Experiment

X Review for the Culminating Lab

I. Purpose

The purpose of this lab is to allow you to prepare for the practical exam by reviewing the apparatus, data taking and analysis used in Experiments I to IX. This review is a required lab and it is a graded lab - it is not optional.

II. Preparing for the Lab

You need to prepare before doing this lab. Start by reading through this lab write-up. If you find that you are unfamiliar with any of the parts, go back over the corresponding Experiments in the Lab Manual. Next, go to:

https://www.youtube.com/watch?v=SIwE6gdHw4k&feature=youtu.be

and watch the video so you know what to expect. Finally, make sure you do all of the Pre-Lab questions and submit your answers to Expert TA before your lab session starts.

III. Pre-lab Questions *(Submit answers to Expert TA before your lab section meets)*

The questions on Expert TA will typically vary somewhat from those given below - be sure to read the Expert TA questions and choices carefully before answering.

#1. Experiment 2: Errors. You measure the length of the same side of a block five times and find: b=11.0, 11.1, 11.2, 11.2 and 11.3 mm. What is the best estimate for b?

#2. Experiment 2: Errors. You measure the width b of a block five times. Each measurement has an uncertainty $\Delta b = 0.1$ mm. What is the uncertainty in the best estimate for b?

#3. Experiment 3: X, V, A. A 1 cm block is placed under one leg of the air-track. How long will it take a cart to reach the bottom of the track? Assume the cart starts from rest, the track is 1.5 m long and the distance covered by the cart is 1.5 m.

#4. Experiment 4: Momentum and Drag. A cart with mass 0.3 kg and velocity 0.1 m/s collides on an air-track with a cart with mass 0.4 kg and velocity -0.2 m/s. What is the final velocity of the two carts if they stick together?

#5. Experiment 5: Centripetal Motion. What is the maximum height y that the pendulum can reach in this experiment? (a) 0.2 m, (b) 0.3 m, (c) y_o, (d) L, (e) y_o+L, (f) y_o-L.

#6. Experiment 6: Pendulum. A pendulum has a length of L=1 m. What is its period?

#7. Experiment 7: Forced Harmonic Motion. Suppose that you wanted to reduce the resonant frequency of the system, what could you do? (a) increase the spring constant, (b) reduce the mass, (c) reduce the drive frequency, (d) increase the damping.

#8. Experiment 8: Waves on a String. A student measures the four lowest resonant frequencies of the string as 12 Hz, 25 Hz, 35 Hz, and 50 Hz, with node-to-node spacing of 2 m, 1 m, 0.67 m, and 0.5 m. Use the spreadsheet to calculate the wave velocity for each of the four different modes.

#9. Experiment 9: Ideal Gas Law. Suppose that the temperature of the bulb in the Charles' law apparatus increases from 20 °C to 100 °C. By what multiplicative factor will the pressure increase by?

#10. Experiment 9: Ideal Gas Law. Starting at 20 ^{o}C, to what temperature would you have to raise the Charles law apparatus to double the pressure?

IV. Equipment

The room has been arranged with at least two setups of each Experiment. Some stations may have apparatus set up for more than one experiment.

Also, at each lab bench there is a single memory stick for you and your lab partner.

V Experiment

Grab a seat at one of the lab benches. While you are waiting for your lab partner to show up, open the **Lab Templates** folder and open the EXCEL template called **Phys 261 Lab 10 template**. Save it on the memory stick. You will need to carry this memory stick with you from one station to the next as you work through each part of the review.

Take a look at the setup on your lab bench and figure out which experiment the setup is for. Go to that part in the write-up below and work through all of the questions for that part. When you are done with that part, turn off the equipment and let your TA know you are done and need to switch to another setup. When another setup that you need becomes available, go to it and work on the corresponding part in the write-up. If you are waiting for a setup, you can work on questions in other parts that do not require the actual setup. Continue this process until you have worked through all parts.

In this review you will be working with your lab partner, but in the exam next week, you will be on your own, so make sure you both understand how to answer each question. Of course, each of you will need to submit a completed spreadsheet at the end of the lab to ELMS Canvas.

