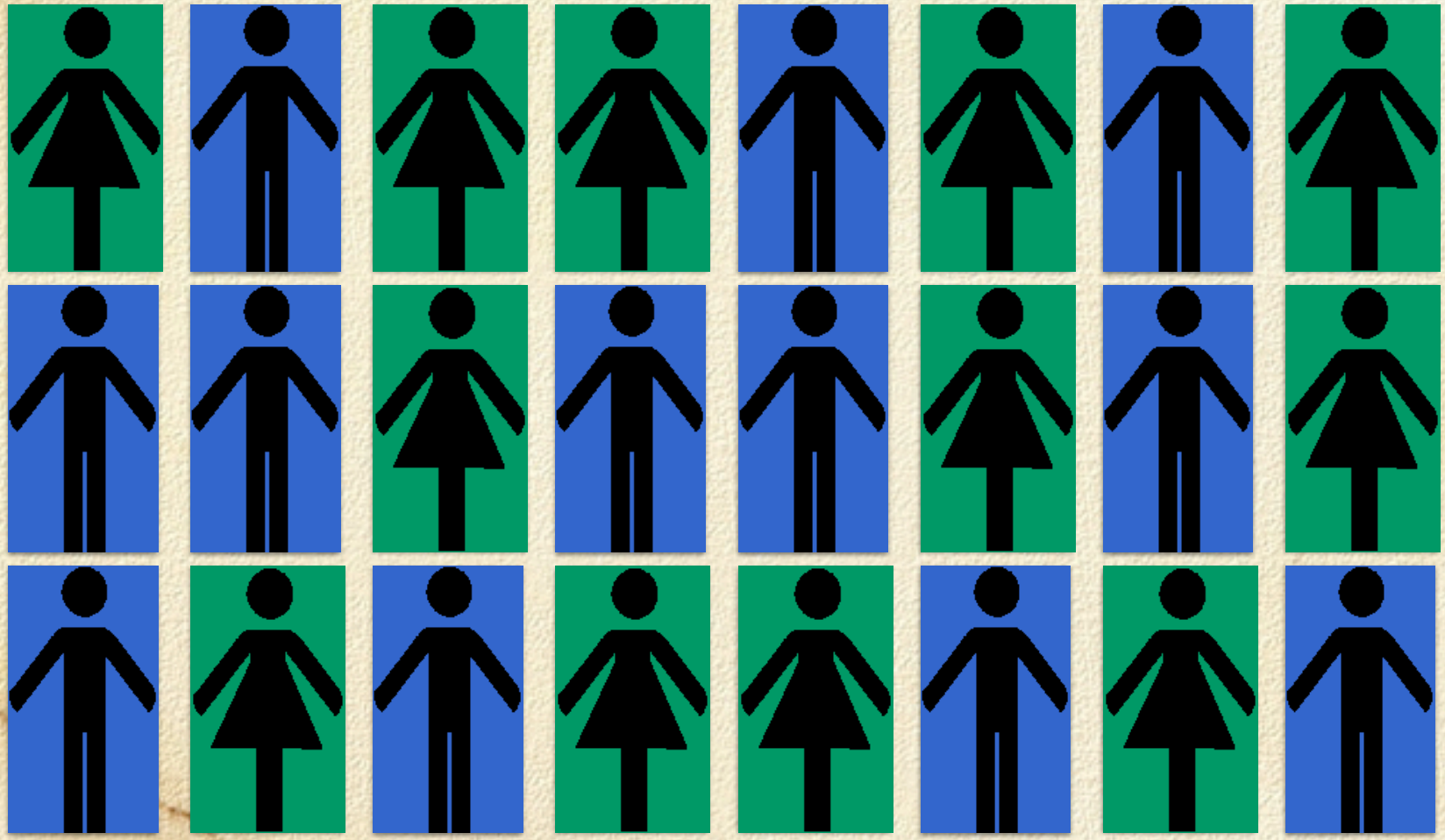
Cannonballs and Baby's Bowls: How Context and Gender Affect Physics Tests

Laura McCullough
University of Wisconsin-Stout
Physics Department

Women and the Physics Classroom

- Women are under-represented in physics
- We need to be encouraging everyone in physics
- Classrooms serve to encourage or discourage participation in a subject
- Physics classrooms should be a place to promote women's participation

