Über Pulley Problem
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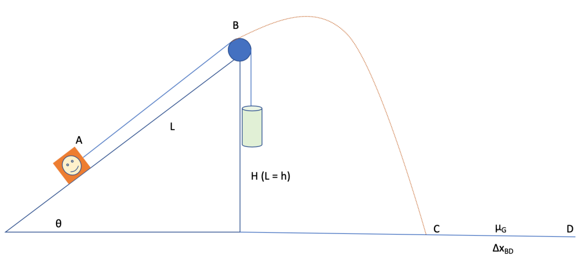
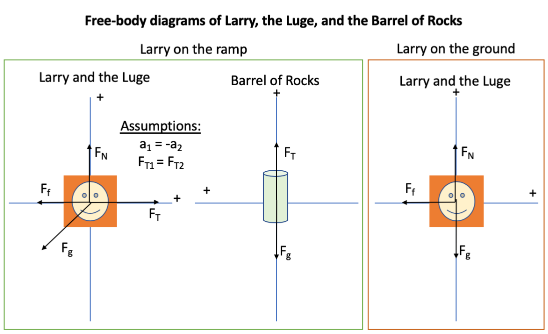
Description

Leaping Larry launched himself into a projectile trajectory by rolling up a cliff using a pulley. As a barrel of rocks accelerates downwards to a displacement at the height of the cliff (A to B), the luge and Larry are rolled up an angled cliff and over a cliff, achieving its final velocity at the edge of the cliff. Larry and the luge are catapulted over the cliff and hit the ground (B to C), transitioning all of their speed in the x-direction before sliding to a stop due to the force of friction (at point D).

Diagram (see Page 2 for enlarged version)





Givens and Constants

$$m_L = 45\ kg \qquad \Delta x_{BD} = 69\ m$$
$$m_B = 60\ kg \qquad \mu_R = 0.22$$
$$\theta = 41\ deg \qquad h = 8.9\ m$$

Strategy and Method

Part 1: Find acceleration going up the ramp.
Luge:

$$\sum F_y = F_N - F_g \cos(\theta)$$
$$F_N = F_g \cos(\theta)$$
$$\sum F_x = F_T - F_f - F_g \sin(\theta) = m a_1$$
$$F_f = \mu F_g \cos(\theta)$$

Rocks:

$$\sum F_y = F_{T2} - F_g = -m_2 a$$
$$F_{T2} - m_2 g = -m_2 a$$

Equate the equations:

$$m_2 g - m_2 a - \mu F_g \cos(\theta) - F_g \sin(\theta) = m_1 a$$
$$a = \frac{m_2 g - \mu F_g \cos(\theta) - F_g \sin(\theta)}{m_1 + m_2}$$

$$a = \frac{60(9.8) - 0.22(9.8)(45) * cos41 - 45(9.8)(sin41)}{45 + 60}$$

$$a = \frac{588 - 73.22 - 289.32}{105}$$

$$\underline{a = 2.14724\ m/s^2}$$

Part 2: Find the final velocity at the tip of the ramp.

$$v_f^2 = v_0^2 + 2ax$$

$$v_f^2 = 2(2.14724)(8.9)$$
$$\underline{v_f = 6.1823\ m/s}$$

Part 3: Find the range that Larry lands at.

$$y = -0.5at^2 + v_0 sin\theta t + y_0$$
$$y = -4.9t^2 + 6.1823 sin41 t + 8.9$$

Calc solve t

$$t = \cancel{-9.95956}\ seconds$$
$$OR$$
$$\underline{t = 1.8237\ seconds}$$

$$x = 6.1823 cos41 t$$
$$\underline{x = 8.50909\ m}$$

Part 4: Find the final velocity when Larry hits the ground (all the speed is transitioned to the horizontal)

$$v_f = v_0 + at$$

$$v_{fy} = 6.1823 sin41 - 9.8(1.8237)$$

$$\underline{v_{fy} = -13.8163\ m/s}$$
$$\underline{v_{fx} = 6.1823cos41\ m/s}$$

$$v_f = \ 13.8163\ ^2 + 6.1823cos41\ ^2$$

$$\underline{v_f = 14.5829\ m/s}$$

Part 5: Find acceleration as Larry slides to a stop (this is acceleration due to friction). 100% of the energy from the fall is transferred to the horizontal.

Find acceleration covered in total distance minus the range found in Part 3:

$$v_f^{\ 2} = \ v_0^{\ 2} + 2ax$$
$$v_f^{\ 2} = \ 14.5829^2 + 2a(69 - 8.50909)$$

$$\underline{a = \ -1.75779\ m/s^2} \leftarrow$$

Part 6: Find total friction (using acceleration for from Part 5).

$$F_f = ma = -1.75779\ m/s^2$$
$$\underline{F_f = 79.1006\ N} \leftarrow$$

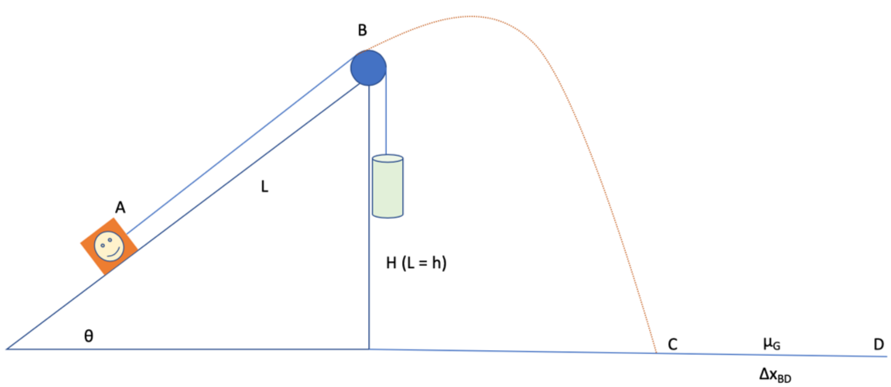
Part 7: Find normal force for Larry and the luge.

$$F_N - F_g = 0$$
$$F_N = 45(9.8)$$
$$\underline{F_N = 441\ N} \uparrow$$

Part 8: Solve for the coefficient of friction.

$$F_N = \ F_f * \mu$$
$$79.1006 = \ 441 * \mu$$
$$\boxed{\mu = 0.1794}$$

Enlarged Diagrams



Free-body diagrams of Larry, the Luge, and the Barrel of Rocks