



## **AP<sup>®</sup> Physics B**

### **2002 Sample Student Responses**

### **Form B**

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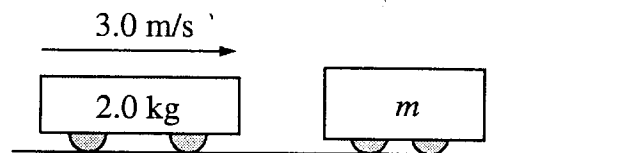
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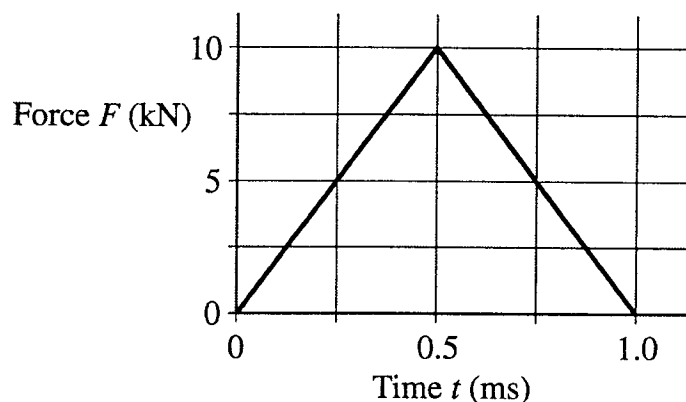
**PHYSICS B**  
**SECTION II**  
**Time—90 minutes**  
**7 Questions**

**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.

~~$F \Delta t = \Delta p$~~

$p_i = p_f$

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

$\frac{m_1 v_{1i} - m_2 v_{2f}}{m_1} = v_{1f}$

$F \Delta t = \Delta p = m \Delta v \rightarrow \frac{F \Delta t}{\Delta v} = m$

$\frac{1}{2} \cdot 1 \text{ ms} / 1000 \text{ ms/s} \cdot 10 \text{ kN} \cdot 1000 \text{ N/kN}$

$\frac{\quad}{1.6 \text{ m/s}} = 3.125 \text{ kg}$

$\frac{(2.0 \text{ kg})(3.0 \text{ m/s}) - (3.125 \text{ kg})(1.6 \text{ m/s})}{2.0 \text{ kg}} = 0.5 \text{ m/s}$

to the right

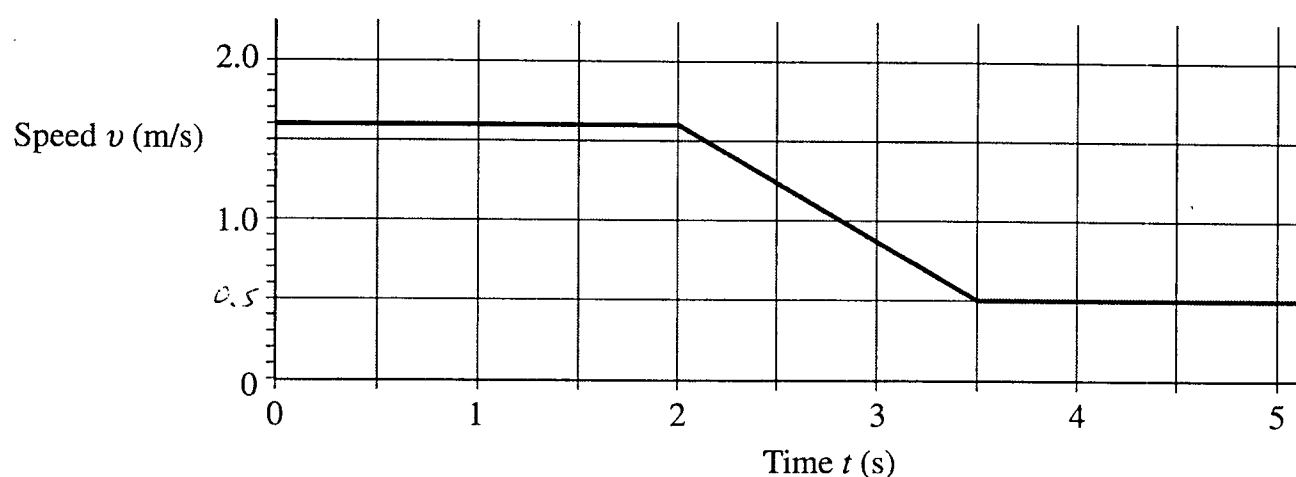
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(b) Calculate the mass  $m$  of the second cart.