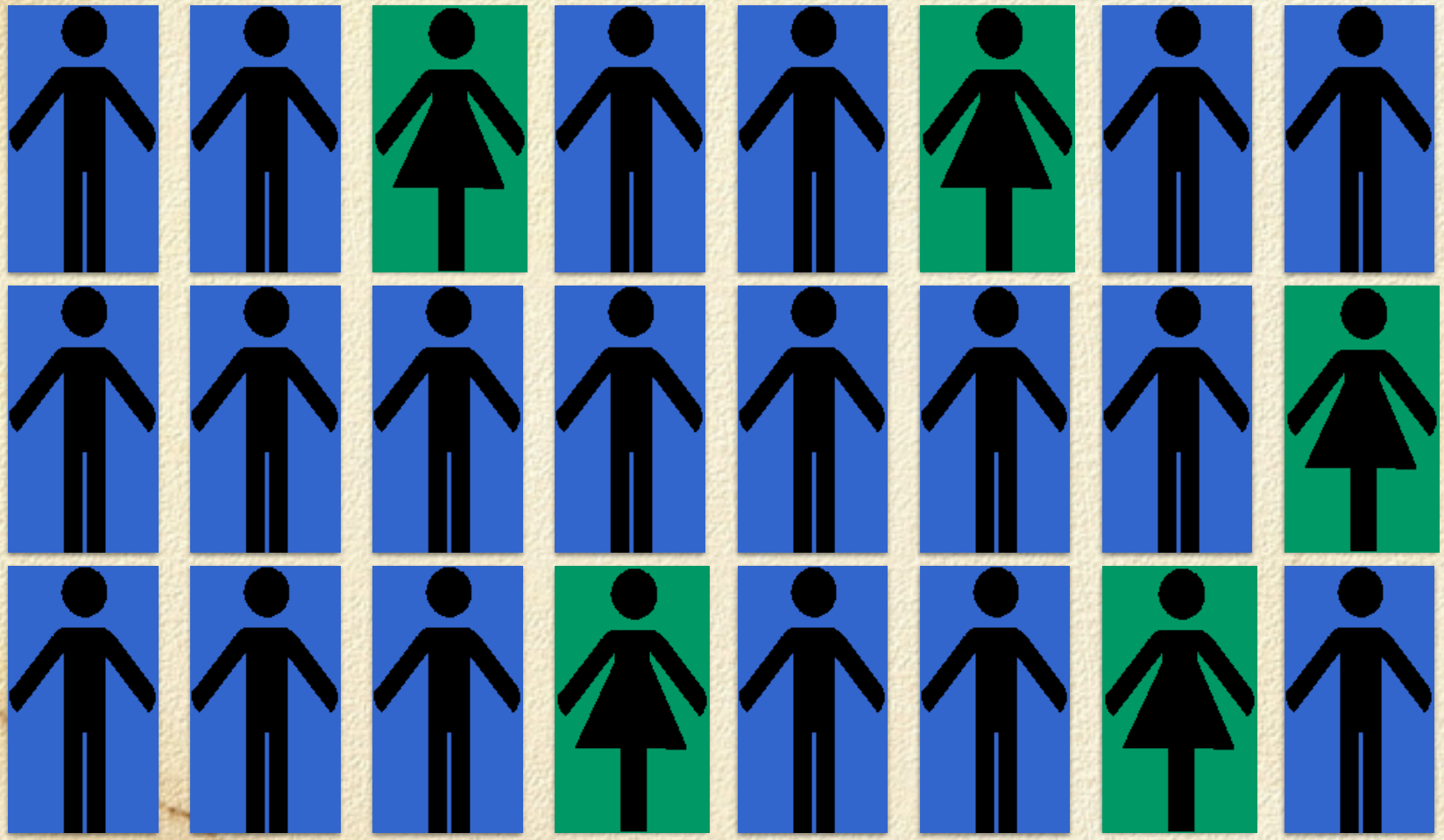
High School Physics



High School Physics

- 50% of high school physics students are women! (28% of students take HS physics)
- But…
- Women are still not found in the AP courses which are better preparation for college coursework

Undergraduate Physics

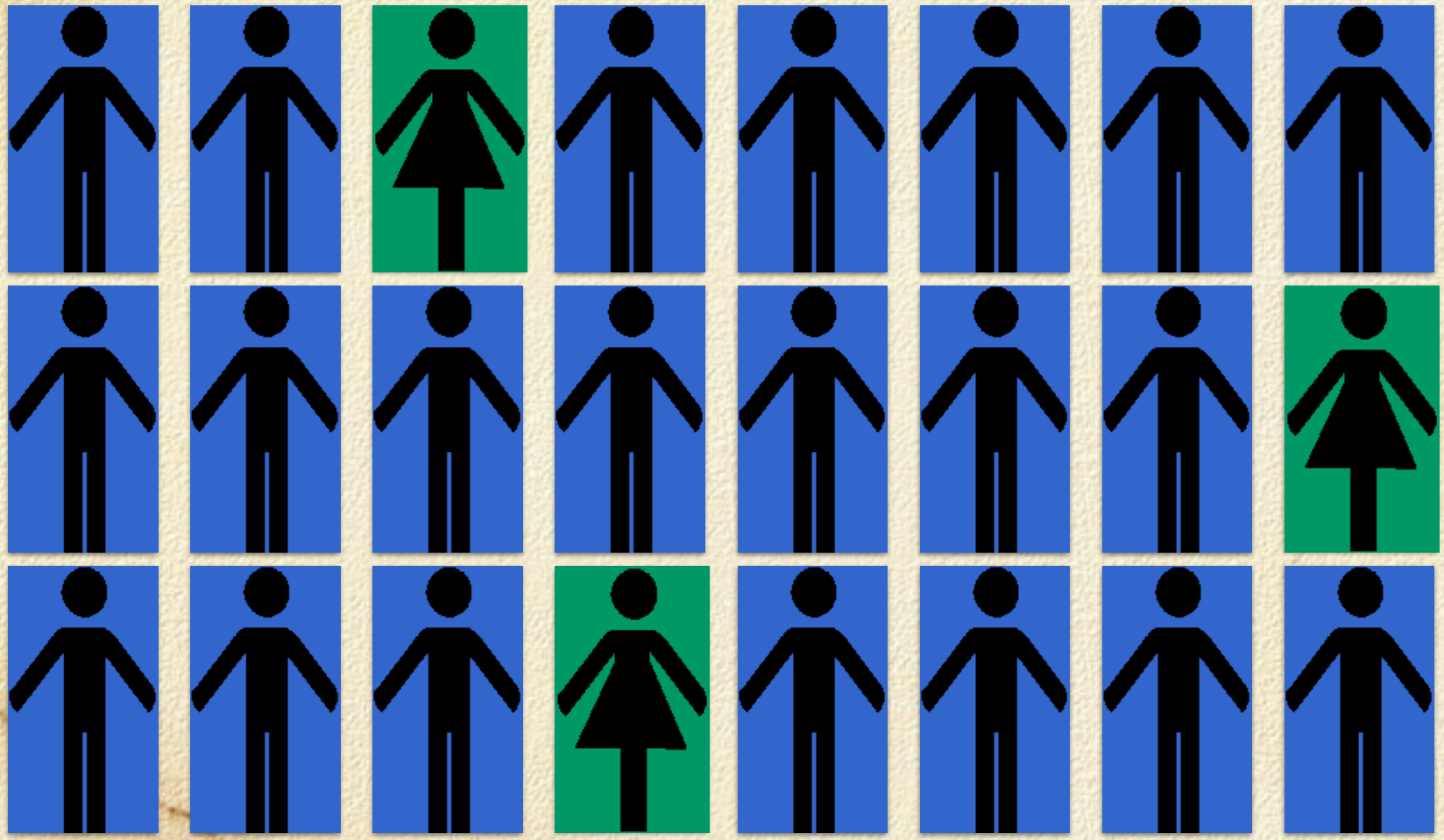


Undergraduate Physics

- Women make up ~31% of two-year college physics students

- Women receive ~21% of physics bachelors degrees

Graduate Physics



Graduate Physics

- Women receive ~20% of master's degrees in physics
- ~14% of physics doctorates go to women
- Is this a problem? Yes!

We Need Scientists!

- Concern over decreasing numbers of science and technical professionals
- Rising Above the Gathering Storm (NAS, 2006)
- US needs to be encouraging more people to enter science
- Women are an underutilized talent pool for science; we should be focusing attention on getting more women into physics

Education as Encouragement

- Teachers and the classroom have a strong effect on motivation/decision to enter science
- We can use this to help promote women's participation in science

What Can a Teacher Do?

- Awareness
- Language
- Role Models
- Contexts

Contexts: Male? Female?

