Name:

7.1 Vectors and Direction

Question: How do you give directions in physics?

1 Reading a compass

There are no questions to answer in Part 1.

2 Making a map

a. Take a sheet of graph paper and draw x- and y-axes pointing east-west (x) and north-south (y).

b. Draw the first vector on the graph, which should be to scale. For example, if you had graph paper with a 1 cm grid, an appropriate scale would be to choose 1 cm = 1 meter.

c. Draw the second vector starting from the end of the first vector. The graph paper now shows a map of two legs of a walking trip.

d. Take the graph paper and draw a third vector from the end of the second vector back to the start—this is the vector back home. Use a protractor and a ruler to measure the angle of the vector and determine its length in meters. Remember, you want compass bearings, so you should measure the angle clockwise from the positive y-axis, which is north on the compass.

3 Calibrating your pace

Table 1: Step lengths

Name	Distance of 10 paces (m)	Avg. length of 1 pace (m)

4 Walking the vectors

Table 2: Vectors in units of steps

Vector	Distance in meters	Distance in steps

5 Vectors in x-y coordinates

a. Take a sheet of graph paper and draw x- and y-axes pointing east-west (x) and north-south (y).

b. Draw the first vector on the graph. The graph should be to scale; 1 cm equals 1 meter might be a reasonable scale. For example, to draw the vector = (1,4)m, you would go over 1 cm in the positive x direction (east) and go up 4 cm in the positive y direction (north).

c. Draw the second vector *starting from the end of the first vector*. The graph paper now shows a map of two legs of a walking trip.

d. Calculate the resultant vector by adding up the *x* and *y* components of the two vectors you already have. For example, if $_1$ = (1,4)m and $_2$ = (2,-6)m, then $_1$ + $_2$ = (3,-2)m.

e. The *resultant vector* is the vector you could have walked straight from the origin (home) to the final destination. To get back home, you need to walk the resultant vector in the opposite direction. Mathematically, that means multiplying the components by -1. In the example, the vector back home would be $_3$ = (-3,2)m. You can see on the map that this is correct.

6 Converting to compass coordinates

Table 3: Converting to polar coordinates

Vector in *x*-*y* coordinates	Angle from north (degrees)	Distance (m)	Distance (steps)

7 Walking the vectors

1. There are no questions to answer in Part 7.

Name:

7.2 Projectile Motion and the Velocity Vector

Question: Can you predict the landing spot of a projectile?

1 Setting up the experiment

There are no questions to answer in Part 1.

2 Measuring the initial speed

Table 1: Ball's time and speed

Time (sec)	Launch speed (m/sec)

3 Predicting the landing spot

a. Work with your group members to come up with a theory that predicts the horizontal distance the ball moves before hitting the floor, The theory should take the form of a formula that involves only the initial height (y_o), initial speed (v_o), and the acceleration due to gravity (g). You should assume the ball leaves the track with a horizontal initial velocity.

b. Using the average of the initial speeds you measured in Part 2, use the theory to calculate how far from the table the ball should land.

4 Testing the theory

There are no questions to answer in Part 4.

5 Analyzing the results

a. How many centimeters is the landing spot from the center of the target? Did the ball travel too far, not far enough, to the left, or to the right?

b. Measure and record the distance along the floor between the landing spot and the place where the ball left the track. If your measurements and calculations were accurate, this distance should be the same as the distance you calculated.

c. Calculate the percent difference between the predicted distance and the actual distance the ball traveled.

d. Discuss some sources of error in the Investigation that may have resulted in your ball not landing in the center of the target.

e. When the ball was in the air, did its horizontal velocity change? Why or why not?

f. When the ball was in the air, did its vertical velocity change? Why or why not?

g. Calculate the velocity vector for the ball the moment before it hit the floor. Is the vector you calculate consistent with the motion of the ball after it hits the floor where the vertical component is abruptly reduced to zero?

h. Sketch each of the following graphs to describe the ball's motion as it was in the air: horizontal distance versus time, vertical distance versus time, horizontal speed versus time, and vertical speed versus time.

i. Imagine that you were to release the ball from a higher location on the track. Would you have to position the target closer to the table, farther from the table, or at the same distance? Why?

j. Now imagine that you were to release the ball with the track on a table that is twice as high off the ground. How far would you have to position the center of the target from the edge of the track? Show any calculations you perform to get your answer.

