Force Interactive
Frictionless Situations

Purpose:
The purpose of this activity is to investigate the variables that affect the acceleration of an object and the manner in which those variables affect the acceleration.

Background:
When forces are unbalanced, objects accelerate. But what exactly affects the acceleration of the object? You will explore this question by running a collection of simulations in the absence of friction. Set the friction value to 0.00 and run the following trials. Collect sufficient velocity-time information (fifth column) for determining the acceleration in the last column.

Data:

Trial	Applied Force (N)	Mass (kg)	Net Force (N)	Velocity-time Information	Acceleration (m/s/s)
1	10.0	2.0			
2	20.0	2.0			
3	40.0	2.0			
4	60.0	2.0			
5	80.0	2.0			
6	100.0	2.0			
7	40.0	1.0			
8	40.0	3.0			
9	40.0	4.0			
10	40.0	5.0			

Use the collected data to answer the questions in the **Analysis** section.

Analysis:

1. What affect does a doubling of the net force have upon the acceleration of the object? Be quantitative. (Don't just say it decreases or increases; indicate *the factor* by which acceleration decreases or increases.)

   Identify a set of two trials that support your answer above: ______________________

2. What affect does a tripling of the net force have upon the acceleration of the object? Be quantitative.

   Identify a set of two trials that support your answer above: ______________________

3. What affect does a doubling of the mass have upon the acceleration of the object? Be quantitative.

   Identify a set of two trials that support your answer above: ______________________

4. What affect does a quadrupling of the mass have upon the acceleration of the object? Be quantitative.

   Identify a set of two trials that support your answer above: ______________________

5. Lab partners Vera and Bill Confuzzens attempted to use Trials 5 and 8 to show the affect that a doubling of force has upon the acceleration. Explain why these two trials cannot be used to show the affect of force upon acceleration.

Conclusion:
Consider the original question that prompted this investigation:

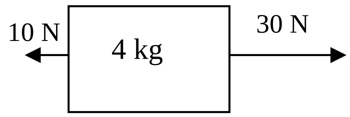
> What variables affect the acceleration of an object and in what manner do they affect the acceleration?

Make a **claim** in which you attempt to answer this question. Then support the claim with **evidence** (specific references to trials of data) and **reasoning** in which you explain how the data support the claim that you have made.

Practice Worksheet: Net Force and Acceleration Name______________________________

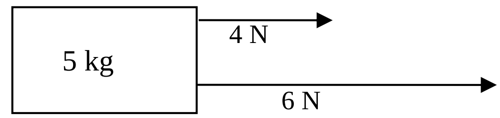
For each of the following problems, give the net force on the block, and the acceleration, including units.

1)



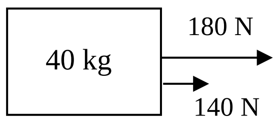
Net Force = ________ a = F/m = _______

2)



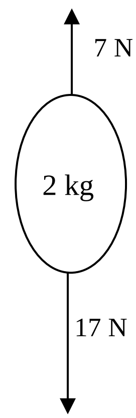
Net Force = ________ a = F/m = _______

3)



Net Force = ________ a = _______

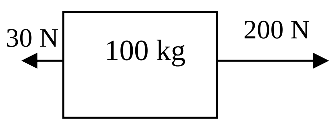
4)



Net Force = ________

a = __________

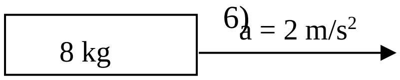
5)



Net Force = ________ a = _______

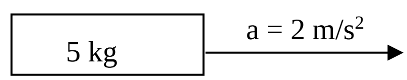
For problems 6-9, using the formula net Force = Mass • Acceleration, calculate the net force on the object.

