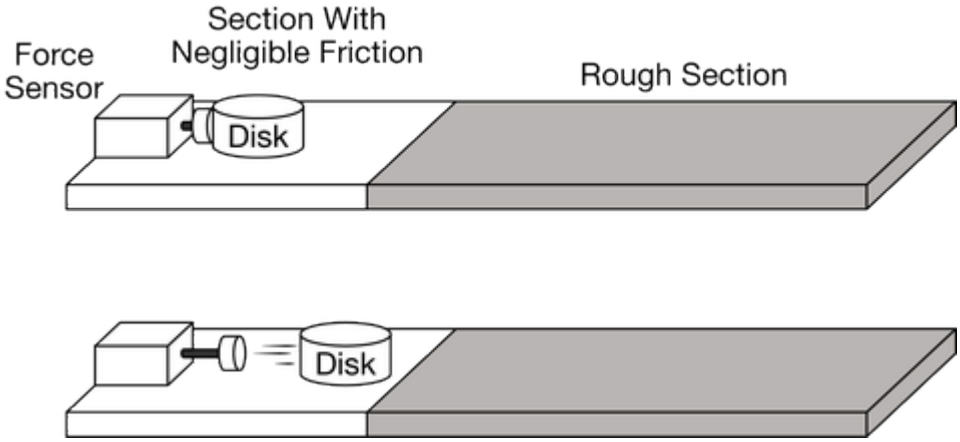
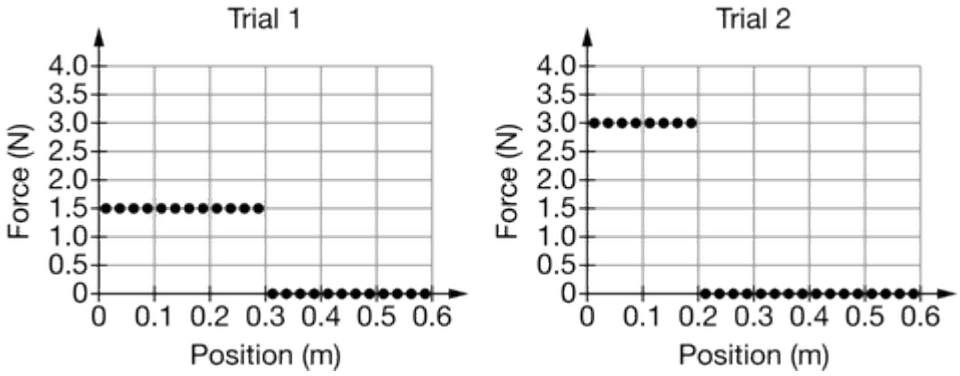
Unit 5 Summative Questions

14. This question is a long free-response question. Show your work for each part of the question. (15 points, suggested time 25 minutes)



Students use a force sensor to push a disk of mass m across a horizontal table. The force sensor pushes the disk over a short distance. The magnitude of the force and the distance the disk is pushed can be set by the students. After being pushed by the sensor, the disk first slides along a surface with negligible friction and then enters a rough section where friction is not negligible, as shown above.

The students perform two trials in which the magnitude of the force exerted by the force sensor and the distance the disk is pushed are different. They create the graphs of force as a function of position shown below. The disk enters the rough surface in each trial after moving 0.6 meters.



(a) In which of the two trials, if either, is the change in energy of the disk the greatest during the interval shown in the graphs? Explain your reasoning.

(b) In both trials, the disk comes to rest in the rough section before reaching the edge of the table. In which trial, if either, does the disk travel a shorter distance in the rough section? Explain your reasoning.

(c) The students repeat Trial 2 with a disk that is made from the same material as the original disk but that is less massive. The same constant force is exerted on the less massive disk over the same distance as in Trial 2. Would the distance traveled in the rough section by the less massive disk be greater than, less than, or the same as the

Unit 5 Summative Questions

distance traveled in the rough section by the original disk in Trial 2? Explain your reasoning.

Students derive the following equation, which may or may not be correct, to describe the distance D traveled by the original disk in Trial 2 on the rough section: $D = \frac{Fx}{\mu mg}$, where F is the force exerted by the sensor, x is the distance over which the sensor exerts a force on the disk, μ (mu) is the coefficient of kinetic friction, and m is the mass of the disk.