Name:

7.3 Forces in Two Dimensions

Question: How do forces balance in two dimensions?

1 Setting up the spring scales

There are no questions to answer in Part 1.

2 Finding the force needed for equilibrium

Table 1: Finding a force to balance two 5-N forces

	Magnitude (N)
Force 3	

3 The conditions of equilibrium

a. Calculate the *x* and *y* components of forces 1, 2, and 3 and enter the values in the table. Use a negative sign to indicate a direction in the negative *x* or *y* direction.

b. Calculate the *x* and *y* components of the net force on the ring. Then use the Pythagorean theorem to calculate the magnitude of the net force on the ring.

c. What should you have found the net force on the ring to be? Why?

d. Why might the net force be slightly different from the theoretical value? Discuss some sources of error that may be causing inaccuracy in your results.

Table 2: Finding a force to balance two 5-N forces

	Magnitude (N)	*x*-component (N)	*y*-component (N)
Force 1			
Force 2			
Force 3			
Net force			

4 Determining the directions for equilibrium

a. Use a protractor to determine the angles of the forces. Calculate the *x* and *y* components of the forces and record them in Table 3. Also, calculate the net force. Are the results what you expected? Your answer should say what your expectation was and why.

Table 3: Finding two forces to balance one 5-N force

	Magnitude (N)	*x*-component (N)	*y*-component (N)
Force 1	5	+5	0
Force 2	10		
Force 3	12		
Net force			

Name:

8.1 Motion in Circles

Question: How do you describe circular motion?

1 Setting up an observation

Circumference of the ball (step 2): ______________________________

Radius of the ball (step 3): ______________________________

Record your observations from step 6:

____

____

2 Setting up an experiment

There are no questions to answer in Part 2.

3 Measuring the average linear speed

Table 1: Linear speed data

Distance (cm)	Time 1 (sec)	Time 2 (sec)	Time 3 (sec)	Avg. time (sec)	Avg. linear speed (cm/sec)

4 Testing a hypothesis

a. Remove the pulley and wrap a single turn of string around it. Use a meter stick to measure the diameter of the circle the string makes. Divide the diameter by two to get the radius of the pulley. This is the radius at which the string moves.

____

b. Use the relationship $v = \omega r$ to calculate the average angular speed (ω) of the pulley in rad/sec.

____

c. With linear speed, the distance (d) an object moves is calculated using the relationship $d = vt$ where v is the linear speed and t is the time. Write a similar relationship between the angle (θ) an object rotates, its angular speed (ω), and the time, t.

d. Use the relationship you just wrote in part (c) to calculate the total angle the pulley turns through while the falling mass moves from top to bottom. Express your answer in radians. There are 2π (about 6.28) radians in a full turn. An angle greater than 6.28 radians means the pulley rotated more than one turn.

e. There are 10 stripes on the pulley for every radian of angle. You can measure the angle (in radians) the pulley turns by counting the stripes and dividing by 10. The Timer has a count mode that works perfectly for this purpose. Set the Timer in count mode. Move the masses from top to bottom by hand and record the number of stripes that pass the light beam. Calculate the total angle the pulley turns (in radians) by dividing the count by 10. NOTE: Pressing reset once clears the display, twice freezes the display, three clears it again, etc. If nothing seems to be counting, press reset again ONCE.

How close did your predicted angle come to the angle you measured?

Name:

8.2 Centripetal Force

Question: Why does a roller-coaster stay on track upside down on a loop?

1 Introduction

a. What do you observe as you dropped the ball from different heights? Think about the speed of the ball and whether it makes it around the loop successfully.

b. Write down a hypothesis about the conditions that are necessary for a ball to make it successfully around the loop.

