

Tracking Steps in Multistep Problems

Bruce Sherwood

Department of Physics
North Carolina State University

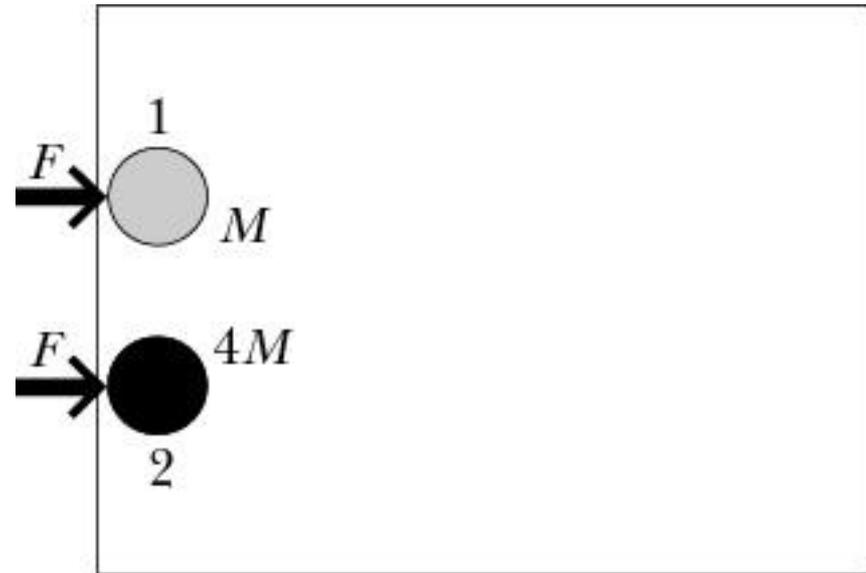
Thanks to Lin Ding for coding NCSU data from final exams.

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Question 1

The diagram depicts two pucks on a frictionless table. Puck 2 is four times as massive as puck 1. Starting from rest, the pucks are pushed across the table by two equal forces. Which puck has the greater kinetic energy after one second? Briefly explain your reasoning.



For closely related questions: T. O'Brien Pride, S. Vokos, and L. C. McDermott, "The challenge of matching learning assessments to teaching goals: An example from the work-energy and impulse-momentum theorems," *Am. J. Phys.* **66**, 147-157 (1998), R. A. Lawson and L. C. McDermott, "Student understanding of the work-energy and impulse-momentum theorems," *Am. J. Phys.* **55**, 811-817 (1987), and D. Hestenes and M. Wells, "A mechanics baseline test," *Physics Teacher* 30 (3), 159-166 (1992).

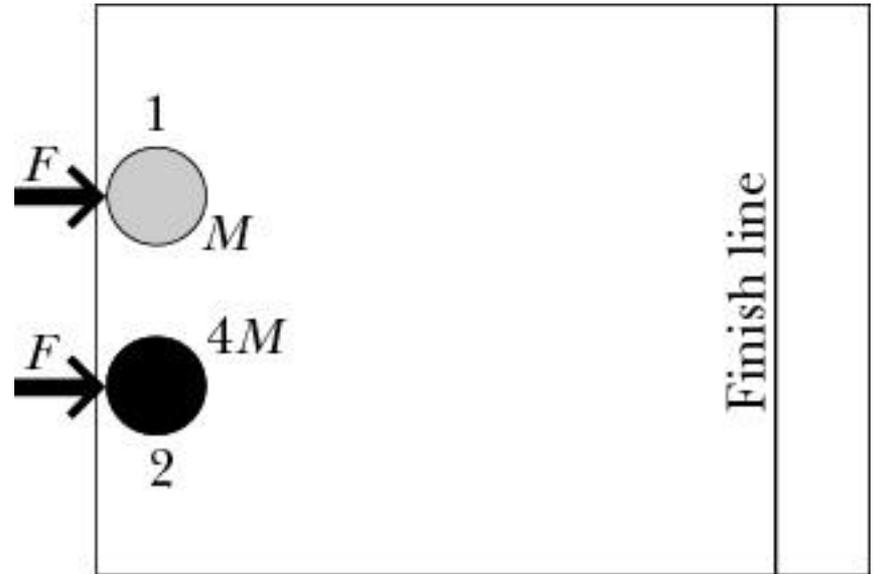
Coding Question 1

- 0 Do nothing
- 1 Start the problem
- 2 Choose a physics principle
- 3 Choose the impulse/momentum relation
- 4 Note impulse is the same
- 5 Conclude final momentum is the same
- 6 Determine kinetic energy from momentum (or speed)
- 7 Conclude lighter puck has more kinetic energy

Do students fail to start from a physics principle, or do they fail to complete the multistep reasoning chain?

Question 2

The diagram depicts two pucks on a frictionless table. Puck 2 is four times as massive as puck 1. Starting from rest, the pucks are pushed across the table by two equal forces. Which puck has the greater kinetic energy upon reaching the finish line? Briefly explain your reasoning.



Coding Question 2

- 0 Do nothing
- 1 Start the problem
- 2 Choose a physics principle
- 3 Choose the work/energy relation
- 4 Note work is the same
- 5 Conclude final kinetic energies are the same

**Do students fail to start from a physics principle, or do they fail to complete the multistep reasoning chain?
(Note: fewer steps in Question 2 than in Question 1.)**

Final exam study

Final exam, NCSU, Fall 2004

Not known to students:

- Three different versions of the questions

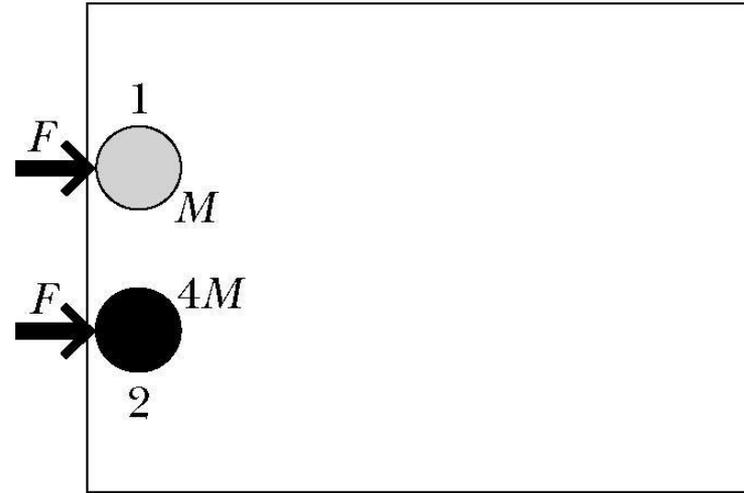
- Scores on these questions excluded from exam grade