6)



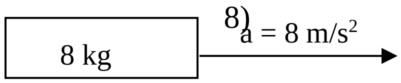
F = m•a = _____________

7)



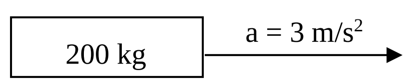
F = m•a = _____________

8)



F = m•a = _____________

9)



F = m•a = _____________

10) Challenge: A student is pushing a 50 kg cart, with a force of 600 N. Another student measures the speed of the cart, and finds that the cart is only accelerating at 3 m/s^2. How much friction must be acting on the cart? Hint: Draw a diagram showing the cart, and the two forces acting on it.

Practice Problem Set F=ma ⇨ FORCE = MASS x ACCELERATION Name ___________________

Equations: $F=ma$ $a=F/m$ $m=F/a$

Plug in the given values for Force/Mass/Acceleration to solve.
Remember, **mass is in kg** - - **force in in N** (newtons) - - **acceleration is in m/s^2**

1. How much force is needed to accelerate a 66 kg skier at 2 m/sec^2?

2. What is the force on a 1000 kg elevator that is falling freely at 9.8 m/sec^2?

3. What is the acceleration of a 50 kg object pushed with a force of 500 newtons?

4. The mass of a large car is 1000 kg. How much force would be required to accelerate the car at a rate of 3 m/sec^2?

5. A 50 kg skater pushed by a friend accelerates 5 m/sec^2. How much force did the friend apply?

6. A force of 250 N is applied to an object that accelerates at a rate of 5 m/sec^2. What is the mass of the object?

7. A bowling ball rolled with a force of 15 N accelerates at a rate of 3 m/sec^2; a second ball rolled with the same force accelerates 4 m/sec^2. What are the masses of the two balls?

8. If a 60 kg person on a 15 kg sled is pushed with a force of 300 N, what will be person's acceleration?

9. A force of 20 N acts upon a 5 kg block. Calculate the acceleration of the object.

10. An object of mass 300 kg is observed to accelerate at the rate of 4 m/s^2. Calculate the force required to produce this acceleration.

11. A 5 kg block is pulled across a table by a horizontal force of 40 N with a frictional force of 8 N opposing the motion. Calculate the acceleration of the object.

12. An object of mass 30 kg is in free fall in a vacuum where there is no air resistance. Determine the acceleration of the object.

13. An object of mass 30 kg is falling in air and experiences a force due to air resistance of 50 newtons.
    a. Determine the net force acting on the object and
    b. calculate the acceleration of the object.

Projectile Motion

You have probably watched a ball roll off a table and strike the floor. What determines where it will land? Could you predict where it will land? In this experiment, you will roll a ball down a ramp and determine the ball's velocity with a Photogate. You will use this information and your knowledge of physics to predict where the ball will land when it hits the floor.

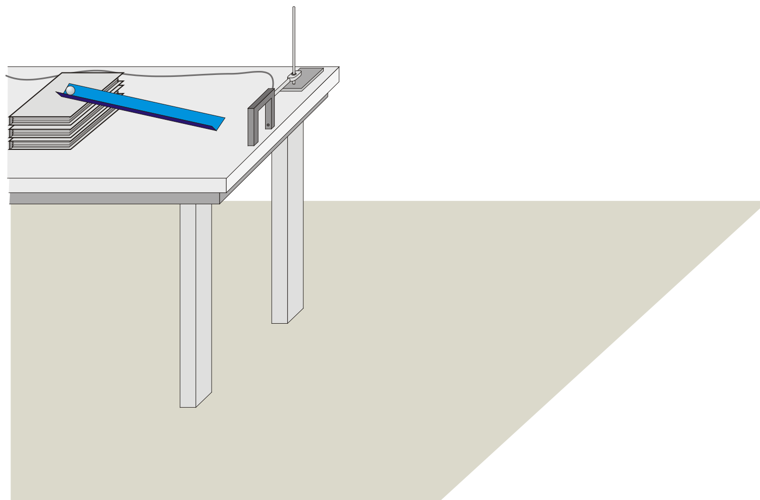


Figure 1

OBJECTIVES

- Measure the velocity of a ball using a Photogate.
- Apply concepts from two-dimensional kinematics to predict the impact point of a ball in projectile motion.
- Take into account trial-to-trial variations in the velocity measurement when calculating the impact point.

