STUDY GUIDE 1: Introduction, Vectors, Kinematics

PH 1110 Study Guides are intended to help you achieve the objectives of this course as completely and as efficiently as possible. Each Study Guide begins with a listing of OBJECTIVES to which we will key our instruction, assignments, and exam for that section of the course. A SUGGESTED STUDY PROCEDURE follows, including hints and elaborations (always intended to be helpful!) about some of the more important or challenging concepts, as well as a listing of those end-of-chapter exercises and problems that best exemplify the application of our course objectives. Finally, there is a listing of the READING QUESTIONS and HOMEWORK ASSIGNMENTS, due each lecture period during that section of the course. The objectives specify the concepts and tasks we want you to master during this course; the suggested study procedure and assigned reading questions and homework provide a playing field on which you can develop your mastery of those concepts and tasks, prior to examination.

As you prepare to immerse yourself in PH 1110, please keep in mind that physics is more than problem solving. On the other hand, no one learns physics without solving lots of problems. Physics teachers smile at the oft-repeated complaint, "I understand the material, but I can't do any of the problems." **THIS IS SIMPLY NOT TRUE**! If you can't do MOST of the problems, you do not yet understand the physics. The entire support structure of this course is geared toward helping you learn how to solve the requisite problems appropriate to learning this physics, but YOU must schedule the necessary practice. Students reaching the end of this course agree! On the end-of-course evaluation form, most students write that their best piece of advice for someone just beginning the course is: **"DO ALL OF THE SUGGESTED EXERCISES AND PROBLEMS!"**

And while we're on the subject of things to do, here's a DON'T: **Don't** just blindly memorize. Rote memory has little to do with learning physics. Almost always, time spent memorizing something could be better spent working on some illustrative problems. Through careful and thoughtful problem solving, those items you need implanted in your memory banks will automatically end up there.

Now back to a DO: **Do** take time to learn from your problem solutions. (In general, the least important detail of a solution is the specific numerical answer!) Did you draw a SKETCH that properly captures all essential detail of the situation at hand? What FUNDAMENTAL PRINCIPLE(S) did you apply? Is there an unbroken logical CHAIN OF REASONING, including proper application of the fundamental principle(s), connecting the given information all the way through to your answer? Does your answer have correct UNITS as well as the proper number of SIGNIFICANT FIGURES? Does your answer seem to be of a PROPER SIZE? This, in a nutshell, is what physics is all about! Welcome aboard!

Objectives for Study Guide 1

1. Express numerical answers to the correct number of significant figures using scientific notation. Convert units from one system to another.

2. Distinguish between scalar and vector quantities; determine the magnitudes of scalar and vector quantities.

3. Determine graphically the sum of two or more vectors.

4. Convert vectors from magnitude/direction form to component form, and vice versa; add and subtract vectors analytically by using their components.

5. Define unit vector; solve for the unit vector parallel to any given vector. Use the **ijk** unit vectors to express a vector in standard **ijk** form.

6. Define displacement, velocity and acceleration. Distinguish between displacement and distance, velocity and speed, average and instantaneous velocities, and average and instantaneous acceleration.

7. Given the graph or functional form of one of the quantities $x(t)$, $v_x(t)$, or $a_x(t)$, determine the graphs of the other two. Describe in words and equations the motion from an analysis of one or more of the graphs.

8. Solve problems of uniformly accelerated motion in one dimension.

9. Solve problems concerning the motion in a plane, including the motion of projectiles in a uniform gravitational field.

10. Solve problems concerning the displacement, velocity, and acceleration of a particle moving along a circular path.

<u>Suggested Study Procedure for Chapter 1.</u>

Skim Secs. 1.1 through 1,6.
Study Secs. 1.7 through 1.9.
Study particularly Examples 1.5 through 1.9.
Answer Discussion Questions 12, 13, 16, 17, 21-first part only (p. 29).
Do Exercises in Chapter 1 – 1, 5, 13, 22, 35, 37, 40, 41 (pp. 28-30)
Do Problems in Chapter 1 – 66, 67, 69, 74 (pp. 31-32).

A. As you read Secs. 1.1 and 1.2, note the discussion about the use of models. The use of models is intrinsic to physics.

B. Pay close attention to Secs. 1.3 through 1.5. As part of the standard language of science and technology, correct use of units and numerical notation is important. If you aren't familiar with the foolproof method of units conversion that involves multiplying by a properly-chosen form of 1, then study Sec. 1.4 carefully. Secondly, you will be expected to express numerical answers to the proper number of significant figures, as discussed in Sec. 1.5, on all of your submitted work (assigned homework, lab reports, and exams). Worked examples in lecture will illustrate what we mean.

