CollegeBoard
Advanced Placement Program

AP® Physics C: Mechanics 2004 Sample Student Responses

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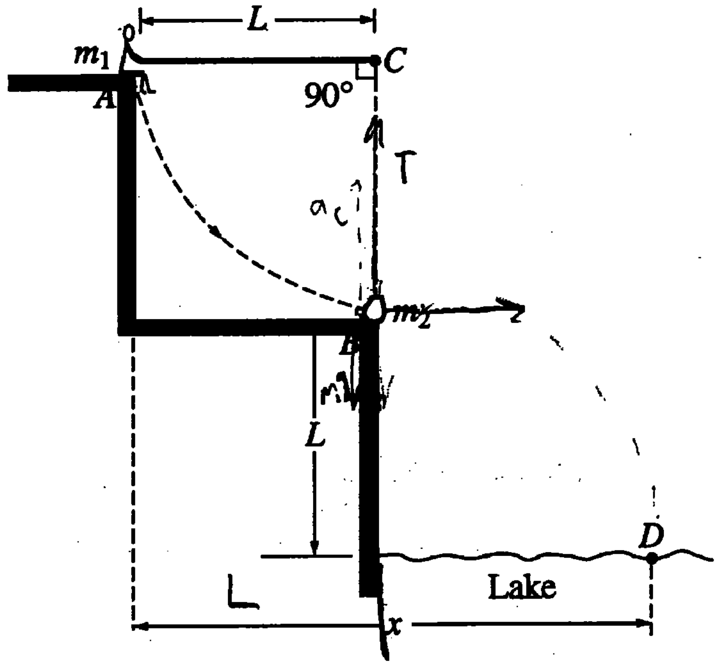
A1

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 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

$E_i = E_f$

$E_i = m_1 g 2L$

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

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

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

$2gL = v^2$

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

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A2

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

ΣF_y: $ma_c = \frac{mv^2}{L} = T - m_1 g$

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

$\boxed{T = 3m_1 g}$

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

$P_i = P_F$

$m_1 v_i = (m_1 + m_2) v_F$

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

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

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

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

$\frac{K_i}{K_F}$ $\quad K_i = \frac{\cancel{1}}{\cancel{2}} m_1 (\cancel{\sqrt{2gL}})^{\cancel{2}}$ over $K_F = \frac{\cancel{1}}{\cancel{2}} \cancel{(m_1 + m_2)} \left(\frac{m_1 \sqrt{2gL}}{m_1 + m_2}\right)^2$ $= \frac{\cancel{m_1}}{m_1^{\cancel{2}}\left(\frac{1}{m_1 + m_2}\right)}$ $= \boxed{\frac{m_1 + m_2}{m_1}}$

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

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

$v_{oy} = -g$

$\hat{r}(x, y) = \hat{r}(v_{x_0} + v_{y_0})t + \frac{1}{2}\hat{r}(a_{x_0} + a_{y_0})t^2$

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

$L = \frac{1}{2}gt^2$

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

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

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

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

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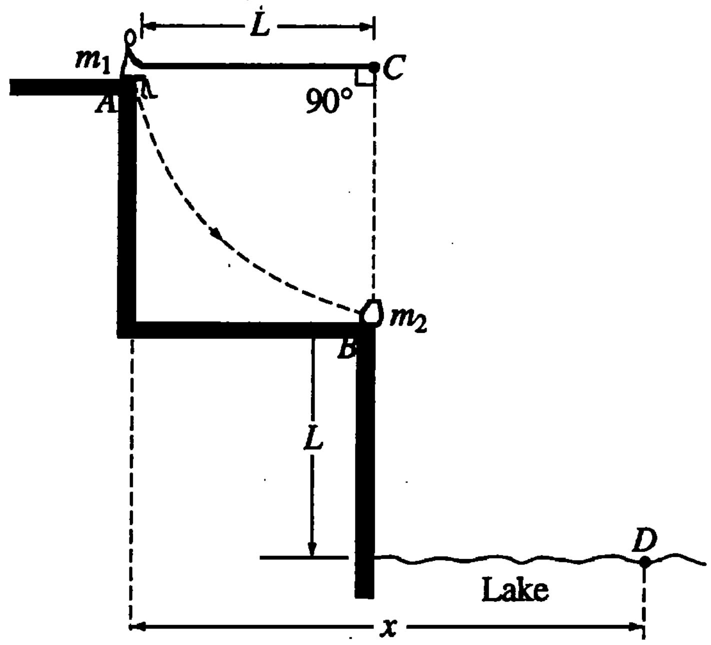

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(a) The speed of the person just before the collision with the object

PE ⇒ KE

$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2$

$2gL = v^2$

$v = \sqrt{2gL}$

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B2

(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

$P_{before} = P_{final}$

$m_1 v_1 = m_2 v_2$

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

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

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

Before

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

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

$= m_1 g L$

$\dfrac{m_1 g L}{\dfrac{2 m_1^2 g L}{m_1 + m_2}}$

$\boxed{\dfrac{m_1 + m_2}{2 m_1}}$

After

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

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

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

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

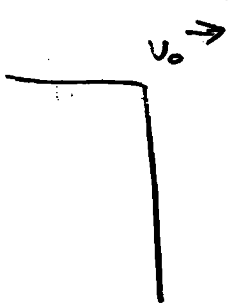
$V_{ox} = \dfrac{m_1 \sqrt{2gL}}{m_1 + m_2}$

$v \cdot t = d$

$y = v_0 t + \frac{1}{2} a t^2$

$-L = -5 t^2$

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



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

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