MATERIALS

LabQuest
LabQuest App
2 Vernier Photogates
target
ball (1 to 5 cm diameter)
masking tape
plumb bob
ramp
ring stand
right-angle clamp
meter stick or metric measuring tape

PROCEDURE

1. Set up a low ramp made of angle molding on a table so that a ball can roll down the ramp, across a short section of table, and off the table edge as shown in Figure 1.

2. Position the Photogates so the ball rolls through each of the Photogates while rolling on the horizontal table surface (but *not* on the ramp). Approximately center the detection line of each Photogate on the middle of the ball. To prevent accidental movement of the Photogates, use tape to secure the ring stands in place.

3. Mark a starting position on the ramp so that you can repeatedly roll the ball from the same place. Roll the ball down the ramp through the Photogate and off the table. Catch the ball as soon as it leaves the table. **Note**: Do not let the ball hit the floor during these trials, or during the following velocity measurements. Make sure that the ball does not strike the side of the Photogates. Move the Photogates if necessary.

4. Set up the Photogates and LabQuest to collect data in Pulse Timing mode.
   a. Connect the Photogates to LabQuest and choose New from the File menu. If you have older sensors that do not auto-ID, manually set up the sensors. **Note:** Connect the sensors so that the ball first passes through the Photogate connected to DIG 1 and then passes through the Photogate connected to DIG 2.
   b. On the Meter screen, tap Mode. Change the Photogate Mode to Pulse Timing.
   c. You must enter the distance between Photogates in order for LabQuest to calculate the velocity. The program will divide this distance by the time interval Δt it measures to get the velocity ($v = \Delta s/\Delta t$). Carefully measure the distance from the beam of Photogate 1 to the beam of Photogate 2. (It may be easier to measure from the leading edge of Photogate 1 to the leading edge of Photogate 2.) To successfully predict the impact point, you *must* enter an accurate measurement. Enter the distance between gates (in meters).
   d. Select OK.

6. Observe the live readings. Block the Photogate 1 with your hand; note that the Photogate is shown as Blocked on the screen. Remove your hand and the display should change to Unblocked. Repeat for Photogate 2.

7. LabQuest will measure the length of time from when the first photogate is blocked until the second photogate is blocked. You can see how this works by blocking the gates briefly with your hand.
   a. Start data collection.
   b. Check to see that the Photogates are responding properly by moving your finger through Photogate 1 and then Photogate 2. LabQuest App will plot a time interval (Δt) value for each instance you run your finger through Photogate 1 then through Photogate 2.
   c. Stop data collection.

8. Collect data.
   a. Start data collection.
   b. Roll the ball from the mark on the ramp, through both Photogates, and catch the ball immediately after it leaves the table.
   c. Repeat nine times. Take care not to bump any of the Photogates, or your velocity data will not be precise.
   d. After the last trial, stop data collection.

9. Tap Table. Record the time and velocity for each pass through the photogates in the data table.

10. Inspect your velocity data. Did you get the same value every time? To determine the average, maximum, and minimum values, tap Graph, then choose Statistics ►Velocity from the Analyze menu. What one value would be most representative of all ten measurements?

11. Carefully measure the distance from the tabletop to the floor and record it as the table height, *h*, in the data table. Use a plumb bob to locate the point on the floor just beneath the point where the ball will leave the table. Mark this point with tape; it will serve as your *floor origin*.

