Name: _____ Date: _____

INVESTIGATION 1A

Time, Distance, and Speed

1 Using the timer as a stopwatch

There are no questions to answer in part 1.

2 Mixed units for time

Arrange the following times from smallest to largest:

a) 3:45:16
3 hours, 45 minutes, 16 seconds

b) 1:45.55
1 minute, 45.55 seconds

c) 1:06:01
1 hour, 6 minutes, 1 second

3 Using the photogates

There are no questions to answer in part 3.

4 How the photogate works

a. Exactly what do you do to start and stop the clock? Be very specific in your answer. Someone who has never seen the photogate before should be able to read your answer and know what to do.

b. If you block the light beam several times in a row, does the time add or does the timer start at zero every time you break the beam? Your answer should provide observations that back up what you say. For example, "the timer does _____ because_____." Fill in the blanks with what you think based on what you observed.

Name: _____ Date: _____

INVESTIGATION 1A

5 Two photogates

Table 1: Timer and photogate rules

A light	B light	How do you start the clock?	How do you stop the clock?	What time interval does the clock measure?
On	Off			
Off	On			
On	On			
Off	Off			

6 Thinking about what you observed

a. Describe a way to measure the speed of a toy car using two photogates and a meter stick.

b. Describe a way to measure the speed of a toy car using one photogate and a meter stick.

c. What does the red Reset button do?

7 Constant speed

There are no questions to answer in part 7.

Name: _____ Date: _____

8 Thinking about what you observed

a. Describe how the photogate measurements prove that the car has constant speed, or nearly constant speed.

b. Calculate the speed of the car in meters per second (m/sec).

9 Position versus time

Table 2: Position versus time data

Position (cm)	Time through photogate A (sec.)	Time through photogate A (sec.)	Time from photogate A to B (sec.)

