PH 1110 **Term C, 2000**

STUDY GUIDE 2: 2-D Motion, Newton's Laws of Motion

<u>Objectives</u>

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 with constant speed 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 "<u>free-body diagram</u>".

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

14. Solve more complicated Newton's 2nd law problems, particularly those involving friction forces or circular motion.

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

Study Secs. 3.1 through 3.5.
Answer Discussion Questions 3, 4, 6, 14.
Study particularly Examples 1, 2, 4, 5, 6, 7, 11, 12.
Do Exercises 5, 7, 11, 12, 19, 25, 27.
Do Problems 44, 45, 49, 55.

A. In Secs. 3.2 and 3.3 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 $\vec{\mathbf{v}}$ changes the DIRECTION but not the magnitude of $\vec{\mathbf{v}}$. The component of acceleration parallel to $\vec{\mathbf{v}}$ changes the MAGNITUDE of $\vec{\mathbf{v}}$ (the speed) but not the direction. Try applying this rule to the various examples in Chapt. 3 and see if it doesn't help demystify seemingly complex two- and three-dimensional motions.

B. Sec. 3-4 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. Try following the Problem-Solving Strategy (p. 71) as you re-work Examples 3-6 and 3-7.

C. Sec. 3-5 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!

<u>Suggested Study Procedure for Chapter 4.</u>

Study Secs. 4.1 through 4.8.
Answer Discussion Questions 2, 3, 6, 28, 33.
Study particularly Examples 3, 4, 5, 6, 9, 10, 11, 13.
Do Exercises 3, 5, 17, 19, 20, 21, 29.
Do Problems 34, 35, 37, 49.

A. We now come to Newton's laws of motion, the key to understanding the way the physical world works. So far, you have learned how to describe the motion of objects; now you will learn what it takes to get an object to move or to change its state of motion -- namely, FORCE.

1. Sec. 4-2 covers the same ground as your first two lab experiments by emphasizing that force is a vector quantity (with magnitude AND direction) and by reminding you how two or more forces add together vectorially to produce a "net force."

2. 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. You might then INCORRECTLY assume that the velocity is proportional to the force you apply. Newton tells us that the foolproof AND CORRECT way to analyze motion is to determine the NET FORCE acting on the object. An object subject to NO NET FORCE moves with CONSTANT VELOCITY (read all about it in Sec. 4-3). If the net force is NONZERO, the object will ACCELERATE in a proportionate amount, where the constant of proportionality is the mass of the object (read all about this in Sec. 4-4!). This is what Newton has summarized in his first two laws of motion.

3. Unlike Newton's first two laws that refer to a single object, Newton's third law pertains to the INTERACTION between TWO objects, and the misunderstanding of this little detail has led countless students astray. If you stick with the text statement on p. 107, you can't possibly go wrong!

> "If body A exerts a force on body B, then body B exerts an equal and opposite force on object A. (Obviously, these two forces act on DIFFERENT bodies.)"

The implications of this law are explored in Sec. 4.6 and subsequent sections.

B. See the Problem-Solving Procedure in Sec. 4-7 -- absolutely ALL problems involving known forces can be analyzed by this SAME approach. The use of the FREE-BODY DIAGRAM is central to this approach, so you should practice drawing such diagrams in your own problem solutions. The text has lots of examples to learn from, starting in Chapt. 4.

<u>Suggested Study Procedure for Chapter 5.</u>

Study Secs. 5.1 through 5.5.
Answer Discussion Questions 3, 5, 11, 17.

Study LOTS of Examples **--** almost all are worth looking at.
Do Exercises 5, 9, 15, 23, 27, 36, 45, 50, 56.
Do Probems 63, 67, 75, 84, 95, 99.

