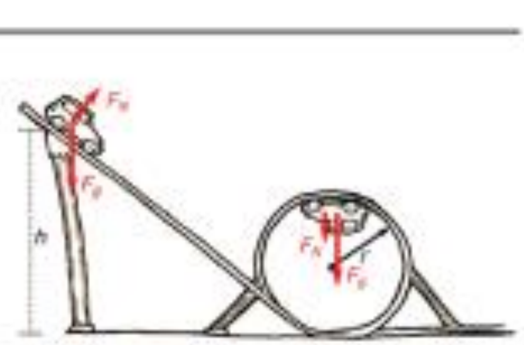
NAME ______________________ DATE ____________

Scenario

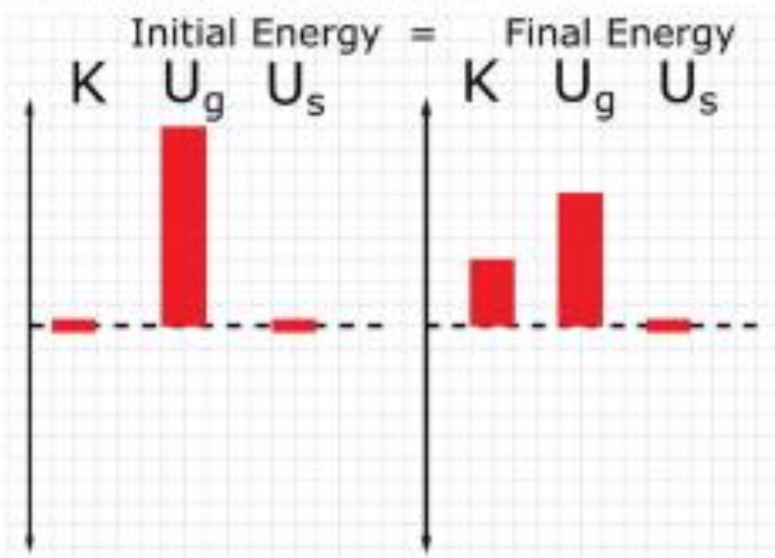
A toy car is released from rest on a smooth track with a loop de loop. The car is released from height h such that it never loses contact with the track. The system includes the car and Earth. Rotational effects from the wheels, friction, and air resistance can be ignored.



Using Representations

PART A: Draw and label free-body diagrams on the figure shown above that depicts the forces (not components) exerted on the car as it goes down the ramp and at the top of the loop. Draw the relative lengths of all vectors to reflect the relative magnitudes of all the forces. Each force must be represented by a distinct arrow starting on and pointing away from the car.

PART B: Fill in the energy bar chart below with the initial energy when the car is first released from height h and the final energy when the car is at the top of the loop.



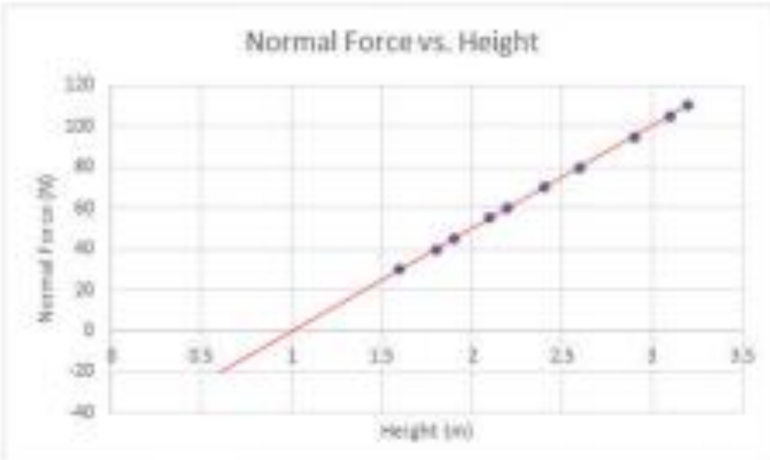
PART C: Citing the bar chart, explain why the release height must be greater than the diameter of the loop.

The car must have velocity to make it past the top of the loop. If there is velocity, there is kinetic energy. The initial energy is all gravitational potential as seen on the chart. The larger the gravitational potential energy is at the top of the loop, the less energy there is allotted to kinetic at that point. Looking at the chart, the sum of the bars on the right must be equal to the sum of the bars on the left side. If the loop's diameter was the same size as h, then there would be no kinetic energy and no speed, and thus, no inertia to keep the car on the loop.

Data Analysis

PART D: Carlos determines that the normal force the car experiences at the top of the loop can be determined by using the equation: $F_n = \frac{2mg}{h}$.

To test the equation, he releases the cart from various heights and records the normal force at the top of the loop from the sensor in the track. The graph below is the student's plot of the data for F_n as a function of height.



Are these data consistent with Carlos's equation?

Briefly explain your reasoning.

No, the data are not consistent with Carlos's equation. In the equation, the normal force and height are inversely proportional, meaning that as the height (h) increases, the normal force should decrease. This is not what happens on the graph because the graph has a positive slope, meaning that as height h increases, the normal force increases.

PART E: Blake suggests that regardless of whether or not the data above are consistent with the equation, the equation could be incorrect for other reasons. Does the equation make physical sense?

The equation suggests that the normal force does not depend on R. However, the normal force will depend on the speed of the cart, which depends on the radius of the loop. Also, the units on the derived equation won't lead to the unit of force (Newtons). Also, if the graph is correct, the equation should have a y-intercept term. The equation suggests that the line of best fit should go through (0, 0), which it clearly does not.

PART F: What would happen if Carlos released the car from a height of 0.8 m?

_____ The car completes loop. __X__ The car does not complete loop.

Justify your claim using relevant features of the data shown.

Looking at the graph, a line of best fit can be drawn through the points. The line of best fit shows that the normal force will be zero (meaning that the car just loses contact with the track) when the height of release is equal to 1. This means that when $h = 1$, the car will have enough energy to just barely make it around the loop. If the height is less than 1, the car will not be moving fast enough to make the loop and will fall.