Interrater reliability of coding about 85%

Condition: No prompt

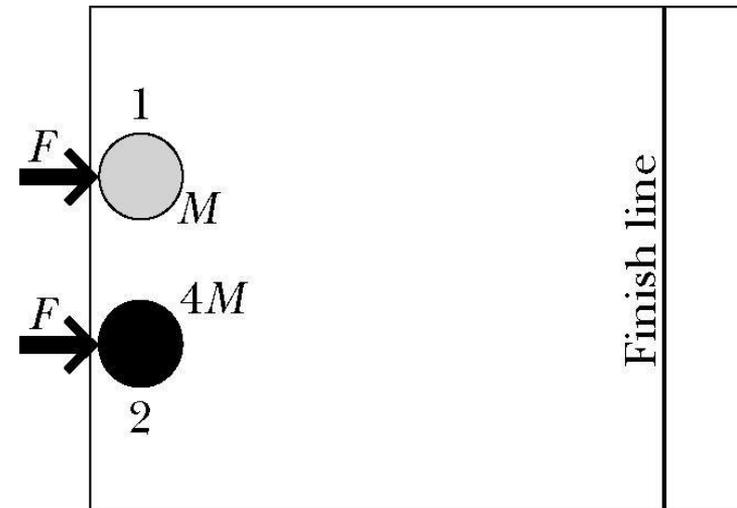
Problem 1 (5 pts)

The diagram depicts two pucks on a frictionless table. Puck 2 is four times as massive as puck 1. Starting from rest, the pucks are pushed across the table by two equal forces. Which puck has the greater kinetic energy after one second? Briefly explain your reasoning.



Problem 2 (5 pts)

The diagram depicts two pucks on a frictionless table. Puck 2 is four times as massive as puck 1. Starting from rest, the pucks are pushed across the table by two equal forces. Which puck has the greater kinetic energy upon reaching the finish line? Briefly explain your reasoning.

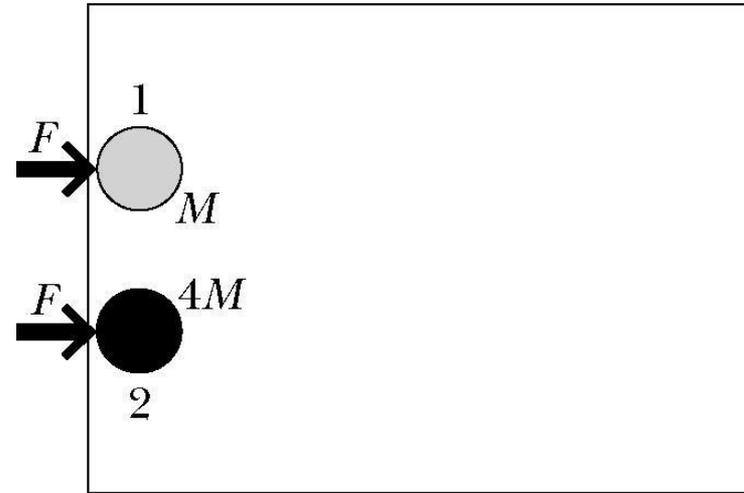


Condition: Prompt for physics principle

Problem 1 (5 pts)

The diagram depicts two pucks on a frictionless table. Puck 2 is four times as massive as puck 1. Starting from rest, the pucks are pushed across the table by two equal forces. Which puck has the greater kinetic energy after one second? Briefly explain your reasoning. **Start from a fundamental principle!**

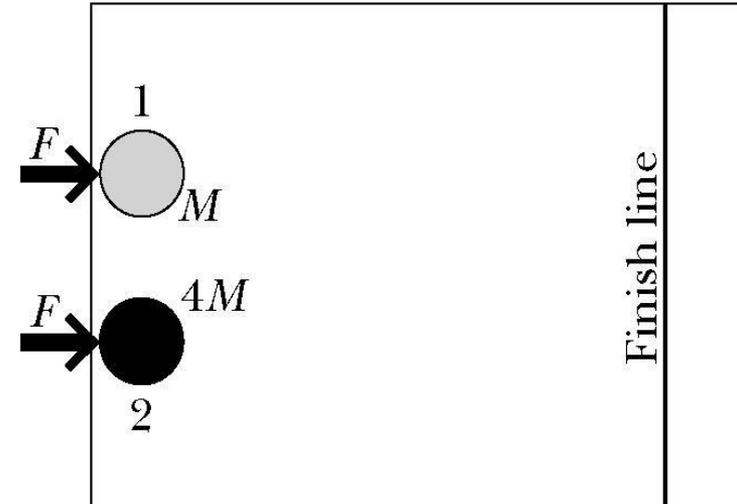
(Reasoning not based on a fundamental physics principle will receive no credit.)



Problem 2 (5 pts)

The diagram depicts two pucks on a frictionless table. Puck 2 is four times as massive as puck 1. Starting from rest, the pucks are pushed across the table by two equal forces. Which puck has the greater kinetic energy upon reaching the finish line? Briefly explain your reasoning. **Start from a fundamental principle!**

(Reasoning not based on a fundamental physics principle will receive no credit.)