C. Although not on our **official** list, another section worth looking at closely is Sec. 1.6. Professionals in every scientific and technical discipline frequently find it convenient to make order-of-magnitude calculations in their head or on scratch paper so that they know what results to expect from a more detailed analysis, should one even be necessary. Example 1.4 is a good illustration of what we're talking about. With a little practice, you can dazzle your friends with your ability to estimate all sorts of offbeat quantities.

D. Here are two important points about Example 1.7. First of all, as Y&F hint in the Problem-Solving Strategy at the top of p. 19, the "arctan" function on your calculator only gives you angles in the first quadrant (for positive arguments) and fourth quadrant (for negative arguments). **You** have to decide when the correct angle is actually in a different quadrant, and **you** have to add the 180^o when appropriate. Secondly, angles are different from other numerical quantities with respect to significant figures, because they are cyclic and because they end up inside of trig functions. To be consistent with calculations to 3 significant figures (as we will **usually** use in PH 1110), you should then use and report **angles to tenths of a degree**, no matter how many or how few digits precede the decimal point. In other words, arctan((9.92)/(-7.99)) = 128.8^o, not 129^o as Y&F present it. (Mostly, Y&F are good about expressing angles to tenths of a degree, but they slipped up in this example!)

E. Section 1.7 shows you how to add and subtract vectors graphically (or geometrically); Sec. 1.8 shows you how to obtain precise, quantitative results in vector addition/subtraction by means of what is called the component, or analytic, method. The whole point is that to deal successfully with vectors you must be able to transform vectors between two equivalent forms,

magnitude/ direction form : $\vec{\mathbf{A}} = \left|\vec{\mathbf{A}}\right| \angle \Theta$

and the component form: $\vec{\mathbf{A}} = A_x \hat{\mathbf{i}} + A_y \hat{\mathbf{j}}$.

Again, we emphasize that these two forms mean exactly the same thing (they **really** are **equivalent!**) – it's just that each form is better suited for different things. For some purposes (visualizing, sketching) we tend to find the magnitude/direction form more useful; for other purposes (precision adding, subtracting, and graphing) we are **much** better off using the component form. Example 1.7 provides good practice in working back and forth between the two forms.

F. The unit vector, discussed in Sec. 1.9, is an enormously useful part of this vector stuff. One little detail the authors should have included is that **i**, **j**, and **k** are not the only unit vectors in the world. You can make a unit vector, $\hat{\mathbf{u}}_A$, which is parallel to some vector $\vec{\mathbf{A}}$ simply by dividing $\vec{\mathbf{A}}$ by its magnitude:

$$\hat{\mathbf{u}}_A \equiv \frac{\vec{\mathbf{A}}}{|\vec{\mathbf{A}}|} \quad .$$

Example: Given that $\vec{\mathbf{A}} = (6.00\,\hat{\mathbf{i}} - 4.00\,\hat{\mathbf{j}})$ m, solve for the unit vector parallel to $\vec{\mathbf{A}}$

$$\text{Answer:} \quad \hat{\mathbf{u}}_A = \frac{(6\hat{\mathbf{i}} - 4\hat{\mathbf{j}})m}{\sqrt{6^2 + (-4)^2}\,m} = 0.832\hat{\mathbf{i}} - 0.555\hat{\mathbf{j}} = 1\angle -33.7^o$$

Suggested Study Procedures for Chapter 2.

Study Secs. 2.1 through 2.5; **Skim** Sec. 2.6.
Study the Examples, especially Examples 2.4 through 2.8.
Answer Discussion Questions 3, 8, 10, 12, 15
Do Exercises in Chapt. 2 – 12, 19, 28, 31, 32, 35, 45
Do Problems in Chapt. 2 – 67, 69, 74, 83, 85

A. Throughout Chapt. 2, Y&F refer to v_x and a_x as velocity and acceleration, respectively. From your studies of Chapt. 1, you learned that v_x is really the x-component of velocity, and a_x is really the x-component of acceleration (and **components** of vectors are, it turns out, **scalars!**). Now Y&F **do** take pains to point out this shortcut in terminology (see for example their commentary on page 39). **But we don't like this shortcut!!!** It will get you into bad habits that will be hard to break later on. So we'll try to be absolutely consistent in our terminology starting right here in Chapter 2! When we say **velocity**, we'll mean the vector quantity **velocity** = v_x **i**, and when we say **acceleration**, we'll mean the vector quantity **acceleration** = a_x **i**. And similarly, when we are talking about v_x, we'll always strive to call that the velocity **component** (in the x-direction), and likewise a_x will be called the acceleration **component** (in the x-direction). And while we're at it, we might as well include the distinction between displacement (**displacement** = x **i**) and the x-component of displacement (which of course would be x itself!).

