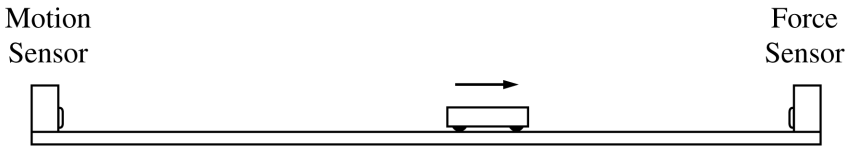
PHYSICS C

Section II, MECHANICS

Time—45 minutes

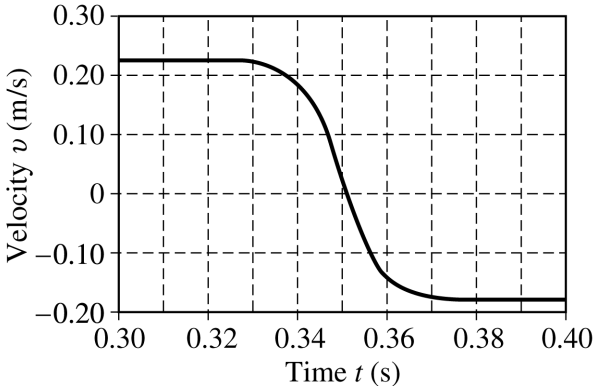
3 Questions

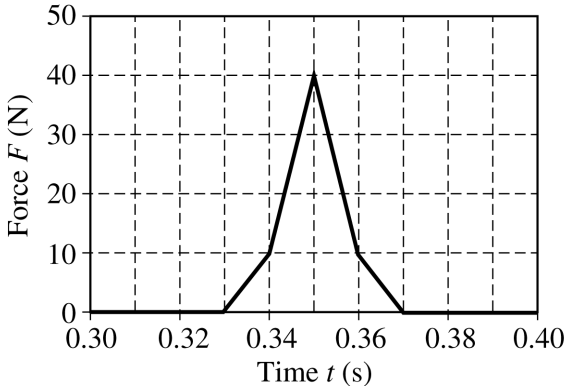
Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in the pink booklet in the spaces provided after each part, NOT in this green insert.



Mech 1.

A motion sensor and a force sensor record the motion of a cart along a track, as shown above. The cart is given a push so that it moves toward the force sensor and then collides with it. The two sensors record the values shown in the following graphs.





(a) Determine the cart's average acceleration between $t = 0.33$ s and $t = 0.37$ s.

(b) Determine the magnitude of the change in the cart's momentum during the collision.

(c) Determine the mass of the cart.

(d) Determine the energy lost in the collision between the force sensor and the cart.

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Question 1

15 points total

1. (a) **6 points** **Distribution of Points**

The average acceleration is the change in velocity divided by the time interval

For correct subtraction to find the time interval **1 point**

$\Delta t = t_f - t_i = 0.37 - 0.33 = 0.04$ s

From graph: $v_i = 0.22$ m/s

For getting v_i in the range $0.2 < v_i \leq 0.25$ m/s **1 point**

From graph: $v_f = -0.18$ m/s

For getting v_f in the range $-0.15 \geq v_f > -0.20$ m/s **1 point**

For getting Δv consistent with the student's values of v_i and v_f, including subtracting in the correct direction **1 point**

$\Delta v = v_f - v_i = -0.18 \text{ m/s} - 0.22 \text{ m/s} = -0.40 \text{ m/s}$

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{-0.4 \text{ m/s}}{0.04 \text{ s}}$$

For correct substitution of values in the above equation **1 point**

$\bar{a} = -10 \text{ m/s}^2$

For showing deceleration (e.g., with a minus sign) **1 point**

Note: There were three alternate methods for solving parts (b) and (c) that could receive full credit.

Method 1.

1. (b) **3 points**

For any indication of the concept of finding the area under the curve in the second graph **1 point**

$\Delta p = \int F\,dt$ or $\Delta p =$ the area under the F *vs.* t curve

$\Delta p = 0.6 \text{ N} \cdot \text{s}$ or $\Delta p = 0.6 \ \frac{\text{kg} \cdot \text{m}}{\text{s}}$

For correct numerical value of 0.6 **1 point**

For correct units **1 point**

1. (c) **2 points**

For any statement of the correct equation for the change in momentum **1 point**

$\Delta p = m \Delta v$

For correct substitution of values consistent with those obtained above **1 point**

$$m = \frac{\Delta p}{\Delta v} = \frac{0.6 \text{ N} \cdot \text{s}}{0.4 \text{ m/s}} = 1.5 \text{ kg}$$

Question 1 (cont.)

Method 2.

1. (b) **3 points** **Distribution of Points**

Expressing the change in momentum in terms of the average force:
$\Delta p = \overline{F}\Delta t$

For some method of using the graph to find the average force for the four non-zero intervals such as indicating that the area is equivalent to 6 boxes each with a height of 10 N, so that $\overline{F} = 60/4 = 15 \text{ N}$ **1 point**

$\Delta p = (15 \text{ N})(0.04 \text{ s}) = 0.6 \text{ N}\cdot\text{s}$ or $\Delta p = 0.6 \ \frac{\text{kg}\cdot\text{m}}{\text{s}}$

For correct numerical value of 0.6 **1 point**
For correct units **1 point**

1. (c) **2 points**

Expressing the average force in terms of the average acceleration:
$\overline{F} = m\overline{a}$

For correct equation ($F = ma$ also accepted) **1 point**
For correct substitution of values consistent with those obtained above **1 point**

$$m = \frac{\overline{F}}{\overline{a}} = \frac{15 \text{ N}}{10 \text{ m/s}^2} = 1.5 \text{ kg}$$

Method 3. Student solved part (c) first and went back to part (b)

1. (c) **3 points**

For some method of using the graph to find the average force for the four non-zero intervals such as indicating that the area is equivalent to 6 boxes each with a height of 10 N, so that $\overline{F} = 60/4 = 15 \text{ N}$ **1 point**

For a correct expression for Newton's second law **1 point**
$\overline{F} = m\overline{a}$

For correct substitution of values consistent with those obtained above **1 point**

$$m = \frac{\overline{F}}{\overline{a}} = \frac{15 \text{ N}}{10 \text{ m/s}^2} = 1.5 \text{ kg}$$

Question 1 (cont.)

Method 3. (continued)

1. (b) **2 points** **Distribution of Points**

$\Delta p = m\Delta v = (1.5\text{ kg})(0.4\text{ m/s}) = 0.6\text{ N}\cdot\text{s}$ or $\Delta p = 0.6\ \frac{\text{kg}\cdot\text{m}}{\text{s}}$

For correct substitution of values consistent with those obtained above **1 point**
For correct units **1 point**

1. (d) **4 points**

For a correct statement of energy change **1 point**
$\Delta E = E_f - E_i$

For a kinetic energy equation **1 point**
$E = \frac{1}{2}mv^2$

For correct substitution of values consistent with those obtained above including the squared velocities **1 point**
$\Delta E = \frac{1}{2}(1.5\text{ kg})(0.22\text{ m/s})^2 - \frac{1}{2}(1.5\text{ kg})(-0.18\text{ m/s})^2$
$\Delta E = 0.012\text{ J}$

For correct units **1 point**