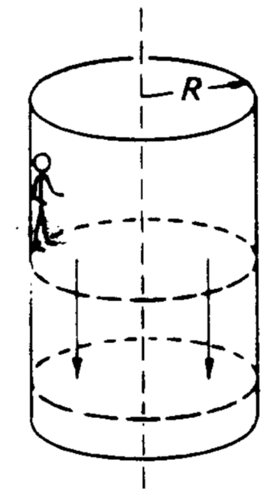
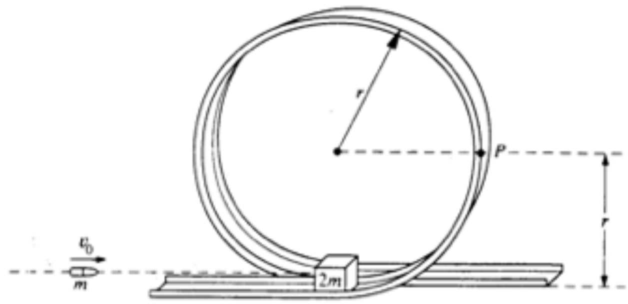
An amusement park ride consists of a rotating vertical cylinder of radius 5 m with rough walls. The floor is initially about halfway up the cylinder. After a 50 kg rider has entered and the cylinder is rotating sufficiently fast, the floor is dropped down, yet the rider does not slide down. The coefficient of friction is 0.6.



a) What provides the centripetal force?

b) What must be the minimum frequency of rotation such that the rider does not slide down when the floor is dropped?

c) At the same rotational speed (from part b), would a rider of twice the mass slide down the wall. Explain your answer.



A small block of mass 2*m* initially rests on a track at the bottom of the circular, vertical loop-the-loop shown above, which has a radius *r*. The surface contact between the block and the loop is frictionless. A bullet of mass *m* strikes the block horizontally with initial speed *v*o and remains embedded in the block as the block and bullet circle the loop. Determine the minimum initial speed of the bullet which allows the block to remain in contact with the loop at all times. Express your answer in terms of *m*, *r*, and *g*.

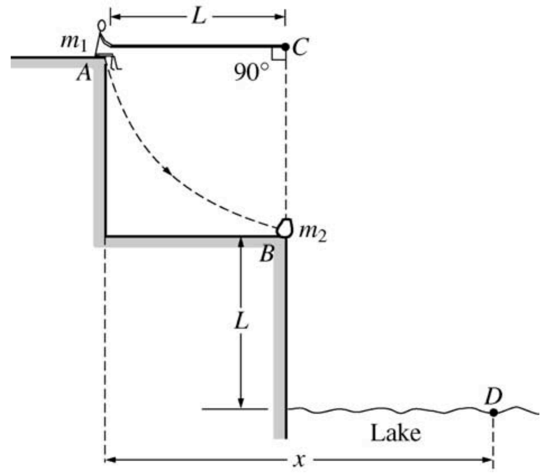
A rope of length L is attached to a support at point C. A person of mass $m1$ sits on a ledge at position A holding the other end of the rope so that it is horizontal and taut, as shown. The person then drops off the ledge and swings down on the rope toward position B on a lower ledge where an object of mass $m2$ 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 $m1$, $m2$, 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 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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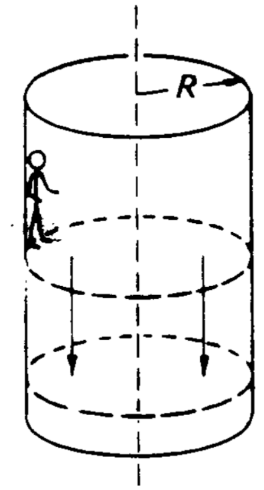

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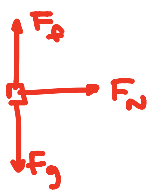
a) F_N (FROM WALL OF VERTICAL CYLINDER)

b)