2 Thinking about centripetal force

a. Using the formulas for weight and centripetal force, write a formula expressing the minimum speed *(v)* needed to keep the ball on the track.

b. Use the formula to calculate the minimum speed required for the ball to make it around the loop and stay on the track. The radius of the track is 10 centimeters.

c. Draw a free body diagram for the ball when it is at the top of the loop. Label the two forces acting on the ball and use vectors to show their directions.

d. Explain why it would *not be* correct to draw a third arrow on your free body diagram and label it "centripetal force."

3 Testing your theory

Table 1: Experimental loop-the-loop data

Mass (kg)	Weight (N)	Photogate time (sec)	Speed (m/sec)	Centripetal force at 10 cm radius (N)	Did the ball stay on the track (yes or no)

4 Analyzing the results

a. Compare the weight to the centripetal force for your experimental data on both balls. How should they be related? Do your experimental results confirm this?

b. If a group in your class found the centripetal force to be significantly larger than the ball's weight in trial 1 for one of the balls, what would you suspect they did wrong?

c. Describe how you would use the centripetal force and the weight to calculate the normal force on the ball.

d. Imagine that your job is to design a roller-coaster layout containing a hill followed by a circular loop with a radius of 20 meters. Use what you learned in this Investigation to estimate the minimum speed required for the roller-coaster to make it around the loop. Do you have to take the mass of the passengers riding the roller-coaster into account in the previous question? Why or why not?

e. Real roller-coasters are always designed to enter a loop after going down a hill that has more than the minimum height. Explain why.

f. You may have noticed that many roller-coaster loops are not circular but teardrop-shaped. This is called a *clothoid* loop, and it has a smaller radius at the top than at the bottom. Use what you have learned in this Investigation to explain the advantages of a clothoid loop over a circular loop.

Extra space for notes and performing calculations:

Name:

8.3 Universal Gravitation and Orbital Motion

Question: How strong is gravity in other places in the universe?

1 The gravitational force between everyday objects

Use Newton's law of universal gravitation to calculate the gravitational force of attraction between the following pairs of objects. For each situation, estimate the masses of the objects and the distances between them.

a. Your pencil and your calculator, having been placed next to each other on your desk.

b. Your left shoe and your right shoe as you stand comfortably.

c. You and another person of similar mass at a distance of two meters.

d. Two cars parked next to each other.

2 The gravitational force of attraction between people and planets

There are no questions to answer in Part 2.

3 Calculate your weight on different planets

Use the law of universal gravitation and the information in Table 1 to calculate your weight at several different locations in the universe. Remember, the r in the formula stands for the distance between the *centers* of the two objects being considered.

a. At the surface of Earth.

b. At a distance of 1,000 kilometers above the surface of Earth.

c. At the surface of Jupiter.

d. At a distance of 5,000 kilometers above the surface of Saturn.

e. At the surface of Venus.

4 The value of g

a. Set the weight *(m_1g)* equal to the gravitational force *($Gm_1m_2 \div r^2$)* and solve the equation to get a formula for g in the form $g = \ldots$.

b. Calculate the value of g at the surface of each of the nine planets (including Earth) using the formula you found in Part a.

Table 1: Mass and radius of the planets

Planet	Value of g
Mercury	
Venus	
Earth	
Mars	
Jupiter	
Saturn	
Uranus	
Neptune	
Pluto	

c. On the surface of which of the nine planets would you weigh the most? On the surface of which would you weigh the least? How do you know?

d. What happens to the strength of gravity as you get farther from the surface of a planet? Sketch a graph that illustrates this relationship.

e. **Advanced Problem:** A bowling ball has a mass of about 5 kilograms. Suppose you shrank the ball until it had a surface gravity equal to Earth's (g = 9.8 N/kg). What would the radius of the ball be? A single atom has a radius of about 10^{-10} meters. How does the size of the shrunken bowling ball compare with an atom? As strange as it seems, neutron stars exceed this incredible density!

Extra space for notes and performing calculations:

Name:

9.1 Torque

Question: How does force create rotation?

1 Setting up the experiment

a. Measure and record the mass of the hanger and its calculated weight.

b. The radius of the pulley is 5 centimeters. Calculate the torque created by the weight of the hanger and washers. Give your answer in units of N-m.