Name: _____ Date: _____

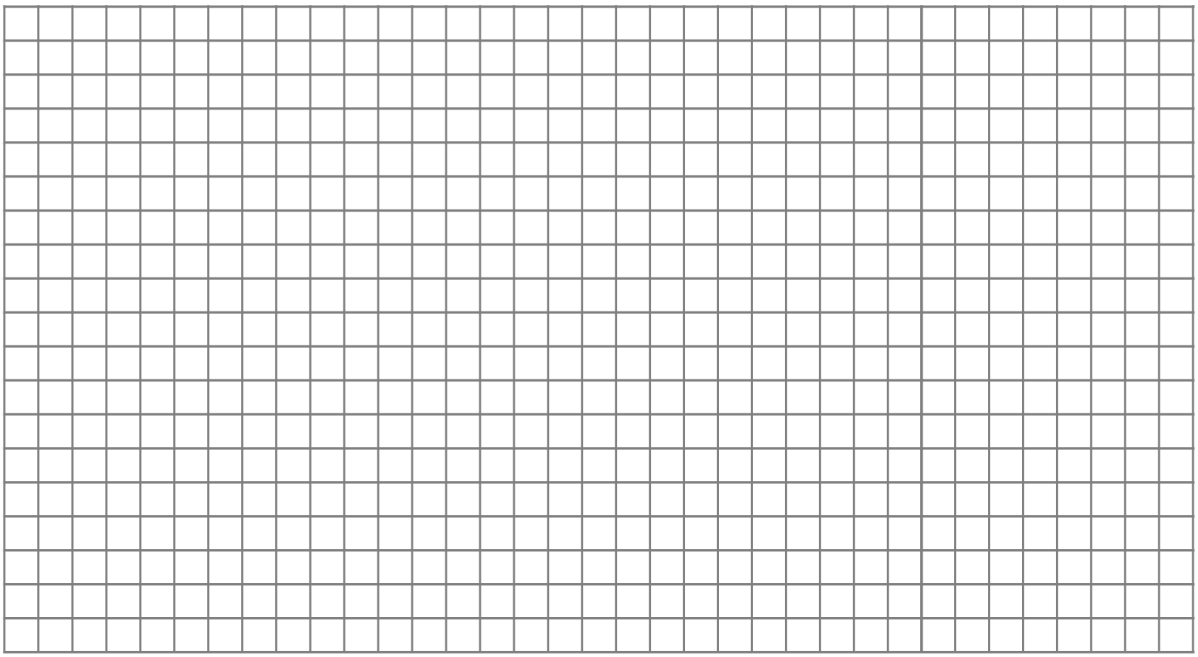
INVESTIGATION 1A

10 Thinking about what you observed

a. Draw a graph showing the position of the car on the vertical (y) axis and the time since the car was released on the horizontal (x) axis. The time you want is the time from photogate A to B.

Title: _____

y label: _____



x label: _____

b. What shape does the position versus time graph have? Describe the line or curve that you produce.

_____

_____

_____

c. Calculate the average speed of the car from the graph or your data.

_____

_____

_____

d. How long would it take the car to travel a distance of 2 meters if it kept the same speed?

_____

_____

_____

Name: _____ Date: _____

INVESTIGATION 1B

Systems, Energy and Change

1 Making a system

There are no questions to answer in part 1.

2 Questions for the experiment

a. What is speed and how can it be measured with two photogates in this experiment?

b. Different cars are rolling on tracks with different angles. Which car should go the fastest? Which car should go the slowest?

c. Which car should have the shortest time from photogate A to photogate B? Which should have the longest time?

3 What do you observe

Each group should drop the car and record the time it takes to get from photogate A to photogate B. Use Table 2 to record the times in the Trial #1 column. Leave the second column black for now.

Table 1: Speed data

Hole #	Trial #1 Time in seconds	Trial #2 Time in seconds

Name: _____ Date: _____

INVESTIGATION 1B

4 Thinking about what you observed

a. Did the times in Table 1 agree with your hypothesis? Explain in one sentence why or why not.

b. What objects and influences should be "in" your system if you want to investigate the motion of the car?

c. Name two things that should not be in your system since they do not influence the motion.

d. What is a variable? What variables affect the motion of the car in your system? Make a list of the variables (Hint: there are at least 6 important ones).

e. What variable is being tested in your class experiment (the experimental variable)? How do you know?

f. What should be done with the other variables which are not the experimental variable? Why?

5 A better experiment

Enter the data into table 1.

Name: _____ Date: _____

6 Thinking about what you observed

a. Did the new times for the second trial of the experiment agree with your hypothesis about which track should have the fastest car? Explain in one sentence why or why not.

7 Energy in the system

Table 2: Energy data

Drop position (cm from center)	Before rubber band		After rubber band	
	Time through photogate (sec)	Speed (cm/sec)	Time through photogate (sec)	Speed (cm/sec)

8 Thinking about what you observed

a. If you drop the car from a certain height does it ever go higher after bouncing off the rubber band?

b. If the car has a certain speed going into the rubber band does it ever have a greater speed after bouncing off? (Hint: use the timer's memory button.)

c. When you drop the car from a certain height it reaches a certain speed at the photogate. If you launch the car with the same speed back up the hill, does the car ever get higher than the height at which you first dropped it? (try this experiment)

d. In one paragraph, explain how the answers to a, b, and c are explained using the idea of energy.