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

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

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.

$$a_{t=3.0} = \frac{\Delta v}{\Delta t} = \frac{0.5 \text{ m/s} - 1.6 \text{ m/s}}{3.5 \text{ s} - 2.0 \text{ s}} = \underline{\underline{-0.733 \text{ m/s}^2}}$$

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

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

$$= \underline{\underline{5.525 \text{ m}}}$$

- (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 ( $0 \text{ s} < t < 5.0 \text{ s}$ ).

it goes up

$$KE_i + PE_i = KE_f + PE_f$$

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

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

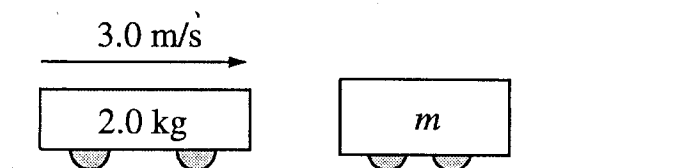
let  $h_i = 0 \text{ m}$   
then  $h_f = \Delta h$

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

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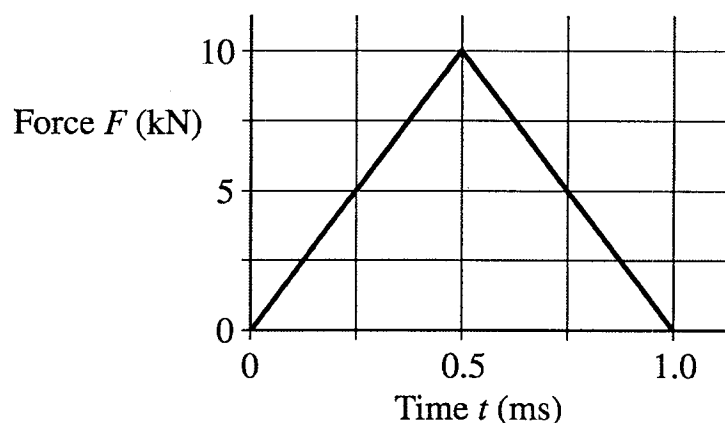
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1. (15 points)

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.

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

$$\text{net } p_{i1} = 3.0 \cdot 2.0 = 6.0 \text{ kg} \cdot \frac{\text{m}}{\text{s}} = \text{net } p_f = p_{\text{second cart}} + p_{\text{first cart}}$$

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

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

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

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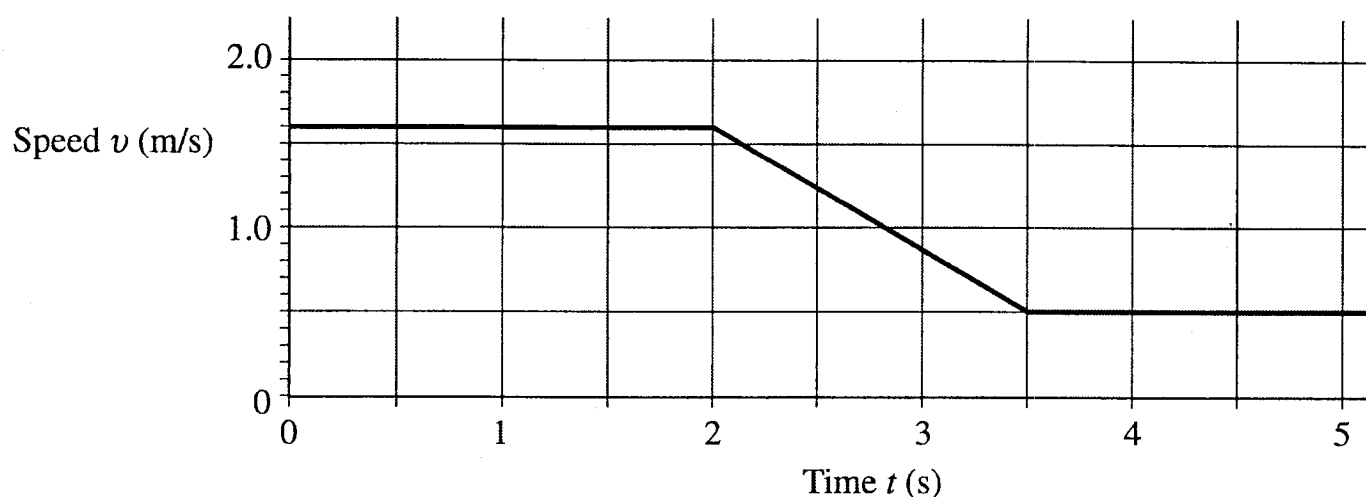
(b) Calculate the mass  $m$  of the second cart.

$$\Delta p_{\text{second cart}} = 5.0 \text{ kg} \cdot \text{m/s} \text{ (see 1a)} = m v$$

$$v = 1.6 \text{ m/s} \Rightarrow 1.6m = 5.0$$

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

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.

$$a = \frac{\Delta v}{\Delta t}$$

$$\Delta v = -1.1 \text{ m/s}$$

$$\Delta t = 1.5 \text{ s}$$

$$\Rightarrow a = -\frac{1.1}{1.5} \approx \boxed{-0.733 \text{ m/s}^2}$$

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- (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

<u>area</u>	<u>time</u>	
$2 \cdot 1.6$	$0 < t < 2$	$\text{net area} = 3.2 + 1.825 + 0.75$ $= \boxed{5.775 \text{ m}}$
$\frac{1.5 \cdot 1.1}{2} + 1.5 \cdot 0.5$	$2 < t < 3.5$	
$0.5 \cdot 1.5$	$3.5 < t < 5$	

- (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.

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

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

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

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

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

$$\approx \boxed{11.32 \text{ m}}$$

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