- Typical physics contexts:
  - Baseball/Sports
  - Cannons/Military
  - Tools
- Abstract, context-less problems

The Force Concept Inventory

- The FCI is commonly used across the country in high schools and colleges
- 30 question test covers topics usually taught in first term introductory physics
- No math/calculations
- "Wrong" answers (distractors) were carefully chosen from research on common student misconceptions
- Significant gender gap favoring males

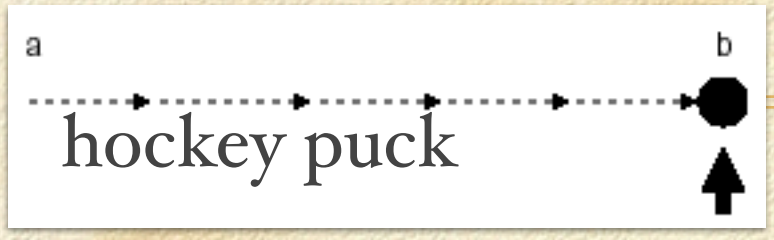
Why the gender gap?

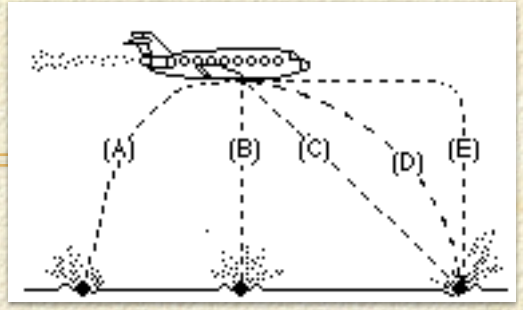
- What's up with this test?
- The men, the women, or the test?
- Possible test bias?

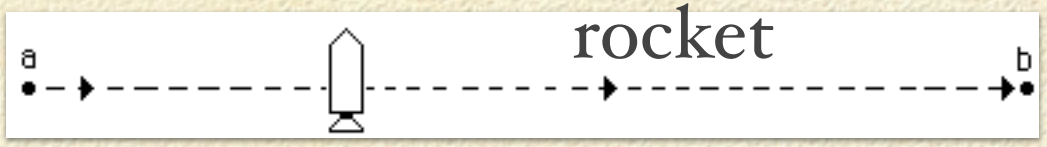
Test by males, for males?

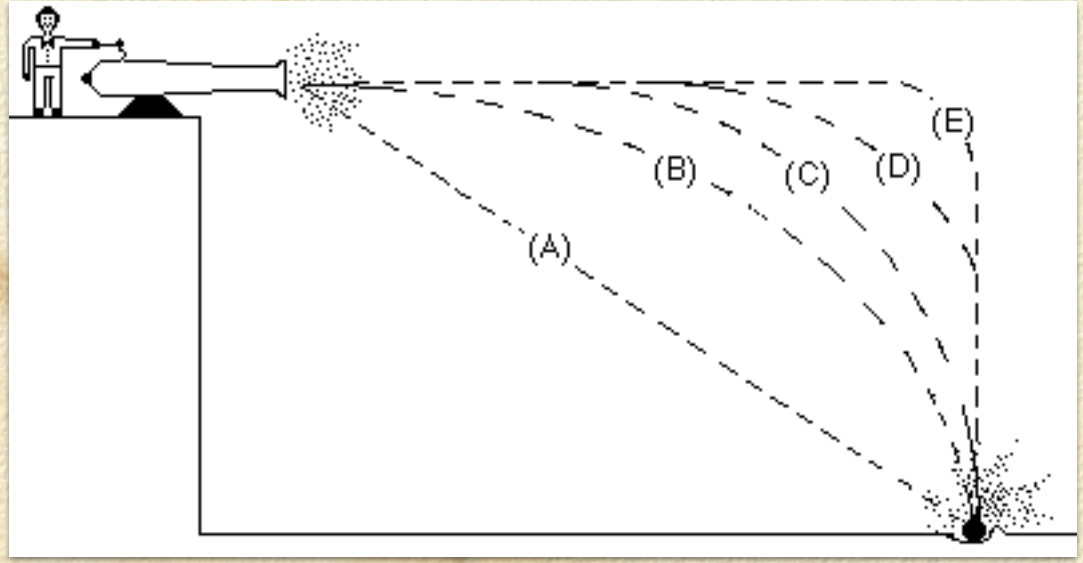
- Written by a team of male physics education researchers
- Tested on mostly male high school students
- Stereotypically male contexts
- Almost every person is a male

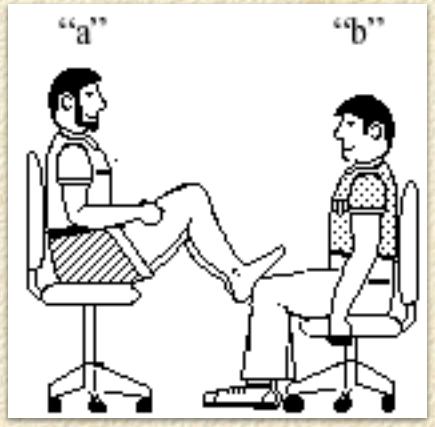
FCI contexts









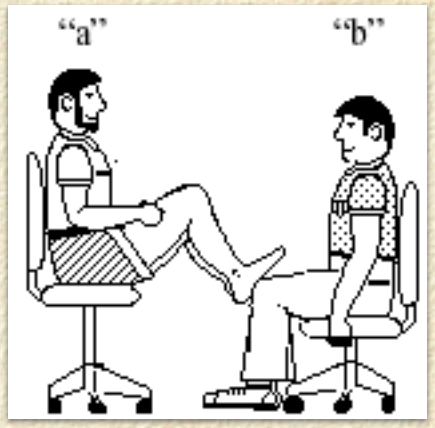


Context & Response?

- Rennie & Parker: changing context affected student response
  - Students preferred real-life context questions
  - More girls than boys preferred contextual questions (found the questions easier)
- Enderstein & Spargo: changing context from native to urban changed responses

Evidence for Contextual Interaction

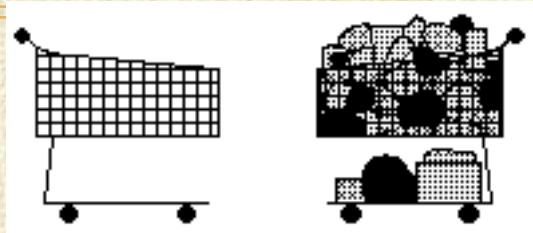
- Translated version of the test in Thailand
- Students had major problems with this question
- Cultural context completely blocked the science of the question
- Context affects performance!

