Lab 1, part II

A take-home set of exercises, due January 15, 6:00 p.m.

Print your full LAST name: ______________________________________________

Print your full first name: _______________________________________________

Print your Lab TA’s name: _______________________________________________

What is your Lab TA’s box # (located outside of Wngr 234)? _________

Print your Lab SECTION # here: ----------------->                      

Sign your name (full signature): __________________________________________

Print today’s date: ____________________________________________________
Lab 1, part II

PH 212 Course Introduction and Math Review

Purpose: To familiarize yourself with the purposes and policies of PH 212, and to practice with some needed math skills.

Directions: The answer to items here can be found either on the OSU web site or the PH 212 web site: http://www.physics.oregonstate.edu/~coffinc/COURSES/ph212. You’ll save a lot of time by first thoroughly reading all parts of the PH 212 web site (starting with the Syllabus and Frequently Asked Questions), rather than just skimming for answers. And note that some answers will be found in the first portion of the online lab manual.

You may either use the space provided here, or you may supplement as needed with your own paper. (If you use your own paper, there is no need to re-state the questions.) But you’ll always need to provide (and complete) the cover sheet (first page) of this file.

1. a. Where will you find the written materials for each lab?

b. What information about each lab will your lab TA provide?

c. A lab group consists of how many students?

d. Why is it important to read each lab and prepare for it prior to arriving in lab?

e. What is the purpose of the labs in PH 212?

f. What portions of lab are covered on the exams?
2. a. If you have to miss a lab (or want to repeat it for a better score), what are your options?

b. What are the consequences of not making up a missed lab or not turning in a take-home lab part?

c. What is your lab section #? What is your TA’s box #? Why are both numbers important enough to put on the front of any take-home lab assignment? Why is it important not to confuse the two numbers?

d. How will you know your lab percentage during the term? Does Chris keep a running total?

3. a. When are the PH 212 exams this term? Give the day of the week, the date, and the starting time for each:
   Midterm 1:
   Midterm 2:
   Final:

   SIGN HERE to confirm that you are aware of the above exam dates and times AND that you will notify Chris no later than Tuesday, January 15 about ANY time conflicts you have for ANY of these exams.  

   (your signature)

b. What are you allowed to bring to the exams? Give a complete and detailed list.

c. When and how will you learn full details about the exam locations, rules and topics?

d. What should you do if you disagree with the scoring on your exam? Where is the form and specific information about this?
4. a. What portion of your total grade are the clicker questions? Can any other portion of the course be substituted for your clicker score?

b. How do you register so that your clicker responses are credited?

c. Does your clicker app work in all three sections of lecture?

d. How does the clicker scoring work? (And what if you’re absent, late, you forget your clicker, or it doesn’t work?)

e. Where are clicker questions posted? How about the answers?

f. How will you know your clicker % during the term? Does Chris keep your running total?

5. a. Where do you find the Prep problem sets? How about the Prep problem solutions?

b. How closely do Prep problems represent typical exam or HW problems?

c. What portion of your grade do you earn with Prep problems?
6. a. Where do you find the HW (homework) assignments? How about the HW solutions?

b. How many HW assignments are there?

c. What are those other links (e.g. Lab 2-V, Lab 4-III, etc.)? What sorts of assignments are they?

d. Where do you get full details on what the HW sets are like—and when/where they are due?

e. How will you know how you did on your HW assignments?

f. What portion of your total grade are the HW assignments?

    Can any other portion of the course be substituted for your HW score?
7. a. What are Chris’ office hours this term—and where is his office?

b. Do you need to make an appointment with Chris in order to visit during office hours?

c. If you need to make an appointment with Chris for any other time, how should you do this?

d. What number of hours does Chris recommend as a rough “time budget” for you to spend per week—outside of class and lab time—studying in this course?