A. Chapt. 5 shows how the physics presented in Chapt. 4 can be applied to a variety of real-world situations including inclines and elevators (Secs. 5.2 and 5.3), frictional forces (Sec. 5.4), and circular motion (Sec. 5.5). The one-size-fits-all Problem-Solving Strategy appears again on p. 125. PLEASE BE AWARE that your instructors and graders expect you to follow this procedure from now on in all of your homework and exam solutions. Proper application of the procedure will help you avoid errors. Believe it or not, your instructors use the same procedure when they do such problems, at least if they want to avoid mistakes!

HOMEWORK ASSIGNMENTS FOR STUDY GUIDE 2

Homework Assignment #4 - due in lecture Monday, Jan 24.

HW 4-1: The driver of a car slams on the brakes when he sees a tree blocking the road. The car slows with a constant acceleration of -5.60 m/s^2 for 4.20 s, making straight skid marks 62.4 m long ending at the tree. **Determine** the speed with which the car strikes the tree.

HW 4-2: Prob. 3-36; PLUS **plot** this displacement point on an *x*-*y* graph and **attach** a properly-aimed arrow to this point to show the acceleration direction; ALSO, **plot** the displacement points for one second earlier and for one second later AND **attach** properly-aimed arrows to each point representing the velocity direction at these points.

HW 4-3: An artillery shell is fired with an initial velocity of 300 m/s at 55.0° above the horizontal. It explodes on a mountainside 42.0 s after firing. **Determine** the *x* and *y* coordinates of the shell where it explodes, relative to its firing point.

Homework Assignment #5 - due in lecture Friday, Jan 28.

HW 5-1: A placekicker must kick a football from a point 36.0 m (about 40 yards) from the goal where the crossbar is located, 3.05 m above the ground. When kicked, the ball leaves the ground with a speed of 20.0 m/s at an angle of 53.0° to the horizontal. **Determine** (a) by how much the ball clears or falls short of clearing the crossbar, and (b) whether the ball approaches the crossbar while still rising or falling.

HW 5-2: Ex. 3-26; PLUS, on a sketch of the rotor tip, **show** the velocity and acceleration directions relative to the rotation axis. **Repeat** for a rotor rotating in the opposite direction.

HW 5-3: Ex. 4-12.

Homework Assignment #6 - due in lecture Monday, Jan 31.

HW 6-1: A Ferris wheel of diameter 18.0 m rotates about its axis four times every minute when up to full speed. For full speed conditions, **calculate** the acceleration (magnitude AND direction) experienced by a passenger when (a) at the top of the rotation, (b) at the bottom of the rotation, and (c) half way in between the previous situations. **Determine** the force (magnitude AND direction) exerted by the seat on a 70.0 kg passenger in each of the three situations.

HW 6-2: Ex. 4-28, except that the 4 kg block is replaced by a 10.0 kg block. ALSO, **draw** a free-body diagram for the 6 kg block and **specify** the reaction force for EACH force shown in the free-body diagram. (Be sure to make it easy for the grader to figure out what you have in mind by drawing appropriate figures and using descriptive labels.)

HW 6-3: A 72.0 kg man stands on a spring scale in an elevator. Starting from rest, the elevator ascends, attaining its maximum speed of 1.20 m/s in 0.800 s. It travels with this constant speed for the next 5.00 s. The elevator then undergoes a constant acceleration in the negative *y* direction for 1.50 s and comes to rest. **Determine** what the reading of the spring scale is (in newtons) (a) before the elevator starts to move, (b) during the first 0.800 s, (c) while the elevator is traveling at constant speed, and (d) during the time it is slowing down.

<u>Homework Assignment #7 - due in lecture Wednesday, Feb 2.</u>

HW 7-1: Prob. 5-68; PLUS **draw** free-body diagrams in each case.

HW 7-2: A crate released from rest at the top of a frictional 4.00 m long incline (sloped 30.0° with the horizontal) slides to the bottom in 2.00 s. Determine the coefficient of friction in this situation.

HW 7-3: Ex. 5-46; PLUS **draw** diagrams showing ALL forces on the car as it rounds the curve. (Be sure to **show** both horizontal and vertical forces, and **show** their directions relative to the center of rotation).