Physics 117M Final Exam - Lab Practical - Spring 2008

Name: ______________________ TA/Section: ________________ Setup: A / B

Welcome to the Physics 117M lab practical exam! You will be asked to make measurements and perform calculations in experimental situations similar to those you encountered during the semester. Be sure to read all of these instructions and ask your TA if any instruction is not clear to you. Your TA will tell you when you can begin work.

1. You may choose any empty lab table at the beginning of the exam. There are two separate setups (setup A and setup B) of each of the four different experimental stations. Note whether you have chosen an A or B setup and circle that letter at the top right corner of this page. The results obtained will be different for A and B setups, and your TA needs this information to grade your exam accurately.

2. During the exam, you will rotate upwards in station number (moving $1 \rightarrow 2$, $2 \rightarrow 3$, $3 \rightarrow 4$ and $4 \rightarrow 1$) and will stay with the setup letter (A or B) with which you began. You have 20 minutes at each station to make measurements, perform calculations, and return the station to its original state. You may continue calculations from a given station at a later station, but may not return to make further measurements at a station. At the end of the exam period, you will have 5 minutes to complete calculations and check your work.

3. In fairness to the other students, you must stop your work when your TA tells you that time is up and return your station to its original state. If you stay at the station significantly past the given time, or don't return the setup to its original condition, your TA may have to assess a penalty by deducting a few points from your exam (for each infraction).

4. Each station counts for 25 points, for a total of 100 points on the exam. At each station will be an equipment list, the condition the station should be returned to after completing the question and any notes relevant to the station. Each exam question will require you to make measurements with the equipment and carry out calculations with the data. In some cases, the experimental procedure may be given to you. Note that statistical data is provided on the last two pages of the exam.

5. Be sure to present your work clearly and show all of your calculations, in order to give yourself the best chance to receive partial credit. Assume that measurements are good to three significant figures unless the directions or a specific piece of equipment indicate otherwise. Unless stated specifically, you do not need to do an error analysis. Be sure to include units when appropriate.

6. You will be graded primarily on your procedure and method of calculation, but as this is a lab practical, the accuracy of your results will also have value. Accuracy will count for 3 points on each station unless noted otherwise. Each question will tell you how accurate your final results need to be for you to receive full credit.

7. If you think a piece of equipment is not working properly, please ask your TA to check it for you. If you are unsure about the meaning of a question, you may ask your TA about it, but keep in mind that under exam conditions your TA is limited in how much information he or she can provide.

Please be sure you are clear on the instructions.
Thanks for an excellent semester, and good luck!

1. It is your objective at this station to determine the surface tension of a fluid using the procedure learned in lab. For the purpose of this exam question, you can use the ring *as it is* as it has already been cleansed for you. Recall that the surface tension was determined via the expression

$$\gamma = \frac{ks}{2\pi d}.$$

   (a) (7 points) Using the mass pan and a 1 g mass, determine the spring constant k for the spring in your apparatus. Express your result in dynes/cm. So as to avoid dropping the mass into the fluid, remove the pyrex dish from the platform during this measurement.

   (b) (5 points) Make a determination of the maximum stretch s the fluid's surface tension can apply to the spring through its contact with the ring.

   (c) (5 points) Make a measurement of the diameter of the ring.

   (d) (5 points) Using your measured values from parts (1a), (1b) and (1c), calculate the surface tension. Express your answer in both units of dynes/cm and $\text{mPa}\cdot\text{m}$. Recall that a Pascal (Pa) is a N/m^2.

   Your result must fall within 20% of the accepted value in order to receive full credit for accuracy. (3 points)

2. The purpose of this station is to indirectly measure the speed of sound. This experimental arrangement is identical to what was done in lab with the exception of replacing the tuning fork with a speaker. Unlike the tuning fork, the speaker can give a constant volume output. Begin by turning the frequency generator on by pressing the **POWER** button. The experiment works best when the **OUTPUT** is set to a minimum; however, you may turn the **OUTPUT** higher just a bit if needed. Please do not adjust the placement of the speaker.

   Recall that the relationship between the resonance n and the water level in the tube L is

$$n = \frac{2f}{v}L + \frac{1}{2} \ . \tag{1}$$

   (a) (6 points) First, choose and record a frequency f between 200hz and 800hz. Any frequency will do, just choose your favorite within that range. Set the frequency generator to this frequency. Record L and n for the first two resonances.

   (b) (8 points) Use the data acquired in part (2a) to plot n vs. L. A grid is provided for your graph.

   (c) (8 points) Use eq. (1) and your results from parts (2a) and (2b) to find the speed of sound. Include all of your work!

   Your result must fall within 5% of the accepted value in order to receive full credit for accuracy. (3 points)

3. At this station, your objective is to measure the average volume of a delicious fruit. The fruit in question is a key lime, and we have provided you with a large quantity of them. There will be variations on the size and shape from lime to lime. For the purpose of this question, assume a lime is a spherical object and use your own judgement when deciding how to measure them. The volume of a sphere as a function of its *radius* is

$$V = \frac{4}{3}\pi r^3 \,. \tag{2}$$

   (a) (7 points) Choose any five (5) limes out of the ones provided. Measure and record each of their *diameters* to the best precision possible. From these measurements, find the mean diameter of a lime. Calculate the mean volume of a lime.

   (b) (7 points) Use the five measurements from part 3a to build a 95% confidence interval for the best value of the diameter of a lime.

