Study Guide 2: 2-D Motion and Newton's Laws of Motion.

Objectives for Study Guide 2

9. Solve problems concerning 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.

11. State Newton's first, second and third laws. Be able to identify the reaction force to any force acting on a body. Distinguish between mass and weight.

12. Draw a diagram representing a body isolated from its environment in an inertial coordinate frame, indicate with arrows all forces that act on it, and identify the source of each force. Such a diagram is called a "free-body diagram."

13. Apply Newton's laws to determine the acceleration of an object subject to one or more forces and present a clear, concise written solution to the problem.

14. Solve more complicated Newton's second law problems, particularly those involving friction forces and/or circular motion.

Suggested Study Procedure for Chapter 3.

Study Sec. 3.1 through 3.4
Study particularly Examples 1 (parts a and c), 2 (part b), 4, 5, 6, 7, 8, 12, 13.
Answer Discussion Questions 1, 2, 4, 7, 10, 12.
Do Exercises 3 (parts b and c,) 7, 9, 19, 25, 31, 33, 35.
Do Problems 47, 53, 63, 67.

1) In Sections 3.1 and 3.2, you will 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.
    a) In multi-dimensional cases, remember that "constant velocity" means constant in *direction* as well as *magnitude*. An object that changes direction under any circumstances is accelerating.
    b) 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.

c) The component of acceleration perpendicular to $\vec{\mathbf{v}}$ changes the direction but not the magnitude of $\vec{\mathbf{v}}$. The component of acceleration parallel to $\vec{\mathbf{v}}$ changes the magnitude of $\vec{\mathbf{v}}$ but not the direction. Try applying this rule to the various examples in Chapter 4 and see if it doesn't help to demystify seemingly complex problems involving two- and three-dimension motion.

2) 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 you can ignore air friction, this case describes the motion of objects tossed around just above the earth's surface. Notice how the Problem-Solving Strategy on p. 91 applies to the related Examples, Exercises and Problems.

3) 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.

Suggested Study Procedure for Chapter 4.

Study 4.1 through 4.6.
Study lots of examples–all of them are worth looking at.
Answer Discussion Questions 2, 5, 7, 9, 14, 30, 31, 32.
Do Exercises 5, 9, 11, 20, 25, 27, 29.
Do Problems 35, 39, 45, 49, 53.

1) Up until now, we have been studying kinematics. We now come to Newton's Laws of motion and begin our study of dynamics. We consider what it takes to get an object to move or change its state of motion, a force.

a) Sec. 4.1 covers the same ground as your first two lab experiments by emphasizing that force is a vector quantity (with a magnitude and a direction) and by reminding you how two or more forces add together vectorially to produce a "net force".

b) Your common sense probably tells you that a force is required to keep an object moving with constant velocity, because that's the way the world around you seems to work. (Indeed, this was the prevailing wisdom in the west for two thousand years.) You might then incorrectly assume that the velocity is proportional to the force you apply. Newton tells us that the correct way to analyze motion is to determine the net force acting on an object. An object subject to no net force moves with constant velocity as discussed in sec. 4.2. If the net force is not zero, the object will accelerate in a proportionate amount, where the constant of proportionality is the mass of the object; this is discussed in Sec. 4.3. This is what Newton summarized in his first two laws of motion although some of this was known before his time.

c) Unlike Newton's first two laws, which refer to a single object, Newton's third law pertains to the interaction between two objects; the misunderstanding of this detail has lead many physics students astray. The text statement on p. 103 says it all:

> "If body A exerts a force on body B (an "action"), then body B exerts a force on body A (a "reaction"). These two forces have the same magnitude but are opposite in direction. **These two forces act on different bodies** [my emphasis]."

The implications of this law are explored in Sec. 4.5 and subsequent sections.

2) Sec. 4.6 introduces the indispensable concept of the free-body diagram. This concept is used to analyze the situation of any object subject to forces. Plan on getting familiar with the rules of constructing free-body diagrams because we will be using these diagrams as an integral part of our work from now

Suggested Study Procedure for Chapter 5.

Study Sec. 5.1 through 5.4.
Study all the examples.
Answer Discussion Questions 1, 4, 10, 11, 15, 19, 27, 30.
Do Exercises 7, 13, 17, 19, 23, 39, 43, 51.
Do Problems 63, 67, 81, 91, 117.

1) Chapter 5 shows how the physics presented in Chapter 4 can be applied to a variety of real-world situations including inclines and elevators (Sec. 5.1 and 5.2), frictional forces (Sec. 5.3), and problems involving circular motion (Sec. 5.4). Study carefully the Problem-Solving Strategy on pp. 161-162. All problems involving known forces can be analyzed by this same approach. Please be aware that your instructors and graders expect you to follow this approach from now on in all of your homework and exam solutions. Proper application of this approach will help you avoid errors.

Homework Assignments.

Homework Assignment 4.
due in lecture Friday, Sep. 3, 2004

HW4-1. Problem 2.64. Also, make a plot of the velocity of each runner as a function of time if they complete the race in a tie. Make a similar plot for the acceleration of the runners.

HW4-2. The position of a small object is given by

$$\vec{\mathbf{r}} = \left(c\,t - b\,t^3\right)\,\hat{\mathbf{i}} + d\,t^2\,\hat{\mathbf{j}}$$

where $b = 0.810\ \frac{\text{m}}{\text{s}^3}$, $c = 6.70\ \frac{\text{m}}{\text{s}}$, and $d = 4.50\ \frac{\text{m}}{\text{s}^2}$. a) Obtain expressions for the velocity and acceleration of the object as functions of time. b) Determine the object's position, velocity and acceleration at $t = -1.00\,\text{s}, 0.00$, and $1.00\,\text{s}$. Plot these three positions on an x-y coordinate system and attach arrows (with labels) to each point showing the vector direction of the velocity and acceleration at that point.

HW4-3. Exercise 3.16.

Homework Assignment 5.
due by 4:00 PM Friday, Sep. 10, 2004

Just as with Homework Assignment 3, this assignment is to be submitted via the web. In your web browser, go to `www.masteringphysics.com`. Login using the username and password you have previously chosen. After logging in, click on "Assignment List" and select "Assignment #5". If you need any review, you can always repeat Assignment 0, a brief, non-credit tutorial on how to enter answers in Mastering Physics. In this assignment, you will get three chances to submit a correct answer. If your first answer is incorrect, you should consider making use of the hints.

Homework Assignment 6.
due in lecture Monday, Sep. 13, 2004

A free-body diagram is required as the first step in your solution for the problems below.

HW6-1. Problem 4.44.

HW6-2. Your mass is 58.0 kg. You are standing on a bathroom scale in an elevator in a tall building; the scale reads in units of force. The elevator starts from rest and travels upward with a speed that varies with time according to $v(t) = 2.00\,\frac{\mathrm{m}}{\mathrm{s}} + \left(0.500\ \frac{\mathrm{m}}{\mathrm{s}^2}\right)\, t + \left(0.0200\,\frac{\mathrm{m}}{\mathrm{s}^3}\right)\, t^2$. At $t = 3.00\,\mathrm{s}$, what is the reading on the scale?

HW6-3. Problem 5.68. Assume that the numeric values in the problem are given to three significant digits.

Homework Assignment 7.
due in lecture Wednesday, Sep. 15, 2004

A free-body diagram is required as the first step in your solution for the problems below.

HW7-1. Exercise 5.38.

HW7-2. Problem 5.90.

HW7-3. Problem 5.104.