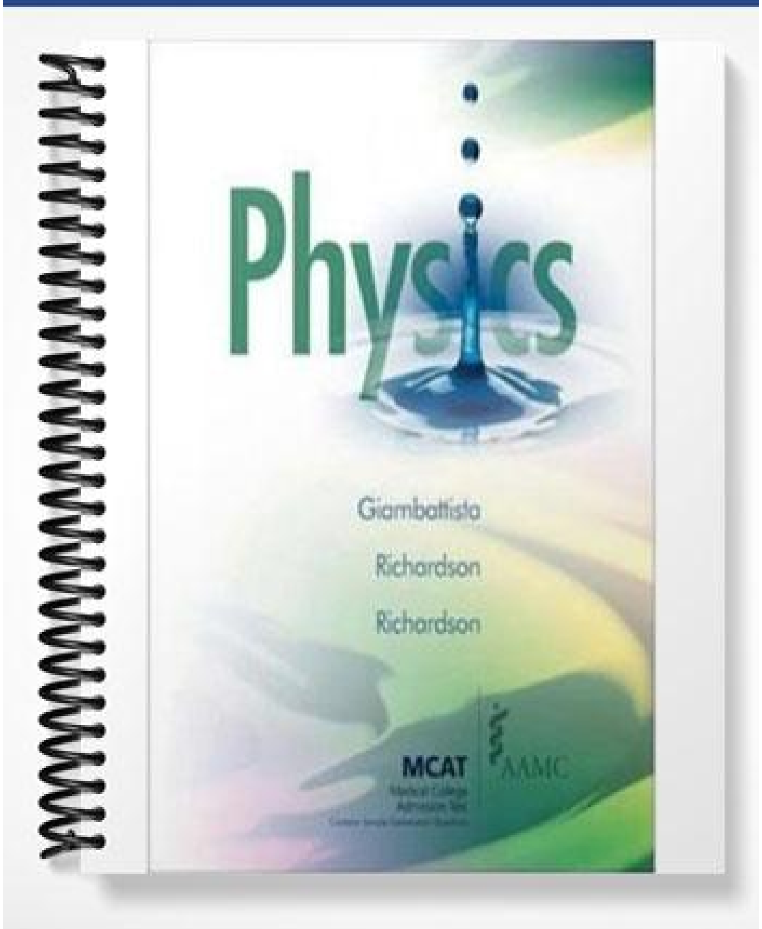
SOLUTIONS MANUAL



Chapter 2: Motion Along a Line

A. Summary of Main Points of Chapter

2.1 Understanding Motion

Introduction to Newton's Laws of Motion: (1) When the net force on an object is zero, the velocity of the object does not change; (2) when a nonzero net force acts on an object, the velocity does change; (3) two interacting objects exert equal and opposite forces on one another.

2.2 Position and Displacement

Vectors and Scalars: Quantities with both magnitude and direction are called vectors. Quantities with magnitude only (such as mass) are called scalars. Scalars can be added arithmetically. Vectors have their own addition rules.

Position: To describe position, we need a reference point along with a distance and direction from the reference point.

Components of a Vector: For one-dimensional motion, the x-component of a vector is all that is called for. It will be along either the $+x$ or the $-x$ direction.

Displacement: Displacement is the change of position. Position is a vector, so displacement is as well, and the two positions (initial and final) must be subtracted as vectors. The negative of a vector has the same magnitude and opposite direction to the original. To subtract a vector from another, take its negative and add as usual.

2.3 Velocity: Rate of Change of Position

Velocity is a measure of how fast, and in what direction, something is moving; it is the displacement divided by the time the displacement took, and, like displacement, is a vector.

Average Velocity: If a displacement occurs during a finite time interval, the average velocity during that time is the displacement divided by that time.

Instantaneous Velocity: We can imagine making the time interval shorter and shorter as we measure the average velocity. Once that interval is infinitesimally short (that is, in the limit that the time interval goes to zero), the velocity we measure is the instantaneous velocity.

Relationship Between Position and Velocity on Graphs of $x(t)$ and $v_x(t)$: If we plot displacement on the vertical versus time on the horizontal axis, the slope of the tangent to the line at a point is the instantaneous velocity at the time corresponding to that point. If the velocity is constant, the line is straight, and the slope is easy to find. Otherwise, the tangent must be found first. If we have a graph of the velocity and want to find the position, we find the area under the v-t curve, keeping in mind that the dimensions are given by multiplying the dimensions of the two axes.

2.4 Acceleration: Rate of Change of Velocity

Average and Instantaneous Acceleration: Acceleration is defined in a similar way to velocity; the average acceleration is the change in velocity divided by the time interval during which the velocity changed, and the instantaneous acceleration is found by letting that time interval become infinitesimally small.

The Direction of the Acceleration Vector: If the velocity and acceleration are in the same direction, the object is speeding up. If they are in opposite directions, it is slowing down.