What number of hours per credit hour does OSU (via its Academic Success Center) recommend that you budget for study in any course?

e. What are the key factors Chris recommends for more effective learning and better success in this course?

f. Where do the Prep problems come from? What is the real purpose of the Prep problem sets and how should you use them?

g. According to OSU’s Academic Regulations, what does a grade of C represent?

h. What portion of all students who enrolled in PH 212 last Winter here at OSU earned a course grade of C or better?
8. a. Suppose that these are your course totals through the first unit (so, through Week 3 of classes and the first three labs, plus the first HW set and the first midterm exam):

<table>
<thead>
<tr>
<th>Component</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clicker (19 questions asked; 15 answered; 7 correct)</td>
<td>27/30</td>
</tr>
<tr>
<td>Labs 1-3 (including the take-home portions)</td>
<td>30/35</td>
</tr>
<tr>
<td>HW 1:</td>
<td>10/35</td>
</tr>
<tr>
<td>MT 1:</td>
<td>115/250</td>
</tr>
</tbody>
</table>

Estimate your overall course % through Week 3. **Show all work here—use the example calculation sheet linked on page 14 of the Syllabus as your guide.** *(To confirm your calculations, you may then use the spreadsheet tool also linked on page 14 of the Syllabus, but you still need to show all your own calculations here.)*

b. Suppose that these are your course totals through the first two units (so, through Week 6 of classes and the first six labs, plus the first two HW sets and both midterm exams):

<table>
<thead>
<tr>
<th>Component</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clicker (42 questions asked; 35 answered; 22 correct)</td>
<td>60/60</td>
</tr>
<tr>
<td>Labs 1-6 (including the take-home portions)</td>
<td>46/65</td>
</tr>
<tr>
<td>HW 1 and HW 2:</td>
<td>22/65</td>
</tr>
<tr>
<td>MT 1 and MT 2:</td>
<td>186/450</td>
</tr>
</tbody>
</table>

Estimate your overall course % through Week 6. **As above, do your own calculations and show them all here.**

c. Suppose that these are your course totals through all three units (so, through Week 10 of classes and all 9 labs, plus all three HW sets and both midterm exams)—everything except the final exam:

<table>
<thead>
<tr>
<th>Component</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clicker (69 questions asked; 58 answered; 33 correct)</td>
<td>100/100</td>
</tr>
<tr>
<td>Labs 1-9 (including the take-home portions)</td>
<td>64/100</td>
</tr>
<tr>
<td>HW 1, HW 2 and HW 3:</td>
<td>37/100</td>
</tr>
<tr>
<td>MT 1 and MT 2:</td>
<td>186/450</td>
</tr>
</tbody>
</table>

Estimate your overall course % **going into the final exam.** **Do your own calculations; show them all here.**

d. Now, using the result of part e above, estimate the net score (i.e. after any final adjustment) that you would need on the final exam to get a C for the course.
8. e. Suppose that these are your course totals for all parts of the course—including the final exam:

- Clicker (69 questions asked; 58 answered; 33 correct): 100/100
- Labs 1-9 (including the take-home portions): 64/100 with no missing lab parts (no “lab zeroes”)
- HW 1, HW 2 and HW 3: 37/100
- MT 1, MT 2 and final exam: 300/700

Estimate your overall course % and final grade. Do your own calculations; show them all here.

f. The data in part e above includes a class session where 2 clicker questions were asked, and you were there in class and you answered both questions—but your answers were both incorrect. Now, what if, instead, you had simply missed that class (with all other data above the same)? Re-estimate your final course % and grade in this case.

g. Return now to the original data in part e above—where you turned in all take-home lab portions and you attended all labs. That included Lab 5, where your lab report score was 5/5. Now, what if, instead, you had simply missed Lab 5 (and forgot to make it up during Week 10)? With all other data from part e above the same (including the take-home portion of Lab 5—you didn’t forget that), re-estimate your final course % and grade in this case.

h. Why are all these calculations (b-h) only estimates (not exact)? And are the estimates probably conservative (too low) or optimistic (too high)?

i. Does Chris help you calculate such estimates at any point in the term? If so, when—and how?
9. a. Consider the figure shown here.

\[\begin{array}{ccc}
1 & 2 & 3 \\
\end{array}\]

