Honors Physics **Name:**

Momentum and Impulse Lab

Introduction

Forces, as studied in introductory physics courses, are presented as often uncomplicated, simple and generally easy to work with. With limited exception, the forces we encounter in everyday life are far from uncomplicated, simple and generally easy to work with (especially from a mathematical perspective). Even the simplest motions such as walking or jumping involve erratic and complex forces as our muscles generate basic locomotion. The application of Newton's Second Law to simple everyday forces is often impractical and, in many cases, impossible. In some instances, the concepts of impulse and momentum can be applied and prove to be powerful tools for studying problems involving real-life forces, especially collisions. In this series of activities, the forces that occur during "simple" activities such as push ups will be studied and analyzed. You will find that "simple" movements are not as simple as they appear and the forces our bodies generate are quite complex. Hopefully, you will develop a new appreciation for the amazing mechanics of our human machinery and, in the process, develop a better understanding of the concepts of impulse and momentum.

Important Concepts

Impulse: is the product of force, F and the time, t, for which it acts. The impulse of a force acting for a given time interval is equal to the time rate change of linear momentum. Graphically, impulse can be determined by finding the area under a force-time curve.

Momentum: the product of the mass and the velocity of an object.

Conservation of linear momentum: linear momentum is also a conserved quantity, meaning that if a closed system is not affected by external forces, its total linear momentum cannot change.

Formulas

$\mathbf{p} = m\mathbf{v}$

$(m_1\mathbf{v}_1 + m_2\mathbf{v}_2)_i = (m_1\mathbf{v}_1 + m_2\mathbf{v}_2)_f$

$\mathbf{J} = \mathbf{F}\,\mathbf{\Delta t}$

$\mathbf{J} = \mathbf{\Delta p}$

Materials

Golf Club

Red Solo Cup

Vernier Video Analysis

Golf Ball

iPhone

Wooden Block

Plinko Game

Newton's Cradle

LabQuest

Force Plates

Balance

Procedure

Part 1: Physics of Push Ups

1. Connect the two force plates to a LabQuest interface. Be sure the force plate is set to 850 Nt.
2. Open LoggerPro.
3. Zero the force plates.
4. Click COLLECT and then place one hand flat on each plate and perform a normal push-up. Go down slowly until your elbows are bent at a 90 degree angle and then return to your starting position. You should be able to produce several push-ups during a single data collection run.
5. While the subject is performing push-ups, the other lab partner should pay special notice to both the push-up motion and the force graphs.
6. Observe the force-time graphs and record your observations. Be sure to note how the force of your arms compare, how the total combined force varies throughout the motion, etc.
7. Save your graph.
8. Analysis: On the graphs, label the up phase of motion and the down phase.

Part 2: More Physics of Push Ups

1. Connect the two force plates to a LabPro interface. Be sure the force plate is set to 850 Nt.
2. Open LoggerPro.
3. Zero the force plates.
4. Click COLLECT and then place one hand flat on each plate. Perform a cheater push up: back straight, balance your knees, go down slowly until your elbows are bent at 90 degrees and then back up slowly.
5. While the subject is performing push-ups, the other lab partner should pay special notice to both the push-up motion and the force graphs.
6. Observe the force-time graphs and record your observations. Be sure to note how the force of your arms compare, how the total combined force varies throughout the motion, etc.
7. Save your graph.
8. Analysis: On the graphs, label the up phase of motion and the down phase.

Part 3: Newton's Cradle

Your goal for this part of the lab is to experimentally determine the mass of the Newton's Cradle ball.

1. Set up the Newton's Cradle.
2. Place a ruler at the base of the cradle.
3. Pull the end ball back to an acceptable height and release. Use your mobile device to record the motion of the Newton's Cradle.
4. Use Vernier Video Analysis to determine the velocity of the Newton's balls before and after the collision.

Part 4: The Price is Right - Plinko!
Your goal for this part of the lab is to experimentally determine the impulse imparted to the Plinko chip by one of the Plinko board pegs.
1. A ruler has been taped to the edge of the Plinko board.
2. Release the Plinko chip. Use your mobile device to record the motion of the Plinko chip as it makes its way down the Plinko board.
3. Watch your video and select one interaction between the Plinko chip and the peg.
4. Use Vernier Video Analysis to determine the velocity of the Plinko chip before the impulse and the velocity of the Plinko chip after the impulse.
Note: Be careful as the impulse may be imparted in the x- and y-direction.
5. Be sure to take the mass of the Plinko chip.

Part 5: The Price is Right - Hole in One
You have been selected as a contestant on The Price is Right, and lucky you, you get to play *Hole in One (or Two!)* for a brand new car. You need to get the golf ball into the red solo cup.

1. Set the red solo cup a distance of 1 m from the "tee." Make sure a meter stick is aligned along the path of the ball.
2. Use your mobile device to record the motion of the ball. Use Vernier Video Analysis to analyze your motion to determine the x-velocity of the ball as a function of time.
3. You need to determine the force required (by the putter on the ball) to get a hole in one.
4. You will need to determine what data you will need to collect and how you wish to analyze it.
5. Make sure you measure the mass of the golf ball.

Part 6: The Price is Right - Hole in One
You will now analyze elastic collisions using a golf ball and a wooden block.

1. Place the wooden block at the zero mark of the meterstick.
2. Use your mobile device to record the collision between the ball and the wooden block. Use Vernier Video Analysis to determine the x-velocity of the golf ball and the block before and after the collision.
3. Make sure you measure the mass of the golf ball and the mass of the block.
4. Using your data, calculate the experimental mass of the block.

Data
Insert screen captures of all appropriate graphs. Make sure each graph has an appropriate title and your axes are labeled.

Analysis
Part 1 and 2

1. For each type of push up, which hand exerted a greater force on the plate? Offer an explanation to support your answer.
2. For which type of push up did you exert a greater force on the plates? Offer an explanation to support your answer.
3. Did the force exerted on the plates change over time? Why do you think it did?
4. Did the contact time on the plates change over time?
5. Based on your answers to 3 and 4, how does the impulse exerted on the plates change over time?
6. The impulse imparted on the force plates can be determined by taking the appropriate area under the curve. Use the Integral function in Logger Pro to determine the area under the curve.
7. Based on your analysis of the area under the curve, how does the impulse exerted on the plates change over time?
8. Based on your analysis of the area under the curve, which hand produced a greater impulse on the plate?
9. Based on your analysis of the area under the curve, which type of push up produced a greater impulse on the plate?

Part 3: Newton's Cradle

1. Show the mathematical steps and data required for your data analysis. Show any formulas used and any necessary derivations and calculations. Remember, you are experimentally determining the mass of the Newton's Cradle ball.

Part 4: The Price is Right - Plinko!

1. Show the mathematical steps and data required for your data analysis. Show any formulas used and any necessary derivations and calculations. Remember, you are calculating the impulse imparted to the Plinko chip by the Plinko board peg.

Part 5: The Price is Right - Hole in One

1. Show the mathematical steps and data required for your data analysis. Show any formulas used and any necessary derivations and calculations. Remember, you are determining the force required (by the putter on the ball) to get a hole in one.

Part 6: The Price is Right - Hole in One

1. Show the mathematical steps and data required for your data analysis. Show any formulas used and any necessary derivations and calculations.
2. Use your data to support the argument that this is an elastic collision.