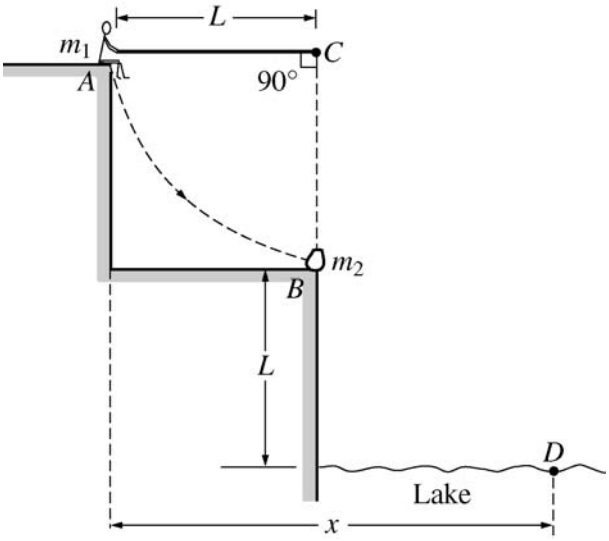
PHYSICS C
Section II, MECHANICS
Time—45 minutes
3 Questions

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 booklet in the spaces provided after each part, NOT in this 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

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

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

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

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

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AP® PHYSICS C MECHANICS
2004 SCORING GUIDELINES

Question 1

15 points total **Distribution of points**

(a) 2 points

For any statement of conservation of energy 1 point

Taking the zero of potential to be at the height of point B, and setting the kinetic energy at point B equal to the potential energy at point A:

$$\frac{1}{2}m_1 v_B^2 = m_1 gL$$

For the correct answer 1 point

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

(b) 4 points

For any indication that there are two forces acting on the person 1 point

For an indication that the acceleration of the person is centripetal, i.e. equal to v^2/r or v^2/L 1 point

For a correct application of Newton's second law that includes the two forces (tension T and weight) and a non-zero acceleration 1 point

$$T - m_1 g = \frac{m_1 v_B^2}{r}$$

$$T = \frac{m_1 v_B^2}{r} + m_1 g$$

For substitution of the expression for v_B from part (a) and L for the radius 1 point

$$T = \frac{m_1 (2gL)}{L} + m_1 g = 2m_1 g + m_1 g$$

$$T = 3m_1 g$$

(c) 3 points

For any statement of conservation of momentum 1 point

For a correct application of conservation of momentum, with a clear indication that both masses have a common final velocity 1 point

$$m_1 v_B = (m_1 + m_2) v_{\text{after}}$$

$$v_{\text{after}} = \frac{m_1}{(m_1 + m_2)} v_B$$

For an answer in terms of the required quantities and of the form:

$$\frac{m_1}{(m_1 + m_2)}(\text{answer from part(a)})$$ 1 point

$$v_{\text{after}} = \frac{m_1}{(m_1 + m_2)}\sqrt{2gL}$$

Question 1 (continued)

Distribution of points

(d) 2 points

For correct expressions for the kinetic energy before and after the collision, using the answers to parts (a) and (c) — 1 point

$K_{\text{before}} = \frac{1}{2} m_1 v_B^2 = \frac{1}{2} m_1 (2gL) = m_1 gL$

$K_{\text{after}} = \frac{1}{2}(m_1 + m_2) v_{\text{after}}^2 = \frac{1}{2}(m_1 + m_2) \frac{m_1^2}{(m_1 + m_2)^2} 2gL = \frac{m_1^2}{(m_1 + m_2)} gL$

For constructing the ratio $K_{\text{before}} / K_{\text{after}}$ from valid expressions for kinetic energy, in terms of the required quantities. The ratio does not need to be simplified, but if it is the algebra needs to be correct. — 1 point

$$\frac{K_b}{K_a} = \frac{m_1 gL}{\left(\frac{m_1^2 gL}{(m_1 + m_2)} \right)}$$

$$\frac{K_b}{K_a} = \frac{(m_1 + m_2)}{m_1}$$

(e) 4 points

For a correct expression relating the distance fallen, L, to the time it takes to fall from point B to the water: — 1 point

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

For indicating that the horizontal displacement from B to D is the answer to part (c) multiplied by the time — 1 point

$x_{BD} = v_{\text{after}} t$

For correctly solving the first equation for t and substituting two quantities into the second equation (this must yield an expression in terms of the required given quantities) — 1 point

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

$x_{BD} = v_{\text{after}} t = \left(\frac{m_1}{m_1 + m_2} \sqrt{2gL} \right) \sqrt{2L/g} = \frac{2m_1 L}{m_1 + m_2}$

For indicating that the total horizontal displacement from A to D is x_{BD} plus L — 1 point

$x_{\text{tot}} = x_{BD} + L = \frac{2m_1 L}{m_1 + m_2} + L$

$x_{\text{tot}} = \frac{(3m_1 + m_2) L}{m_1 + m_2}$