Part A: Experiment 2: Uncertainty in Measurements

(1) Using the ruler, and without using the vernier calipers, estimate how precisely you can measure the length of one of the sides of one of the blocks.

(3) Suppose you use the scale to measure the mass of the brass block. What is the uncertainty in the mass?

(3) A block is measured to have a mass M = 25.3 g and volume V = 9.16 cm^3 with an uncertainty of ΔM =0.05 g in the mass and ΔV =0.05 cm^3 in the volume. What is the uncertainty in the density?

Part B: Experiment 3: Position, Velocity and Acceleration

(1) If a 1 cm block is placed under one leg of the air-track, what is the tilt angle of the air-track?

(2) Place a 1 cm block under the apparatus and measure the position versus time for a cart that accelerates down the track. Save your data on the spreadsheet. Make a plot showing position versus time. Be sure to properly label your plot.

(3) A cart starts at x = 0.5 m with an initial velocity of 1 m/sec heading up the air-track. Assuming that the air-track is tilted at 0.01 radians, use the spreadsheet to calculate and plot the position versus time and the velocity versus time of the cart.

Part C: Experiment 4: Momentum and Drag

(1) Two carts approach each other, collide, and stick together after the collision. This is an example of what type of collision: (a) perfectly inelastic collision, (b) inelastic collision, (c) elastic collision, (c) perfectly elastic collision, (e) sticky collision.

(2) Place one of the carts on the track outside of the optical gates. The picket fence end should be away from the gates. Open up the Logger Pro template for this experiment and click “Collect”. It will wait for a trigger, so don’t worry if nothing happens on the screen. Send the cart through the gates, making sure to release the cart well before it enters the first gate. Allow the cart to bounce off the end and pass through both gates in the opposite direction before clicking “Stop” in Logger Pro. Once you have a good data set, select all of the data LoggerPro is displaying in its columns (do this by typing Ctrl-A on the keyboard), then go to the edit menu in Logger Pro and click on Copy. Then go to your spreadsheet and Paste this data into the designated area labeled in your spreadsheet.

(3) A cart with mass 0.3 kg and velocity 0.1 m/s collides on an air-track with a cart with mass 0.4 kg and velocity -0.2 m/s. If the final velocity of the first cart is -0.1 m/s after the collision, what is the velocity of the second cart?

Part D: Experiment 5: Centripetal Motion

(1) Place the black and white screen grid directly under and centered on the rotator arm, with the pendulum bob hanging just in front so that you can see it in the live video image. Use the Logitech controls to zoom in and adjust the height and angle of the camera until you can see just the tip of the pendulum support and there are about 5 horizontal lines below the bob. Also make sure the bob is as close to being horizontally centered as possible. Do your best to keep the vertical lines vertical and the horizontal lines horizontal. You may have to manually adjust the height and angle of the camera to get the desired orientation. **Do not use the Logitech controls to pan or tilt the camera; this will cause errors in the MatLab routine. If you do, click the button in the center of the arrows to re-center the camera.** Use the Logitech controls to adjust the camera focus so the grid is clear and in focus. Next **close the Logitech software and keep it closed for the rest of the lab. It will cause errors if left open.** In your template, click “Grid Background”. MatLab should open, take a picture and import it into your template. If you get an error message, click “End” and try again.

(2) Remove the background grid. Turn the motor controller power on and adjust the potentiometer on the small box to set the motor rotation frequency to about 3000 rpm. Wait a few minutes for the bob to sync up with the rotating gear and reach dynamic equilibrium at this drive frequency. When the orbit of the pendulum has stabilized, open the relevant Logger Pro template and click "Collect". The data collection should finish after 15 s. Look at the statistics window and enter into your template the values of the mean period τ_{avg}, the standard deviation of the periods $\Delta\tau$, and the number of periods N recorded from the statistics display.