$$F_f = F_g$$

$$\mu F_N = mg$$

$$F_N = \frac{mg}{\mu}$$

$$F_c = ma_c$$

$$F_N = m\frac{4\pi^2 R}{T^2}$$

$$\frac{\cancel{m}g}{\mu} = \cancel{m}\frac{4\pi^2 R}{T^2}$$

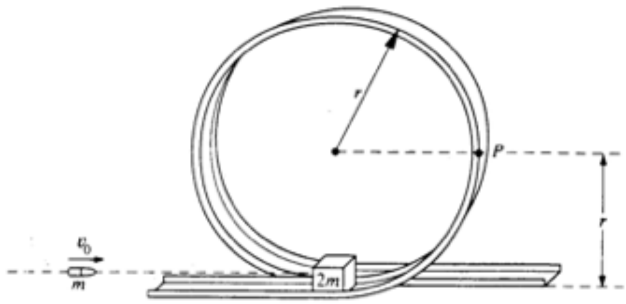
$$T = \sqrt{\frac{4\pi^2 R\mu}{g}}$$

$$f = \frac{1}{T} = \sqrt{\frac{g}{4\pi^2 R\mu}}$$

$$= \sqrt{\frac{9.8}{4\pi^2(5)(0.6)}}$$

$$= 0.288 \text{ Hz}$$

c) NO. MINIMUM FREQUENCY/SPEED DOES NOT DEPEND ON MASS.



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① MINIMUM SPEED OF COMBINED MASS AT TOP OF LOOP

F_g

* $F_N = 0$

$F_c = m a_c$

$F_g = m \frac{v^2}{R}$

$\cancel{m} g = \cancel{m} \frac{v^2}{R}$

$v = \sqrt{gR}$

② SPEED OF COMBINED MASS AT BOTTOM OF LOOP

$E_i = E_f$

$E_{k_i} + \cancel{E_{p_i}}^{0} = E_{k_f} + E_{p_f}$

$\frac{1}{2} \cancel{m} v_i^2 = \frac{1}{2} \cancel{m} v_f^2 + \cancel{m} g h_f$

$v_i = \sqrt{v_f^2 + 2 g h_f}$

$$= \sqrt{\left(\sqrt{gR}\right)^2 + 2g(2R)}$$

$$= \sqrt{5gR}$$

③ SPEED OF BULLET BEFORE COLLISION

$$P_i = P_f$$

$$P_{1i} + \cancel{P_{2i}}^{\,0} = P_f$$

$$m_1 v_{1i} = M v_f$$

$$v_{1i} = \frac{M v_f}{m_1}$$

$$= \frac{3m\sqrt{5gR}}{m}$$

$$= \boxed{3\sqrt{5gR}}$$

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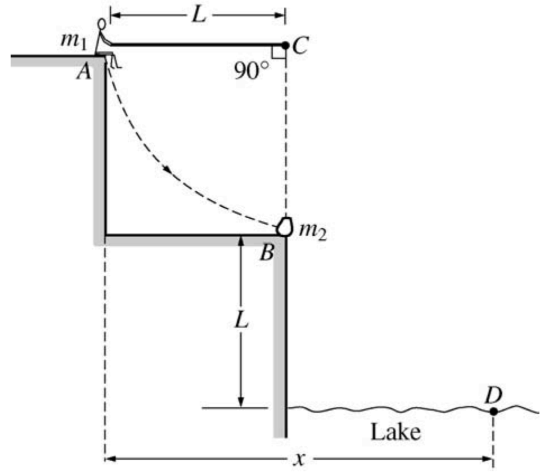


a)

$$E_i = E_f$$

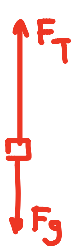
$$E_{p_i} + \cancel{E_{k_i}}^{0} = \cancel{E_{p_f}}^{0} + E_{k_f}$$

$$\cancel{m} g h_i = \frac{1}{2} \cancel{m} v_f^2$$

$$v_f = \sqrt{2 g h_i}$$

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

b)



$$F_c = m a_c$$

$$F_T - F_g = m \frac{v^2}{R}$$

$$F_T - mg = m \frac{v^2}{R}$$

$$F_T = mg + m\frac{v^2}{R}$$

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

$$= \boxed{3m_1 g}$$

c)

$$p_i = p_f$$

$$p_{1i} + \cancelto{0}{p_{2i}} = p_f$$

$$m_1 v_{1i} = M v_f$$

$$v_f = \frac{m_1 v_{1i}}{M}$$

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

d)

$$d_y = \cancelto{v_{iy}=0}{v_{iy}} t + \frac{1}{2} a_y t^2$$

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

FROM POINT B

$$d_x = v_x t$$

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

$$= \frac{2m_1 L}{m_1 + m_2}$$

$$d_{x,TOT} = L + \frac{2m_1 L}{m_1 + m_2} = \boxed{\left(1 + \frac{2m_1}{m_1 + m_2}\right)L}$$