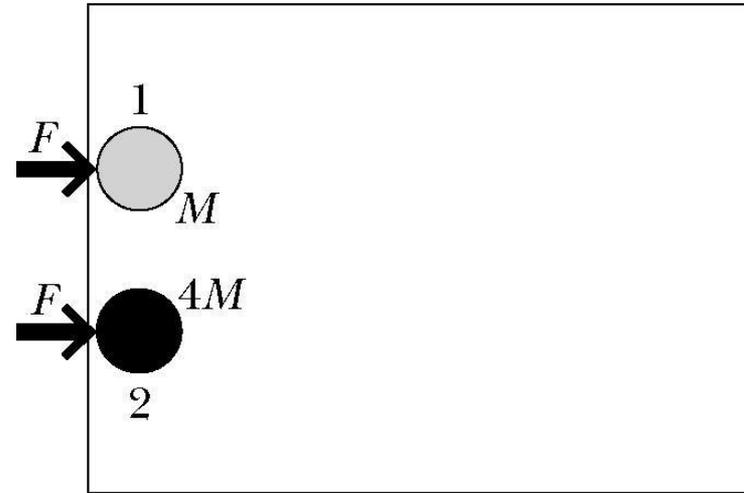


Condition: Prompt for correct physics principle

Problem 1 (5 pts)

The diagram depicts two pucks on a frictionless table. Puck 2 is four times as massive as puck 1. Starting from rest, the pucks are pushed across the table by two equal forces. Which puck has the greater kinetic energy after one second? Briefly explain your reasoning. **Start from the momentum principle.**

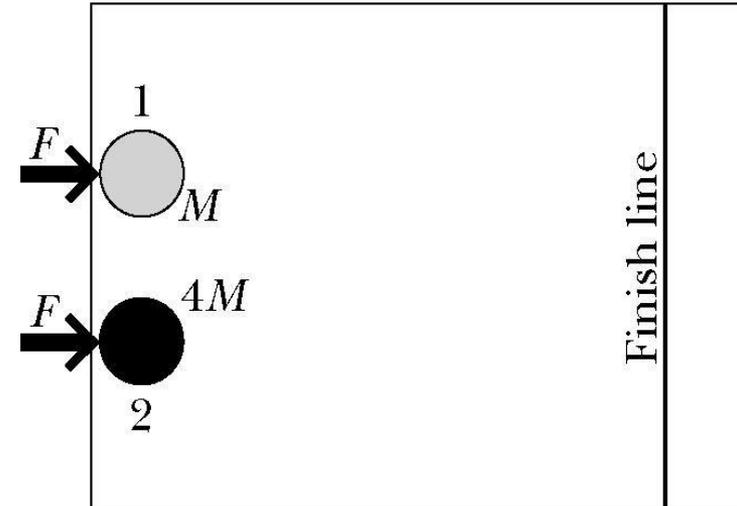
(Reasoning not based on the momentum principle will receive no credit.)

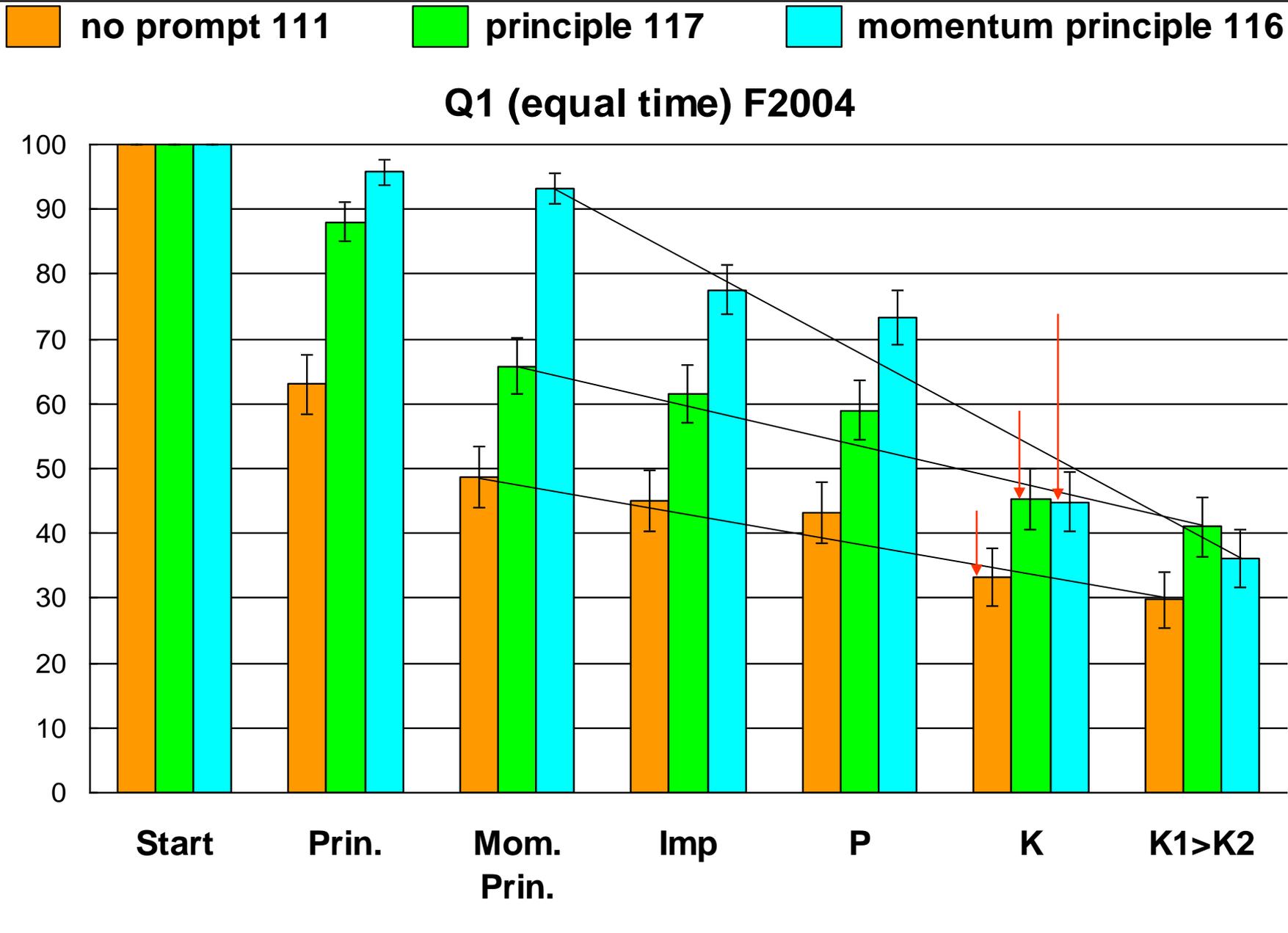


Problem 2 (5 pts)

