Lab on Motion: To Determine the Brief Interval of Time for a Hopper Toy to Snap Itself into the Air?

Equipment: a meter stick, a hopper toy and triple beam balance mass scale

Purpose: Today's lab is a review of the concepts of mechanics; including Newton's Laws, the relations determining accelerated motion (ULAM) and the impulse-change of momentum equation. The goal of this lab is to correctly determine the "snap time interval" for a dynamic little toy called the hopper. By repeatedly launching the toy, we can estimate the average height to which it rises. Measure this using the meter stick. Next use the kinematical equations for a rising (and falling) body in gravity to determine the initial speed with which it launches upward when it first hops off the table. Remember this is approximately the same as the final speed on the way down for a free falling body dropped from the same height (but in the opposite direction). To determine the mass of the hopper in grams use the balance scale. Convert that mass to kilograms so the unbalanced force acting is in the MKS unit of Newtons. Measure the short distance over which the toy acts when it inverts itself and convert that distance into meters. Again by using the kinematical equations for uniformly accelerated motion, determine the large and sudden acceleration which acts when the toy snaps against the table during launch. To determine the force which acts use $F = ma$. And finally to determine the very brief time interval during which the toy inverts itself use the impulse equation - solve it for delta t, that brief time interval during which the launch force acts. This is the brief time interval of the "snap action".

Procedure:

- Launch the toy three times and estimate the height it rises to. Use a meter stick to determine the distance in centimeters it rises to (and falls from). Take the average of three good trials and convert the average rise distance into meters.

  ________________ cm       ________________ cm      _______________ cm

  Average rise height ______________ m
• With the known acceleration of gravity and the height to which it rises to, about how much time does it take to rise to the measured height? The time to fall in gravity from the same height is about the same. We can determine the final speed after it falls the distance in one of two ways. To calculate the final speed as it falls; with the height it falls from and the known acceleration of gravity (use $g = -9.8 \text{ m/s}^2$ downward), determine the fall time using $h = \frac{1}{2} g t^2$ solved for time. Then use $v = g t$ to determine the final speed after falling. This is the same as the initial rise speed.

   Fall time __________________ seconds

   Initial rise speed ________________ m/s

Another equivalent way to determine the initial rise speed of the hopper is to use $v^2 = 2 g h$ solved for the initial speed. When the toy launches itself as it rises off the table (as free fall in gravity) and then falls the same height it rises to; with the known acceleration of gravity, solve this equation for speed. This is the same speed that it returns back to the table upon falling the same distance it rises to. We can properly apply this equation when we recognize that the hopper comes to rest ($v = 0$) at the top of flight and it falls from the same height from rest. Therefore the initial speed for the rising toy is the same as the final speed for the falling toy (which fell from the same height from rest).

   Initial rise speed ________________ m/s

• Measure the distance which the toy's action occurs over, when it inverts itself and snaps back into shape; that is the distance over which the unbalanced launch force acts. In this case it is the height of the toy itself. (Is this a true assumption?) Convert this small distance into meters and record it here.

   Snap acting distance ________________ m

• Determine the mass using the triple beam balance scale. Is it a large or small number? Now convert the gram mass into kilograms and record it here.

   Mass of toy ________________ kg

• With the kinematical laws of uniform acceleration, determine the acceleration (Is it a large or small number?) which acts during launch on the toy as it flies off the table. In this case, with the distance and final launch speed known, use $v^2 = 2 a x$ and solve for the acceleration.

   Launch acceleration ________________ m/s²
• Use the measured mass and the acceleration determined to calculate the force acting to launch the toy into the air. Use the units of kilograms and meters per second squared so the force will be expressed in Newtons. The equation \( F = ma \) will give the brief unbalanced force acting to launch the toy upward when it snaps.

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\text{Unbalanced Force Acting} \quad \text{_______________} \quad \text{N}
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• Write the impulse / change of momentum equation in symbolic form and determine the brief time interval during which the toys snaps back into shape and launches itself off the table. Remember that in this case the toy hops up from rest. At what two locations in it's motion is the toy at rest? Now equate the force acting on the object multiplied by the time it acts on the object to the momentum it gained during the event when it snapped off the table. With the toy at rest, we can solve this equation to give the brief time interval when the force acted and the hopper launched itself off the table.

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\text{Time to invert and snap into shape}
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\text{(time for force to act)} \quad \text{_______________} \quad \text{seconds}
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Questions for the Hopper Lab

1. In your own words, please write out in complete sentences; what you determined, how you determined it and how well you did at determining it. Be honest and explain any difficulties and possible sources of confusion or errors in the procedures and/or results.

2. Report the results determined for the initial launch speed, the acceleration which acted on the hopper, the applied unbalanced force that causes it to hop up and the brief time interval during the toy's snap back into shape which launched it. Write out each equation used to determine the snap time. When the hopper launches what does it push against? State the rule associated with these pair of equal but oppositely directed forces acting.

3. Describe the meaning of the equation "impulse equals change of momentum". Describe what impulse represents in physics. What must occur to cause a change in the momentum of a body? What must act to cause a change in motion for a body? Describe the effects of an unbalanced force acting on a body? What is momentum? Describe the three different ways a force can act to change the momentum of a body?
4. Simple toys and games as well as playthings can help to illustrate the basic rules of physics in their behavior. The physics of toys is fun and basic to learning. Name a toy, which illustrates a physics behavior, and describe the physics it exhibits. Please explain how the toy you selected demonstrates a physics principle or behavior. If you prefer, describe the physics involved in a selected playground or amusement park ride.

5. Why does a ball bounce off the wall when it is thrown against it? Does the wall push on the ball? Is this an action or reaction force? Explain your answer. What rule explains how this force increases when the ball is thrown harder against the wall? In what direction does the wall push the ball? When two objects collide, the more massive object shows a lesser change in motion with the same mutual force acting upon a larger mass. What basic property of matter does this illustrate? Explain your answer and give a statement of this most important principle of mechanics.