Name: _____ Date: _____

INVESTIGATION 2A

The Law of Inertia

1 Launching cars of different mass

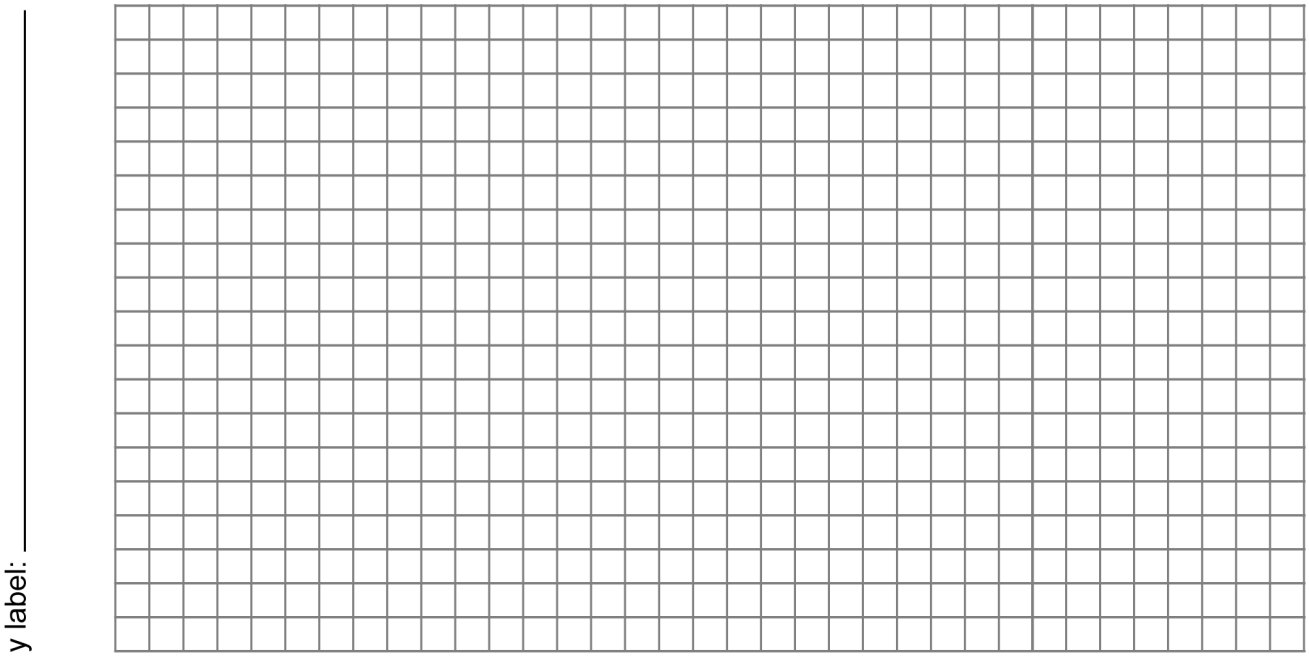
Table 1: Constant force data

Mass of car (kg)	Time through photogate (sec)	Speed (m/sec)

2 Thinking about what you observed

a. Use Table 1 to graph the speed of the car (y) against the mass (x).

Title: _____



x label: _____

b. Why did the speed change when the same launching force from the rubber band was applied to cars of different mass? How do your observations support your answer?

_____

_____

_____

Name: _____ Date: _____

INVESTIGATION 2A

3 Inertia and weight

Table 2: Constant height data

Mass of car (kg)	Time through photogate (sec)	Speed (m/sec)

4 Thinking about what you observed

a. What force makes the car go down the hill? What property of matter does this force act upon?

b. Does increasing the mass of the car increase its speed by a proportional amount? Does the speed decrease with increasing mass? Does the speed stay about the same, no matter what the mass?

c. Discuss and propose an explanation for why changing the mass has a very different effect on the speed when gravity provides the force compared to when the force is provided by a rubber band.

Name: _____ Date: _____

INVESTIGATION 2A

d. Research and define the terms “inertia”, “weight” and “mass”. Write 2-3 sentences that describe how these three concepts are similar and how they are different.

Name: _____ Date: _____

INVESTIGATION 2B

Newton's Second Law

1 Looking at the motion along the track

Table 1: Speed data

	Time photogate A (sec)	Time photogate B (sec)	Time from A to B sec)	Speed at A (m/sec)	Speed at B (m/sec)
Level section					
Down hill section					

2 Thinking about what you observed

a. Where is there a net force acting on the car? How do you know?

b. Where is there zero net force on the car? How do you know?

c. Can you have constant speed with zero net force? What experimental data support your answer?

d. Write down a formula for the acceleration of the car in terms of the speeds at photogates A and B and the time from A to B.

e. Calculate the acceleration of the car in m/sec^2 on both the level section and the downhill section.

f. Explain the difference in acceleration between the level and downhill sections using Newton's second law and the concept of force.

