



Introduction

Over the past two years we have conducted three iterations of think-aloud interviews with students as they grappled with questions on the Force Concept Inventory (FCI). Doing so has shown us that the difficulties they have with some questions have nothing to do with their understanding of physics. These difficulties involve diagrams, notations, and vocabulary that make perfect sense to physics teachers but can easily confuse beginning students. Informed by those think-aloud interviews, we have been modifying a subset of questions to improve clarity and then administered each version of the clarified FCI to students in two introductory physics courses. In addition, the latest version contained some new questions also motivated by student input. Here we discuss the specific construction of these questions and how students responded to them on our latest version of the clarified FCI administered prior to instruction.

Revised FCI Methodology

- Spring 2012: Interviews with algebra- and calculus-based introductory physics students after instruction
- Fall 2012: V. 1 Revised FCI administered to both algebra- and calculus-based courses
- Spring 2013: Interviews with algebra- and calculus-based physics students after instruction
- Summer 2013: V. 2 Revised FCI administered to algebra-based course; Interviews with algebra-based physics students before instruction
- Fall 2013: V. 3 Revised FCI administered to both algebra- and calculus-based courses

Comparing Populations

Population Demographics

The historical data set includes four years of responses (N=431) collected in the fall semesters of 2007 – 2010. The most recent modified FCI responses (N=157) were collected fall semester of 2013. All administrations were given during lab the first week of class to both the introductory algebra and calculus-based courses.

Percentage of Students

	original	modified
alg-based	53%	61%
calc-based	47%	39%
male	51%	49%
female	49%	51%

The table above shows how the recent and historical populations were divided between gender and type of course. There is a noticeable difference between the two populations due to the fact that the calculus-based course has not grown but the algebra-based course has increased in size by 25%.

Comparison of Response Profiles for the Unmodified Questions

We previously reported at AAPT W2013 the comparison between our first revised FCI V. 1 to answer the question, "Are the percentages of correct responses statistically different between the historical and new data set?" We compared correct responses on unmodified questions both by individual question and as a whole. A few additional questions have been modified and now we have 9 questions to compare.

Per question: Standard error was determined for individual questions assuming a binomial distribution: shistorical = 1.9%, snew = 3.2-3.8%. Difference in % correct ranges from: 0.04% to 7.5% which is within the 90% expected distribution range.

Total score: An average score on the FCI for the 9 unmodified questions was compared between the historical data and the new data.

Historical:	32.94 +/- 1.00%
New:	32.48 +/- 1.72%

Chi-squared We used Chi-squared to compare the pre-test responses of the recent and historical response profiles of each of the unmodified FCI questions. A p-value greater than 0.10 indicates differences in the profiles are likely due to chance. The profiles for question 2, which is now question 1, show significant variations. However, the other questions have response patterns that are statistically similar with p-values ranging from 0.180 – 0.777.