(3) Next, click the macro button labelled “3000 rpm” in your spreadsheet template. The macro should run for about 30 seconds during which MatLab will take a series of pictures and stack

the images together to create a single image of the trajectory of the bob. In the center the bob is moving too fast to be observed, but towards the edges the bob should be noticeable. Since we are concerned with the radius of the orbit, this is acceptable. The routine will also overlay your background grid image so that you can use it to measure the radius of the orbit. If you encounter an error, click "End" and try again. Carefully examine the output image on your screen. Use the 1 cm by 1 cm background grid to find the apparent diameter D' of each of the orbits. Measure from the **center** of the ball on the extreme left side of the orbit to the **center** of the ball on the extreme right side. If it is difficult to determine where the center is, estimate the radius of the bob and find where the approximate center would be. Plug your values for D' for each orbit into the designated area of your spreadsheet in part B.

Part E: Experiment 6: The Pendulum and g

(1) Using the ruler, how precisely can you measure the length of the pendulum?

(2) Measure the time for 20 swings of the pendulum. What is the period; i.e. the time for one swing.

(3) Why is it important to keep the angle small in this experiment? Explain.

Part F: Experiment 7: Forced Harmonic Motion

(1) To what uncertainty can the drive frequency be determined in this experiment?

(2) Measure the resonant frequency of this system.

(3) Suppose that you wanted to increase the quality factor Q of the system, what could you do?

Part G: Experiment 8: Waves on a String

(1) With a total mass of 200 gm hanging on the end of the string, measure the frequency of the fundamental.

(2) How is the spacing between nodes of a standing wave related to the wavelength?

(3) How is the velocity of the wave related to the mass hanging off the end?

Part H: Experiment 9: Ideal Gas Law and Absolute Zero

(1) How precisely can you measure temperature in the Charles law apparatus? How precisely can you measure the pressure?

(2) Explain how you can use the Charles' Law apparatus to determine the absolute zero temperature.

(3) Using the Boyle's law apparatus, a student finds volumes of 40, 30, 20, and 15 cm^3 at pressures of 7.5, 10, 15, and 20 lb/in^2. Use the spreadsheet to make a log-log plot of P versus V and find the slope of the resulting straight line (hint: plot the log of P versus the log of V rather than using the spreadsheets log plotting option.). Does the data agree with Boyle's law? Briefly explain.

VI. Finishing Up Before Leaving the Lab

(1) Check your spreadsheet to make sure that you have not missed any steps, have filled everything in, and have no red feedback messages displayed. Check your answers carefully.

(2) Save the spreadsheet. To do this, make sure you have entered your name, your lab partner's name, and your section number into the designated area and click on the gray save button. EXCEL will automatically save two copies, one with your name in the title, and another with your lab partners name in the title in the My Documents folder.

(3) Before leaving the lab, Log onto your area in ELMS Canvas, go to the Physics 261 assignments, and submit your spreadsheet before the deadline.

(4) Log off ELMS Canvas and make sure that your lab partner logs onto his or her own area in ELMS Canvas and submits the copy of the spreadsheet with his or her own name in the file name. Make sure to log off ELMS Canvas when you are done!

(5) After you and your lab partner have each submitted individual copies of your spreadsheet, exit from EXCEL and close all files. Do not turn off the lab computers.

Each student needs to submit a copy of their spreadsheet to their own area in ELMS Canvas before leaving the lab ... don't believe anyone who tells you otherwise.

VII. Additional Practice and Study Questions

The questions below are provided to help you prepare for the practical Exam. They are not to be submitted to Expert TA or ELMS but versions of these questions may appear on the practical Exam.

(1) Each of the experiments you did this semester had a purpose or goal. Briefly state the purpose of each experiment.

(2) <u>Experiment 2: Errors:</u> You measure the lengths of three sides of a block and find a=12.23 mm, b=14.51 mm and c = 7.45 mm with an error of ±0.03 mm in each measurement. What is the uncertainty ΔV in the volume of the block?

(3) <u>Experiment 2: Errors:</u> Using the vernier calipers, estimate the uncertainty in a measurement of the length of a side of one of the blocks.

(4) <u>Experiment 2: Errors:</u> A block is measured to have a density $\rho = 2.76$ g/cm^3 with an uncertainty of $\Delta\rho = 0.03$ g/cm^3. Find χ^2 when the measured density is compared to the accepted density of pure aluminum $\rho = 2.70$ g/cm^3.

(5) Experiment 3: X, V and A: Explain how the sonic ranger works.

(6) Experiment 3: X, V and A: Suppose the air-track is tilted at an angle of 0.01 radians from level, what will be the acceleration of a friction-less cart?