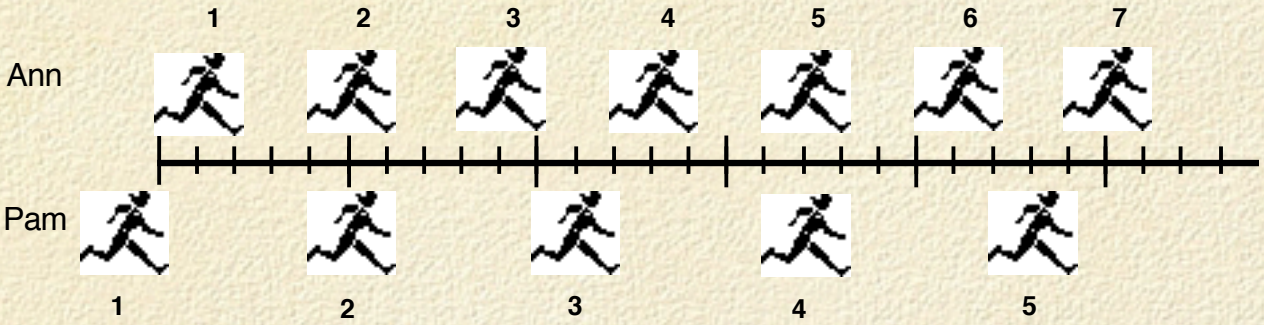


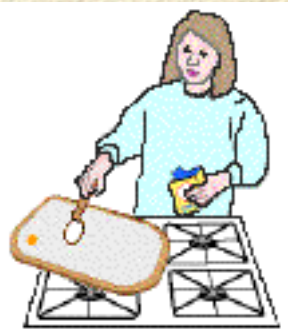
How to test context?

- Change the context!
- New version of FCI with stereotypically female contexts
- As far towards a female bias as possible
- Also more daily-life situations

New FCI contexts





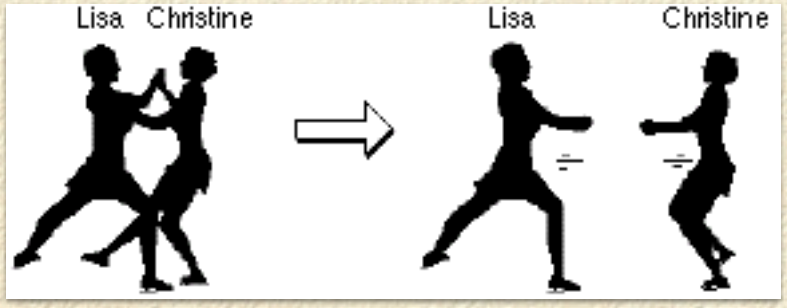


Original question

In the figure, student “a” has a mass of 95 kg and student “b” has a mass of 77 kg. They sit in identical office chairs facing each other. Student “a” places his bare feet on the knees of student “b”. Student “a” then suddenly pushes outward with his feet, causing both chairs to move.

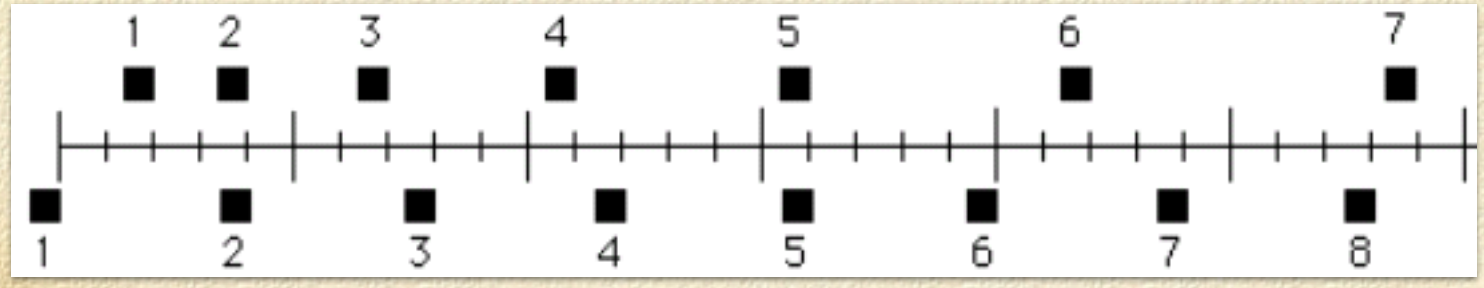
Revised question

Two figure skaters, Lisa who has a mass of 95 kg and Christine who has a mass of 77 kg are standing on the ice with Lisa's hands braced against Christine. Lisa suddenly pushes off of Christine, causing them both to move.



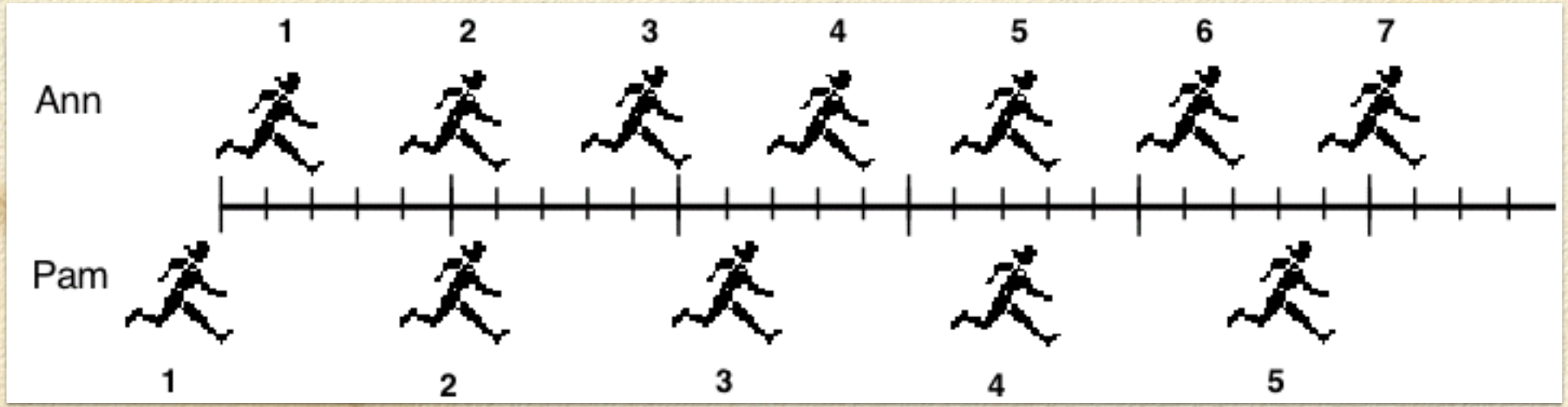
Original question

The positions of two blocks at successive 0.20-second time intervals are represented by the numbered squares in the figure. The blocks are moving toward the right.



Revised question

The positions of two joggers, Ann and Pam, are shown below. The joggers are shown at successive 0.20-second time intervals, and they are moving towards the right.