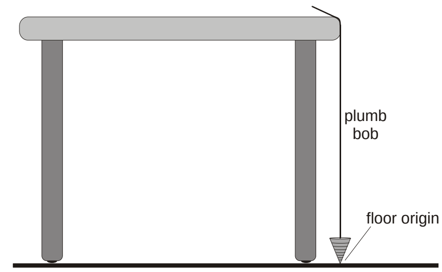


Figure 2

12. Use your average velocity value to calculate the distance from the floor origin to the impact point where the ball will hit the floor. You will need to algebraically combine relationships for motion with constant acceleration

$$\Delta x = v_{0x}t + \tfrac{1}{2}a_x t^2$$

$$\Delta y = v_{0y}t + \tfrac{1}{2}a_y t^2$$

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What is the value of the initial velocity in the vertical direction (v_{0y})? (1 point)

What is the acceleration in the horizontal direction (a_x)? What is the acceleration in the vertical direction (a_y)? (1 points)

Simplify the equations above taking into account the values above. (1 points)

Remember that the time the ball takes to fall is the same as the time the ball flies horizontally. Use this information and the simplified equations to calculate how far the ball should travel horizontally during the fall. Record the value in your data table as the predicted impact point.

Mark your predicted impact point on the floor with tape and position a target at the predicted impact point. Be sure the impact point is along the line of the track.

13. To account for the variations you saw in the Photogate velocity measurements, repeat the calculation in the preceding step for the minimum and maximum velocity. These two additional points show the limits of impact range that you might expect, considering the variation in your velocity measurement. Mark these points on the floor as well, and record the values in your data table.

14. After your instructor gives you permission, release the ball from the marked starting point, and let the ball roll off the table and onto the floor. Mark the point of impact with tape. Measure the distance from the floor origin to the actual impact and enter the distance in the data table.

PRELIMINARY QUESTIONS (2 POINTS EACH)

1. If you were to drop a ball, releasing it from rest, what information would be needed to predict how much time it would take for the ball to hit the floor? What assumptions must you make?

2. If the ball in Question 1 is traveling at a known horizontal velocity when it starts to fall, explain how you would calculate how far it will travel horizontally before it hits the ground.

3. When an object passes through a Photogate, it blocks the passage of light from one side to the other. The interface can accurately measure the duration of time that a gate is blocked. If you wanted to know the velocity of the object, what additional information would you need?

4. A gun shoots a bullet with a velocity of 500. m/s. The gun is aimed horizontally and fired from a height of 1.50 m. How far (horizontally) does the bullet travel?

5. A coin rolls off the edge of a table. The coin was traveling with a speed of 0.40 m/s. It lands 0.20 m away from the table leg (which is straight down from the table edge). How high is the table?

6. A baseball is hit horizontally. It leaves the bat with a speed of 40.0 m/s. The batter hit the ball at a height of 1.00 m above the ground. What distance horizontally does it travel before it hits the ground?

DATA TABLE (5 POINTS)

Trial	Time (s)	Velocity (m/s)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Maximum velocity	m/s
Minimum velocity	m/s
Average velocity	m/s
Table height	m
Predicted impact point	m
Minimum impact point distance	m
Maximum impact point distance	m
Actual impact point distance	m

ANALYSIS

1. Show your calculations to predict the impact point. Include all calculations (labelled, with units). (4 points)

2. Explain why a *range* for the prediction is more appropriate than an exact location? (2 points)

3. Was your actual impact point between your minimum and maximum impact predictions? If not, state where the impact point was and explain why you think it did not land as predicted. (4 points – graded on accuracy)

4. Did you account for air resistance in your prediction? If so, how? If not, how would air resistance change the distance the ball flies? (3 points)

5. Calculate the velocity of impact. (3 points)

6. Place a ring on a ring stand part way to the eventual target. The ball must pass through the ring successfully and then hit the target. You are required to position the ring as well as the target on the floor. ***Draw a diagram and show the calculations*** that you will use to make your prediction. DO NOT try the experiment without the instructor. (5 points)

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5. Lab partners Vera and Bill Confuzzens attempted to use Trials 5 and 8 to show the affect that a doubling of force has upon the acceleration. Explain why these two trials cannot be used to show the affect of force upon acceleration.

Conclusion:
Consider the original question that prompted this investigation:

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Make a **claim** in which you attempt to answer this question. Then support the claim with **evidence** (specific references to trials of data) and **reasoning** in which you explain how the data support the claim that you have made.