



## AP<sup>®</sup> Physics C: Mechanics 2004 Sample Student Responses

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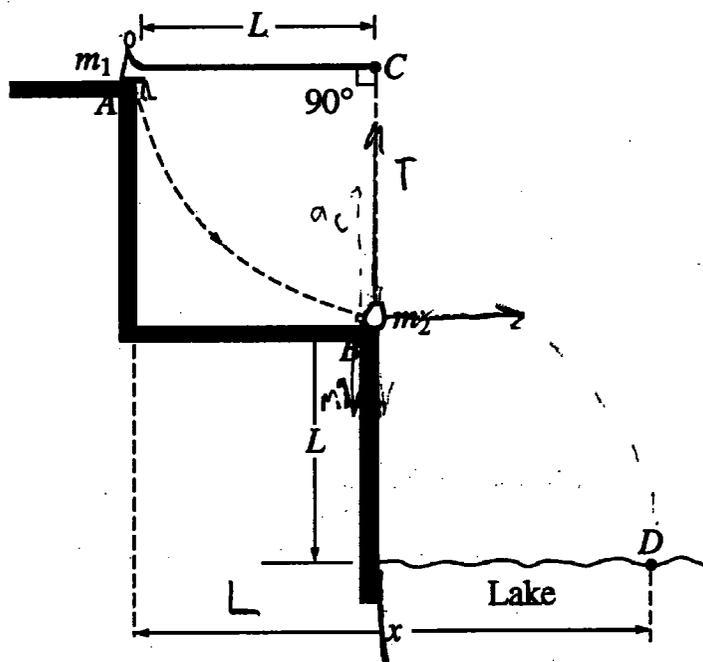
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**PHYSICS C**  
**Section II, MECHANICS**  
**Time—45 minutes**  
**3 Questions**

A1

**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, NOT in the green insert.



**Mech. 1.**

A rope of length  $L$  is attached to a support at point  $C$ . A person of mass  $m_1$  sits on a ledge at position  $A$  holding the other end of the rope so that it is horizontal and taut, as shown above. The person then drops off the ledge and swings down on the rope toward position  $B$  on a lower ledge where an object of mass  $m_2$  is at rest. At position  $B$  the person grabs hold of the object and simultaneously lets go of the rope. The person and object then land together in the lake at point  $D$ , which is a vertical distance  $L$  below position  $B$ . Air resistance and the mass of the rope are negligible. Derive expressions for each of the following in terms of  $m_1$ ,  $m_2$ ,  $L$ , and  $g$ .

(a) The speed of the person just before the collision with the object

$$E_i = E_f$$

$$E_i = m_1 g 2L$$

$$E_f = \frac{1}{2} m_1 v^2 + m_1 g L$$

$$m_1 g 2L = \frac{1}{2} m_1 v^2 + m_1 g L$$

$$gL = \frac{1}{2} v^2$$

$$2gL = v^2$$

$$v = \sqrt{2gL}$$

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A2

(b) The tension in the rope just before the collision with the object

$$\sum F_y: ma_c = \frac{m_1 v^2}{L} = T - m_1 g$$

$$\frac{m_1 2gL}{L} = T - m_1 g$$

$$T = 3m_1 g$$

(c) The speed of the person and object just after the collision

$$P_i = P_f$$

$$m_1 v_i = (m_1 + m_2) v_f$$

$$m_1 (\sqrt{2gL}) = (m_1 + m_2) v_f$$

$$v_f = \frac{m_1 (\sqrt{2gL})}{m_1 + m_2}$$

(d) The ratio of the kinetic energy of the person-object system before the collision to the kinetic energy after the collision

$$K = \frac{K_i}{K_f}$$

$$K_i = \frac{1}{2} m_1 (\sqrt{2gL})^2$$

$$K_f = \frac{1}{2} (m_1 + m_2) \left( \frac{m_1 \sqrt{2gL}}{m_1 + m_2} \right)^2$$

$$K = \frac{\frac{1}{2} m_1 (\sqrt{2gL})^2}{\frac{1}{2} (m_1 + m_2) \left( \frac{m_1 \sqrt{2gL}}{m_1 + m_2} \right)^2} = \frac{m_1}{m_1^2 \left( \frac{1}{m_1 + m_2} \right)} = \frac{m_1 + m_2}{m_1}$$

(e) The total horizontal displacement  $x$  of the person from position A until the person and object land in the water at point D.