Testing conditions

- Four groups of data
  - Non-physics classes
  - UW-Stout physics students
    - Matched students (both tests)
  - UW-Stout physics students cued to test

Non-Physics Classes

% correct by gender and version (standard error)

	Original	Revised
Women	21.7 (0.94) N=106	22.3 (0.91) N=79
Men*	33.7 (1.9) N=56	28.5 (1.4) N=71

UW-Stout Physics-Unmatched

% correct by gender and version (pretest)

	Original	Revised
Women*	23.5 (0.95) N=99	29.4 (1.3) N=93
Men*	34.3 (0.99) N=184	39.4 (1.6) N=132

UW-Stout Physics-Matched

% correct by gender and version (pretest)

	Original	Revised
Women	25.3 (1.7) N=30	24.9 (1.4) N=30
Men	35.0 (1.6) N=100	33.6 (1.5) N=100

UW-Stout Physics-Cued

% correct by gender and version (pretest)

	Original	Revised
Women	23.3 (4.3) N=10	26.3 (2.7) N=10
Men	38.8 (3.6) N=31	38.5 (3.5) N=31

UW-Stout Physics-Matched

- Average scores are the same; are they answering the questions the same? No!
- Overall an average of 13 questions answered differently; individuals had between 1 and 21 different answers
- Women averaged 15 questions different; individual answers between 5 and 21
- Men averaged 13 questions different; individual answers between 1 and 21

UW-Stout Physics-Cued

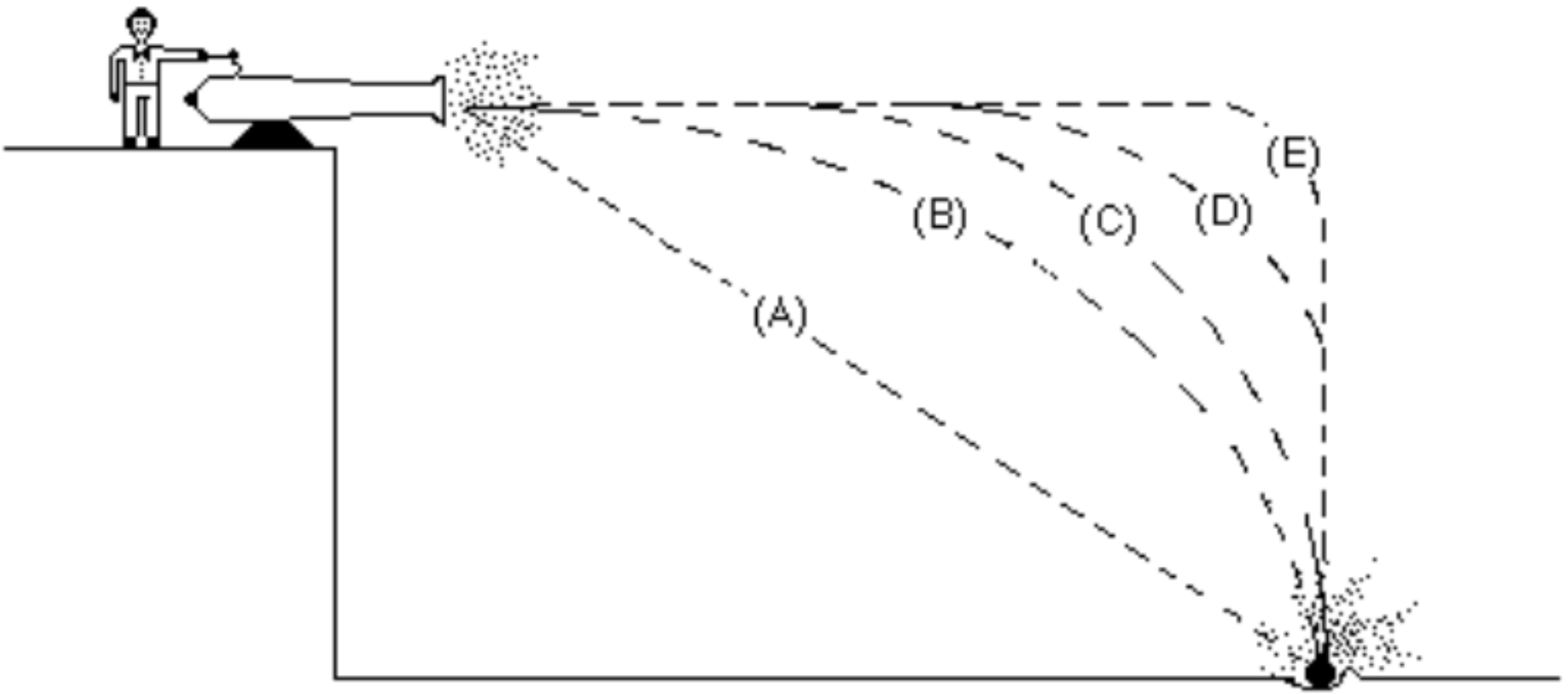
- Did the cued students answer the questions the same? No!
- Overall average of 11 questions answered differently; individuals answered between 4 and 21 questions differently
- Women averaged 13 questions different; individual answers between 7 and 21
- Men averaged 10 questions different; individual answers between 4 and 17

Questions provoking changed responses

- Looking at individual questions (not individual persons) the average % of the class changing responses to any particular question was 44%
- The biggest change was 58%, the smallest was 22% (on one question 58% of the class changed their answer)

