AP® Physics B
2002 Sample Student Responses
Form B

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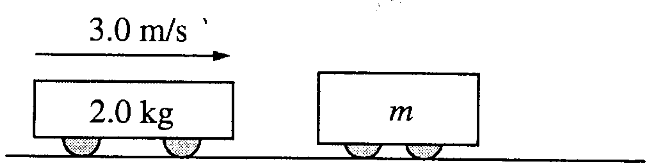
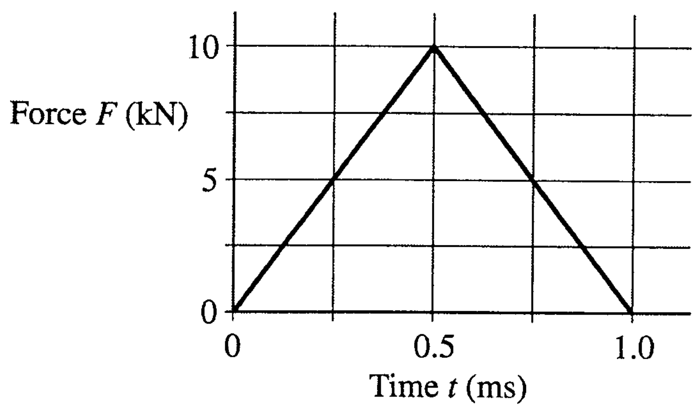
PHYSICS B
SECTION II
Time—90 minutes
7 Questions

Directions: Answer all seven questions, which are weighted according to the points indicated. The suggested time is about 15 minutes for answering each of questions 1-4, and about 10 minutes for answering each of questions 5-7. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part, NOT in the lavender insert.



1. (15 points)

A 2.0 kg frictionless cart is moving at a constant speed of 3.0 m/s to the right on a horizontal surface, as shown above, when it collides with a second cart of undetermined mass m that is initially at rest. The force F of the collision as a function of time t is shown in the graph below, where $t = 0$ is the instant of initial contact. As a result of the collision, the second cart acquires a speed of 1.6 m/s to the right. Assume that friction is negligible before, during, and after the collision.



(a) Calculate the magnitude and direction of the velocity of the 2.0 kg cart after the collision.

$F\Delta t = \Delta p_2 = m_2 V_2 \rightarrow \frac{F\Delta t}{V_2} = m_2$

$\frac{\frac{1}{2} \cdot 1\,ms / 1000\,ms/s \cdot 10\,kN \cdot 1000\,N/kN}{1.6\,m/s} = 3.125\,kg$

$P_i = P_f$

$V_{1i} = 0\,m/s \Rightarrow m_1 V_{1i} = m_2 V_{2f} + m_1 V_{1f}$

$\frac{m_1 V_{1i} - m_2 V_{2f}}{m_1} = V_{1f} = \frac{(2.0\,kg)(3.0\,m/s) - (3.125\,kg)(1.6\,m/s)}{2.0\,kg} = 0.5\,m/s$ to the right

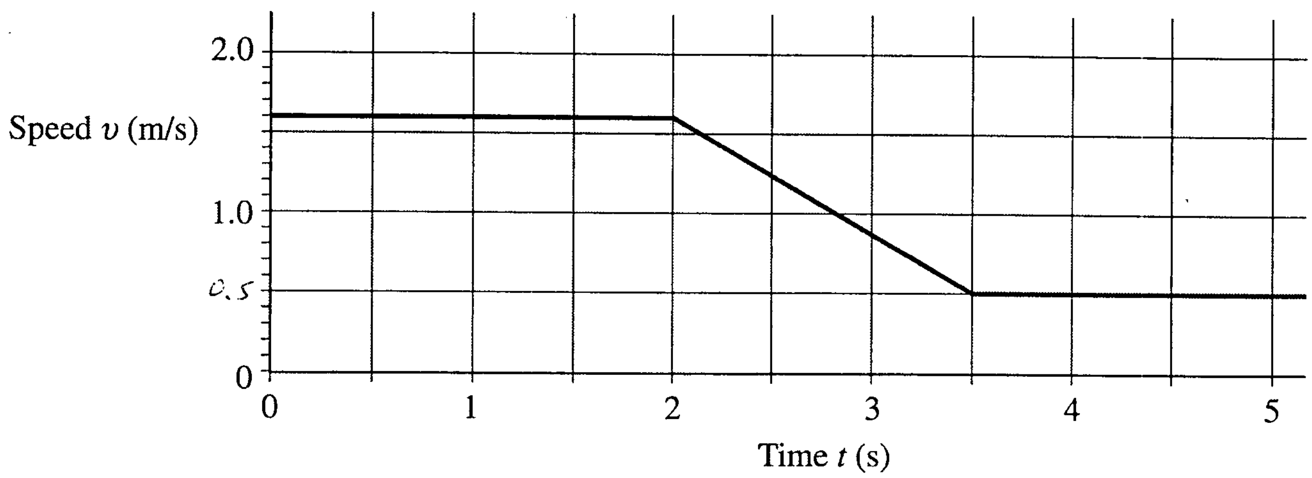
GO ON TO THE NEXT PAGE.

