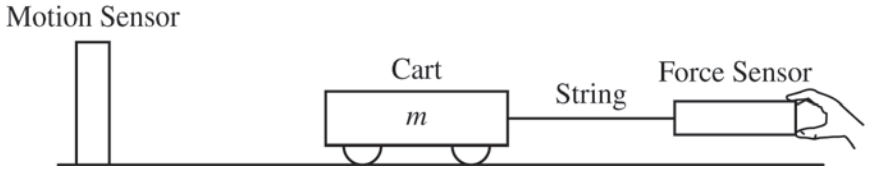
PHYSICS C: MECHANICS
SECTION II
Time—45 minutes
3 Questions

Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part.



Mech.1.

A cart of mass m is pulled along a level dynamics track as shown above. A force sensor is attached to the cart with a string and used to measure the horizontal force exerted on the cart to the right. A motion sensor is used to measure the acceleration of the cart with the positive direction toward the right. Friction is not negligible.

(a) On the dot below, which represents the cart, draw and label the forces (not components) that act on the cart. Each force must be represented by a distinct arrow starting on, and pointing away from, the dot.

A student pulls the force sensor with a constant force, and the cart accelerates. This is repeated for several trials, with a different constant force used for each trial. The data are recorded in the table below.

Trial	1	2	3	4	5
Force sensor reading (N)	0.32	0.38	0.44	0.50	0.60
Acceleration $\left(\mathrm{m/s^2}\right)$	0.12	0.22	0.33	0.50	0.70

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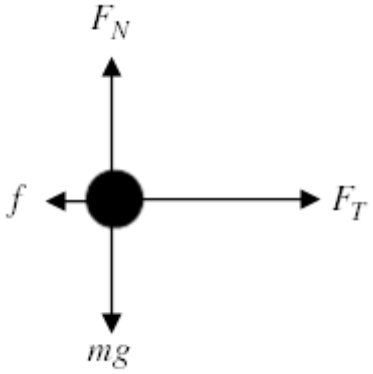
Question 1

15 points total **Distribution of points**

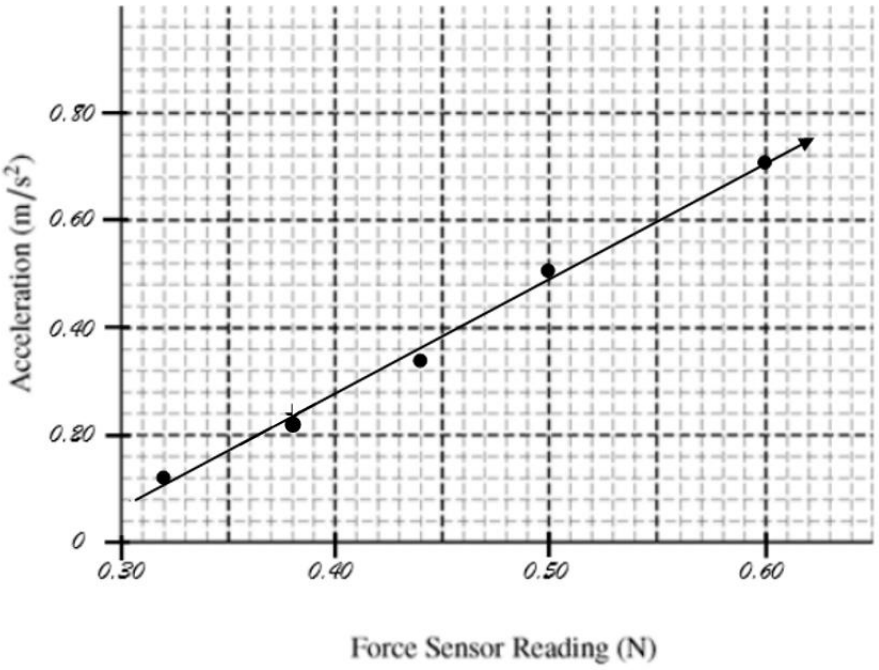
(a) 3 points



For correctly drawing and labeling the force of tension 1 point
For correctly drawing and labeling the force of friction 1 point
For correctly drawing and labeling both forces in the vertical direction 1 point
Note: A maximum of two points may be earned if there are any extraneous vectors.

(b)

i. 3 points



For a correct scale that uses more than half the grid 1 point
For correctly plotting the given data 1 point
For drawing a straight line consistent with the given data 1 point
Note: Full credit can be earned if the axes are switched.

Question 1 (continued)

Distribution of points

(b)

ii. 2 points

For correctly calculating slope using the best-fit straight line and not data points — 1 point

$$\text{slope} = \frac{(y_2 - y_1)}{(x_2 - x_1)} = \frac{(0.70 - 0.16)}{(0.60 - 0.35)}\text{kg}^{-1} = 2.16\ \text{kg}^{-1}$$

Note: Linear regression gives slope $= 2.12\ \text{kg}^{-1}$.

For correctly calculating the mass of the cart using the slope — 1 point

$$m = \frac{1}{\text{slope}} = \frac{1}{\left(2.16\ \text{kg}^{-1}\right)}$$

Correct answer:

$m = 0.463\ \text{kg}$ (Note: linear regression gives $m = 0.472\ \text{kg}$)

iii. 1 point

For an answer with correct units consistent with the x-intercept of the graph from (b) i. — 1 point

$f = 0.272\ \text{N}$

(c)

i. 1 point

Applying Newton's second law and substituting the values from part (b)

$$\sum F = ma = F_a - f$$

$$a = \frac{F_a - f}{m} = \frac{0.45\ \text{N} - 0.272\ \text{N}}{0.463\ \text{kg}}$$

For an answer with correct units consistent with part (b), either from the graph or calculated using the mass and frictional force. — 1 point

$a = 0.376\ \text{m/s}^2$

Question 1 (continued)

Distribution of points

(c)

ii. 3 points

For using a correct equation to solve for the speed of the cart when the string breaks, with an acceleration consistent with part (c) i. — 1 point

$v_2 = v_1 + at$

$v_2 = 0 + \left(0.376 \text{ m/s}^2\right)(2.0 \text{ s})$

$v_2 = 0.752 \text{ m/s}$

For recognizing that the acceleration of the cart after the string breaks is due to the frictional force determined in part (b) — 1 point

Use a correct equation to solve for the time for the cart to stop after the string breaks

$v_2 = v_1 + at$

$0 = v_1 - \frac{f}{m}t$

For using the final velocity before the string breaks as the initial velocity for the cart stopping in the correct equation for time — 1 point

$t = \frac{mv_1}{f}$

$t = \frac{(0.463 \text{ kg})(0.752 \text{ m/s})}{(0.272 \text{ N})}$

Correct answer

$t = 1.28 \text{ s}$

Alternate solution — *Alternate points*

For setting the magnitude of the impulse before the string breaks equal to the magnitude of the impulse after the string breaks — *1 point*

$F_1 t_1 = F_2 t_2$

For correctly using the proper force (e.g., the tension force minus the friction force) for F_1 — *1 point*

For correctly using the proper force (e.g., the friction force) for F_2 — *1 point*

Correct answer

$t = 1.28 \text{ s}$

(d)

i. 1 point

For selecting "Equal to" — 1 point

ii. 1 point

For selecting "Greater than" — 1 point