Our First New FCI Question

New Question 4

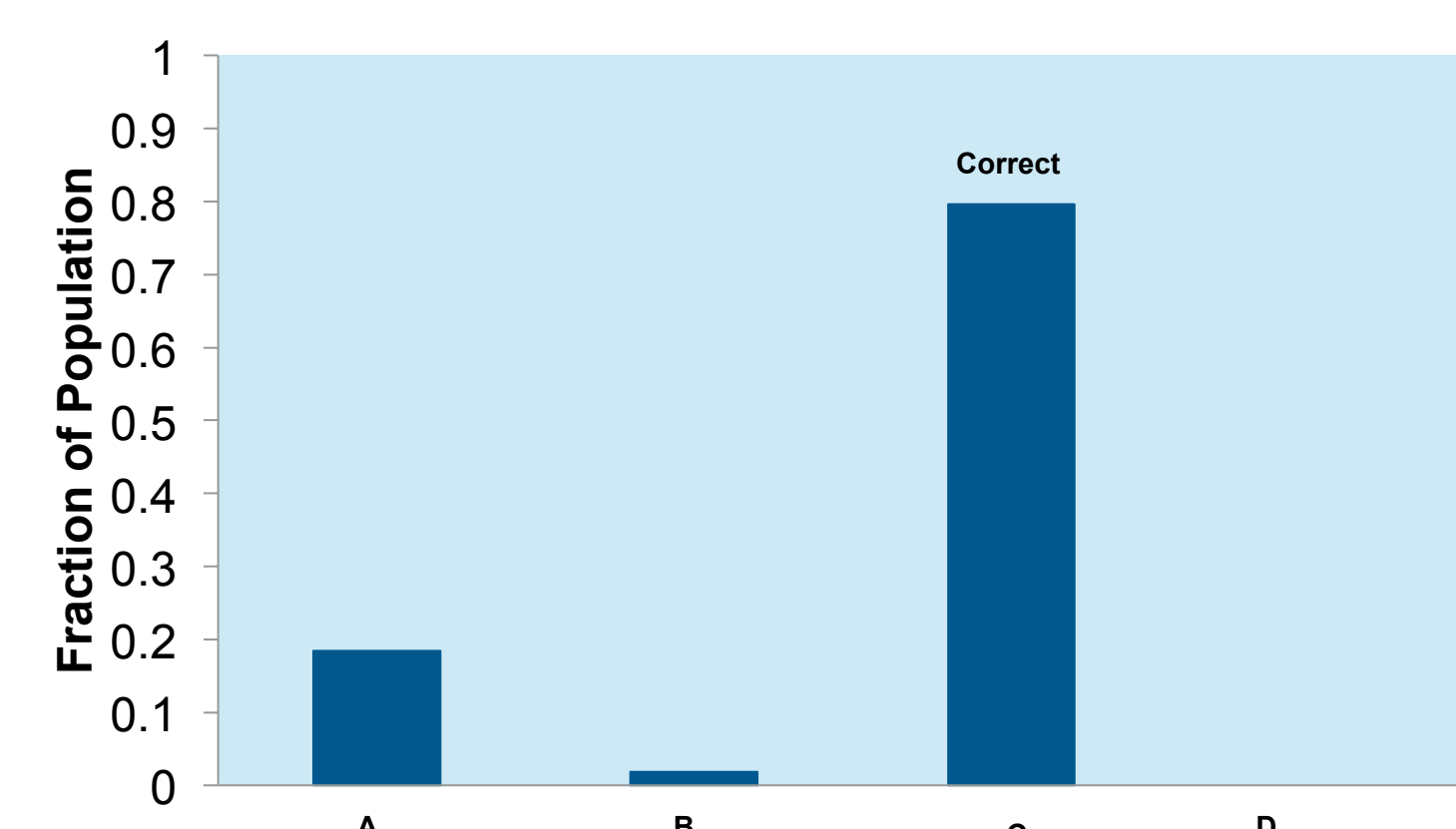
4. A book is resting on your desk. Consider the following forces:

- A downward force due to gravity
- An upward force exerted by the surface

Which of the above forces are acting on the book?

- (A) 1 only
(B) 2 only
(C) Both 1 and 2
(D) Neither

Response Profile for New Question 4 on FCI Pre-test Fall 2013



This question was motivated by interviews on Question 11, shown below. When talking about the question they would choose B over C because they explained that inanimate objects cannot exert forces.

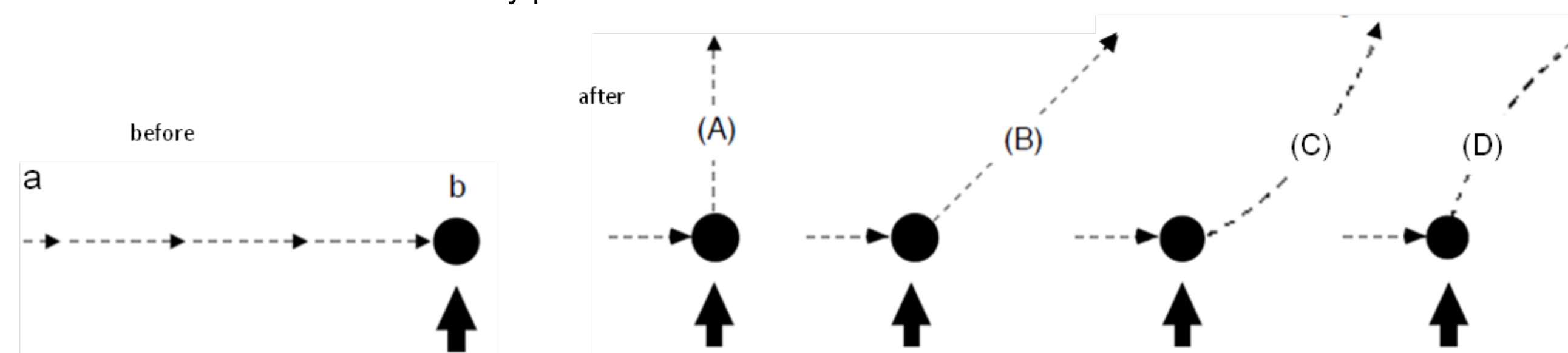
We decided to write a question that only addressed this alternate conception to identify what fraction of students hold this idea.