3 Speed and time graphs

Table 2: Speed versus time data

Position (cm)	Time through A (sec)	Time through B (sec)	Time from A to B (sec)	Speed at A (m/sec)	Speed at B (m/sec)

Name: _____ Date: _____

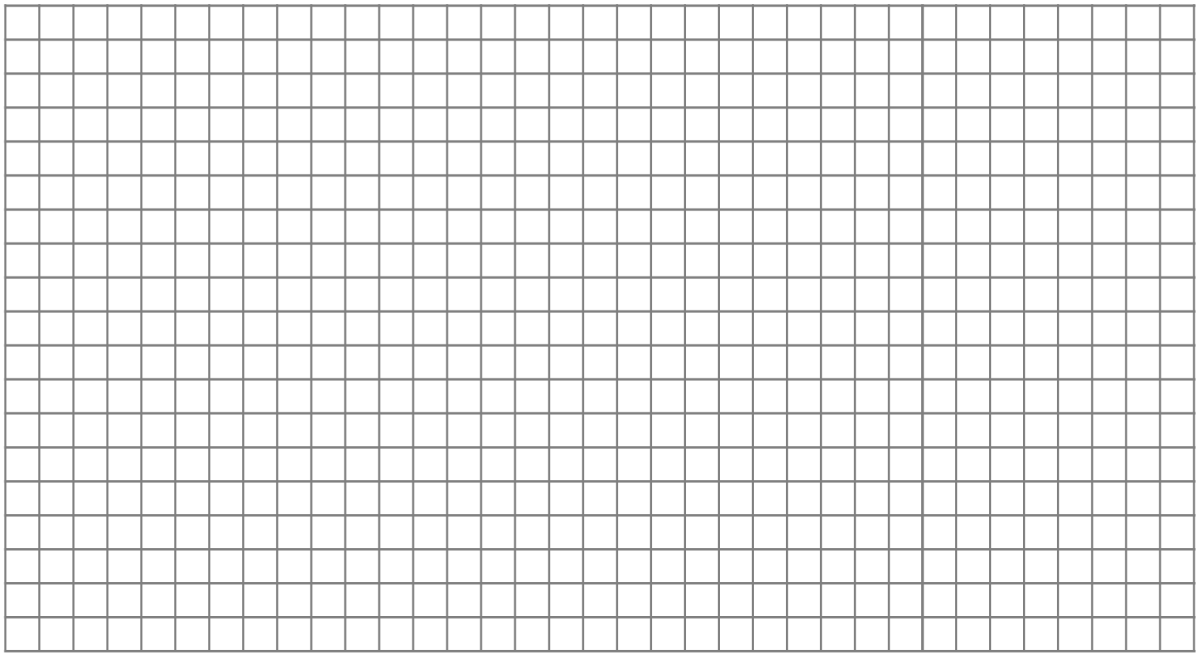
INVESTIGATION 2B

4 Thinking about what you observed

a. Draw the graph of speed vs. time for the track. For the x-axis use the time from photogate A to B.