$$v_{ox} = \frac{m_1 \sqrt{2gL}}{m_1 + m_2}$$

$$v_{oy} = -g$$

$$\hat{r}(x, y) = \hat{r}(v_{x0} + v_{y0})t + \frac{1}{2} \hat{r}(a_{x0} + a_{y0})t^2$$

$$(x, L) = \left( \frac{m_1 \sqrt{2gL}}{m_1 + m_2} + 0 \right) t + \frac{1}{2} (0 + -g) t^2$$

$$L = \frac{1}{2} g t^2$$

$$\sqrt{\frac{2L}{g}} = t$$

$$x = \left( \frac{m_1 \sqrt{2gL}}{m_1 + m_2} \right) t$$

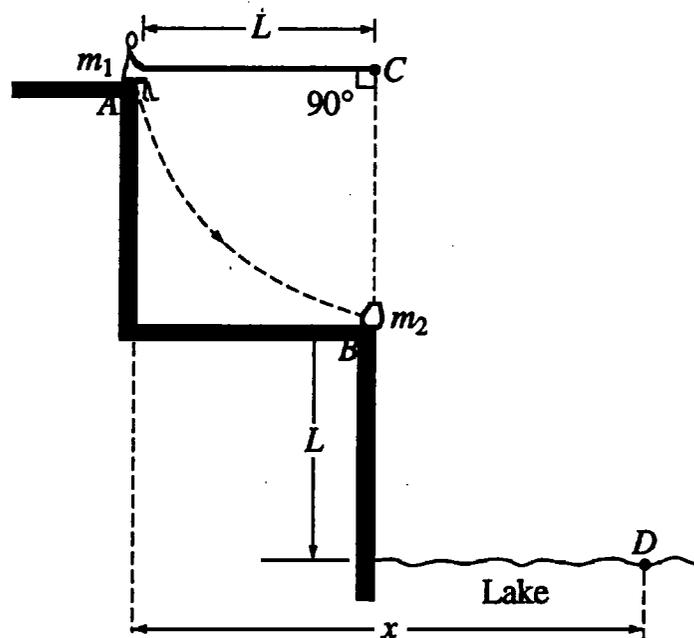
$$x = \frac{m_1 \sqrt{2Lg}}{m_1 + m_2} \left( \sqrt{\frac{2L}{g}} \right)$$

$$x = \frac{m_1 \sqrt{2Lg} \left( \sqrt{\frac{2L}{g}} \right)}{m_1 + m_2}$$

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Mech. 1.

A rope of length  $L$  is attached to a support at point C. A person of mass  $m_1$  sits on a ledge at position A holding the other end of the rope so that it is horizontal and taut, as shown above. The person then drops off the ledge and swings down on the rope toward position B on a lower ledge where an object of mass  $m_2$  is at rest. At position B the person grabs hold of the object and simultaneously lets go of the rope. The person and object then land together in the lake at point D, which is a vertical distance  $L$  below position B. Air resistance and the mass of the rope are negligible. Derive expressions for each of the following in terms of  $m_1$ ,  $m_2$ ,  $L$ , and  $g$ .

(a) The speed of the person just before the collision with the object

$$PE \Rightarrow KE$$

$$mgh = \frac{1}{2}mv^2$$

$$2gL = v^2$$

$$v = \sqrt{2gL}$$

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(b) The tension in the rope just before the collision with the object

$$T = mg$$

$$\boxed{T = m_1 g}$$

(c) The speed of the person and object just after the collision

Before = P final

$$m_1 v_1 = m_2 v_2$$

$$m_1 \sqrt{2gL} = (m_1 + m_2) v$$

$$v = \frac{m_1 \sqrt{2gL}}{m_1 + m_2}$$

(d) The ratio of the kinetic energy of the person-object system before the collision to the kinetic energy after the collision

Before

$$K = \frac{1}{2} m v^2$$

$$= \frac{1}{2} m_1 \cdot 2gL$$

$$= m_1 gL$$

After

$$K = \frac{1}{2} m v^2$$

$$= \frac{1}{2} (m_1 + m_2) \frac{m_1^2 \cdot 2gL}{(m_1 + m_2)^2}$$

$$= \frac{m_1^2 \cdot 2gL}{m_1 + m_2}$$

$$\frac{m_1 gL}{\frac{2m_1^2 gL}{m_1 + m_2}}$$

(e) The total horizontal displacement  $x$  of the person from position A until the person and object land in the water at point D.

$$v_{0x} = \frac{m_1 \sqrt{2gL}}{m_1 + m_2}$$

$$y = v_y t + \frac{1}{2} a t^2$$

$$-L = -5 t^2$$

$$\sqrt{\frac{L}{5}} = t$$

$$v \cdot t = d$$

$$\boxed{\frac{m_1 \sqrt{2gL}}{m_1 + m_2} \cdot \sqrt{\frac{L}{5}}}$$


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