This fall we found that a substantial portion, 20%, of the population indicated no force from the surface of the table.

We now compare the results of Question 4 with those of Question 11. Question 11 has been modified by emphasizing the word "after".

Use the statement and figure below to answer the next four questions (8 through 11).

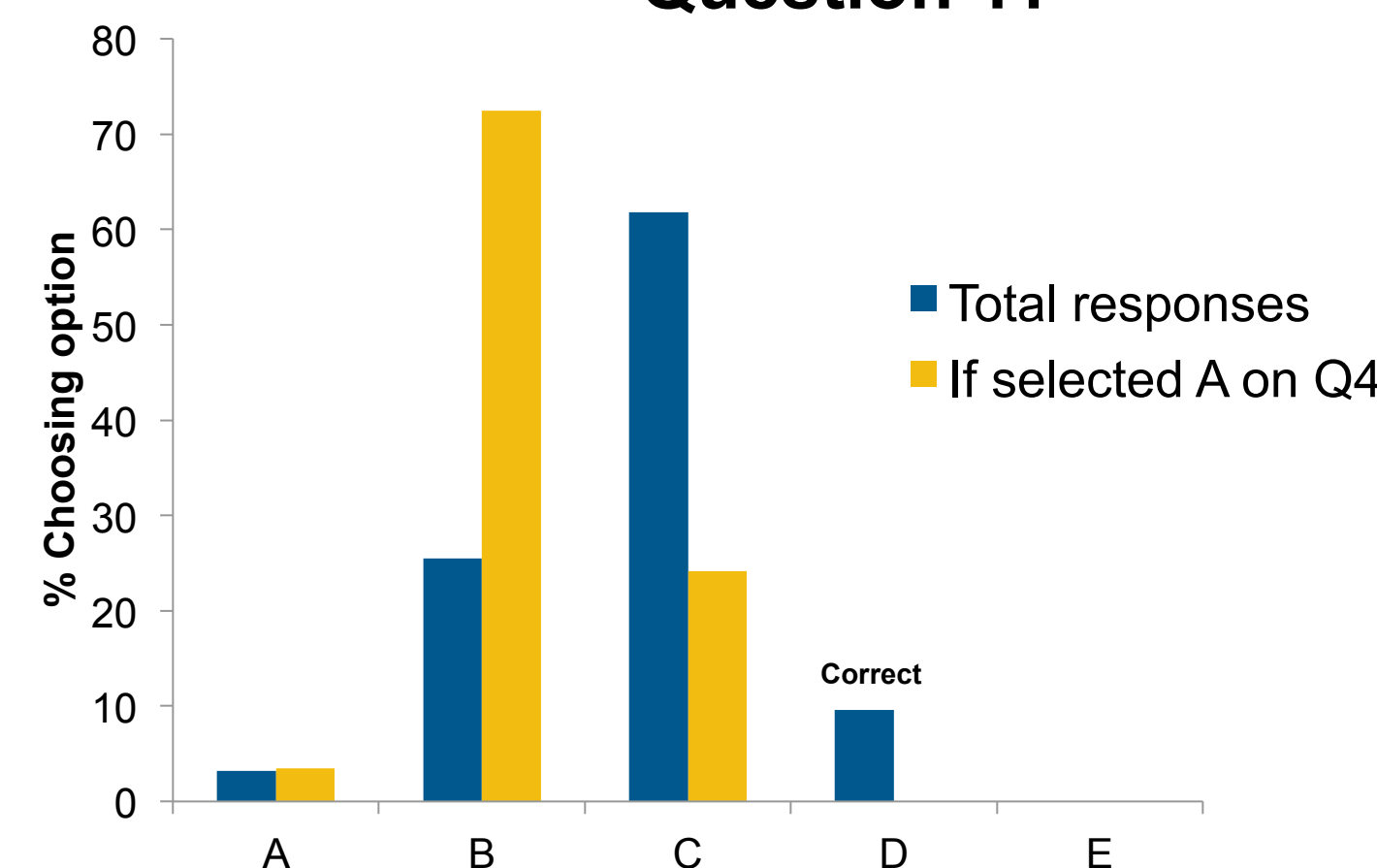
The figure depicts a bar of soap sliding on a horizontal wet floor with constant speed in a straight line from point "a" to point "b". Forces exerted by the air are negligible. You are looking down on the bar of soap. When the soap reaches point "b," it receives a kick in the direction of the heavy print arrow.