B. Although we want you to be familiar with average velocity (Eqn. 2.2) and average acceleration (Eqn. 2.4), it is actually the **instantaneous** velocity and acceleration (Eqns. 2.3 and 2.5, respectively) we are most often interested in. The notions of average velocity and average acceleration are just stepping-stone concepts to help you understand the meaning of the instantaneous values. Thus, when we refer to velocity and acceleration, we **always** mean the instantaneous version of each. In contrast, average speed **is** a useful concept, and it will show up in your work from time to time.

C. Graphs of x, v_x, and a_x vs. t help us understand the relationships among these quantities. Fig. 2.8a is intended to help you see that v_x at any given moment is the slope of the x vs. t graph at that very instant. Fig. 2.13a is intended to help you see that a_x at any given moment is the slope of the v_x vs. t graph at that same moment.

Once you think that you understand this, try your hand at drawing the v_x and a_x vs. t graphs corresponding to Fig. 2.9 or to an x vs. t graph of your own invention.

D. Just as you can move from x vs. t to v_x vs. t to a_x vs. t by taking slopes, you can go in the other direction (a_x to v_x to x) by taking areas under the graphs, expressed as functions of time. The authors show this in Sec. 2.6. In lecture, we'll show how to apply this idea in constant-a_x situations.

E. All motion problems can be analyzed and solved graphically as described above in C and D. In the important case of constant acceleration, however, the graphs lead to a standard set of equations which automatically link the various system parameters. Sec. 2.4 shows how to solve such problems algebraically. The two approaches are really equivalent, so we urge you to practice both approaches for the added insights you will gain.

F. When analyzing freely falling bodies (Sec. 2.5), we like Y&F's convention of choosing vertically upward to be the positive y-axis direction. Because the Earth causes a downward acceleration, the y-component of the acceleration is thus negative:

$$a_y = -g = -9.80 \text{ m/s}^2 .$$

Please note that a_y is the negative quantity here, <u>not g</u>. The acceleration due to gravity (g) is **ALWAYS** stated as a positive number (i.e., as the magnitude of an acceleration) – just look in any listing of physical constants, such as inside the front cover of your text, and see for yourself. The negative sign in -9.80 m/s^2 comes entirely from choosing the vertically-upward direction to be positive!

<u>Suggested Study Procedure for Chapter 3.</u>

Study Secs. 3.1-3.4.
Study Examples 1-12, especially 5, 6, 9, 11, and 12.
Answer Discussion Questions 1, 2, 3, 7, 10, and 12.
Do Exercises 3bc, 7, 9, 11, 23, 29, and 30.
Do Problems 47, 53, 67,71.

A. Note that projectile motion involve motion with constant acceleration in the vertical direction while, in the horizontal direction, the motion is with constant velocity.

B. In Secs. 3.1 and 3.2 you find how displacement, velocity, and acceleration are handled when motion is NOT constrained to lie along a single straight-line direction. Note that we simply apply the machinery of one-dimensional motion and of vectors in order to generalize to ANY possible motion.

1. In multi-dimensional cases, remember that "constant velocity" means constant in DIRECTION as well as MAGNITUDE (the object moves in a straight line at a constant speed -- this is quite uncommon as far as the motion of "everyday" objects is concerned). An object that changes direction under ANY circumstances is accelerating.

2. Similarly, "constant acceleration" means that the acceleration vector is constant in magnitude AND direction throughout the motion. When acceleration is not zero, the velocity vector MUST necessarily be changing with time, either in magnitude, in direction, or both.

3. The component of acceleration perpendicular to $\vec{v}$ changes the DIRECTION but not the magnitude of $\vec{v}$. The component of acceleration parallel to $\vec{v}$ changes the MAGNITUDE of $\vec{v}$ (the speed) but not the direction. Try applying this rule to the various examples in Chapt. 4 and see if it doesn't help demystify seemingly complex two- and three-dimensional motions.

C. Sec. 3.3 introduces an important special case of motion where the vertical component of acceleration is CONSTANT and the horizontal component is ZERO. Provided that we can ignore air friction, this case describes the motion of objects tossed around just above the Earth's surface. Notice how following the Problem-Solving Strategy (p. 82) applies to the Examples, Exercises, and Problems.