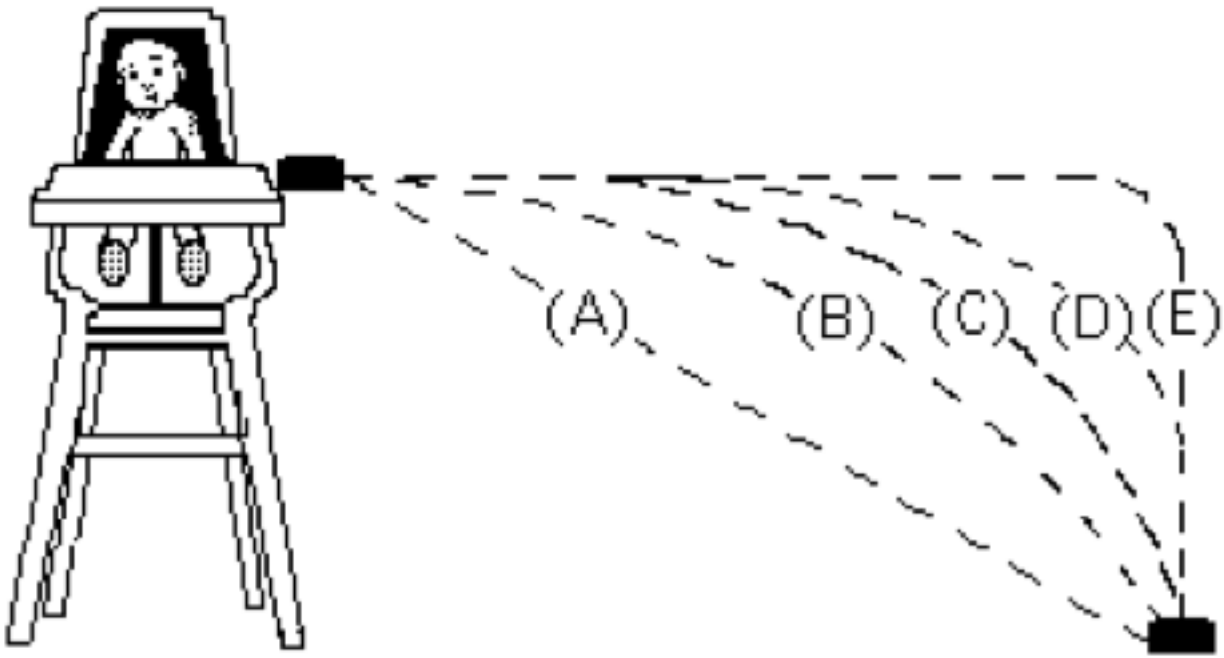
Original Question #12

12. A ball is fired by a cannon from the top of a cliff as shown in the figure below. Which of the paths would the cannon ball most closely follow?



Revised Question #12

12. A baby in a high chair slides her bowl of food horizontally off the side of her flat tray with a quick push. Which path below best represents the path of the bowl?



Changed responses by gender

% of students answering by choice (Matched pretest sample N=130, 30 women, 100 men)

	Original-Women	Revised-Women	Original-Men	Revised-Men
A	0	3	0	1
B	**40**	**67**	**65**	**67**
C	57	23	33	27
D	0	3	2	4
E	3	3	0	1

41% of the class changed their answer (47% W, 39% M)

Original Question #29

29. An empty office chair is at rest on a floor. Consider the following forces:

    1. A downward force of gravity.
    2. An upward force exerted by the floor.
    3. A net downward force exerted by the air.

Which of the forces is (are) acting on the office chair?

(A) 1 only.
(B) 1 and 2.
(C) 2 and 3.
(D) 1, 2, and 3.
(E) none of the forces. (Since the chair is at rest there are no forces acting upon it.)

Revised Question #29

29. A diary is at rest on a nightstand. Consider the following forces:

1. A downward force of gravity.
2. An upward force exerted by the nightstand.
3. A net downward force exerted by the air.

Which of the following force(s) is (are) acting on the diary?

(A) 1 only
(B) 1 and 2
(C) 2 and 3
(D) 1, 2, and 3
(E) none of these. Since the book is at rest there are no forces acting on it.

Changed responses by gender

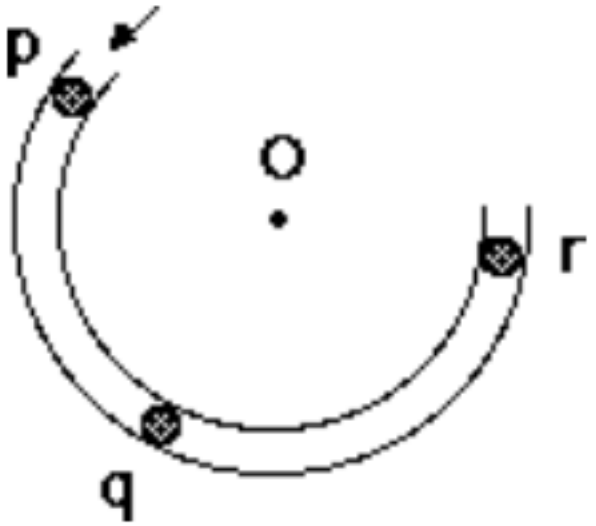
% of students answering by choice (Matched pretest sample N=130, 30 women, 100 men)

	Original-Women	Revised-Women	Original-Men	Revised-Men
A	17	30	22	32
B	**50**	**20**	**46**	**37**
C	0	0	1	2
D	23	40	30	29
E	3	3	0	1

48% of the class changed their answer (70% W, 41% M)

Original Question #5

The accompanying figure shows a frictionless channel in the shape of a segment of a circle with 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."



5. Consider the following distinct forces:

1. A downward force of gravity.
2. A force exerted by the channel pointing from q to O.
3. A force in the direction of motion.
4. A force pointing from O to q.

Which of the above forces is (are) acting on the ball when it is within the frictionless channel at position "q"?

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

Revised Question #5

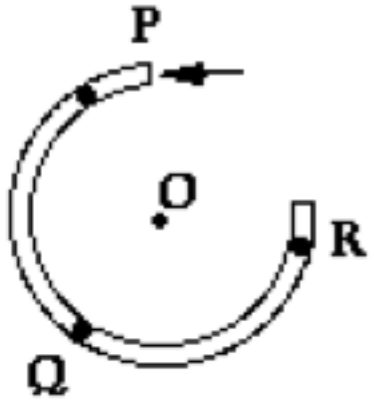
At a water park, a spiral water slide empties into a pool. The slide curves around, and the last curve is completely horizontal, set on a concrete patio. You are looking down at the slide from directly above. A child enters the **flat** part of the slide at point " P" at high speed and leaves the slide at point " R," as shown on the diagrams below.

5. Consider the following distinct forces:

1. A downward force of gravity.
2. A force exerted by the slide pointing from Q to O.
3. A force in the direction of motion.
4. A force pointing from O to Q.

Which of the above forces is (are) acting on the child as she is on the horizontal slide at position " Q" ?