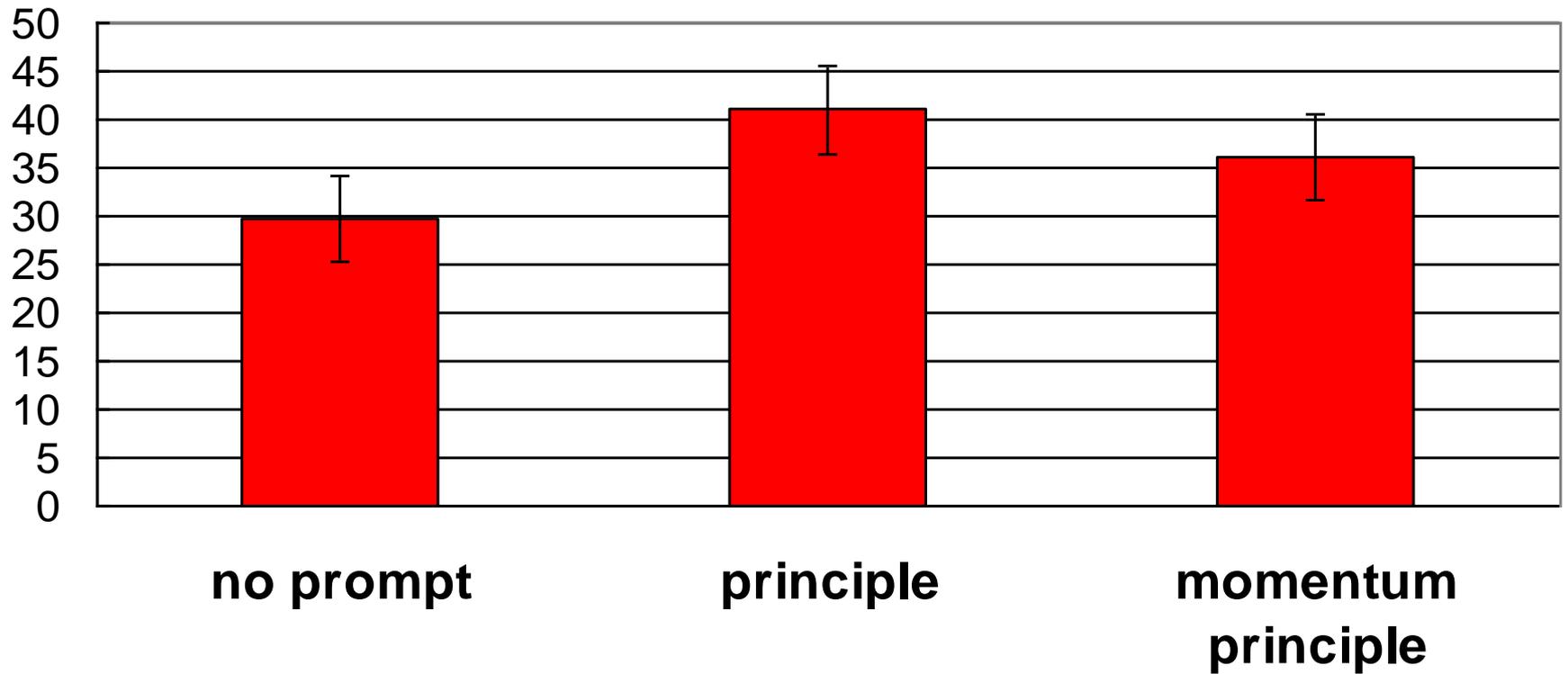
The diagram depicts two pucks on a frictionless table. Puck 2 is four times as massive as puck 1. Starting from rest, the pucks are pushed across the table by two equal forces. Which puck has the greater kinetic energy upon reaching the finish line? Briefly explain your reasoning. **Start from the energy principle.**

(Reasoning not based on the energy principle will receive no credit.)