(b) Calculate the mass m of the second cart.

$F\Delta t = \Delta p = m\Delta v$

$\frac{F\Delta t}{\Delta v} = m = \frac{\frac{1}{2} \cdot 1\,ms \,/\, 1000\,ms/s \cdot 10\,kN \cdot 1000\,N/kN}{1.6\,m/s} = \underline{\underline{3.125\,kg}}$

After the collision, the second cart eventually experiences a ramp, which it traverses with no frictional losses. The graph below shows the speed v of the second cart as a function of time t for the next 5.0 s, where $t = 0$ is now the instant at which the carts separate.



(c) Calculate the acceleration of the cart at $t = 3.0$ s.

$a_{t=3s} = \bar{a}_{2s<t<3.5s} = \frac{\Delta v}{\Delta t} = \frac{0.5\,m/s - 1.6\,m/s}{3.5\,s - 2.0\,s} = \underline{\underline{-0.733\,m/s^2}}$

GO ON TO THE NEXT PAGE.

(d) Calculate the distance traveled by the second cart during the 5.0 s interval after the collision (0 s < t < 5.0 s).

$D = \int v(t)dt = 2s \cdot 1.6\,m/s + 1.5s \cdot 0.5\,m/s + \frac{1}{2} \cdot 1.5s\,(1.6-0.5)\,m/s + 1.5s \cdot 0.5\,m/s$

$= 5.525\,m$

(e) State whether the ramp goes up or down and calculate the maximum elevation (above or below the initial height) reached by the second cart on the ramp during the 5.0 s interval after the collision (0 s < t < 5.0 s).

it goes up

$KE_i + PE_i = KE_f + PE_f$

$\frac{1}{2}mv_i^2 + mgh_i = mgh_f + \frac{1}{2}mv_f^2$

$\frac{\frac{1}{2}v_i^2 + gh_i - \frac{1}{2}v_f^2}{g} = h_f$

let $h_i = 0\,m$ ∴ then $h_f = \Delta h$

$\Delta h = \frac{\frac{1}{2}v_i^2 - \frac{1}{2}v_f^2}{g} = \frac{\frac{1}{2}(1.6\,m/s)^2 - \frac{1}{2}(0.5\,m/s)^2}{9.80\,m/s^2} = 0.118\,m$

GO ON TO THE NEXT PAGE.

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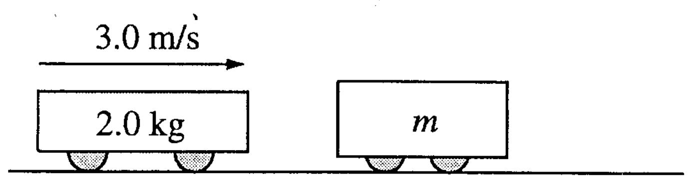
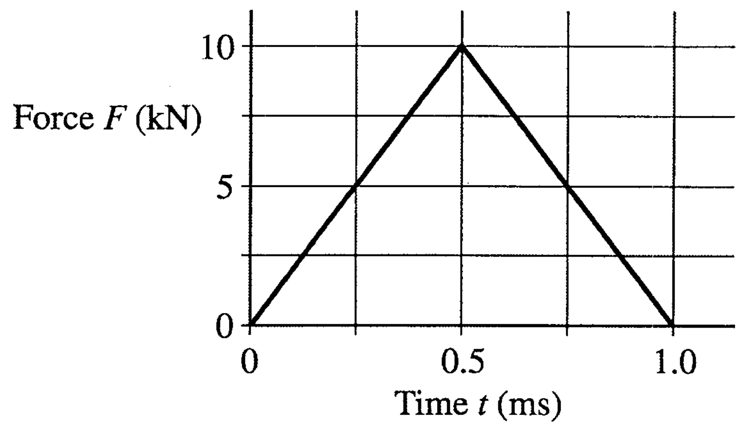


1. (15 points)

A 2.0 kg frictionless cart is moving at a constant speed of 3.0 m/s to the right on a horizontal surface, as shown above, when it collides with a second cart of undetermined mass m that is initially at rest. The force F of the collision as a function of time t is shown in the graph below, where $t = 0$ is the instant of initial contact. As a result of the collision, the second cart acquires a speed of 1.6 m/s to the right. Assume that friction is negligible before, during, and after the collision.



(a) Calculate the magnitude and direction of the velocity of the 2.0 kg cart after the collision.