11. After receiving the kick, the main force(s) acting on the soap is (are):

- (A) a downward force of gravity.
(B) a downward force of gravity, and a force in the direction of motion.
(C) a downward force of gravity, an upward force exerted by the surface, and a force in the direction of motion.
(D) a downward force of gravity and an upward force exerted by the surface.
(E) none. (No forces act on the soap.)

Question 11



This graph compares the total responses to Question 11 compared to the responses from those students that answered "A" on Question 4. An interesting note: ~24% of students who selected option A on Q4, selected "C" on Q11, indicating in one instance there is not a force applied by the surface but in another there is.

It is also worth noting that 18 students found there to be a force exerted by the table in Question 4, but indicated no force is exerted by the surface in Question 11.

Our Thoughts

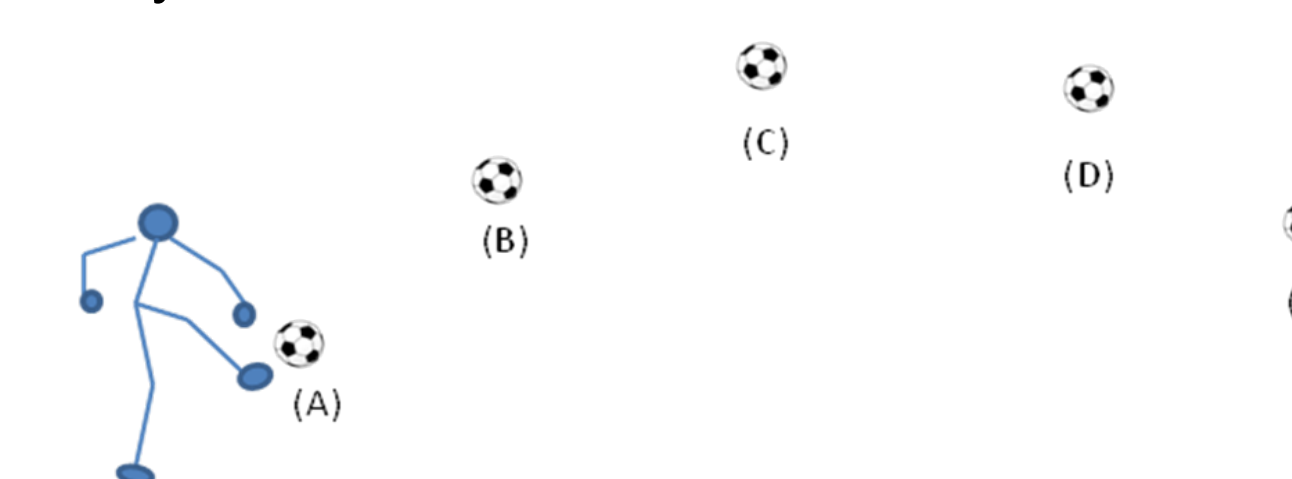
Q11 involves motion where Q4 does not. It is possible that the students may be confusing friction due to motion with a force exerted by the surface.

For those identifying a force from the surface on the book, but not a force from the surface on the puck/soap; has the fact that the object in Q11 is in motion, led to the idea that a normal force acts only in static situations?