(i) Count the boxes. How many?
(ii) Count the dots. How many?
(iii) What is the average density (dots per box) of the entire set of boxes?
(iv) What is the average density (dots per box) of just the set of boxes 2 and 3 (together)?
(v) What is the density (dots per box) of just box 1?

b. Now consider the figure shown here, formed by combining two exact copies of the figure above.

\[\begin{array}{cccccc}
1 & 2 & 3 & 4 & 5 & 6 \\
\end{array}\]

(i) Count the boxes. How many?
(ii) Count the dots. How many?
(iii) What is the average density (dots per box) of this entire set of boxes?
(iv) What is the average density (dots per box) of just the set of boxes 3, 4 and 5?
(v) What is the density (dots per box) of just box 6?

c. Now consider the figure shown here, formed by combining three exact copies of the figure at the top of the page.

\[\begin{array}{cccccccc}
1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\
\end{array}\]

Answer all of the questions below without doing any counting, but explain your reasoning for each answer.

(i) What is the average density of this entire set of boxes?
(ii) How many total boxes are there?
(iii) How many total dots are there?
(iv) How many total dots are in boxes 2, 6 and 7?
(v) How many dots are in any single box?

Key points:
- Density is a ratio of two measures—in this case, dots/boxes. If you double (or triple, or halve...) the object, you double (or triple, or halve...) both these measures; so the density does not change.
- The above are examples of uniform density: The dots per box are the same no matter where or what part of the object you consider. So the average for the whole box—or for any part—is truly the measure of how many dots are in any single box. (Of course, this won’t always be the case....)
10. a. Consider the figure shown here.

(i) Count the boxes. How many?
(ii) Count the dots. How many?
(iii) What is the average density (dots per box) of the entire set of boxes?
(iv) What is the average density (dots per box) of just the set of boxes 1 and 2?
(v) What is the density (dots per box) of just box 3?
(vi) Is this an example of uniform or non-uniform density?
(vii) Which single box, if any, has a density equal to the average density of the entire set of boxes?

b. Now consider the figure shown here.

(i) Count the boxes. How many?
(ii) Count the dots. How many?
(iii) What is the average density (dots per box) of this entire set of boxes?
(iv) What is the average density (dots per box) of just the set of boxes 3, 4 and 5?
(v) What is the density (dots per box) of just box 2? Box 6?
(vi) What is the density (dots per box) of a single box \( n \) (where \( 1 \leq n \leq 6 \)?
(vii) Which single box, if any, has a density equal to the average density of the entire set of boxes?

c. Now consider the figure shown here, which is longer but has the same density pattern as case b, above.

Answer all of the questions below \textbf{without doing any counting}, but show your reasoning for each answer.

(i) What is the density (dots per box) of a single box \( n \) (where \( 1 \leq n \leq 9 \))?
(ii) How many total dots are in boxes 2, 5 and 7?
(iii) How many dots are there in the whole object?
(iv) What is the average density of this entire set of boxes?

\textbf{Key points:}  • With \textbf{non-uniform} density (all of the above examples), the average density of the \textbf{whole} object does not necessarily represent the actual density for any one part. But when you take the average density of a smaller portion—as in cases a(iv) and b(iv) above—that average approaches the actual \textbf{local density} (the density of any location \textbf{within} that portion). This is the nature of averaging. (Recall how smaller and smaller samples of non-uniform velocity approach an instantaneous value.)

• In some cases of non-uniform density, such as cases b and c above, the density has a \textbf{pattern}; you can express it with a density \textbf{function}, where the density at any given location within the object (that's the box \# here) is \textbf{related mathematically} to that location.
11. a. Consider the figure shown here.

(i) Express the local density (dots per box) as a function of the box #. That is: \( d(n) = ? \)
(In other words: What is the density of a single box \( n \) (where \( 1 \leq n \leq 4) \)?)

(ii) Calculate the total number of dots in the entire object.

(iii) Calculate the average density (dots per box) of the entire object.

(iv) **Without counting:** Calculate a “local total”—the total dots within the set of boxes 2 and 3.

(v) Calculate the local average density (dots per box) of the set of boxes 2 and 3.

