

APPENDIX: FCI AND FCIT

This appendix contains the FCI questions and the corresponding FCIT questions. The FCI questions were given as part the full 30-question Force Concept Inventory. The FCIT questions were re-ordered and given as part of a separate 10-question test that was administered either immediately before or after the FCI. The first test was collected before the second was passed out. Approximately half the students received the FCI first, half the FCIT first. The transformations applied to the FCI question to generate the FCIT question are discussed.

FCI Question 1: FCI question 1 was transformed by changing a concrete physical system, metal balls, to an abstract system, spheres. Redundant distractors, 1 and 2, were removed. The removal of the distractors produced an effective re-ordering of the distractors.

FCI[1] Two metal balls are the same size but one weighs twice as much as the other. The balls are dropped from the roof of a single story building at the same instant. The time it takes the balls to reach the ground will be

- 1. about half as long for the heavier ball as for the lighter one.
- 2. about half as long for the lighter ball as for the heavier one.
- 3. about the same for both balls.
- 4. considerably less for the heavier ball, but not necessarily half as long.
- 5. considerably less for the lighter ball, but not necessarily half as long.

FCIT[1] Two spheres are the same size but the mass of one is twice as much as the other. The spheres are dropped from a height of 5m at the same time. The time it takes the spheres to reach the ground will be

- 1. about the same for both spheres.
- 2. considerably less for the heavier sphere.
- 3. considerably less for the lighter sphere.

FCI Question 4: FCI question 4 was transformed by changing a concrete physical system, truck and car, to another concrete system, bowling ball and marble. Distractors were changed from textual to symbolic, a change in representation, and re-ordered.

FCI[4] A large truck collides head-on with a small compact car. During the collision

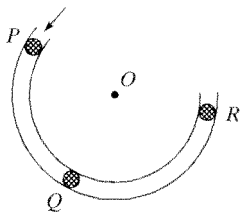
- 1. the truck exerts a greater amount of force on the car than the car exerts on the truck.
- 2. the car exerts a greater amount of force on the truck than the truck exerts on the car.
- 3. neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
- 4. the truck exerts a force on the car but the car does not exert a force on the truck.
- 5. the truck exerts the same amount of force on the car as the car exerts on the truck.

FCIT[4] A bowling ball collides with a marble. The bowling ball is much heavier than the marble. During the collision, let the force of the bowling ball on the marble be $F_{b.ball\ on\ marble}$ and the force of the marble on the bowling ball be $F_{marble\ on\ b.ball}$. During the collision

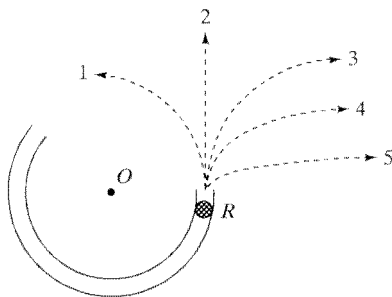
- 1. $F_{b.ball\ on\ marble} = F_{marble\ on\ b.ball}$
- 2. $F_{b.ball\ on\ marble} > F_{marble\ on\ b.ball}$
- 3. $F_{b.ball\ on\ marble} < F_{marble\ on\ b.ball}$
- 4. $F_{b.ball\ on\ marble} = 0, F_{marble\ on\ b.ball} = 0$
- 5. $F_{b.ball\ on\ marble} > 0, F_{marble\ on\ b.ball} = 0$

FCI Question 6: FCI question 6 was transformed by erasing paths 4 and 5 from the figure and by removing redundant distractors 4 and 5. Problem 6 is part of a two question group (questions 5 and 6) on the FCI. The FCIT contains only question 6 and the description given for both questions 5 and 6 was merged with the question as shown.

(This text prefixed question 5 and 6 on the FCI.) Use the statement and figure below to answer the next two questions (5 and 6). The accompanying figure shows a frictionless channel in the shape of a segment of a circle with its center at O . The channel has been anchored to a frictionless horizontal table top. You are looking down at the table. Forces exerted by the air are negligible. A ball is shot at high speed into the channel at P and exits at R .

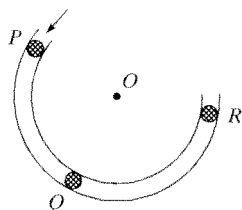


FCI[6] Which of the paths 1-5 below would the ball most closely follow after it exits the channel at R and moves across the frictionless table top?

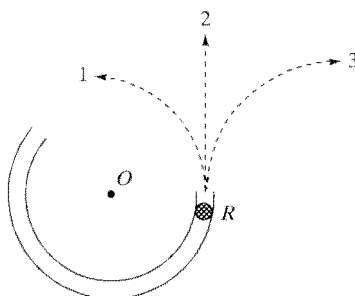


- ___ 1. path 1.
 ___ 2. path 2.
 ___ 3. path 3.
 ___ 4. path 4.
 ___ 5. path 5.

