Dynamics & Kinematics: Newton's Laws of Motion in One-Dimensional Motion

Universiti Teknologi MARA
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PHY406: A Physical Science Activity

Name:_____ HP: _____ Lab # 5:

The goal of today's activity is to explore and describe vertical motions and explore and explain the nature of one-dimensional horizontal motion pictorially, textually, graphically and mathematically when the object is simultaneously pulled in opposite directions.

At the end of the activity, you will be able to:

1. Draw and describe the pictorial representations of motion for an object thrown vertically up (positive y-axis) and for an object that fall vertically down.
2. Determine the acceleration of an object that fall down vertically.
3. Draw and describe pictorial representations of motion along the x-axis for an object experiencing simultaneous pull from opposite directions.
4. Describe and discuss the features of position vs. time, velocity vs. time and acceleration vs. time graphs you constructed from your investigation of motion along the horizontal when it is simultaneously pulled from opposite directions.
5. Explain the motion of an object which is experiencing simultaneous pull from opposite directions.
6. Discuss the worth of your planned investigation methods in terms of the physical quantities investigated, the devices chosen to perform the investigations, the errors and uncertainties involved with the devices and measurements, the physical quantities manipulated in your investigation and the quantities derived from the data after observing objects experiencing simultaneous pull in opposite directions.

Background Information

In lab # 4, you investigated the horizontal motion of an object which moved at a constant velocity (initiated by an instantaneous push on the glider) and an object which had a constant increasing speed or constant acceleration (continuous pull on the glider). You had used ticker tapes and determined the distance travelled by the object by measuring the length between dots on the ticker tape. Since the time interval (time between the initial and final clock readings) for the ticker timer to print the dots is 0.02 seconds, you calculated the average speed between the dots by taking the ratios of distance travelled (length between dots) to the time interval. Mathematically, $v_{avg} = \frac{x_{n+1} - x_n}{0.02\ s}$. In addition, you also determined the average acceleration, $a_{avg} = \frac{v_{n+1} - v_n}{0.02\ s}$. How was the position-time graph different between the constant-velocity motion to the constant-acceleration ("speeding up") motion? How was the velocity-time and acceleration-time graph similar or different for both cases? How are the picture of the motion and the graphs you obtained different from your prediction and from the PHeT simulation? What can you summarize and conclude from your investigation?

The continuous pull which caused the glider to “speed up” in lab #4 was made possible by attaching the glider to a hanging mass at the end of the air track. The hanging mass was allowed to “fall down” onto the floor which then pulled the glider along with it. The “acceleration” or “speeding up” of the glider happened because the hanging mass caused it to “speed up”. The falling of the hanging mass is a natural phenomenon and is attributed to the gravitational pull by the earth on all objects near the surface of the earth.

How then would the motion of an object along the vertical direction be different from motion along the horizontal direction? How will the motion look like when it is thrown vertically up or dropped vertically down? How will its position-time, velocity-time and acceleration-time graphs be similar or different than motion along the horizontal? Is the “speeding up” when objects are falling the same for all objects regardless of size, shape, types of material and its mass? Is the same “gravitational pull” that caused objects to fall also responsible to cause objects to “slow down”, stop and then fall down when an object is thrown vertically up?

In today’s investigation, you will explore, measure and try to answer these questions. In addition, you will also investigate how the speeding up of an object change when it is simultaneously pulled in opposite directions and you will also compare your findings with Newton’s Laws of motion in one dimension.

STUDENT ACTIVITIES

INVESTIGATION 1-PICTORIAL REPRESENTATIONS & DESCRIPTION OF OBJECTS FALLING DOWN AND THROWN VERTICALLY UP

In this investigation you will observe, record and discuss the motion of objects along the vertical direction when the object is thrown vertically up and when it fall back down to its initial position. You will then carefully record the fall of a metal ball and a tennis ball respectively by using a ticker-tape.

Activity 1: Observe & record the motion of objects being thrown up vertically

Upon completion of this activity, you will be able to:

- Draw and describe the pictorial representations of motion for an object thrown vertically up (positive y-axis) and for an object that fall vertically down.

Materials:

2 metal balls of different diameters, a tennis ball, a Styrofoam ball, a pen or pencil and a stop watch.

Prediction 1.1:

- Predict and draw a picture of the motion (position of the object) that you will observe when the objects are thrown vertically up a height of 5 meters and then falling down to its initial position.