(vi) Suppose you didn’t have any of the above information (no diagram, no density function) except for the results of step (v)—the local average density of boxes 2 and 3. Describe how you would estimate step (iv).

b. Now consider the figure shown here.

(i) Express the local density (dots per box) as a function of the box #. That is: \( d(n) = ? \)

(ii) Calculate the total number of dots in the entire object.

(iii) Calculate the average density (dots per box) of the entire object.

(iv) **Without counting:** Calculate a “local total”—the total dots within the set of boxes 2 and 3.

(v) Calculate the local average density (dots per box) of the set of boxes 2 and 3.

(vi) Suppose you didn’t have any of the above information (no diagram, no density function) except for the results of step (v)—the local average density of boxes 2 and 3. Describe how you would estimate step (iv).

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**Key point:** Notice the way you did the estimates in steps a(vi) and b(vi) above:

\[ \text{Local total dots} = [\text{local density average (in dots per box)}] \times [\text{number of boxes being estimated}] \]

Of course, these estimates don’t always produce accurate results; some density functions allow better estimates than others. But as you have already seen, the more localized (smaller) the box sample, the more accurate that estimate—using the local density average—becomes.

In the limit—making the box sample as small as possible—the estimate is as accurate as possible.
12. Now apply a physical meaning to “dots” and “boxes.” Suppose every dot represents a molecule with a mass of, say, $1 \times 10^{-25}$ kg. And suppose every box represents a length of 1 nm ($1 \times 10^{-9}$ m). So the sets of boxes represent strings of molecules—strings of various lengths and, in many cases, various spacings between molecules.

So you could express the density in terms of molecules/nm. Or, you could express it in terms of kg/m—a mass density (in SI units).

a. Consider this string of molecules and use the above assumptions.

![String of molecules diagram]

(i) Find the average molecular density (molecules/nm) of the entire string.

(ii) Find the average mass density (kg/m) of the entire string.

Key points:

- Notice that these densities are expressed in only one dimension—along a path, or line (i.e. not over a surface or in a volume). For that reason, each is called a linear density (rather than a surface or volumetric density), and it’s denoted as $\lambda$ (lambda). A linear molecular density would be called $\lambda_{mol}$; a linear mass density is usually just $\lambda$.

- Just because we express local mass density, $\lambda$, in kg/m, that doesn’t mean we’re actually looking at an entire meter length of the string. In fact, we’re looking at a very tiny portion (say, a nm), but we’re expressing how much mass is contained there by relating it to the mass we would have in an entire meter if that meter were uniformly packed exactly like that nm.

- $\lambda$ is good for all sorts of purposes; we often use it for macroscopic strings, too—particularly if they have uniform linear mass densities. For example, a 50-cm guitar string of total mass 0.650 g would have this uniform linear mass density: $\lambda = (6.50 \times 10^{-4} \text{ kg})/(0.50 \text{ m}) = 1.30 \times 10^{-3} \text{ kg/m}$.

- But $\lambda$ is a key tool for strings with non-uniform linear mass densities, especially if the strings are tiny in scale, where we can’t conveniently count individual mass elements. This is where it makes most sense (and is often most accurate) to express $\lambda$ as a smooth, continuous linear mass density function, where the local mass density depends on the location….
Again, suppose every dot represents a molecule with a mass of $1 \times 10^{-25}$ kg. And every box represents a length of 1 nm ($1 \times 10^{-9}$ m). So again, the sets of boxes represent strings of molecules—strings of various lengths and, in many cases, various spacings between molecules.

12. b. Consider this string of molecules and use the above assumptions.

![Diagram of a string of molecules]

(i) Write a linear molecular density function, $\lambda_{\text{mol}}$ that relates the number of molecules contained in a given nm of the string to the "box" position, $n$, of that particular nm. That is, write $\lambda_{\text{mol}}(n)$, expressed in molecules/nm.

(ii) Now convert your result from part (i) into a linear mass density function that relates the local mass density of the string to the path position, $s$ (measured in meters) of that location. That is, write $\lambda(s)$, expressed in kg/m.

c. Repeat part b, using this string of molecules instead.