Title: _____

y label: _____



x label: _____

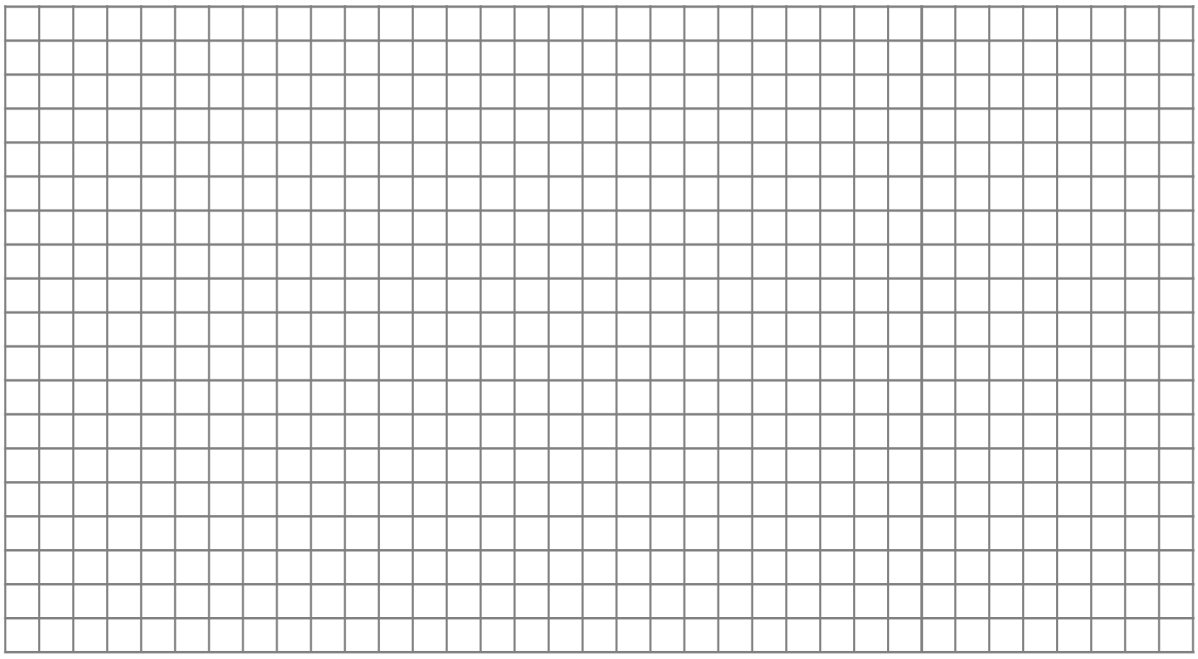
b. Use Newton's second law to calculate the force acting on the car at each position. Measure the acceleration from your speed vs. time graph. Where does the force come from?

Position:						
Force:						

c. Draw the graph of force vs. time and compare this graph to the speed vs. time graph.

Title: _____

y label: _____



x label: _____

What relationship is there between the two graphs?

d. Explain how speed and acceleration are different using your speed vs. time graph as an example.

Name: _____ Date: _____

INVESTIGATION 3A

Momentum and the Third Law

1 Making a collision

There are no questions to answer in part 1.

2 Thinking about what you observed.

Table 1: Collision data

Mass of target car (kg)	Mass of rolling car (kg)	Rolling car before collision		Rolling car after collision		Target car after collision	
		Photogate (sec)	Speed (m/sec)	Photogate (sec)	Speed (m/sec)	Photogate (sec)	Speed (m/sec)

a. Consider two colliding cars of equal mass. Describe in words the motion of the two cars before and after the collision.

_____

_____

_____

b. The target car must exert a force on the rolling car to stop it. How strong is this force relative to the force the rolling car exerts on the target car to get it moving? What experimental evidence supports your answer?

c. Look up Newton's third law and state how it applies to the collision of the two cars.

3 Momentum

There are no questions to answer in part 3.

4 Thinking about what you observed

a. Describe the motion of the two cars when the target car has more mass than the rolling car.

b. Describe the motion of the two cars when the target car has less mass than the rolling car.

c. Research and write down a formula for the momentum of a moving object. State what each of the variables are and what units they have.

d. Calculate the total momentum of the two cars before and after each collision. Be sure to remember that momentum can be positive or negative depending on the direction of motion.

Trial	Momentum before collision	Momentum after collision
1		
2		
3		
4		
5		
6		
7		
8		
9		

e. Research and write down the law of conservation of momentum. Describe how your data either support or do not support this law.

