A CART ON AN INCLINED PLANE

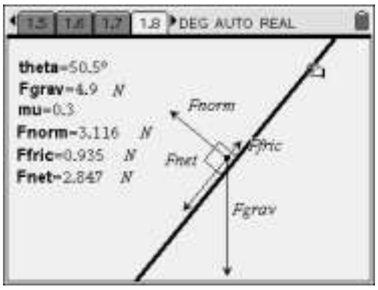
In this activity you will experience that your experimental equipment is precise enough to make things visible Galileo not even could dream of. Like Galileo had done in the early part of the 17th century, you will determine the mathematical relationship between the angle of an incline and the acceleration of a cart down a ramp by using a motion detector.

Galileo was able to measure acceleration only for small angles. You will collect similar data. Rather than measuring time, as Galileo did, you will use a motion detector to determine the acceleration.

Can these data be used to determine the acceleration of free fall?

A. Preparation

Use a free-body diagram (see figure on the right) to investigate the forces acting on a mass placed on an inclined plane. Explore the relationships between the coefficient of friction, the critical angle, the gravitational force, and the normal force and predict the acceleration as a function of the ramp angle.



– What is the relationship between the angle of an inclined plane and the normal force/the gravitational force/the frictional force on an object resting on the plane?

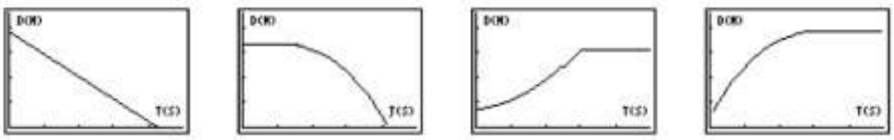
– What happens to an object on an inclined plane when the net force is greater than zero?

– What is the relationship between the magnitude of the normal force and the magnitude of the gravitational force?

B. Observation of an experiment

Preliminary experiments:

Which graph best describes the motion of the cart on the incline?



C. Modeling the situation in the laboratory

1) Analyze the forces on a rolling cart. Predict the acceleration as a function of ramp angle.

2) Place the motion detector at the top of an incline so that the cart will never be closer than 0.3m. Setup the data-collection program and release the cart. Adjust and repeat this step until you get a good run showing approximately constant slope on the velocity vs. time graph during the rolling of the cart.

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3) Vary the angle α of the incline and determine the acceleration of the cart from the obtained graphs for each run and record your data in a table. Compare sinα and the corresponding acceleration of the cart and determine the mathematical relationship between these two quantities.

4) *Extension 1*: Vary the mass of the cart and repeat steps 1 and 2.

5) *Extension 2*: Use the motion detector to measure the actual free fall of a ball.

D. Evaluating the data obtained

1) Determine the acceleration of the cart using both distance vs. time graphs and velocity vs. time graphs.

2) Then plot a graph of the average acceleration (y-axis) vs. sinα (x-axis).

3) After that, draw a best fit line for the data in step 2 by hand or use the regression function of your calculator. Explain why the slope of this line can be used to determine the acceleration of the cart on an incline of any angle.

4) On the graph, carry the fitted line out to sin (90°) = 1 on the horizontal axis, and read the value of the acceleration. Decide how well the extrapolated value agree with the accepted value of free-fall acceleration ($g = 9.8\ m/s^2$).

5) Discuss the validity of extrapolating the acceleration value to an angle of 90°.

6) Compare the results of your extrapolation with the measurements for free fall (see C5)

E. Show your results

1) Compare your experimental results to your prediction made in C1.

2) Thinking about your observations, discuss the correctness of the following statements:

a) If an object is moving down an incline with constant acceleration, there are no forces acting on the object.

b) If an object is moving down an incline with constant acceleration, the shape of its velocity vs. time graph is a straight line.

c) As the velocity of a rolling cart down an incline increases, the force acting on it also increases.

d) The distance vs. time graph of a cart rolling down an incline is a parabola. The coefficient of x^2 indicates the acceleration of the cart.

e) The slope of the distance vs. time graph at a point is equal to the velocity of the cart.