Another New FCI Question to Consider

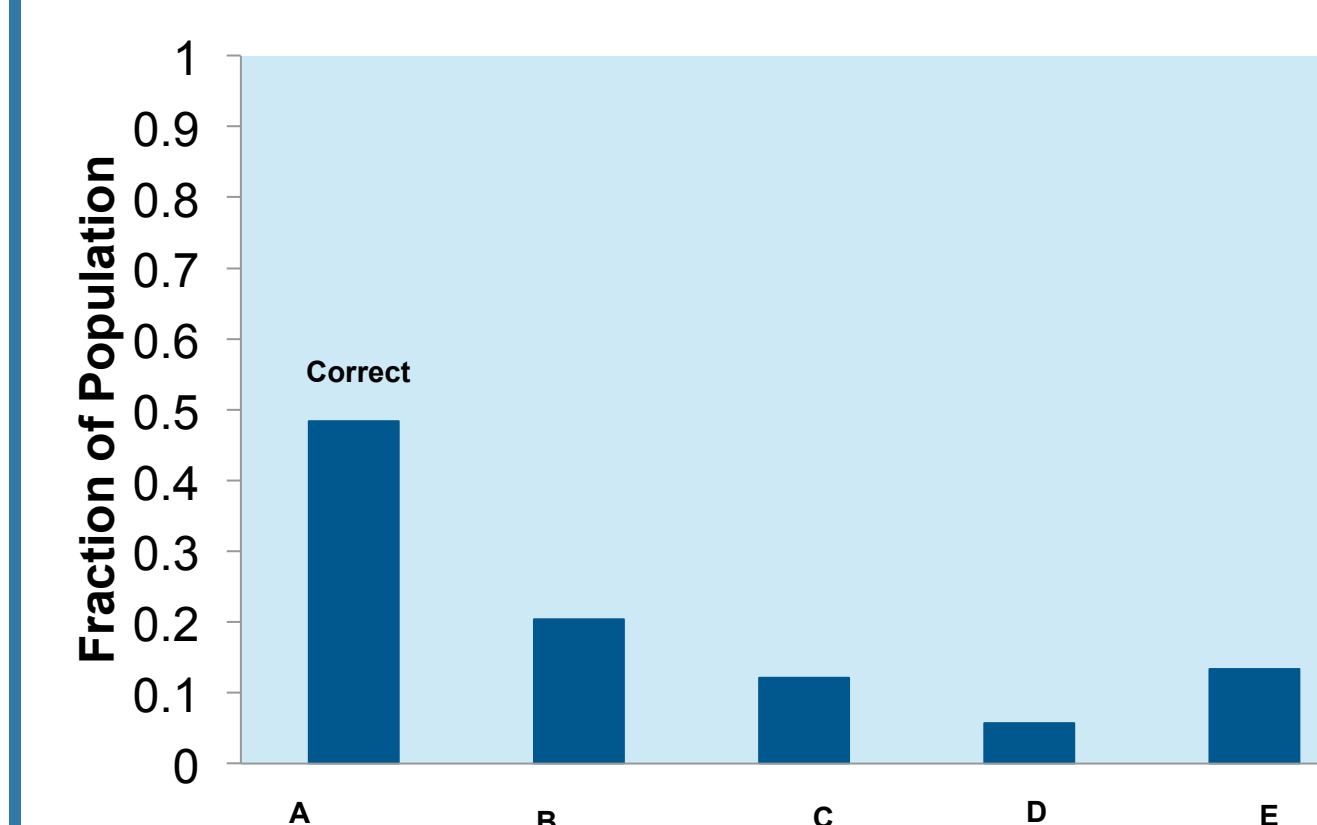
New Question 31

31. A soccer player kicks a ball on a calm day.



At which of the points shown is the ball moving the fastest?

Response Profile for New Question 31 on FCI Pre-test Fall 2013



This question was inspired by a conversation with a person during a soccer game. After a player in the game was kicked in the face with a soccer ball, the person said, "Good thing he wasn't standing further back or he would have been hurt worse." Further conversation found that this person felt that the ball needed more distance to "get up to speed."

During class, a video was shown to students depicting a similar situation and students were asked where they would stand if they were to be kicked in the face by the ball. Students responded with a variety of answers, similar to the FCI response profile. There were similar arguments for the ball getting up to speed. Also, there was a strong argument against standing further away because "gravity would cause the ball to accelerate."

In an interview with a student, they were able to correctly identify the best place to stand; but, could not identify where the ball was travelling the fastest. This was because the student was using the conservation of energy along with thinking about the x- and y-components separately, but forgot about gravitational potential energy.

Although 48% of the student population answered this question correctly, the other 52% surprised us by picking the other distracters. In particular, 20% gave response B which fits with the getting up to speed reasoning.

A physicist uses similar reasoning to answer both questions 30 and 31. Because of this we looked at students who correctly answered question 31 to see if they are more successful on question 30.

30. Despite a very strong wind, a tennis player manages to hit a tennis ball with her racquet so that the ball passes over the net and lands in her opponent's court.

- Consider the following forces:
- A downward force of gravity.
 - A force by the "hit".
 - A force exerted by the air.

Which of the above forces is (are) acting on the tennis ball after it has left contact with the racquet and before it touches the ground?

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

During student interviews, the three most prevalent student alternate conceptions made it clear that students were confusing force with momentum, students also had difficulty isolating or focusing a specific moment in time, they could analyze the hit, but had trouble focusing on a specific moment. It wasn't completely clear but it seemed a few students may have thought there was a force still acting on the ball.

Our Thoughts

During interviews we found that each of these questions elicit multiple student alternate conceptions. So it is not unexpected to find that students who correctly answer question 31 are no better at answering question 30 than the students who missed question 31.

Conclusion

We continue to explore the consequences of modifying some FCI questions in order to achieve greater clarity in their presentation. Also, new questions were constructed based on student think-aloud interviews as well as class discussion. We plan to conduct further student interviews on the new and modified questions to find out if we have successfully created questions that clearly probe student alternate conceptions about force and motion.

Question 30