FCIT[6] The figure below shows a frictionless channel in the shape of a segment of a circle with its center at O . The channel has been anchored to a frictionless horizontal table top. You are looking down at the table. Forces exerted by the air are negligible. A ball is shot at high speed into the channel at P and exits at R .



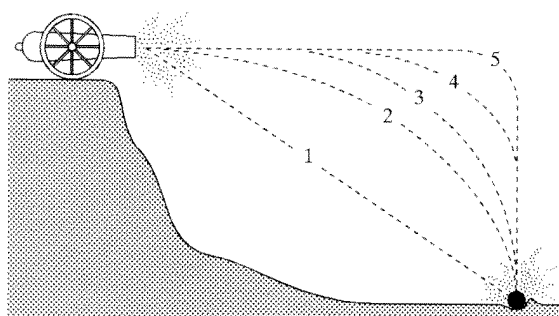
Which of the paths 1-3 below would the ball most closely follow after it exits the channel at R and moves across the frictionless table top?



1. path 1.
 2. path 2.
 3. path 3.

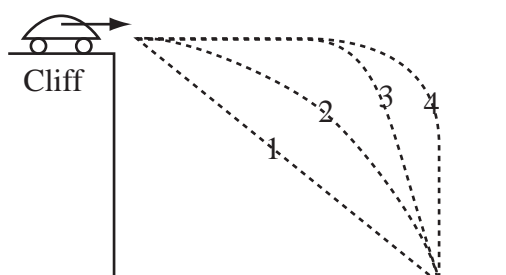
FCI Question 12: FCI question 12 was transformed by changing a concrete physical system, a cannonball, to another concrete system, a car. The figure was redrawn appropriately. Multiple redundant distractors 4 and 5 on the FCI were combined in distractor 4 on the FCIT.

FCI[12] A ball is fired by a cannon from the top of a cliff as shown below. Which of the paths 1-5 would the cannon ball most closely follow?



- 1. path 1.
- 2. path 2.
- 3. path 3.
- 4. path 4.
- 5. path 5.

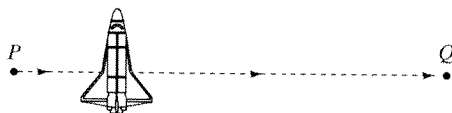
FCIT[12] A car is driven off the top of a cliff at high speed as shown below. Which of the paths 1-4 would the car most closely follow?



- 1. path 1.
- 2. path 2.
- 3. path 3.
- 4. path 4.

FCI Questions 22 and 24: FCI questions 21 through 24 use the figure and statement below. The FCIT contained only questions 22 and 24 without the accompanying figure and statement. The questions were reworded appropriately. **Use the statement and figure below to answer the next four questions (21 through 24)**

A spaceship drifts sideways in outer space from point P to point Q as shown below. The spaceship is subject to no outside forces. Starting at position Q , the spaceship's engine is turned on and produces a constant thrust (force on the spaceship) at right angles to the line PQ . The constant thrust is maintained until the spaceship reaches a point R in space.



FCI Question 22: FCI question 22 was transformed by removing a figure and removing questions 21 and 23 from a four-question group.

FCI[22] As the spaceship moves from point Q to point R its speed is

- 1. constant.
- 2. continuously increasing.
- 3. continuously decreasing.
- 4. increasing for a while and constant thereafter.
- 5. constant for a while and decreasing thereafter.

FCIT[22] A space ship is drifting sideways in outer space. It is subject to no outside forces. It turns on its engine which generates a constant thrust (constant force on the space ship). While the engine is turned on the spaceship's speed is

- 1. constant.
- 2. continuously increasing.
- 3. continuously decreasing.
- 4. increasing for a while and constant thereafter.
- 5. constant for a while and decreasing thereafter.

FCI Question 24: FCI question 24 was transformed by removing a figure and removing questions 21 and 23 from a four question group. The statement that the engine was turned off at R was added to the FCIT question from FCI question 23.

FCI[24] Beyond position R the speed of the spaceship is

- 1. constant.
- 2. continuously increasing.
- 3. continuously decreasing.
- 4. increasing for a while and constant thereafter.
- 5. constant for a while and decreasing thereafter.

FCIT[24] After some time, the spaceship's engine in question 22 is turned off and the thrust immediately drops to zero. After the engine is turned off, the speed of the spaceship is

- 1. constant.
- 2. continuously increasing.
- 3. continuously decreasing.
- 4. increasing for a while and constant thereafter.
- 5. constant for a while and decreasing thereafter.