![Diagram of a string of molecules]

(i) $\lambda_{\text{mol}}(n) =$

(ii) $\lambda(s) =$

**Key points:**
- It’s entirely possible for some small portion of a string to have zero local density (i.e. no mass within that particular segment).
- And again, notice how “local averaging” here wouldn’t necessarily be very accurate—because these density functions are non-uniform.
13. Pause a moment and re-read the Key Point at the bottom of page 11. Then do the following.

a. Suppose a certain string is 4.00 m long and is located along the \( x \)-axis \((0 \leq x \leq 4.00 \text{ m})\). And suppose that its total mass is 864 g.

(i) Calculate the string’s overall average linear mass density. Express this in SI units.

(ii) Under what circumstances would that overall average density be correct also as a local average density for any given portion of the string?

(iii) Assuming the circumstances described in item (ii) above, how much mass is located in the region \( 1.5 \text{ m} \leq x \leq 1.6 \text{ m} \)? Show all your work/reasoning.

(iv) Assuming the circumstances described in item (ii) above, how much mass is located in the region \( 1.51 \text{ m} \leq x \leq 1.52 \text{ m} \)? Show all your work/reasoning.

(v) Assuming the circumstances described in item (ii) above, how much mass is located in the region \( 1.501 \text{ m} \leq x \leq 1.502 \text{ m} \)? Show all your work/reasoning.
13. b. Suppose a certain string is 4.00 m long and is located along the x-axis (0 ≤ x ≤ 4.00 m).
And suppose that its linear mass density function is given by: \( \lambda(x) = ax^{1/2} \)
where \( a = 0.795 \text{ kg} \cdot \text{m}^{-3/2} \), and \( x \) is expressed in m.

(i) \textbf{Without integrating}, use \( \lambda(1.25) \) to \textbf{estimate} the total mass located in the region 1.25 m ≤ x ≤ 1.26 m.
Show all your reasoning.

(ii) \textbf{Without integrating}, use \( \lambda(1.25) \) to \textbf{estimate} the total mass located in the region 1.251 m ≤ x ≤ 1.252 m.
Show all your reasoning.

(iii) \textbf{Without integrating}, use \( \lambda(1.25) \) to \textbf{estimate} the total mass located in the region 1.2501 m ≤ x ≤ 1.2502 m.
Show all your reasoning.

(iv) Of the above three estimates, (i)-(iii), which is likely to be the most accurate? Explain.

\textbf{Key points:} • \textit{Take the above to its logical conclusion—take it to the infinitesimal limit:}
If mass is distributed in a linear density function \( \lambda(s) \), then at any path position \( s \),
the tiny amount of mass \( dm \) present there (along a tiny path length \( ds \)) is: \( dm = \lambda ds \)

\textbf{Likewise (by reasoning similar to the previous few pages):}
• If mass is distributed in a surface density function \( \eta(x, y) \) or \( \eta(r, \theta) \), then at any position \( (x, y) \) or
\( (r, \theta) \), the tiny amount of mass \( dm \) present there (across a tiny surface area \( dA \)) is: \( dm = \eta dA \)
• If mass is distributed in a volume density function \( \rho(x, y, z) \) or \( \rho(r, \theta, \phi) \) or \( \rho(r, \theta, z) \), then at any
position \( (x, y, z) \) or \( (r, \theta, \phi) \) or \( (r, \theta, z) \), the tiny amount of mass \( dm \) present there (within a tiny
amount of volume \( dV \)) is: \( dm = \rho dV \)
14. Show all your work. Two strings have the same overall average linear mass density. Also known:

String A \( \lambda_A(x) = ax^2 \), where \( a = 1.57 \text{ kg·m}^{-3} \), and \( 0 \leq x \leq 1.80 \text{ m} \)

String B \( \lambda_B(x) = bx + c \), where \( b = 0.630 \text{ kg·m}^{-2} \), \( c = 0.249 \text{ kg·m}^{-1} \), and \( 0 \leq x \leq L_B \text{ m} \)

a. Find \( L_B \), the length of string B.

b. If you cut string A into three equal lengths, what’s the mass of the middle section?