2 Equilibrium and torque

a. Calculate the torque created by the nuts and washers you added to the threaded rod. To do the calculation, use the distance measured from the spindle to the approximate center of the washers.

b. If you move the washers farther from the center, does the torque increase or decrease? For this question, consider only the magnitude of the torque and not the direction.

3 Torque when the force and distance are not perpendicular

a. Draw a diagram showing the torques acting on the system by the hanger on the string and the mass on the spinner arm. Make your drawing as accurate as you can, especially the angle of the spinner arm relative to horizontal.

b. Explain why the system is *not* in equilibrium when the spinner is horizontal but *is* in equilibrium when the spinner is at a certain angle. Your explanation should use the concept of lever arm and include a diagram showing the lever arm for both torques acting on the system.

Name:

9.2 Center of Mass

Question: How do objects balance?

1 Locating the center of mass

a. Remove the shape from the pencil and try to balance the shape on the tip of one finger at its center of mass. Try to balance the shape at other locations by supporting it with one fingertip. Explain why the shape balances at the center of mass but not at other points.

b. Gently toss the shape up into the air in such a way that it rotates while it moves up and then back down. Watch the circle at the shape's center of mass while it spins. What do you notice?

2 Balancing books

Table 1: Book overhang distances

Length of one book (cm)	Number of books	Overhang distance (cm)
	1	
	2	
	3	
	4	
	5	

a. Explain the method you used to determine how to position the books. Use the term *center of mass* in your explanation.

b. Make a graph of overhang distance versus number of books. Plot the distance on the *y*-axis and the number of books on the *x*-axis.

Title: ______________________________

y label: ______________________________

x label: ______________________________

c. Explain the relationship between the number of books and the overhang distance. Is it linear?

d. How many books had to be stacked to reach an overhang distance of one book length?

e. How many books do you think it would take to reach an overhang distance of two book lengths?

3 Your body's center of mass

a. Stand with your back and heels against a wall. Slowly bend down and try to touch your toes. Explain what happens and why.

b. Position a chair so that it is facing you. Stand with your toes 2 feet away from the front edge of the chair. Bend over at the waist, touch the sides of the chair, and bend your body up to a standing position. Now bend over in the same way but grab the sides of the chair this time. Try to bend upward while holding the chair. Explain what happens and why.

c. Why might these activities be easier for some students than for others?

Extra space for notes and performing calculations:

Name:

9.3 Rotational Inertia

Question: Does mass resist rotation the way it resists acceleration?

1 Setting up the experiment

a. Does the rod rotate faster when the washers are close to the center, near the outside, or does the position of the washers not affect the rotation speed? You may want to time how long it takes to spin 10 turns for both configurations.

2 Angular acceleration

a. Assume that the mass of the pulley itself and the white plastic rod is so small that it may be neglected compared with the mass of the steel washers. Assuming the washers act like a single mass at a distance r from the axis, calculate the moment of inertia. Your answer should come out in units of kg-m^2.

3 Measuring angular acceleration

a. Calculate the average time and period for the three trials of each variation. Use the averages to calculate the angular speeds (from the period) then the angular accelerations (angular speed divided by falling time). The result should come out in units of rad/sec^2.

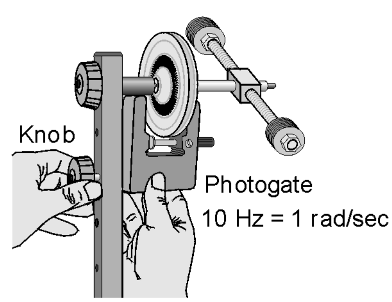

Table 1: Angular Acceleration Data

Masses in

Falling Time (sec)			
Period (sec)			

Masses out

Falling Time (sec)			
Period (sec)			

b. Compare the angular acceleration you measured in the two cases. Note that the mass is exactly the same in both cases. The torque applied is also exactly the same. Explain why the angular acceleration is different. Your explanation should use the concept of moment of inertia.

Extra space for notes and performing calculations: