LABORATORY V
PREDICTING NON-REPETITIVE MOTION

In this section, you will continue working on problems in dynamics, the relationship of force and acceleration especially in complex situations that occur in biological systems. Of particular interest are problems involving dynamic equilibrium (e.g. terminal velocity), and the motion of an object that takes place in two dimensions.

OBJECTIVES:

After successfully completing this laboratory, you should be able to:

- Make and test quantitative predictions about the relationship of forces on objects and the motion of those objects for real systems.
- Improve your problem solving skills.

PREPARATION:

Read Serway & Jewett, chapter 2, chapter 3 (sections 1-4), chapter 4 (sections 1-7), chapter 5 (sections 1-4), chapter 10 (section 1), chapter 15 (section 4). It is likely that you will be doing some of these laboratory problems before your lecturer addresses this material. It is very important that you read the text before coming to lab.

Before coming to lab you should be able to:

- Determine the components of forces.
- Add forces by adding their components.
- Use Newton's second law to relate force to acceleration.
- Draw and use free-body diagrams.
- Use calculus to relate position, velocity, and acceleration.
- Write down the form of the retarding or drag force against an object moving through a liquid.

PROBLEM #1:
MOTION IN A FLUID

You are studying bacteria as migrate through the body. You know that when single-cell organisms such as bacteria move, the medium through which they move plays a dominant role. The fluid surrounding the organism exerts a force which depends on the organism's size and velocity. When it begins to move, the tiny organism quickly reaches a terminal velocity, after which it must constantly expend energy to continue at the same velocity. Your have been asked to investigate that stage in a microorganism's motion. As a first step to understanding the approach to terminal velocity, you decide to model the organism as a spherical bead falling through a liquid. You calculate the velocity of a bead as a function of time, the properties of the bead, and the properties of the fluid. You then check your calculation in the lab.

EQUIPMENT

For this problem you will have small spheres or beads of different sizes, water to serve as a viscous fluid, beakers, a stopwatch, a meter stick, a balance, magnets, a video camera and a computer with a video analysis application written in LabVIEW™.

PREDICTION

Restate the problem in terms of quantities you know or can measure. Beginning with basic physics principles, show how you get an equation that gives the solution to the problem. Make sure that you state any approximations or assumptions that you are making.

WARM-UP QUESTIONS

Read Serway & Jewett, section 5.4, example 5.10, and section 15.4.

1. Draw a picture of a bead, immersed in fluid, dropping with some velocity along the vertical direction. In this picture, draw and label all the forces acting on the bead.
2. Write down an expression for the buoyant force acting on the bead. What is the direction of this force?
3. Write down an expression for the drag force encountered by the bead as it moves through the fluid. Explain why this force is proportional to the velocity of the bead. What is the direction of this force relative to the velocity? How does this force depend on the properties of the bead and the fluid?
4. Write down Newton's second law for the bead, putting in all the forces you identified in the previous steps. What is the value of the bead's acceleration after it has reached terminal velocity?

5. Solve for the velocity of the bead as a function of time and find the terminal velocity. How does the terminal velocity depend on the properties of the bead and the viscosity of the fluid?

EXPLORATION

Choose an appropriate container for the fluid. Determine the amount of fluid and the range of distances the bead falls through that would suffice to measure the approach to terminal velocity accurately. Use a stopwatch to estimate the terminal velocity. Check if the height at which the bead is dropped affects the velocity. Check if dropping the bead near the walls of the container affects the measurement. Decide on the best position of the camera. Determine the range of mass and size of the beads available. How many different beads will you need for your measurement?

Write down your measurement plan.

MEASUREMENT

Measure the relevant properties of each bead. Measure the density of the fluid.

Drop a bead and video its descent. While analyzing the video, make sure you set the scale for the axes of your graph so that you can see the data points as you take them. Determine the velocity from both the plot of position versus time and the plot of velocity versus time. Which one do you think is more reliable?

Repeat the procedure for beads of different sizes.

ANALYSIS

Make a graph of the terminal velocity as a function of the diameter of the bead and compare it to your prediction. Calculate the viscosity of the fluid from the measured relationship between velocity and bead diameter. Does the computed value seem reasonable?

CONCLUSION

Do your measurements agree with your predictions? If not, explain why not.

How fast does the bead reach terminal velocity? How does this depend on the properties of the bead?

PROBLEM #2:
MOTION UP AND DOWN AN INCLINE

You are a safety consultant for the Valley Fair amusement park. They have asked you to examine the safety of a proposed ride. The ride launches a roller coaster car up an inclined track. Near the top of the track, the cart reverses its direction and rolls backward. The regulations set the maximum acceleration that is safe for most people. The launcher and catching mechanism at the beginning and end of the ride have already been shown to be safe. However, your employers are worried about the acceleration as the car goes up and down the track, especially at the top where the car reverses direction. To address the issue, you calculate the car's position and velocity up and down the track as a function of time, the properties of the track, and the properties of the car. From these graphs you determine the car acceleration paying particular attention to its acceleration at the top of the track? You decide to test your calculation in the lab.

EQUIPMENT

For this problem you will have a stopwatch, a meter stick, an end stop, wood block, a video camera and a computer with a video analysis application written in LabVIEW™. You will also have a cart and a track.

PREDICTION

Restate the problem in terms of quantities you know or can measure. Beginning with basic physics principles, show how you get an equations that give a solution to the problem. Make sure that you state any approximations or assumptions that you are making.

What is the acceleration (direction and magnitude) of the cart when it reaches its highest point on the inclined track? What is its acceleration (direction and magnitude) as it moves up to that point? As it moves down from that point?

WARM-UP QUESTIONS

Read Serway & Jewett chapter 2 and chapter 4.

1. Draw a picture of a cart moving up an inclined track. Label all forces acting on the cart. Are there any forces that can be neglected? Indicate the direction of acceleration.
2. Choose a coordinate system and draw it next to your diagram.
3. For the coordinate system you have chosen, use Newton's Second Law to write equations for each axis separately. Check that the sign of each term in your equations matches your coordinate system. Write an expression for the acceleration (magnitude and direction) in terms of other quantities that you know or can measure.

4. Repeat steps 1-3 for the cart moving down the incline.
5. Repeat steps 1-3 for the cart at its highest point. Is it possible that the acceleration of the cart at the top of the track is zero? What would that imply about the forces on the cart at the top of the ramp? Is this realistic? Explain.
6. Compare the three expressions for the acceleration obtained from questions 3, 4, and 5 in both magnitude and direction. How does the acceleration change during the motion up and down the ramp?
7. Use calculus to write an equation for the cart's velocity as a function of time from its acceleration. Is there any time at which the velocity of the cart is zero? From your equation, what is the cart's acceleration at that time?
8. Use calculus to write an equation for the cart's position as a function of time from its velocity. From this equation, is there a time at which the position of the cart is a maximum? From your equation, write an equation for the velocity of the cart at that time. From your equation, determine the acceleration of the cart at that time.
9. Use the simulation "Lab1Sim" to explore the approximate the conditions of your experiment. Produce graphs *position vs. time* and *velocity vs. time* graphs of simulated motion up and down a ramp. You will likely need to select more frames than previous simulations to get the correct motion. If you believe friction or air resistance may affect your results, explore the effects of each with the simulation. If you believe that uncertainty in position measurements may affect your results, use the simulation to compare the results with and without error. Note the difference in the effect in the *position vs. time* and *velocity vs. time* graph. Remember to check for the effects of measurement uncertainty in your VideoTOOL measurements later in lab.

EXPLORATION

Start the cart up the track with a gentle push. **BE SURE TO CATCH THE CART BEFORE IT HITS THE END STOP ON ITS WAY DOWN!** Observe the cart as it moves up the inclined track. Is it speeding up or slowing down? What is the direction of its acceleration? When the cart reaches its highest point, what is its velocity? Just before it reached that point was it speeding up or slowing down? What was the direction of its acceleration? Observe the cart as it moves down the inclined track. Just after it reached its highest point was it speeding up or slowing down? What was the direction of its acceleration? Do your observations agree with your prediction? If not, this is a good time to change your prediction.

Where is the best place to put the camera? Which part of the motion do you wish to capture? Is there any advantage to rotating the angle of the camera? What is your calibration object?

Try several different angles. **Be sure to catch the cart before it collides with the end stop at the bottom of the track.** If the angle is too large, the cart may not go up very far and give you too few video frames for the measurement. If the angle is too small it will be difficult to measure the acceleration. Determine the useful range of angles for your track. Take a few practice videos and play them back to make sure you have captured the motion you want.

Choose the angle that gives you the best video record.

What is the total distance through which the cart rolls? How much time does it take? Use these measurements to determine the scales for the axes of the graphs for your computer data acquisition.

Determine how you will measure the angle, the distance rolled, the cart's acceleration and its velocity. Write down your measurement plan.

MEASUREMENT

Using the plan you devised in the exploration section, make a video of the cart moving up and down the track at your chosen angle. Make sure you get enough points for each part of the motion to determine the behavior of the acceleration. *Don't forget to measure and record the angle (with estimated uncertainty).*

Make sure you set the scale for the axes of your graph so that you can see the data points as you take them.

ANALYSIS

Choose a function to represent the *position vs. time* graph. How can you estimate the values of the parameters of the function? You may waste a lot of time if you just try to guess the constants. What kinematics quantities do these constants represent? Can you tell from your graph where the cart reaches its highest point?

Choose a function to represent the *velocity vs. time* graph. How can you calculate the values of the constants of this function from the function representing the *position vs. time* graph? Check how well this works. What kinematics quantities do these constants represent? Can you tell from your graph where the cart reaches its highest point?

From the *velocity vs. time* graph determine if the acceleration changes as the cart goes up and then down the ramp. Use the functions representing the *velocity vs. time* graph and the *position vs. time* graph to calculate the acceleration of the cart as a function of time. Do the two calculations agree? Make a graph of *acceleration vs. time*. Can you tell from your *acceleration vs. time* graph where the cart reaches its highest point?

As you analyze your video, *make sure everyone in your group gets the chance to operate the computer.*

CONCLUSION

How do your *position vs. time* and *velocity vs. time* graphs compare with your answers to the warm-up questions and the prediction? What are the limitations on the accuracy of your measurements and analysis?

Does the cart have the same acceleration throughout its motion? Does the acceleration change direction? Is the acceleration zero at the top of its motion, or nonzero? Describe the acceleration of the cart through its entire motion **after** the initial push. Justify your answer. What are the limitations on the accuracy of your measurements and analysis?

How does the direction of the acceleration of the cart going down a track correspond to the direction of the total force on the cart as it goes down that track? Up the track? When the cart reaches its highest point, what is the total force on the cart? How does this total force correspond to the cart's acceleration?

SIMULATION

If your data did not match your expectations, you should go back and use the simulation to explore what could have happened.

A computer simulation of the motion, "Lab1Sim", will let you determine how parts of the experiment outside your control in the real world could affect your results. See *Appendix F* for an introduction to the Simulation Programs.

Adjust the simulation settings to find conditions that will produce motion similar to the cart in this problem. For example, you can adjust friction or air resistance to see what role they play in the results. Produce simulated *position vs. time* and *velocity vs. time* graphs of constant velocity motion, and verify that they meet your expectations.

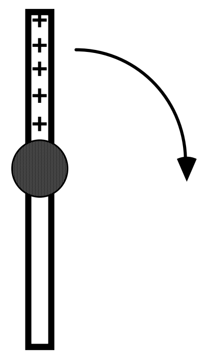
Now produce graphs that more closely match the motion you measured. Add the amount of uncertainty that you estimated for your measurement to the position measurements by pressing "Add Error" in the "Graph frame." Can you more easily see the effect in the *position vs. time* graph or in the *velocity vs. time* graph? Compare the simulated graphs to your graphs of the car's motion.

PROBLEM #3:
CIRCULAR MOTION

You have been asked to help evaluate a new ultracentrifuge for the microbiology laboratory. The device consists of hole in a steel beam, which is pivoted about its center, to insert test tubes. For most of the process, the beam rotates about its center in a horizontal circle at a constant speed. Your task is to calculate the acceleration of each test tube as a function of its speed and position. To check your calculation in the laboratory, you also calculate the perpendicular components of each test tube's velocity as a function of time and use those equations to calculate the magnitude of the acceleration as a function of time. Then you go to test your calculations using a laboratory model of a centrifuge that operates at lower speeds.

EQUIPMENT

You will be using a rotational apparatus that spins a horizontal beam on a stand. A top view of the device is shown to the right. You will have a stopwatch, a meter stick and the video analysis equipment.



PREDICTION

Restate the problem in terms of quantities you know or can measure. Beginning with basic physics principles, show how you get an equation that gives the solution to the problem. Make sure that you state any approximations or assumptions that you are making.

Make a graph of *position vs. time* and *velocity vs. time* for one position on your rotating beam.

WARM-UP QUESTIONS

Read Serway & Jewett sections 3.4, 5.3, and 10.1.

1. Draw the trajectory of an object moving in a horizontal circle with a constant speed. Choose a convenient origin and coordinate axes. Draw the vector that represents the position of the object at some time when it is not along an axis.

2. Write down an equation for one component of the position vector as a function of the radius of the circle and the angle the vector makes with one axis of your coordinate system. Sketch a graph of x-*position vs. time* and *y-position vs. time*.

3. Use calculus (and the Chain Rule) to write an equation for each component of the velocity. For this motion, the rate that the angle changes with time, called the angular speed, is constant.

4. Using your equations for the components of the velocity of the object as a function of time, write an equation for the speed of the object. Is the speed a function of time or is it constant? Use this equation to express the angular speed in terms of the speed of the object.

5. Since angular speed is constant, use calculus to write down an equation for the angle as a function of time. Substitute this into your equations for position and velocity and sketch a graph for each component as a function of time.

6. Use the calculus relationship between velocity and acceleration to write down the equation for each component of the acceleration of the object. Sketch a graph for each component of the acceleration as a function of time.

7. Using your equations for the components of the acceleration of the object as a function of time, write an equation for the magnitude of the acceleration of the object. Is the magnitude of acceleration a function of time or is it constant?

EXPLORATION

Practice spinning the beam at different speeds. How many rotations does the beam make before it slows down appreciably? Use the stopwatch to decide which spin gives the closest approximation to constant speed. At that speed, make sure you will get enough video frames for each rotation to make your measurement.

Check to see that the spinning beam is level.

Move the apparatus to the floor and adjust the camera tripod so that the camera is directly above the middle of the spinning beam. Practice taking some videos. How will you make sure that you always click on the same position on the beam?

Decide how to calibrate your video. Decide how many different positions on the beam you need to measure and write down your measurement plan.

MEASUREMENT

Use the video software to acquire data for the position of a fixed point on the beam in enough frames of the video so that you have the sufficient data to accomplish your analysis. Your video should consist of more than two complete rotations. Make sure you set the scale for the axes of your graph so that you can see the data points as you take them. Use your measurements of total distance the object travels and total time to determine the maximum and minimum value for each axis before taking data.

Measure as many different positions as called for by your plan.

ANALYSIS

Analyze the motion for both of the components that you chose. How can you tell from each graph when a complete rotation occurred?

Compare the speed that you obtain from your graphs with your measurements using a stopwatch and meter stick.

CONCLUSION

How do your graphs compare to your predictions and warm-up questions? What are the limitations on the accuracy of your measurements and analysis?

Is it true that the velocity of the object changes with time while the speed remains constant?

Is the instantaneous speed of the object that you calculate from your measurements the same as its average speed that you measure with a stopwatch and meter stick?

Have you shown that an object moving in a circle with a constant speed is always accelerating? Explain.

Compare the magnitude of the acceleration of the object that you calculate from your measurements to the "centripetal acceleration" that you can calculate from the speed and the radius of the object.

PROBLEM #4: TWO-DIMENSIONAL MOTION

You are investigating the integration of the nervous system, and how the brain processes sensory input to guide the body's movements. While a subject performs a task, the subject's brain activation and neural response are mapped. You decide to investigate the common but complex activity of catching a ball. One goal of the investigation is to determine if the brain's activity when perceiving an object moving in two dimensions is qualitatively different from its activity when the object moves in only one dimension. Before study begins, you have been assigned to calculate the position, velocity, and acceleration for a ball tossed through the air, as functions of time and make graphs of those functions. They will later be checked against the observer's brain activity. The next step is to check your calculations in the lab.

EQUIPMENT

For this problem, you will have a ball, a stopwatch, a meter stick, a video camera and a computer with a video analysis application written in LabVIEW™.

PREDICTION

Restate the problem in terms of quantities you know or can measure. Beginning with basic physics principles, show how you get an equation that gives the solution to the problem. Make sure that you state any approximations or assumptions that you are making.

WARM-UP QUESTIONS

Read Serway & Jewett section 3.3 and examples 3.2, 3.3 and 3.4.

1. Draw a picture of the path of motion for the tossed ball. Draw the ball at several points along the trajectory. At each of those positions draw and label the forces on the ball as well as the velocity and acceleration vectors that describe the motion of the ball. If any angles are involved, label them as well.
2. Are there any forces you assume are so small they can be neglected? Do the forces on the ball change or remain constant as it moves? Is the acceleration indicated in your drawing constant or does it change with time?
3. Draw a convenient coordinate system. For each position of the ball that you drew on its trajectory, draw the x and y components of the velocity and acceleration of the ball. Check to see that the change of each component of the velocity vector is consistent with that component of the acceleration vector. Also check that the vector sum of the x-velocity and y-velocity you have drawn matches the magnitude and direction of the velocity vector you have drawn at that position. Explain your reasoning.
4. Write down an equation for horizontal acceleration as a function of time. What causes this acceleration? Is this acceleration changing with time or is it constant? Use the relationship between velocity and acceleration to write an equation for horizontal velocity

as a function of time for this situation. Use calculus and the relationship between position and velocity to write an equation for the horizontal position as a function of time.

5. Repeat Question 4 for the vertical direction.
6. Use the simulation "Lab2Sim" to simulate the situation in this problem. Note that in this case the initial velocity should have non-zero horizontal and vertical components.

EXPLORATION

Position the camera and adjust it for optimal performance. Make sure everyone in your group gets the chance to operate the camera and the computer.

Practice throwing the ball until you can get the ball's motion to fill the video screen **after** it leaves your hand. Determine how much time it takes for the ball to travel and estimate the number of video points you will get in that time. Are there enough points to make the measurement? Adjust the camera position to give you enough data points. You should be able to reproduce the conditions described in the predictions.

Measure the distance that the ball goes. The distance and time you measure here will be useful to set the scales of the graphs in your video analysis.

Although the ball is the best item to use to calibrate the video, the image quality due to its motion might make this difficult. You might need to place an object of known length in the plane of motion of the ball, near the center of the ball's trajectory, for calibration purposes. Take a test video to determine if you need a separate calibration object and where it is best to place it if needed.

Quickly step through the video and determine which part of the ball is easiest to consistently locate. You should use the same part of the ball for each measurement.

Write down your measurement plan.

MEASUREMENT

Make a video of the ball being tossed. Make sure you can see the ball in every frame of the video.

Use the video software to acquire data for the position of the ball in enough frames of the video so that you have the sufficient data to accomplish your analysis. Make sure you set the scale for the axes of your graphs so that you can see the data points as you take them. Use your measurements of total distance the ball travels and total time from the exploration section to determine the maximum and minimum value for each axis before taking data.

ANALYSIS

Choose a function to represent the horizontal position versus time graph and another for the vertical position graph. How can you estimate the values of the constants of the functions from the graph and other information that you know? You can waste a lot of time if you just try to guess the constants. What kinematics quantities do these constants represent?

Choose a function to represent the *velocity vs. time* graph for each component of the velocity. What kinematics quantities do the constant parameters of the function represent? How can you calculate the values of the constants of these functions from the functions representing the position versus time graphs? Check how well this works. Determine the launch velocity of the ball from this graph. Is this value reasonable? Determine the velocity of the ball at its highest point. Is this value reasonable?

From the *velocity vs. time* graph determine the acceleration of the ball independently for each component of the motion. Determine the magnitude of the ball's acceleration at its highest point. Is this value reasonable?

CONCLUSION

Did your measurements agree with your predictions? Why or why not? What are the limitations on the accuracy of your measurements and analysis?

What is the total vertical force on the ball? How does this explain the behavior of its vertical velocity? What is the total horizontal force on the ball? How does this explain the behavior of its horizontal velocity?

SIMULATION

If your results did not completely match your expectations, use the simulation "Lab2Sim" (*Appendix F*) to see the effects of air resistance.

Produce simulated *position vs. time* and *velocity vs. time* graphs, in both the horizontal and the vertical directions, for a ball tossed into the air and verify that they meet your expectations. Use the simulation controls to vary the amount of air resistance and the error. Can you more easily see the effects in the *position vs. time* graph or in the *velocity vs. time* graph? Compare the simulated graphs to your graphs of the ball's motion.

Add measurement uncertainty to the simulation to see if it agrees with your measurements.

PROBLEM #5:
BOUNCING

You are working for NASA to design a low cost landing system for a mission to look for life on Mars. The payload will be surrounded by a big padded ball and dropped onto the surface. When it reaches the surface, it will simply bounce. The height and the distance of the bounce will get smaller with each bounce so that it finally comes to rest on the surface. Your group needs to design the biological probes to survive the landing and subsequent bouncing. The group is also concerned with the distance that the bouncing might carry the probe away from the primary landing site. You have been assigned to determine how the ratio of the horizontal distance covered by two successive bounces depends on the ratio of the heights of each bounce and the ratio of the horizontal components of the velocity of each bounce. After making the calculation you decide to check it in your laboratory on Earth.

EQUIPMENT

For this problem, you will have a ball, a stopwatch, a meter stick, and a computer with a video camera and an analysis application written in LabVIEW™.

PREDICTION

Restate the problem in terms of quantities you know or can measure. Beginning with basic physics principles, show how you get an equation that gives the solution to the problem. Make sure that you state any approximations or assumptions that you are making.

WARM-UP QUESTIONS

Read Serway & Jewett section 3.3 and examples 3.2, 3.3 and 3.4.

1. Draw a picture of the situation including the velocity and acceleration vectors at all relevant times. Decide on a coordinate system to use. Is the acceleration of the ball during the bouncing constant or is it changing? Why? What is the relationship between the acceleration of the ball before and after a bounce? Are the time intervals for two successive bounces equal? Why or why not? Clearly label the horizontal distances and the heights for each of those time intervals. What reasonable assumptions will you probably need to make to solve this problem? How will you check these assumptions with your data?

2. For the time between successive bounces write down an equation that gives the horizontal distance traveled as a function of the time and the horizontal component of velocity. Is that component of velocity constant or changing in that time interval? Why? Write down another equation to solve for that time from the vertical motion.

3. Combining the previous steps gives you an equation for the horizontal distance of a bounce in terms of the ball's horizontal velocity, the height of the bounce, and the vertical acceleration of the ball.

4. Repeat the above process for the next bounce and take the ratio of horizontal distances.

5. Examine the forces on the ball during the bounce. Over that very short time interval, what is the direction of its acceleration? Does the horizontal component of the ball's velocity change or remain constant during the bouncing process? Explain.

EXPLORATION

Position the camera and adjust it for optimal performance.

Practice bouncing the ball without spin until you can get at least two full bounces to fill the video screen. Three is better so you can check your results. It will take practice and skill to get a good set of bounces. Everyone in the group should try to determine who is best at bouncing the ball.

Determine how much time it takes for the ball to have the number of bounces you will video and estimate the number of video points you will get in that time. Is that enough points to make the measurement?

Although the ball is the best item to use to calibrate the video, the image quality due to its motion might make this difficult. Instead, you might need to place an object of known length in the plane of motion of the ball, near the center of the ball's trajectory, for calibration purposes. Where you place your reference object does make a difference to your results. Determine the best place to put the reference object for calibration.

Step through the video and determine which part of the ball is easiest to consistently determine. Write down your measurement plan.

MEASUREMENT

Make a video of the ball being bounced. Make sure you can see the ball in every frame of the video.

Digitize the position of the ball in enough frames of the video so that you have the sufficient data to accomplish your analysis and check to see if your assumptions about the motion are correct. Make sure you set the scale for the axes of your graph so that you can see the data points as you take them.

ANALYSIS

Analyze the video to get the horizontal distance of two successive bounces, the height of the two bounces, and the horizontal components of the ball's velocity for each bounce. The point where the bounce occurs will usually not correspond to a video frame taken by the camera so some estimation is necessary to determine this position. Can you tell where the bounce occurs in the vertical *position vs. time graph*? Can you tell where the bounce occurred in the horizontal *position vs. time* graph? How about the *velocity vs. time* graphs?

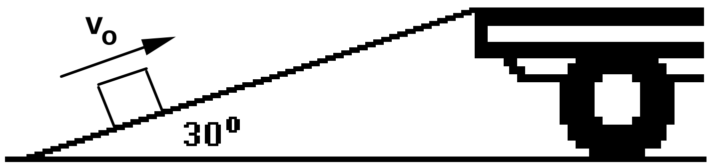
CONCLUSION

How do your graphs compare to your predictions and warm-up questions? What are the limitations on the accuracy of your measurements and analysis? Use your data to measure the gravitational acceleration to give you a measure of its accuracy.

Will the ratio you calculated be the same on Mars as on Earth? Why or why not?

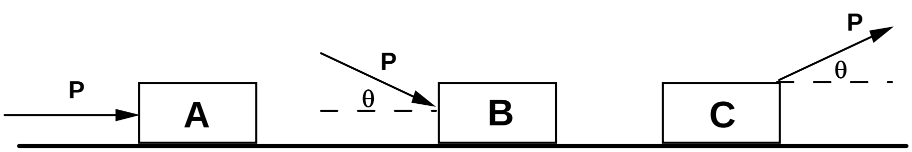
☑ CHECK YOUR UNDERSTANDING

1. A crate is given an initial push up the ramp of a large truck. It starts sliding up the ramp with an initial velocity v_o, as shown in the diagram below. The coefficient of kinetic friction between the box and the floor is μ_k.



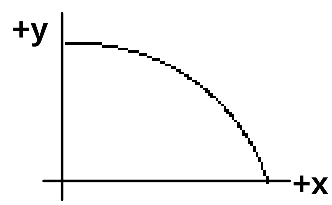
Will the magnitude of the acceleration of the sliding crate be greater on the way up or on the way back down the ramp? Or will the accelerations be the same? Explain using appropriate force diagrams.

2. The same constant force (P) is applied to three identical boxes that are sliding across the floor. The forces are in different directions, as shown in the diagram below.



On which of the three boxes is the frictional force the largest? The smallest? Or is the frictional force on each box the same? Explain using appropriate force diagrams and Newton's second law.

3. A baseball is hit horizontally with an initial velocity v_o at time $t_o = 0$ and follows the parabolic arc shown at right.



a. Which graph below best represents the *horizontal position (x) versus time* graph? Explain your reasoning.

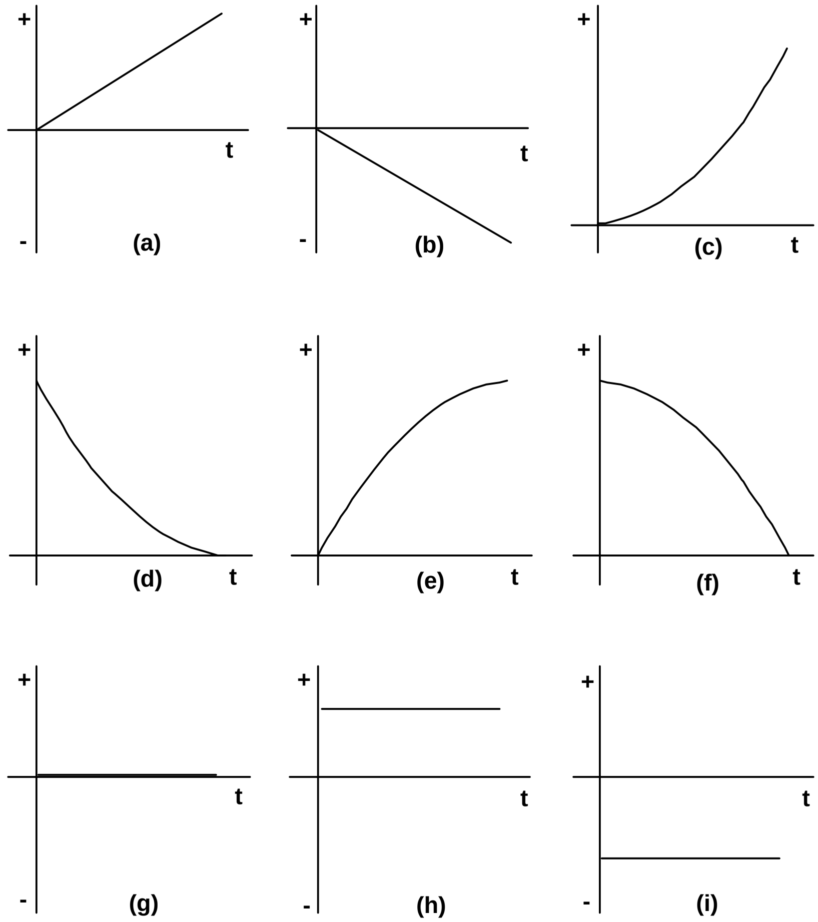
b. Which graph below best represents the *horizontal velocity (v_x) versus time* graph? Explain your reasoning.

c. Which graph below best represents the *horizontal acceleration (a_x) versus time* graph? Explain your reasoning.

d. Which graph below best represents the *vertical position (y) versus time* graph? Explain your reasoning.

e. Which graph below best represents the *vertical velocity (v_y) versus time* graph? Explain your reasoning.

f. Which graph below best represents the *vertical acceleration (a_y) versus time* graph? Explain your reasoning.

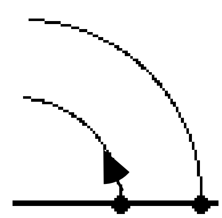


4. Suppose you throw a ball vertically up into the air with an initial velocity v_o.

a. What is the acceleration of the ball at its maximum height? Explain your reasoning.

b. How would the acceleration versus time graph look from the moment the ball leaves your hand to the moment before it returns to your hand?

5. Two beads are fixed to a rod rotating at constant speed about a pivot at its left end, as shown in the drawing at right.



a. Which bead has the greater speed? Explain your reasoning.

b. Which bead has the greater acceleration? Explain your reasoning.

TA Name:______________________________

PHYSICS 1201 LABORATORY REPORT

Laboratory V

Name and ID#: ____

Date performed: ____________ Day/Time section meets: ______________________

Lab Partners' Names: ______________________________________

____

____

Problem # and Title: _______________________________________

Lab Instructor's Initials: _________

Grading Checklist	Points*
LABORATORY JOURNAL:	
PREDICTIONS (individual predictions and warm-up questions completed in journal before each lab session)	
LAB PROCEDURE (measurement plan recorded in journal, tables and graphs made in journal as data is collected, observations written in journal)	
PROBLEM REPORT:	
ORGANIZATION (clear and readable; logical progression from problem statement through conclusions; pictures provided where necessary; correct grammar and spelling; section headings provided; physics stated correctly)	
DATA AND DATA TABLES (clear and readable; units and assigned uncertainties clearly stated)	
RESULTS (results clearly indicated; correct, logical, and well-organized calculations with uncertainties indicated; scales, labels and uncertainties on graphs; physics stated correctly)	
CONCLUSIONS (comparison to prediction & theory discussed with physics stated correctly ; possible sources of uncertainties identified; attention called to experimental problems)	
TOTAL(incorrect or missing statement of physics will result in a maximum of 60% of the total points achieved; incorrect grammar or spelling will result in a maximum of 70% of the total points achieved)	
BONUS POINTS FOR TEAMWORK (as specified by course policy)	

* An "R" in the points column means to rewrite that section only and return it to your lab instructor within two days of the return of the report to you.