(7) Experiment 4: Momentum and Drag: Explain how the optical picket fence works and how this system can find the velocity of the cart.

(8) Experiment 4: Momentum and Drag: How can it happen that when two carts collide in this experiment that the total momentum of the two carts is not conserved?

(9) Experiment 4: Momentum and Drag: The table below lists the position versus time for a cart moving on a tilted air-track. Use the spreadsheet to calculate and plot the velocity versus time and acceleration versus time.

t (sec)	x(m)	t (sec)	x (m)
0.0	1.00	0.5	2.20
0.1	1.45	0.6	2.10
0.2	1.80	0.7	1.90
0.3	2.10	0.8	1.53
0.4	2.20	0.9	1.10

(10) Experiment 5: Centripetal Motion: If the motor is turning at 3000 RPM and the gear steps this motion down by a factor of 27, what is the frequency of the rotation of the mass in Hz?

(11) Experiment 5: Centripetal Motion: Make a sketch that shows how the period of the rotating mass varies with the radius of the masses orbit (hint: look at your data from this lab).

(12) Experiment 5: Centripetal Motion: Using your spreadsheet and the formula:

$$\tau = 2\pi\sqrt{\frac{r\sqrt{L^2-(r-r_o)^2}}{g(r-r_o)}}$$

find the theoretical value for the rotation period τ for the mass when the height of the mass is $y = 0.07$ m, pendulum length $L = 0.20$ m, minimum height $y_o = 0.02$ m, the extension arm length $r_o = 0.02$ m, and $g = 9.801\ m/s^2$.

(13) Experiment 6: The Pendulum and g: What effect does the weight of the bob have in this experiment?

(14) Experiment 6: The Pendulum and g: Is a calibration error in the timer a systematic or random error in determining g? Can you overcome this by making more measurements with the same timer?

(15) Experiment 6: The Pendulum and g: Suppose a pendulum bob is swinging with an amplitude $\Theta_o = 0.1$ radians and a frequency $\omega_0 = 2\pi$ radians/sec. The angle the pendulum's

string makes with the vertical direction can be written as $\Theta = \Theta_o \cos(\omega_o t)$. Use the spreadsheet to compute Θ at times = 0, 0.1, 0.2, 0.3,..., 1.9, 2.0 seconds and then plot Θ versus t.

(16) Experiment 7: Forced Harmonic Motion: Make a sketch, which shows how the phase depends on frequency.

(17) Experiment 7: Forced Harmonic Motion: Make a sketch, which shows how the amplitude depends on frequency.

(18) Experiment 7: Forced Harmonic Motion: Explain how you could measure the Q of the resonance in this system?

(19) Experiment 7: Forced Harmonic Motion: Suppose that you wanted to decrease the resonance frequency of the system, what could you do?

(20) Experiment 8: Waves on a String: What is the relationship between the frequency of a wave and its wavelength? Be sure to define any constants you introduce.

(21) Experiment 8: Waves on a String: Sketch the shape of the string when it is excited in the third harmonic.

(22) Experiment 8: Waves on a String: A student measures wave speeds of 5 m/s, 7 m/s, 10 m/s and 15 m/s for tensions of 1 N, 2 N, 4 N, and 9 N respectively. Use the spreadsheet to make a log-log plot of the wave speed versus the tension. Also find the slope of the resulting straight line.

(23) Experiment 9: Ideal Gas Law and Absolute zero: Without using a thermometer, how can you establish a temperature of 100 °C?

(24) Experiment 9: Ideal Gas Law and Absolute zero: Use the thermometer to accurately measure room temperature and estimate the uncertainty in this measurement. Be sure to give proper units.

(25) Experiment 9: Ideal Gas Law and Absolute zero: What does "absolute zero temperature" mean?

(26) Experiment 9: Ideal Gas Law and Absolute zero: Using the Charles' law apparatus, a student finds pressures of 760, 840, 950 mm of Hg at temperatures of 26 °C, 57 °C, and 100 °C respectively. Use the spreadsheet to make a plot of P versus T and find the slope of the resulting straight line. Does the data agree with Charles's law? Briefly explain.