(d) Without algebraic manipulation of equations or attempting to derive this equation, indicate whether the equation is consistent with your answer in part (b). Explain your reasoning.

A student measures the time t that the disk is in contact with the force sensor in Trial 2. The disk then travels a distance D along the rough section. The student claims that if the same force is exerted on the disk for a time $2t$, the disk would travel a distance $2D$ in the rough section.

(e) Is the above claim correct or incorrect? Justify your answer without citing or manipulating equations.

The student finds the following equation on the Internet describing the relationship between the time t the disk is pushed and the distance D it slides in the rough section: $D = C\frac{F^2t^2}{2\mu m^2 g}$, where C is a constant with appropriate units.

(f) Indicate whether or not the above equation is consistent with your statement in part (e) relating D and t. Explain your reasoning.

Part A

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

0	1	2	3 ✓

The response accurately includes **all** of the following criteria.

- ☐ 1 point is earned for indicating that trial 2 has the graph with the greatest area under the curve
  OR
  For recognizing that the acceleration can be determined from the force.
- ☐ 1 point is earned for indicating the area represents the work done
  OR
  For addressing that the mass value is the same OR need not be known.
- ☐ 1 point is earned for relating the greatest work done to the greatest change in energy
  OR
  For correct application of kinematics including the use of the distance traveled.

Example Response:

Trial 2. The work done on the disk is represented by the area under the force vs position graph, so the graph with the largest area under the curve has the greatest work done on it. Graph 2 has the greatest area, and so the disk in trial 2 had

Unit 5 Summative Questions

the greatest amount of work done on it.

Part B

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

0	1	2 ✓

The response accurately includes **both** of the following criteria.

- ☐ 1 point is earned for indicating that the disk experiences the same frictional force in both trials, so the acceleration will be the same for both disks.
- ☐ 1 point is earned for indicating that the disk with the smaller launch speed will travel a shorter distance in the rough section.

Example Response:

Trial 1. The disk experiences the same frictional force in both trials, so the acceleration will be the same for both disks. This means that the disk with the smaller speed after the push will travel a smaller distance.

Part C

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

0	1	2	3 ✓

The response accurately includes **all** of the following criteria.

- ☐ 1 point is earned for indicating a less massive disk would have a greater launch speed with the same force over the same distance.
- ☐ 1 point is earned for indicating that the distance traveled in the rough section, for a given speed, does not depend on the mass of the disk.
- ☐ 1 point is earned for indicating that the less massive disk will travel farther before stopping.

Example Response:

Farther than the original disk in trial 2. When pushed by the same force over the same distance, a less massive disk would have a larger launch speed. Since the mass of the disk doesn't affect the distance traveled through the rough section, the less massive disk will travel farther before stopping.

Part D

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

Unit 5 Summative Questions

0	1	2 ✓

The response accurately includes **both** of the following criteria.

- ☐ 1 point is earned for an answer consistent with part (b), with an attempt to use the functional dependence of D on F and/or x.
- ☐ 1 point is earned for correct reasoning (i.e., that Fx is greater in Trial 2, so D is greater).

Example Response:

This equation matches my reasoning in part (b). Since D is inversely proportional mass, if the mass increases, the distance D decreases, since m is in the numerator.

Part E

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

Correct answer: “Incorrect”.

0	1	2	3 ✓

The response accurately includes **all** of the following criteria.

- ☐ 1 point is earned for indicating a disk that is pushed for twice the time will have twice the speed.
- ☐ 1 point is earned for a correct application of conservation of energy or work for the disk in the rough section.
- ☐ 1 point is earned for indicating that the stopping distance is proportional to kinetic energy, not speed.

Example Response:

A disk that is pushed from rest with the same force for twice the time will have twice the momentum. Since the mass of the disk doesn’t change, the second disk will have twice the speed. However, the stopping distance is proportional to the kinetic energy which is proportional to the velocity squared.

Part F

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

Unit 5 Summative Questions

0	1	2 ✓

The response accurately includes **both** of the following criteria.

- ☐ 1 point is earned for indicating the equation is consistent (or inconsistent) with the statement in part (e) AND an attempt at a justification using functional dependence.
- ☐ 1 point is earned for indicating that the distance is proportional to *t* squared.

Example Response:

It is consistent. If t is doubled, the distance traveled should quadruple, because D is proportional to t squared.