Picture of the motion				
Small Metal Ball	Big Metal Ball	Tennis Ball	Styrofoam ball	Pen or Pencil

1.1.0 METHOD

- This activity is best done in groups of 3 or 4 and will be done outside the classroom. It is recommended that you throw the ball up to a height of at least 5 or 6 meters (you need

to estimate this height based on the height for each storey of a building. You can throw higher as long as the height is approximately the same for all your throws.

- Plan and discuss your investigation procedure with your group members. Identify the variables (quantities) that you are measuring and that you keep constant. Jot down all the information that you had discussed. Discuss how you will record the data (such as where you group members will be stationed, how many trials you will run and your justification for choices you made) and how your data will be organized and presented. You and your group members will verbally report your procedure to the lab instructor before you proceed with the investigation. YOU MUST DISCUSS AND AGREE ON YOUR PROCEDURE WITH GROUP MEMBERS BEFORE COMING TO THE LAB AND BE READY TO PRESENT IT TO THE LAB INSTRUCTOR UPON THE START OF THE LAB.
- Do a trial run of your investigation. When everyone in the group is comfortable that your procedure is workable, proceed with the investigation.
- Remember to repeat your investigation at least twice

1.1.1 DATA

Record the observation and the data that you collected in an organized manner. In addition, be sure to record the things that you do and the things you decide to change at the last minute and the reasons why you made those changes.

1.1.2 RESULTS

- Include any calculations and graphs that you constructed (if any). Discuss any inference you made or any derived quantities that you obtained (if any).

- Compare your results to your prediction.

- Describe what happens to the ***velocity*** and ***acceleration*** of the object when it is thrown up vertically.

- Describe what happens to the ***velocity*** and ***acceleration*** of the objects when it falls down.

- Describe what happens to the ***velocity*** and ***acceleration*** when the ball is at the highest position and temporarily stops.

- Is the time taken to travel the same distance during the climb up the same as the time taken to travel that same distance while it is falling? Use the results to explain your answer.

- Is the time taken to reach its highest position after the throw the same as the time taken for it to fall from its highest position to its initial (starting) position? Use the results to explain your answer.

Activity 2: Observe, Record and Discuss the motion of objects in a free fall

In this activity, you will determine the acceleration of objects undergoing a fall without any restraint (this is termed free fall) by using ticker tapes. Choose the tennis ball and the metal ball as objects for investigation. Upon completion of this activity, you will be able to:

- Determine the acceleration of objects that fall down vertically (free fall).

Materials:

A small metal ball, a tennis ball, a ticker timer, a power supply for the timer, ticker tapes and a ruler.

Prediction 1.2:

- Predict and draw a picture of the falling motion (position of the objects as it falls)

Picture of the motion	
Small metal ball	Tennis ball

- Predict the time taken for the metal ball and the time taken for the tennis ball to reach the ground respectively.

Time of flight for the metal ball, t_{mb} = _____ s
Time of flight for the tennis ball, t_{tb} = _____ s

1.2.0 METHOD

- This activity is best done in groups of 3 or 4.
- Plan and discuss your investigation procedure with your group members. Identify the variables (quantities) that you are measuring and that you keep constant. Jot down all the information that you had discussed. Discuss how you will record (such as height of the drop, how many trials you will run for each ball and the justification for your decision) and how your data will be organized and presented (such as table and the use of excel and the graphs you will construct). You and your group members will verbally report your procedure (you must show the diagrams and table with units and proposed graphs to be constructed before you are allowed to do the experiment) to the lab instructor before you proceed with the investigation. YOU MUST DISCUSS AND AGREE ON YOUR PROCEDURE WITH GROUP MEMBERS BEFORE COMING TO THE LAB AND BE READY TO PRESENT IT TO THE LAB INSTRUCTOR UPON THE START OF THE LAB.

- Do a trial run of your investigation. When everyone in the group is comfortable that your procedure is workable, proceed with the investigation.
- Remember to repeat your investigation at least once.

1.2.1 DATA

Tabulate your data. Include all units involved for the quantities you measured and the quantities you calculated.

1.2.2 RESULTS

CALCULATION USING SPREADSHEET

- If you construct graphs using MS EXCEL, include the equation you wrote in the cells. Show all your graphs you constructed and the quantities you calculated from the graphs. Describe and discuss the graphs you constructed and the quantities you calculated.

- How is your result compared to your prediction?

- Should the velocities and distance travelled be the same for the metal ball and the tennis ball when the clock reads 0.12 s and when it reads 0.50 s respectively? Use the results to explain your answer.