Name: _____ Date: _____

INVESTIGATION 3B

Conservation of Energy

1 Energy exchange from potential to kinetic

Table 1: Downhill data

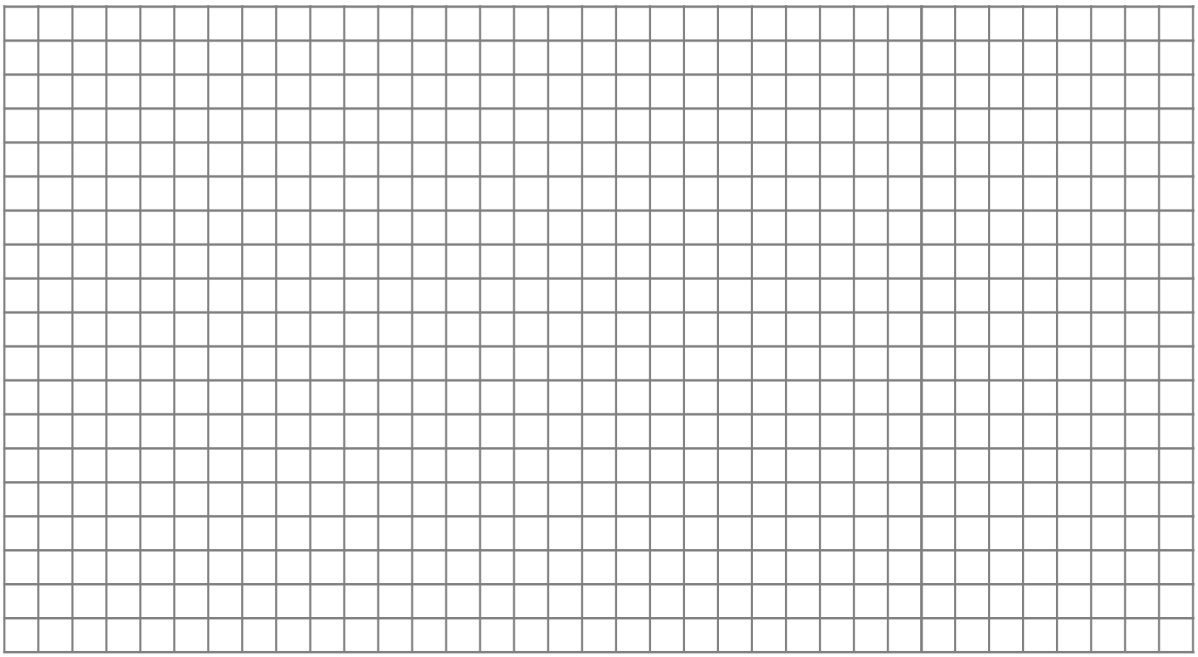
Drop Height (m)	Mass of car (kg)	Photogate time (sec)	Speed (m/sec)

2 Thinking about what you observed

a. Graph the speed of the car vs. the height. Use different symbols for different masses.

Title: _____

y label: _____



x label: _____

b. What does the graph tell you about the relationship between speed and height?

3 Analyzing the data

a. Use the formula for potential energy to fill in the first column of Table 2.

b. Use energy conservation to derive a formula for the speed of the car in terms of the energy it has at the start. (Hint: your formula should include only two variables, energy and height.)

c. Use the formula you just derived to fill in the column for the predicted speed of the car.

d. Plot the curve for the predicted speed on the same graph as you made in part 2a above.

Table 2: Energy data and predicted speeds

Drop Height (m)	Potential energy (J)	Predicted speed (m/sec)	Measured speed from Table 1 (m/sec)

4 Thinking about what you observed

a. Explain the relationship between speed and height using the idea of energy conservation.

b. Explain any difference between the predicted and measured speeds. If there is a difference, what does it tell you about the energy of the car as it rolls along the track?

c. Did changing the mass have a significant effect on the relationship between height and speed? How does your data support your answer?

d. Let the car roll downhill, bounce off the rubber band and go back up hill again. Does it reach the same height as it was dropped from? Explain why or why not using the idea of energy conservation.

e. Challenge experiment. Use a rubber band to launch the car uphill so it goes through the photogate with the same speed as it had going down. You won't be able to get it precisely the same, but come as close as you can. If the speeds are the same, the car's kinetic energy is also the same. Does the car reach the same height on the hill that it was dropped from to get the same speed in part 1? Explain any difference using the idea of energy lost to friction.