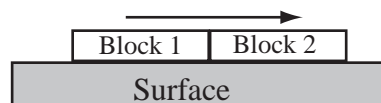
FCI Question 25: FCI question 25 was transformed by changing a concrete physical system, woman and box, to an abstract system, blocks. Because the system was abstract the students were told to assume friction and gravity. A figure was added to the transformed question. Problem 25 was a part of a three question group on the FCI, question 26 was removed from this group on the FCIT. Since the students had not encountered the missing question when answering question 25, a transformation of re-structuring a question group is not assigned to question 25 but is assigned to question 27.

FCI[25] A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed v_0 .

The constant horizontal force applied by the woman

- 1. has the same magnitude as the weight of the box.
- 2. is greater than the weight of the box.
- 3. has the same magnitude as the total force that resists the motion of the box.
- 4. is greater than the total force that resists the motion of the box.
- 5. is greater than either the weight of the box or the total force that resists its motion.

FCIT[25] Block 1 is used to push block 2. Block 1 applies a constant horizontal force to block 2. As a result, the blocks move across a horizontal surface at a constant speed v_0 . The surface has friction.



Gravity Acts Downward
The surface has friction.

The constant horizontal force applied by block 1 on block 2

- 1. has the same magnitude as the weight of block 2.
- 2. is greater than the weight of block 2.
- 3. has the same magnitude as the total force that resists the motion of block 2.
- 4. is greater than the total force that resists the motion of block 2.
- 5. is greater than either the weight of block 2 or the total force that resists its motion.

FCI Question 27: FCI question 27 was transformed by changing a concrete physical system, woman and box, to an abstract system, blocks. Because the system was abstract the students were told to assume friction and gravity. Problem 27 was a part of a three-question group on the FCI, question 26 was removed from this group on the FCIT. Since a figure was added to the question group, the addition of figure transformation is credited to this question as well as question 25.

FCI[27] If the woman in question 25 suddenly stops applying a horizontal force to the block, then the block

- 1. immediately comes to a stop.
- 2. continues moving at a constant speed for a while and then slows to a stop.
- 3. immediately starts slowing to a stop.
- 4. continues at a constant speed.
- 5. increases its speed for a while and then starts slowing to a stop.

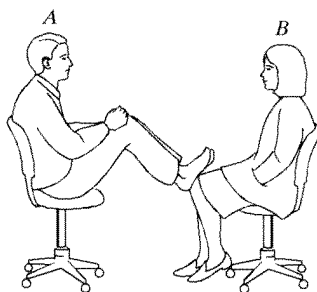
FCIT[27] If block 1 in question 25 suddenly disappears along with its force, then block 2

- 1. immediately comes to a stop.
- 2. continues moving at a constant speed for a while and then slows to a stop.
- 3. immediately starts slowing to a stop.
- 4. continues at a constant speed.
- 5. increases its speed for a while and then starts slowing to a stop.

FCI Question 28: FCI question 28 was transformed by changing a concrete physical system, two students on rolling chairs, to another concrete system, two people on ice. FCI question 28 contained a figure, but no figure was provided for FCIT question 28. Distractors were re-ordered.

FCI[28] In the following figure, student *A* has mass 75 kg and student *B* has a mass of 57 kg. They sit in identical office chairs facing each other.

Student *A* places his bare feet on the knees of student *B*, as shown. Student *A* then suddenly pushes outward with his feet, causing both chairs to move.



During the push while the students are still touching one another.

- 1. neither student exerts a force on the other.
- 2. student *A* exerts a force on student *B*, but *B* does not exert any force on *A*.
- 3. each student exerts a force on the other, but *B* exerts the larger force.
- 4. each student exerts a force on the other, but *A* exerts the larger force.
- 5. each student exerts the same amount of force on the other.

FCIT[28] Two people stand on a frictionless icy surface. Person 1 has a larger mass than person 2. Person 1 pushes person 2 with his hands causing both people to slide. During the push while persons 1 and 2 are still touching one another,

- 1. neither person exerts a force on the other.
- 2. each person exerts the same amount of force on the other.
- 3. person 1 exerts a force on person 2, but 2 does not exert any force on 1.
- 4. each person exerts a force on the other, but 2 exerts the larger force.
- 5. each person exerts a force on the other, but 1 exerts the larger force.

FCI Question 30: FCI question 30 was transformed by changing a concrete physical system, tennis ball, to another concrete system, baseball.

FCI[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. a downward force of gravity.
- B. a force by the "hit."
- C. 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?

- 1. A only
- 2. A and B
- 3. A and C
- 4. B and C
- 5. A, B, and C

FCIT[30] On a very windy day, a baseball player throws a baseball from the outfield to second base. Consider the following forces:

- A. a downward force of gravity.
- B. the force of the "throw."
- C. a force exerted by the air.

Which of the above forces is (are) acting on the baseball while it is in flight?

- 1. A only
- 2. A and B
- 3. A and C
- 4. B and C
- 5. A, B, and C