- Are the accelerations for both objects constant and the same throughout the free fall? Use the results to explain your answer.

- What inference can you make for objects experiencing free fall?

- How would you determine the gravitational pull that act on the object?

INVESTIGATION 2-DESCRIBING POSITION, VELOCITY AND ACCELERATION WITH PICTURES. WORDS AND GRAPHS WHEN OPPOSING FORCES ACT ON A GLIDER

In this investigation, you will apply opposing pulls to an object and observe, describe and explain the horizontal motion of the object as the magnitude of the pull is varied.

Activity 1: Observe & record the horizontal motion of objects that are simultaneously pulled in opposing directions.

Upon completion of this activity, you will be able to:

1. Draw and describe pictorial representations of motion along the x-axis for an object experiencing simultaneous pull from opposite directions.
2. Describe and discuss the features of position vs. time, velocity vs. time and acceleration vs. time graphs you constructed from your investigation of motion along the horizontal when it is simultaneously pulled from opposite directions
3. Explain the motion of an object which is experiencing simultaneous pull from opposite directions.

Materials:

Air track and power supply, a glider (or use toy cars in place of glider and air track), 2 pulleys, 2 hanging weights, ticker timer, a power supply for the timer, ticker tapes and a ruler.

Prediction 2.1:

- Predict and draw the motion of the glider when:
  - Hanging weights at both ends of the air track are equal.
  - Hanging weight on the right is twice the hanging weight on the left.
  - Hanging weight on the right is three times the hanging weight on the left.
  - Hanging weight on the left is twice the hanging weight on the right.
  - Hanging weight on the left is twice the hanging weight on the right.

Hanging weights	Predicted motion represented by the ticker tape dots
Equal Weights	
Right is 2X left	
Right is 3X left	
Left is 2X right	
Left is 3X right	

2.2.0 METHOD

- This activity is best done in groups of 3 or 4.
- Plan and discuss your investigation procedure with your group members. Identify the variables (quantities) that you are measuring and that you keep constant. Jot down all the information that you had discussed. Discuss how you will record your data (such as amount of weight you will hang, where you should place the ticker timer, how many trials you will run for each motion and the justification for your decision) and how your data will be organized and presented (such as table and the use of excel and the graphs you will construct). You and your group members will verbally report your procedure (you must show the diagrams and table with units and proposed graphs to be constructed before you are allowed to do the experiment) to the lab instructor before you proceed with the investigation. YOU MUST DISCUSS AND AGREE ON YOUR PROCEDURE WITH GROUP MEMBERS BEFORE COMING TO THE LAB AND BE READY TO PRESENT IT TO THE LAB INSTRUCTOR UPON THE START OF THE LAB.
- You will need to adjust the screws underneath the air track to ensure it is leveled. Be sure to test that it is leveled before beginning your investigation.
- Do a trial run of your investigation. When everyone in the group is comfortable that your procedure is workable, proceed with the investigation.
- Remember to repeat your investigation at least once.

2.2.1 DATA

Tabulate your data. Include all units involved for the quantities you measured and the quantities you calculated.

2.2.2 RESULTS

Hanging weights	Observed motion represented by the ticker tape dots
Equal Weights	
Right is 2X left	
Right is 3X left	
Left is 2X right	
Left is 3X right	

Describe the differences and similarities between your results and your prediction of the motion for each case.

CALCULATION USING SPREADSHEET

- If you construct graphs using MS EXCEL, include the equation you wrote in the cells. Show all your graphs you constructed and the quantities you calculated from the graphs. Describe and discuss the graphs you constructed for each case and the quantities you calculated.

- Describe how the acceleration of the object changed when the masses are changed on either ends of the air track.

- Use the results to propose a mathematical modeling between the pulls on the glider and its acceleration.

- Suppose an additional string with its own hanging weights is added onto the right end of the air track. Use the model you proposed to predict the glider's motion in the following situation. Show all calculations

Hanging weight on the left (kg)	Hanging weight on the right (kg)	Additional Hanging weight on the right (kg)
0.100	0.200	0.100
0.50	0.20	0.30
0.50	0.20	0.20

- Explain how the hanging mass in the table above is related to a pulling force and calculate and tabulate the gravitational pull generated from the mass table above.

- Compare your results with the "Forces in 1 Dimension" PHeT simulation which can be downloaded from the PHeT website.

- Compare your results in investigation 1 and investigation 2 to Newton's Laws of motion.