$J = \text{impulse} = \Delta p_m = 1 \cdot \frac{10}{2} = 5.0\,kg \cdot \frac{m}{s}$

$\text{net } p_i = 3.0 \cdot 2.0 = 6.0\,kg \cdot \frac{m}{s} = \text{net } p_f = p_{\text{second cart}} + p_{\text{first cart}}$

$p_{\text{second cart}} = 5.0\,kg \cdot \frac{m}{s} \Rightarrow p_f = 6.0 = 5.0 + p$

$\Rightarrow p = 1.0\,kg \cdot \frac{m}{s} = mv$

$m = 2 \Rightarrow v = \boxed{\frac{1}{2}\,m/s}$

GO ON TO THE NEXT PAGE.

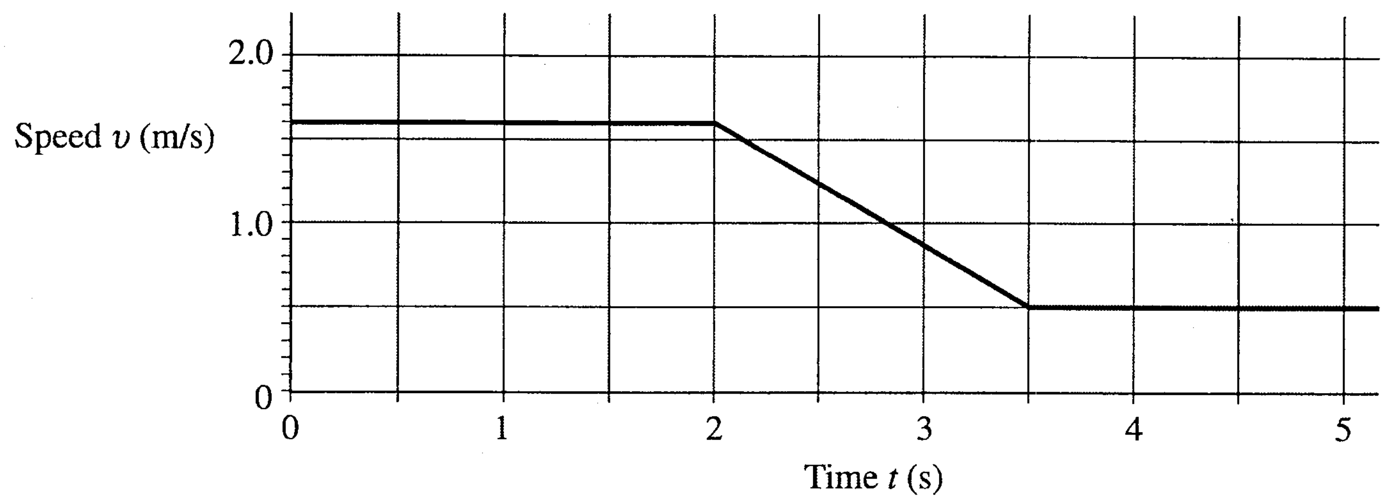
(b) Calculate the mass m of the second cart.

$\Delta p_{\text{second cart}} = 5.0$ kg·m/s (see 1©) = mv

$v = 1.6$ m/s $\Rightarrow 1.6m = 5.0$

$\Rightarrow m = \frac{5.0}{1.6} = $ **3.125 kg**

After the collision, the second cart eventually experiences a ramp, which it traverses with no frictional losses. The graph below shows the speed v of the second cart as a function of time t for the next 5.0 s, where $t = 0$ is now the instant at which the carts separate.



(c) Calculate the acceleration of the cart at $t = 3.0$ s.

$a = \frac{\Delta v}{\Delta t}$ $\Rightarrow$ $a = \frac{-1.1}{1.5}$ ≈ **−0.733 m/s²**

$\Delta v = -1.1$ m/s

$\Delta t = 1.5$ s

GO ON TO THE NEXT PAGE.

(d) Calculate the distance traveled by the second cart during the 5.0 s interval after the collision ($0 \text{ s} < t < 5.0 \text{ s}$).

distance = area under curve

area	time
$2 \cdot 1.6$	$0<t<2$
$\frac{1.5 \cdot 1.1}{2} + 1.5 \cdot 0.5$	$2<t<3.5$
$0.5 \cdot 1.5$	$3.5<t<5$

net area = $3.2 + 1.825 + 0.75$

= **5.775 m**

(e) State whether the ramp goes up or down and calculate the maximum elevation (above or below the initial height) reached by the second cart on the ramp during the 5.0 s interval after the collision ($0 \text{ s} < t < 5.0 \text{ s}$).

The ramp goes up because the cart slows down by converting kinetic energy to gravitational potential energy.

loss KE = gain PE = $\frac{1}{2} m v_i^2 - \frac{1}{2} m v_f^2 = mg\Delta h$

$v_i = 1.6 \text{ m/s}$

$v_f = 0.5 \text{ m/s}$

$\Rightarrow \Delta h = \frac{g}{2}(v_i^2 - v_f^2)$

$\Delta h = \frac{9}{2}(1.6^2 - 0.5^2)$

$\approx$ **11.32 m**

GO ON TO THE NEXT PAGE.