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



Changed responses by gender

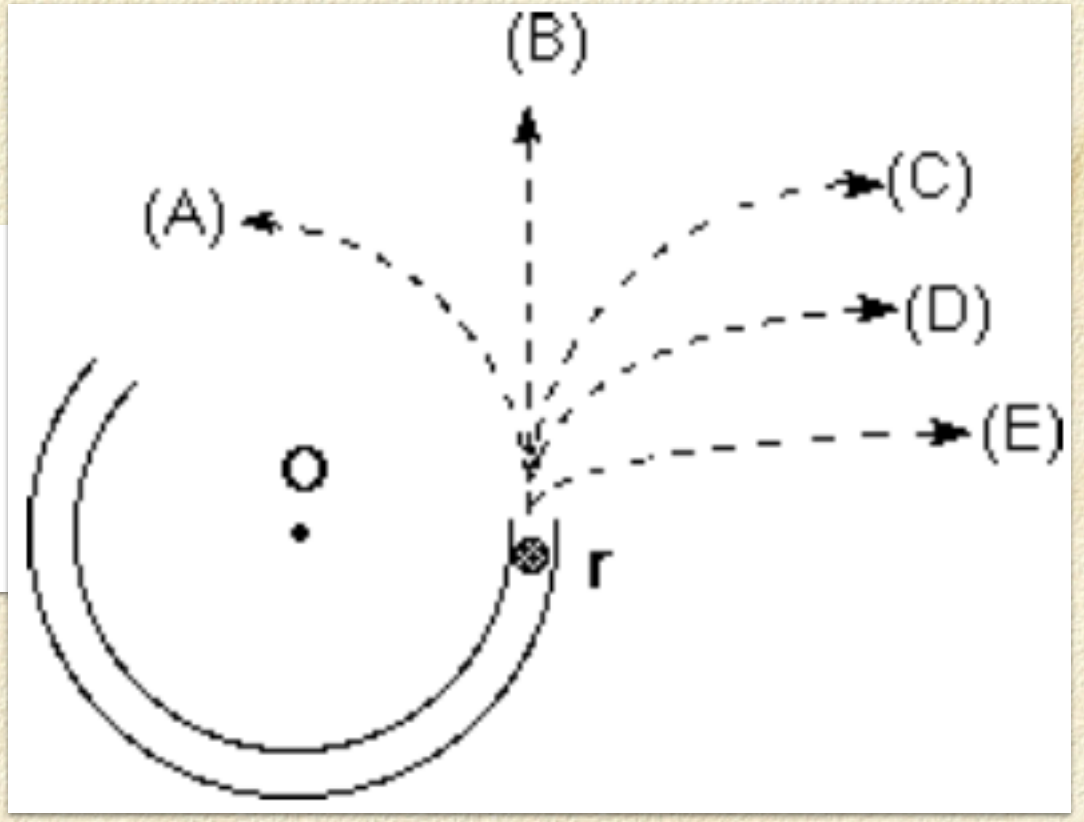
% of students answering by choice (Matched pretest sample N=130, 30 women, 100 men)

	Original-Women	Revised-Women	Original-Men	Revised-Men
A	0	3	6	2
B	**10**	**7**	**15**	**10**
C	48	47	36	26
D	14	23	23	21
E	28	20	20	40

57% of the class changed their answer (47% W, 60% M)

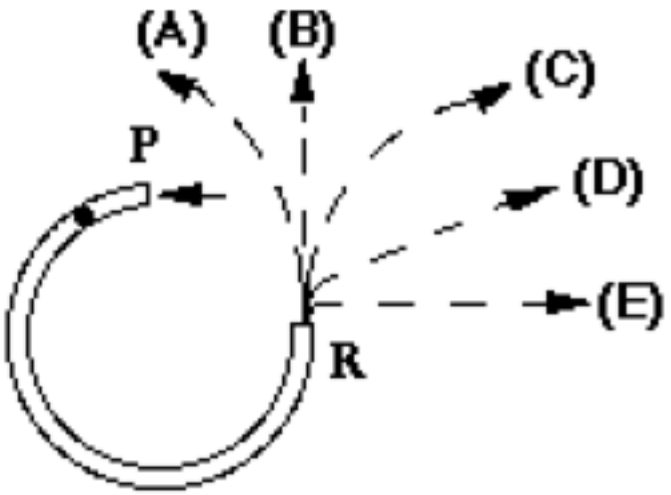
Original Question #6

6. Which path in the figure at right would the ball most closely follow after it exits the channel at "r" and moves across the frictionless table top?



Revised Question #6

6. Which of the paths shown would most nearly correspond to the path of the child as she leaves the horizontal slide and splashes into the pool?



Changed responses by gender

% of students answering by choice (Matched pretest sample N=130, 30 women, 100 men)

	Original-Women	Revised-Women	Original-Men	Revised-Men
A	53	30	10	11
B	**43**	**70**	**76**	**79**
C	3	0	11	9
D	0	0	2	1
E	0	0	0	0

22% of the class changed their answer (33% W, 19% M)

Overall results

- Context does affect response on individual questions
- Different misconceptions are cued by different contexts

Next steps

- Post-test analysis
- Interview students as they work through both versions of questions
- Create alternative phrasings for certain questions
- Eventually create a version of the test that is gender-neutral

Conclusions

- US society needs more scientists
- Women are a good pool to draw upon
- Physics classrooms can promote or inhibit women's participation
- Physics teachers need to be aware of context; can affect student response to the physics classroom

- Thank you very much!
- McCulloughL@uwstout.edu

Gender and the FCI

- Study with 8 different higher education institutions
- Men and women took FCI
- Collected data on pre-test score, post-test score, gender, and where possible, previous physics background

The Problem: Gender gap?

	Pre %	Post %	% Gain
Women (N=780)	35.6 (se=.5)		
Men (N=1997)	50.3 (se=.4)		

The Problem: Gender gap?

	Pre %	Post %	% Gain
Women (N=780)	35.6 (se=.5)	57.4 (se=.7)	
Men (N=1997)	50.3 (se=.4)	68.6 (se=.5)	

The Problem: Gender gap?

	Pre %	Post %	% Gain
Women (N=780)	35.6 (se=.5)	57.4 (se=.7)	21.8 (se=.6)
Men (N=1997)	50.3 (se=.4)	68.6 (se=.5)	18.4 (se=.4)

Individual Questions: #5

The accompanying figure shows a frictionless channel in the shape of a segment of a circle with 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."
Consider the following distinct forces:
1. A downward force of gravity.
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Which of the above forces is (are) acting on the ball when it is within the frictionless channel at position "q"?
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(D) 1, 2, and 3.
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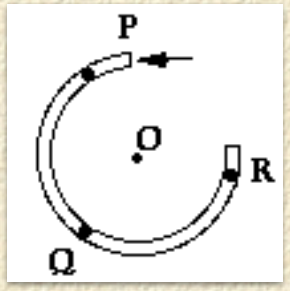

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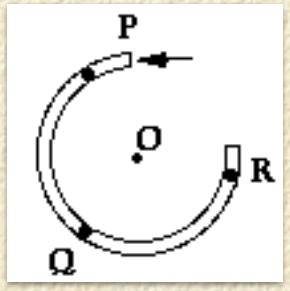
1. A downward force of gravity.
2. A force exerted by the slide pointing from Q to O.
3. A force in the direction of motion.
4. A force pointing from O to Q.

Which of the above forces is (are) acting on the child as she is on the horizontal slide at position "Q"?

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



Changed responses

% of students answering by choice
(Matched pretest sample N=130)

	Original	Revised
A	5	2
B	**14**	**9**
C	39	31
D	21	22
E	22	36

57% of the class changed their answer

Individual Questions: #13

A boy throws a steel ball straight up. Consider the motion of the ball only after it has left the boy's hand but before it touches the ground, and assume that forces exerted by the air are negligible. For these conditions, the force(s) acting on the ball is (are):

(A) a downward force of gravity along with a steadily decreasing upward force.

(B) a steadily decreasing upward force from the moment it leaves the boy's hand until it reaches its highest point; on the way down there is a steadily increasing downward force of gravity as the object gets closer to the earth.