   (c) (8 points) Take half the width of your confidence interval in part 3b as the uncertainty in your diameter ΔD. Use the method of propagation of errors to build a 95% confidence interval for the volume of a lime ΔV.

   Your accurately calculated confidence interval from part 3b should be within 20% of the accepted value in order to receive full credit. (3 points)

4. The purpose of this station is to find the center of mass of a doll and its uncertainty.

   (a) (6 points) Record the appropriate measurements to find the center of mass of the doll as measured from the feet with its arms to the side. Remember to include error in your measurements and assume a 0.02 g error in the mass measurements.
   (b) (10 points) Use your knowledge of systems in equilibrium to find the center of mass of the doll.
   (c) (6 points) Use propagation of errors to find the error in the center of mass.

   (3 points) Your accurately calculated confidence interval for the center of mass of the doll should include its accepted value.

Propagation of errors: $\Delta f = \sum_j \left| \frac{\partial f}{\partial_j} \right| \Delta x_i$.

Confidence Level	Confidence Interval
50%	$x - 0.67\sigma < \mu < x + 0.67\sigma$
68%	$x - 1.00\sigma < \mu < x + 1.00\sigma$
75%	$x - 1.15\sigma < \mu < x + 1.15\sigma$
90%	$x - 1.64\sigma < \mu < x + 1.64\sigma$
95%	$x - 1.96\sigma < \mu < x + 1.96\sigma$
99%	$x - 2.58\sigma < \mu < x + 2.58\sigma$

Table 1: Confidence intervals for various levels of confidence, assuming a normal population with known σ.

z	$P(z)$	A	z	$P(z)$	A	z	$P(z)$	A
0.00	0.399	0.0000	1.05	0.230	0.3531	2.10	0.0440	0.48214
.05	.398	.0199	1.10	.218	.3643	2.20	.0355	.48610
.10	.397	.0398	1.15	.206	.3749	2.30	.0283	.48928
.15	.394	.0596	1.20	.194	.3849	2.40	.0224	.49180
.20	.391	.0793	1.25	.183	.3944	2.50	.0175	.49379
.25	.387	.0987	1.30	.171	.4032	2.60	.0136	.49534
.30	.381	.1179	1.35	.160	.4115	2.70	.0104	.49653
.35	.375	.1368	1.40	.150	.4192	2.80	.0079	.49744
.40	.368	.1554	1.45	.139	.4265	2.90	.0060	.49813
.45	.361	.1736	1.50	.130	.4332	3.00	.0044	.49865
.50	.352	.1915	1.55	.120	.4394	3.25	.0020	.49942
.55	.343	.2088	1.60	.111	.4452	3.50	.0009	.49977
.60	.333	.2257	1.65	.102	.4505	3.75	.0004	.49991
.65	.323	.2422	1.70	.094	.4554	4.00	.0001	.49997
.70	.312	.2580	1.75	.086	.4599			
.75	.301	.2734	1.80	.079	.4641			
.80	.290	.2881	1.85	.072	.4678			
.85	.278	.3023	1.90	.066	.4713			
.90	.266	.3159	1.95	.060	.4744			
.95	.254	.3289	2.00	.054	.4772			
1.00	.242	.3413						

Table 2: Area under the normalized probability curve.

[1]

[1] The value A denotes the area between the line of symmetry at $z = 0$ and the line at the listed value of $\pm z$. The ordinates are listed under the heading $P(z)$.

ν	$A=0.50$	$A=0.68$	$A=0.75$	$A=0.90$	$A=0.95$	$A=0.99$
1	1.00	1.84	2.41	6.31	12.7	63.7
2	0.82	1.32	1.60	2.92	4.30	9.92
3	0.77	1.20	1.42	2.35	3.18	5.84
4	0.74	1.14	1.34	2.13	2.78	4.60
5	0.73	1.11	1.30	2.02	2.57	4.03
6	0.72	1.09	1.27	1.94	2.45	3.71
7	0.71	1.08	1.25	1.89	2.36	3.50
8	0.71	1.07	1.24	1.86	2.31	3.36
9	0.70	1.06	1.23	1.83	2.26	3.25
10	0.70	1.05	1.22	1.81	2.23	3.17
11	0.70	1.05	1.21	1.80	2.20	3.11
12	0.70	1.04	1.21	1.78	2.18	3.05
13	0.69	1.04	1.20	1.77	2.16	3.01
14	0.69	1.04	1.20	1.76	2.14	2.98
15	0.69	1.03	1.20	1.75	2.13	2.95
16	0.69	1.03	1.19	1.75	2.12	2.92
17	0.69	1.03	1.19	1.74	2.11	2.90
18	0.69	1.03	1.19	1.73	2.10	2.88
19	0.69	1.03	1.19	1.73	2.09	2.86
20	0.69	1.03	1.18	1.72	2.09	2.85
∞	0.67	1.00	1.15	1.64	1.96	2.58

Table 3: Coefficients k for a given confidence interval level A and number of degrees of freedom ν for the Student's t-distribution.

The mean $\bar{x}$ of n observations $x_1, x_2, \ldots, x_n$ is

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i\,,$$

and the sample standard deviation s_{n-1} is

$$s_{n-1} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}\,.$$

The pooled estimate of the standard deviation s between two sets is

$$s = \sqrt{\frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2}}\,.$$