D. Sec. 3.4 introduces another VERY IMPORTANT special case of motion – namely, circular motion at constant speed. Here is the acid test of whether you have yet bought into the vector nature of velocity and acceleration. Until you have, it will seem nonsensical that something traveling with constant speed can be continuously accelerating!

LABORATORY WORK FOR STUDY GUIDE 1

During the time you work on Study Guide 1, you will do three experiments in the laboratory. **Experiment #0** will introduce you to the lab and lead you through exercises on uncertainty. **Experiment #1** will give you practical experience with the parameters of motion – x, v_x, and a_x -- all as a function of time, using a computer for data acquisition and analysis. In **Experiment #2** you will study the motion of an object under constant acceleration.

Experience shows that students who read the instructions and answer the preliminary questions before going to the lab complete the work more quickly and easily. See http://www.wpi.edu/Academics/Depts/Physics/Courses/ph1110a13/ph1110a13Labs/.

READING QUESTIONS AND HOMEWORK ASSIGNMENTS FOR STUDY GUIDE 1

There will be formal reading questions and homework assignments associated with each lecture, except the first (except on exam days). The formal reading questions and assignments will be submitted online via Mastering Physics (see Reading Questions 1 and Assignment 1). The informal homework assignment associated with the first lecture is to watch the logistics video. There is a link to it at the main course website, http://www.wpi.edu/Academics/Depts/Physics/Courses/ph1110a13/ph1110a13.html.

Reading Questions #1 – due in by **6AM Friday, Aug. 30. -** based on Sects. 1.3, 1.4, 2.1-2.4

Solutions for Reading Questions #1 will be submitted via the web. In your web browser, go to www.masteringphysics.com . Then (if this is your first time at that site) follow the instructions packaged with your textbook to register. You will need the six-word access code that comes with your textbook to register. For your information, the zip code at WPI is 01609. After you register, you will be able to login at any time using the username and password you have chosen. At your first login, you will be asked to enter the course ID for PH1110, which is PH1110A13SECTIONS7TO18.

After logging in, click on Assignment List. Before you do Reading Questions #1, you should complete Introduction to Mastering Physics – Assignment 0 (the very last of the reading questions and assignment set) , a brief, noncredit tutorial on how to enter answers in Mastering Physics.

In Reading Questions #1, you will get 4 chances to submit a correct answer. These are short reading assignments. They help prepare you for that day's lecture.

Homework Assignment #1 – due in by **Noon Saturday, Aug. 31.**

Solutions for Assignment #1 will be submitted via the web. In your web browser, go to www.masteringphysics.com . Then (if this is your first time at that site) follow the instructions packaged with your textbook to register. You will need the six-word access code that comes with your textbook to register. For your information, the zip code at WPI is 01609. After you register, you will be able to login at any time using the username and password you have chosen. At your first login, you will be asked to enter the course ID for PH1110, which is PH1110A13SECTIONS7TO18.

After logging in, click on Assignment List. Before you do Assignment #1, you should complete Introduction to Mastering Physics – Assignment 0, a brief, noncredit tutorial on how to enter answers in Mastering Physics.

In Assignment #1, you will get 4 chances to submit a correct answer. If your first answer is incorrect, you should consider making use of the hints.

Reading Questions #2 – due in by **6AM Wed, Sept. 4. -** based on Sects. 2.5, 3.1, 3.2, 3.4

Just as with Reading Questions #1, Reading Questions #2 will be submitted via the web. Go to www.masteringphysics.com. Then login using the username and password you have chosen.

After logging in, click on Assignment List and select Reading Questions #2. If you need any review you can repeat Assignment #0.

In Reading Questions #2, you will get 4 chances to submit a correct answer. These are short reading assignments. They help prepare you for that day's lecture.

Homework Assignment #2 – due by **Noon** on **Thursday, Sep. 5.**

Just as with Assignment #1, Assignment #2 will be submitted via the web. Go to www.masteringphysics.com. Then login using the username and password you have chosen.

After logging in, click on Assignment List and select Assignment #2. If you need any review you can repeat Assignment #0.

In Assignment #2, you will get 4 chances to submit a correct answer. If your first answer is incorrect, you should consider making use of the hints.

Reading Questions #3 – due in by **6AM Friday, Sept. 6.** - based on Sect. 3.3

Homework Assignment #3 – due by **Noon** on **Saturday, Sep. 7.**

Reading Questions #4 – due in by **6AM Monday, Sept. 9.** - based on Sects. 4.1 - 4.6

Homework Assignment #4 – due by **Noon** on **Tuesday, Sept. 10.**