(C) an almost constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point; on the way down there is only a constant downward force of gravity.

(D) an almost constant downward force of gravity only.

(E) none of the above. The ball falls back to ground because of its natural tendency to rest on the surface of the earth.

Individual Questions: #13

A girl throws a teddy bear straight up. Consider the motion of the bear only after it has left the girl's hand but before it touches the ground, and assume that forces exerted by the air are negligible. For these conditions, the force(s) acting on the bear is (are):

(A) a downward force of gravity along with a steadily decreasing upward force.

(B) a steadily decreasing upward force from the moment it leaves the girl's hand until it reaches its highest point; on the way down there is a steadily increasing downward force of gravity as the bear gets closer to the earth.

(C) an almost constant downward force of gravity along with an upward force that steadily decreases until the bear reaches its highest point; on the way down there is only a constant downward force of gravity.

(D) an almost constant downward force of gravity only.

(E) none of the above. The bear falls back to the ground because of its natural tendency to rest on the surface of the earth.

Changed responses

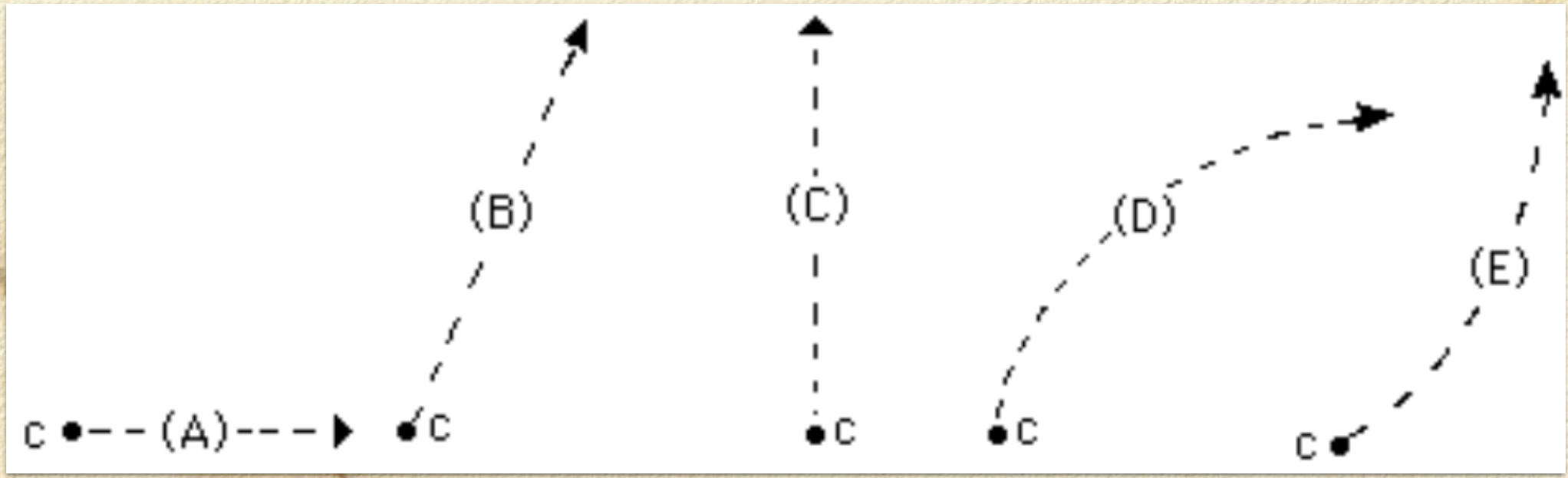
% of students answering by choice
(Matched pretest sample N=130)

	Original	Revised
A	18	14
B	29	24
C	38	50
D	**15**	**12**
E	0	0

49% of the class changed their answer

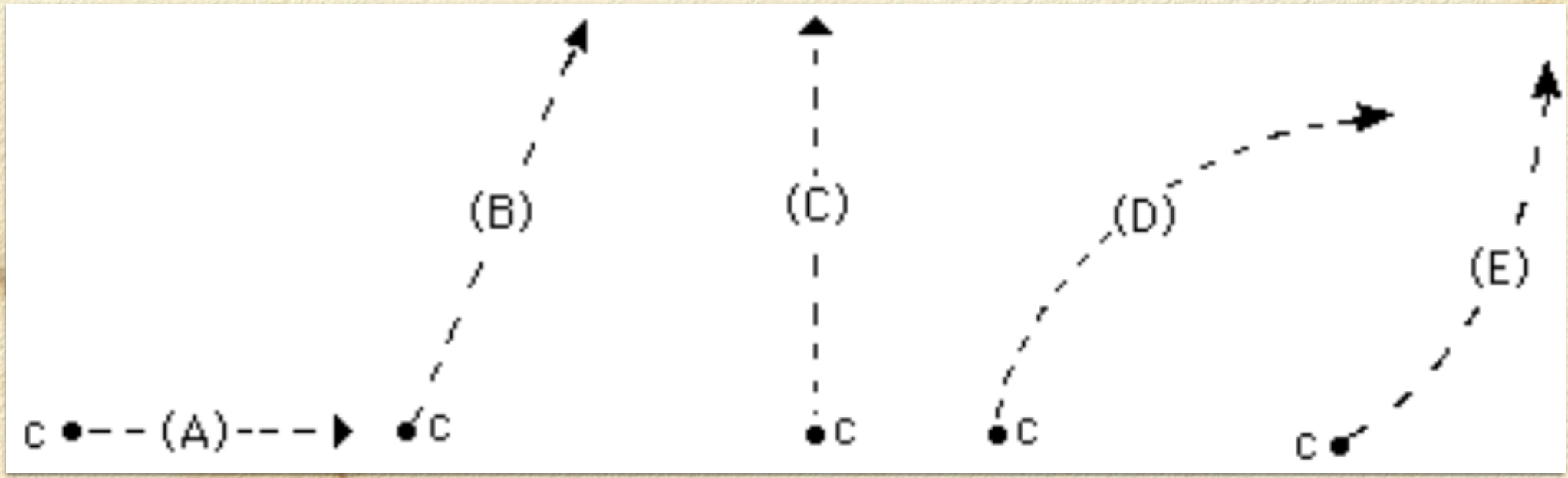
Individual Questions: #23

At point "c" the rocket's engine is turned off and the thrust immediately drops to zero.
Which of the paths below will the rocket follow beyond point "c"?



Individual Questions: #13

At point "c" the extinguisher is suddenly turned off completely. Which of the paths below will you follow beyond "c" as you continue to slide along the frictionless ice?



Changed responses

% of students answering by choice
(Matched pretest sample N=130)

	Original	Revised
A	9	11
B	**30**	**33**
C	17	28
D	37	23
E	6	5

48% of the class changed their answer