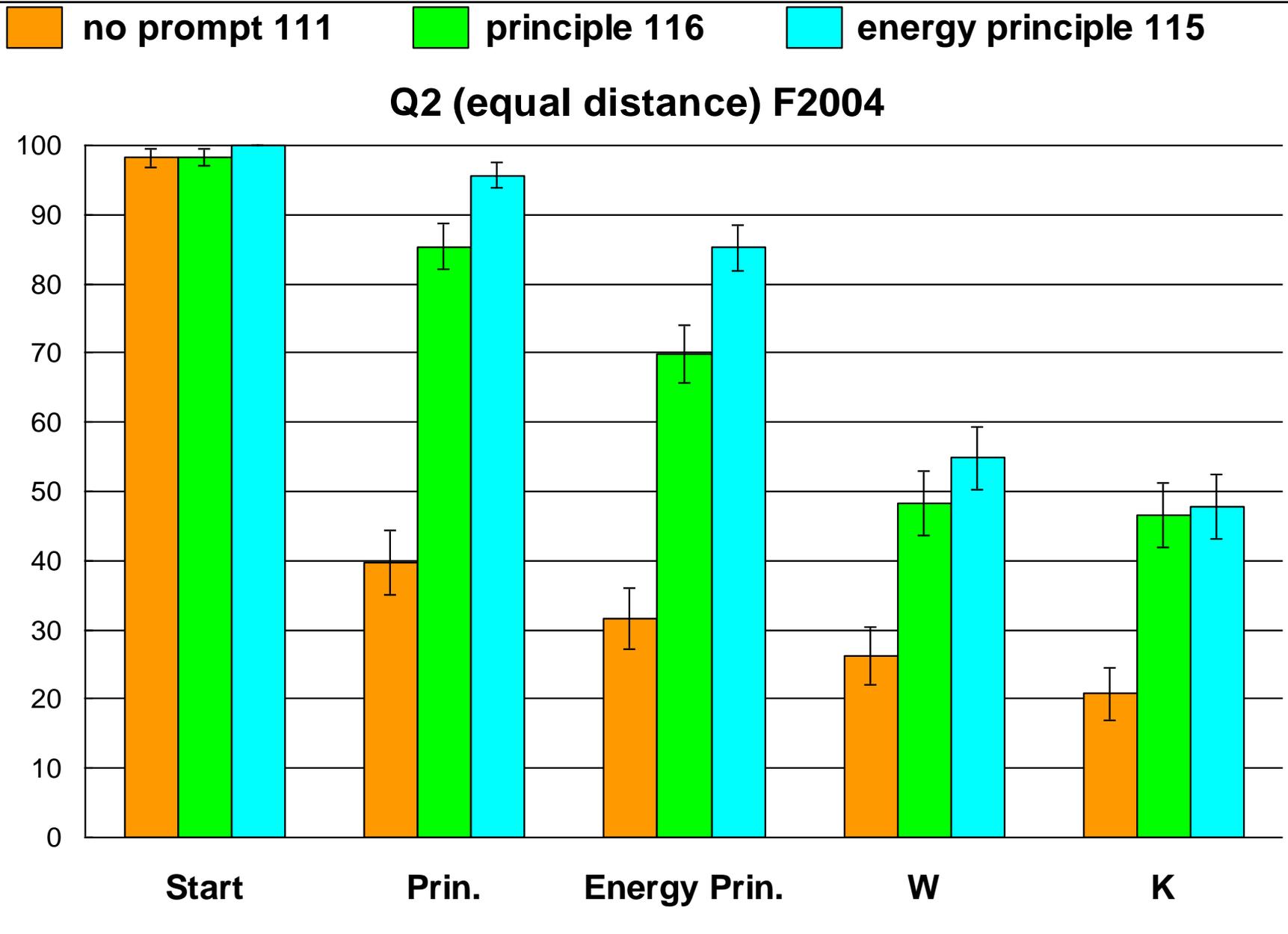


Q1 % correct vs. prompt type

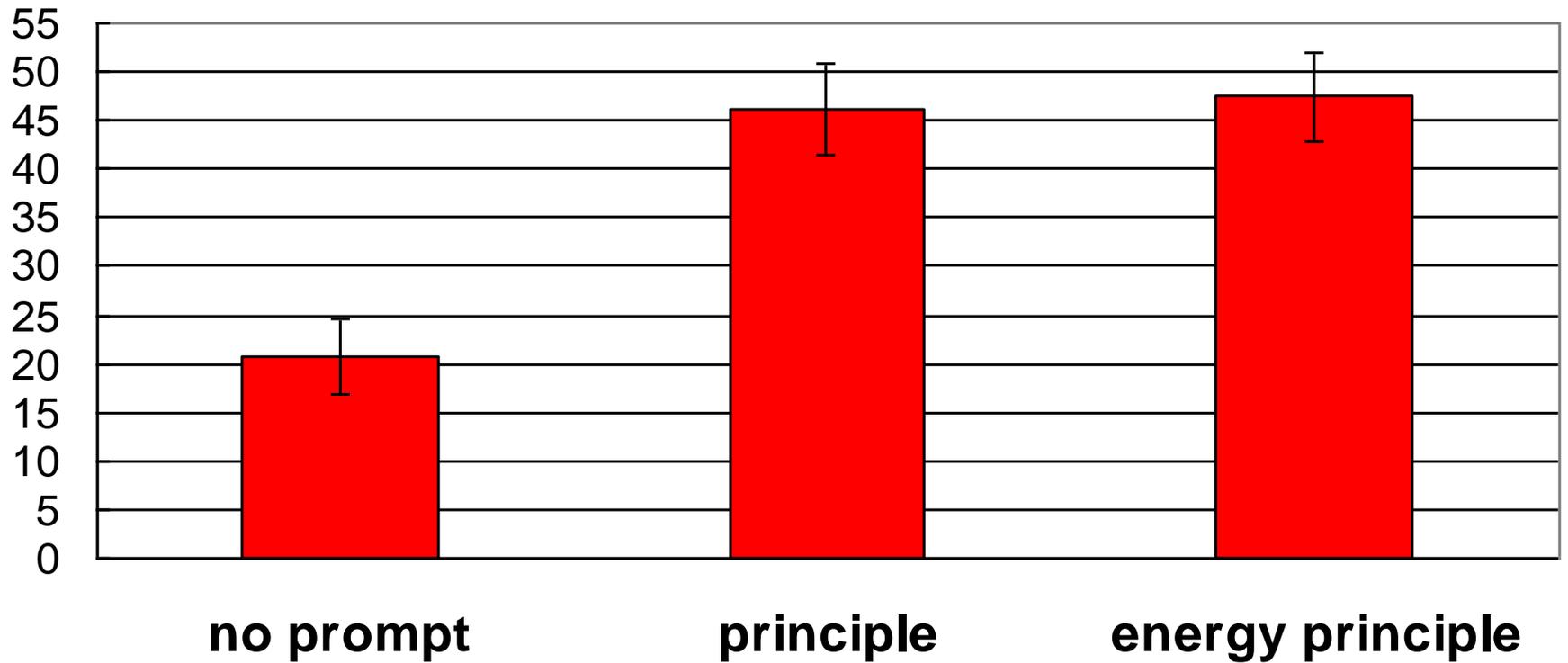


Q1: Choosing a Principle, vs. Multistep Reasoning Chain

- Only 60% of the students started with a principle if not prompted.
- Starting from a principle is necessary but not sufficient.
- The reasoning chain was so long that prompting to start with a principle didn't make much difference.

