boy swinging on a rope, starting at a point higher than A.

Consider the following distinct forces:

1. A downward force of gravity.
2. A force exerted by the rope pointing from A to O.
3. A force in the direction of the boy's motion.
4. A force pointing from O to A.

Which of the above forces is (are) acting on the boy when he is at position A?

- (A) 1 only.
(B) 1 and 2.
(C) 1 and 3.
(D) 1, 2, and 3.
(E) 1, 3, and 4.

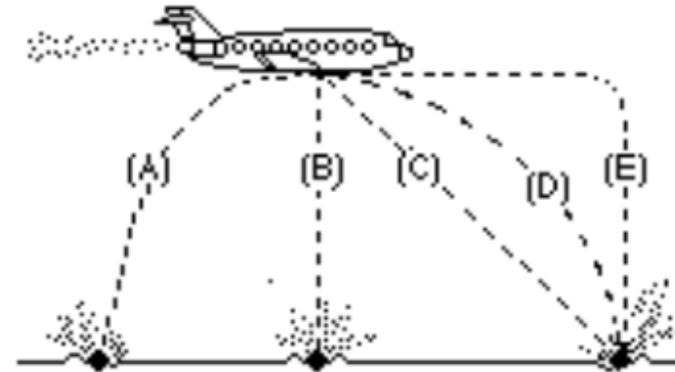


The gender gap

- Women perform less well than men on the FCI (with a particularly large gap on some questions) even when women's outcomes on their physics qualification as a whole are better than men's.^{6,7}
- Might this be because, in general, men are more likely than women to prefer multiple-choice questions over ones in which they give free text answers, and are found to do better on them?⁸

14. A bowling ball accidentally falls out of the cargo bay of an airliner as it flies along in a horizontal direction.

As observed by a person standing on the ground and viewing the plane as in the figure at right, which path would the bowling ball most closely follow after leaving the airplane?



There is an alternative: automatically marked short-answer free-response questions

- We developed a question type called OpenMark PMatch that can automatically mark and give feedback on free-text responses of up to about 20 words in length. The Moodle Pattern-match question type uses the same approach.
- PMatch and Pattern-match can cope with:
 - Alternative answers
 - Incorrect spelling
 - Negation
 - Particular word order
- Based on a training set of 100-300 marked responses for each question, a marking accuracy greater than that of human markers was obtained^{9,10}

A raindrop falls vertically with a constant speed. What does this tell you about the forces acting on the raindrop?

*Please give your answer as a **short** phrase or sentence.*

The forces are equal and opposite.

Enter answer

Figure: A PMatch question (Copyright: The Open University)

A free-text Force Concept Inventory

- Mark Parker's PhD project investigated the viability of creating a version of the FCI comprising a combination of multiple-choice and free-response questions.
- FCI Question 4 (shown in Figure A) became the question shown in Figure B.
- Marking accuracy and user perception was found to be acceptable^{11,12}.

4. A large truck collides head-on with a small compact car. During the collision:
- (A) the truck exerts a greater amount of force on the car than the car exerts on the truck.
 - (B) the car exerts a greater amount of force on the truck than the truck exerts on the car.
 - (C) neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
 - (D) the truck exerts a force on the car but the car does not exert a force on the truck.
 - (E) the truck exerts the same amount of force on the car as the car exerts on the truck.

A large lorry collides head-on with a small car. Compare the force on the lorry from the car with the force on the car from the lorry during the collision. Which force, if either, is larger?

Answer:

Figure A: Force Concept Inventory Question 4 (source: https://www.talkphysics.org/wp-content/uploads/2015/07/fci-rv95_1.pdf)

Figure B: A free-response version of the question shown in Figure A

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