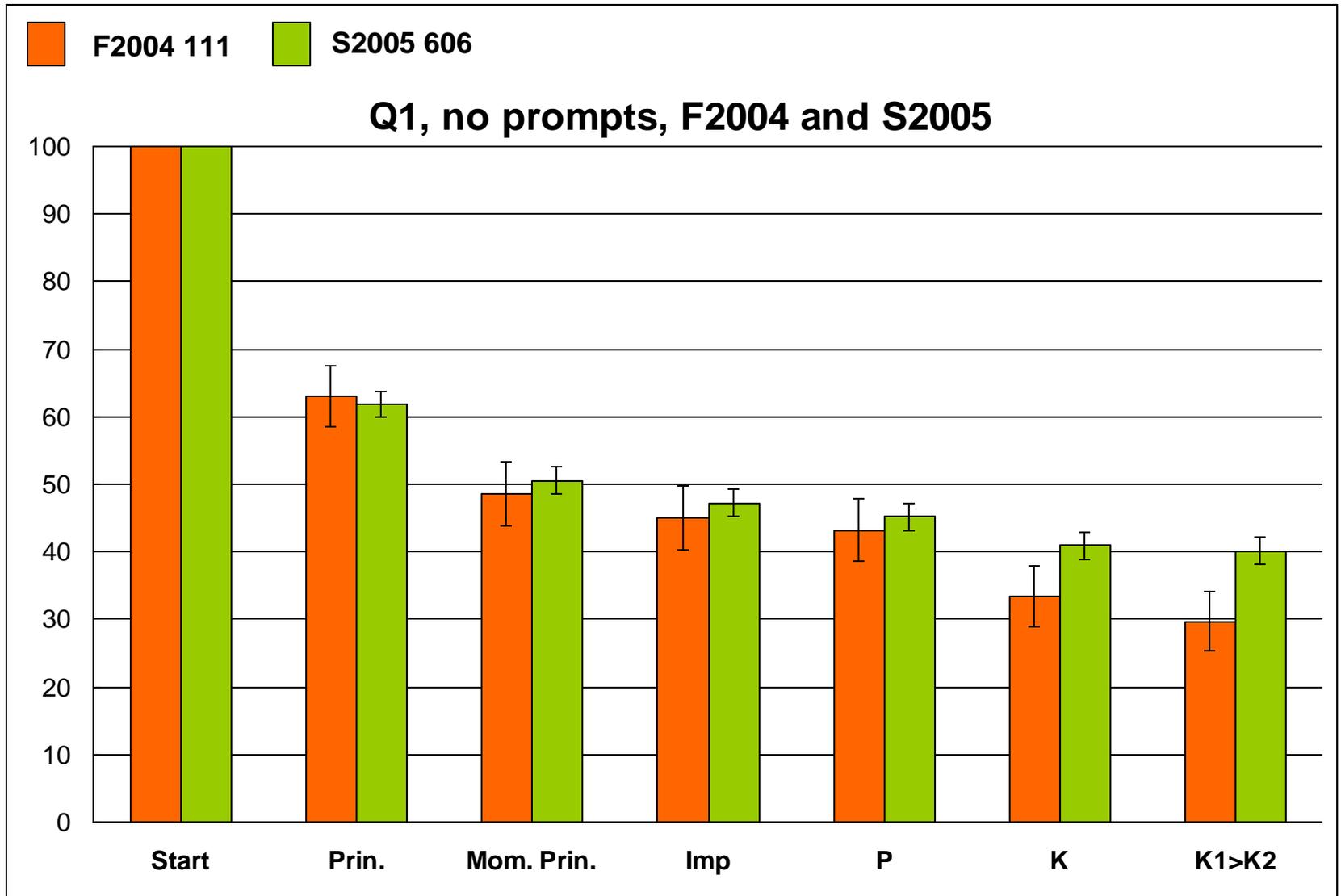


Q2 % correct vs. prompt type

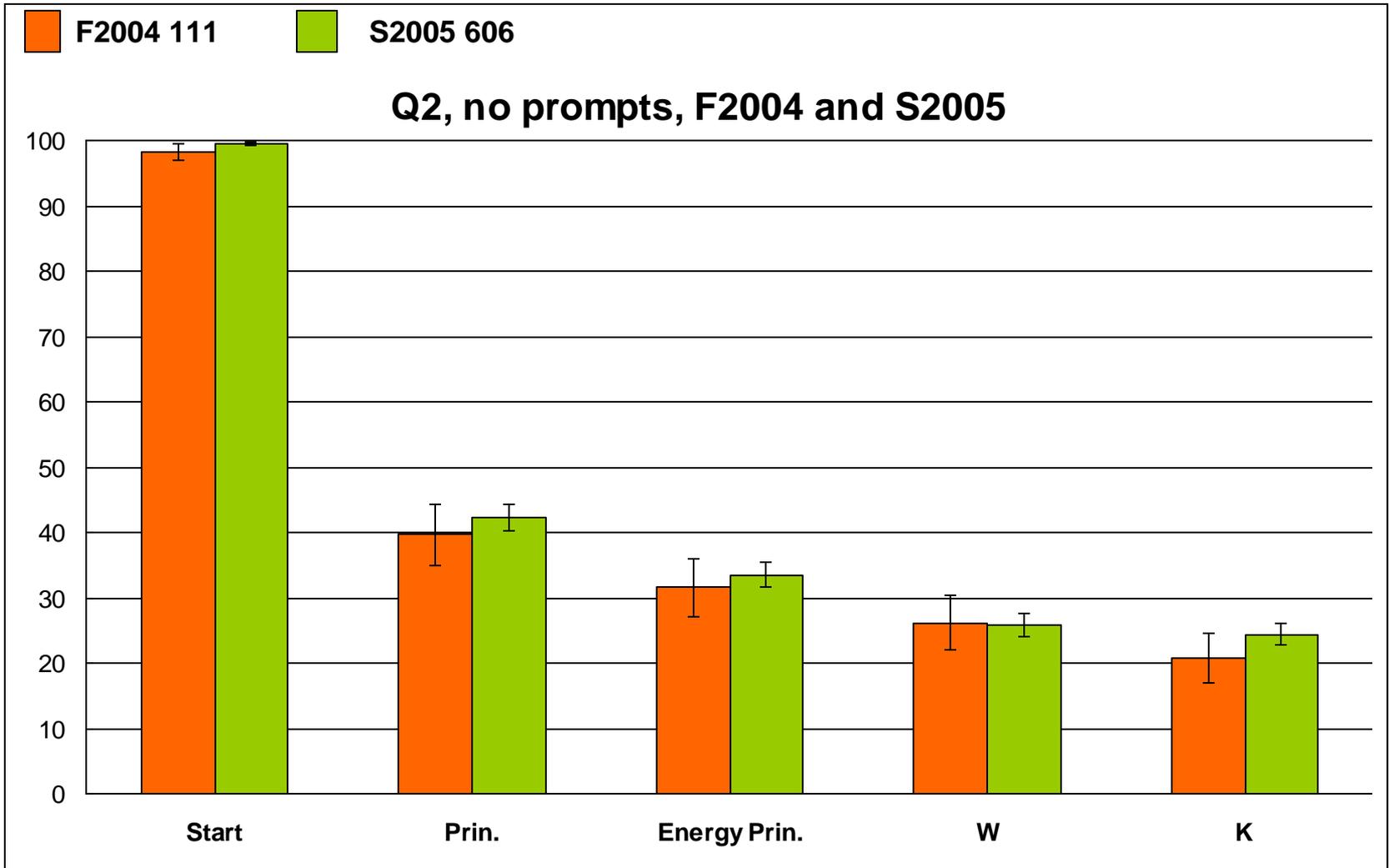


Q2: Choosing a Principle, vs. Multistep Reasoning Chain

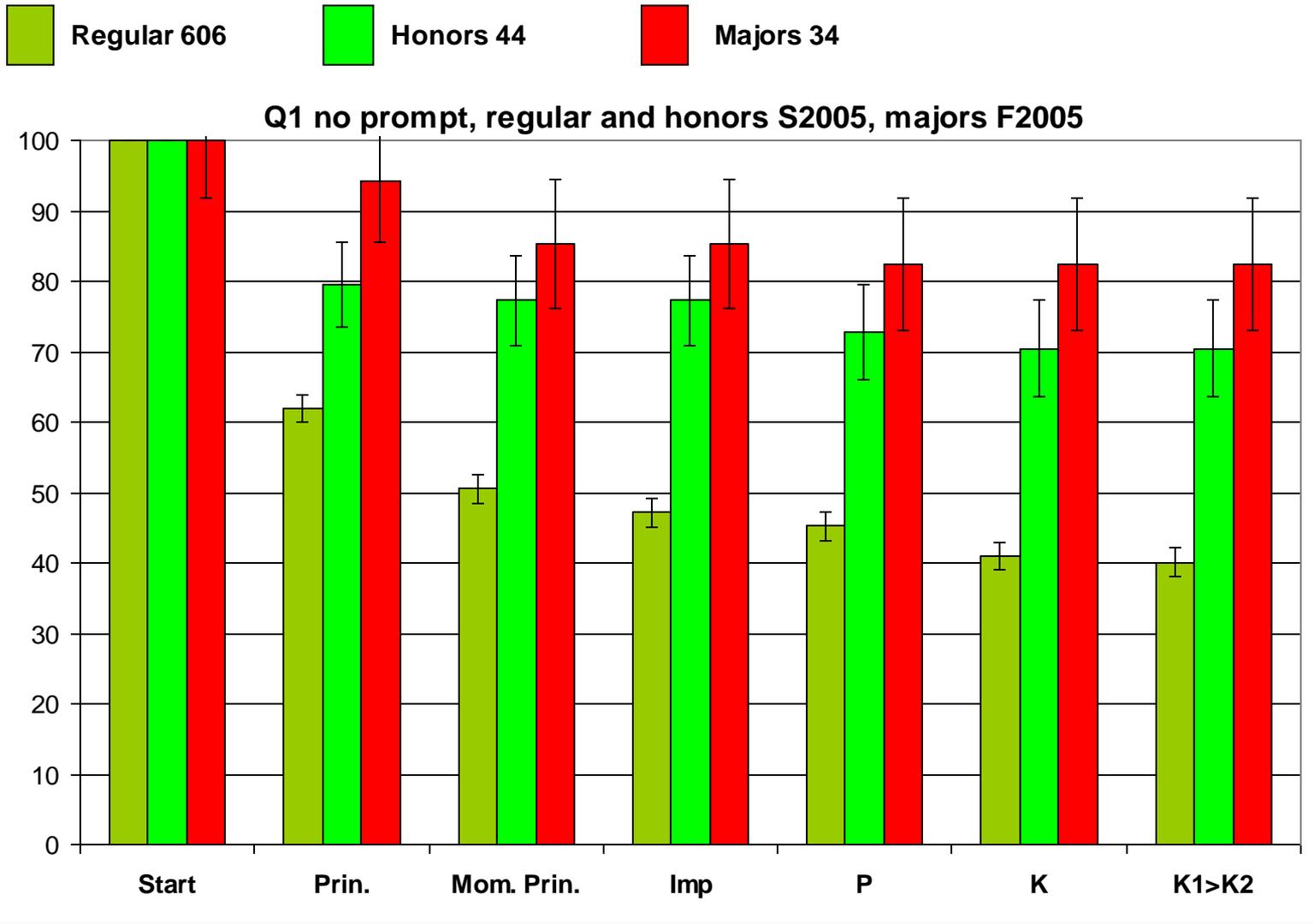
- Only half of those students who started with a principle could carry out the multistep reasoning.
- Only 40% started with a principle if not prompted.
- So only 20% were correct if not prompted.



Same % choice of principle; better reasoning chain S2005

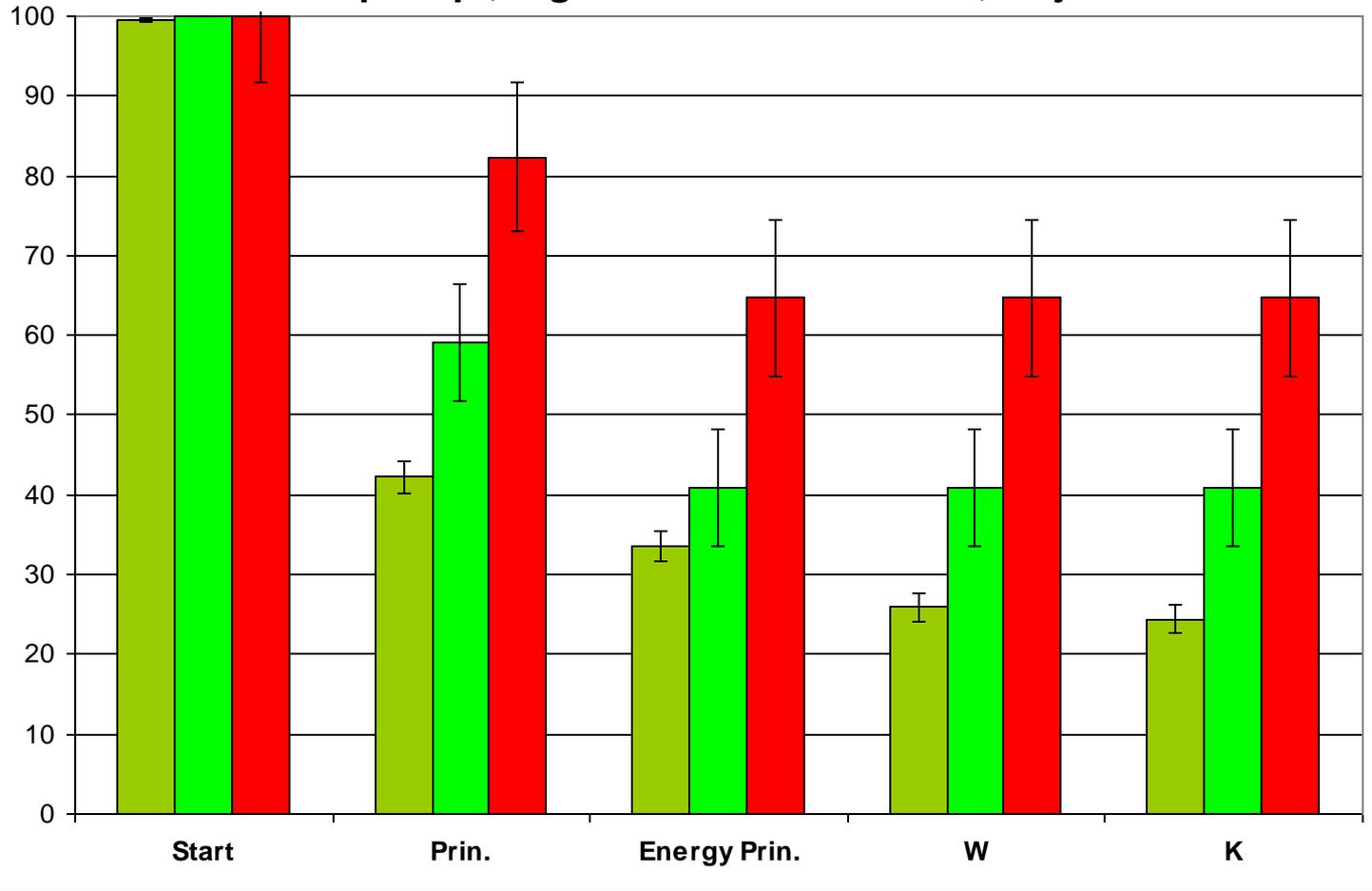


Same low % choice of principle; reasoning chain about the same; note that Q2 has shorter reasoning chain



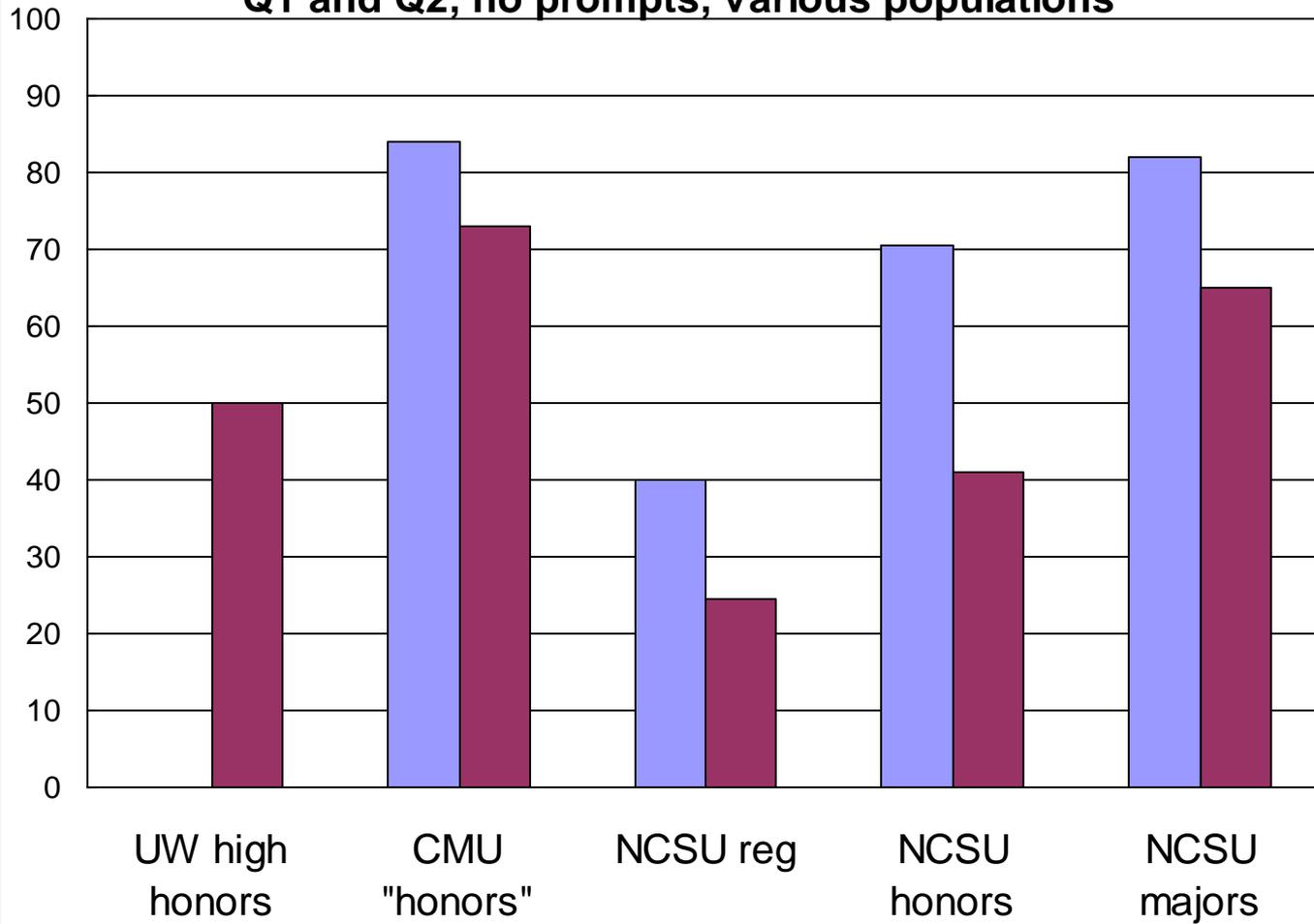
Regular 606 Honors 44 Majors 34

Q2 no prompt, regular and honors S2005, majors F2005



Q1 Q2

Q1 and Q2, no prompts, various populations



Conclusion

Two important factors

- Invoking a physics principle
- Long chain of reasoning