Relationship Between Velocity and Acceleration on Graphs of $v_x(t)$ and $a_x(t)$: Acceleration is the slope of the *v-t* line, just as velocity is the slope of the *x-t* line. Velocity is the area under the curve in an *a-t* graph.

2.5 Motion Along a Line with a Constant Acceleration

The equations of motion for constant acceleration are relatively simple to derive. Positions, velocities, and times need to be carefully designated. Besides the acceleration, one needs to know initial or final conditions (velocities, positions, and time elapsed) in order to solve the equations.

2.6 Visualizing Motion Along a Line with a Constant Acceleration

"Strobe" drawings or photographs of objects with constant acceleration show that, if the interval between "flashes" is constant, the distance traveled either increases or decreases.

2.7 Free Fall

If we ignore air resistance (which we can in various circumstances), objects falling near the earth have a constant acceleration, which we label **g**.

B. Common Errors of Students Learning This Material

It is not always obvious to students which quantities are vectors and which are scalars, especially with signed scalars such as temperature (they confuse the sign with a direction). Students are often confused by vectors, and many never really do grasp the fundamentals of what a vector actually represents. Adding parallel vectors is usually not too much of a problem, but even antiparallel (a word which the students are not likely to know) vectors present problems. Another confusion comes from students thinking about wind directions – an easterly wind comes from the east, and therefore heads west (this in itself is confusing), whereas physicists always label vectors according to the direction they are going (so a wind blowing to the west would be represented by a vector pointing west).

The vector nature of displacement can be troublesome. Getting students to be aware of what is happening physically should help. Net displacement, after a trip of several stages, needs to be clearly differentiated from total distance traveled. Motivation is useful too - that is, give examples where knowing the displacement, rather than the distance traveled, would be useful, such as figuring out how far one is from home.

The distinction between speed (scalar) and velocity (vector) should be carefully maintained. Students will be familiar with speed, but the distinction between average velocity and instantaneous velocity may give them pause. Again, the usefulness of the concept of average velocity should be demonstrated. After all, if it isn't useful, why would we spend time on it?

Graphs are always troublesome for some students. Finding the slope of a tangent to a line, and relating it to the instantaneous velocity, should be practiced at length. Finding the area under the curve, and relating it to the displacement (velocity) or velocity (acceleration) is another large step in a direction unknown and confusing to the students.

Acceleration will be less familiar to the students than velocity (even if they don't think so), especially as a vector. They will be confused between negative acceleration and deceleration. Practice with the relationship between the direction of the velocity, the direction of the acceleration, and whether the velocity is increasing or decreasing in magnitude will help. Of course, if the velocity is decreasing, it cannot do this forever. Eventually the object will stop and begin to move in the direction of the acceleration. This can be emphasized, repeatedly, using objects which are thrown up and then come back down.

Graphs of velocity versus time, from which the students are supposed to find the acceleration, are confusing to most. If used, they require a lot of practice on the students' part, and a lot of feedback from the instructor.

The equations of motion for constant acceleration become like a mantra for the students. They memorize them and can recite them at will, but are often very unclear about what they mean, and in particular, that they are relevant only if the acceleration is indeed constant. Also, once acceleration has been introduced, students may be confused by constant-velocity problems, or parts of problems, such as the *x*-component of projectile motion.

Falling objects are useful examples, as they are common and familiar. The constancy of the acceleration is not obvious, however, and the students need a lot of practice with it. Students often confuse acceleration with velocity anyway, and many will insist that the acceleration is zero when the velocity is zero at the highest point of motion of an object thrown upwards. They usually have less difficulty with the constancy of acceleration of objects which are simply dropped.

C. Suggested Classroom Demonstrations

Below are some suggestions for classroom demonstrations. For demonstration ideas with detailed instructions, please visit the Instructor's Resources in the Instructor's Edition of the ARIS site for *College Physics* at: http://www.mhhe.com/grr.

1. Students have difficulty with the idea that acceleration can be nonzero when velocity is zero. An object tossed up in the air can be used as a demonstration, but moves rather fast. An object rolling up and then back down an inclined plane is easier to see. An experiment which the students can try on their own in a car (or on a bicycle or other wheeled vehicle): Roll to a stop on flat ground (using friction, not the brakes), then step on the brake. Nothing happens. Both the velocity and acceleration were already zero. Now roll up a hill and apply the brakes just

as the car comes to a stop. Even though the velocity is zero, and applying the brake doesn't change that, you will feel a "jerk" due to the sudden change in acceleration.

2. Make two long strings, one with equally spaced weights (such as large hex nuts) tied to it, and one where the spacing between weights increases as the square (with the closer weights near the bottom). Drop each string from as high as possible and have the students listen to the sound of the weights striking the floor, or use a sheet of metal, which makes a better sound. The equally spaced weights do not make equally spaced sounds, but the others do if you get the distances right. This is an aural way of demonstrating acceleration.

D. Suggested Small-Group, Just-in-Time, and Active Learning Exercises

1. End-of-chapter questions suitable for small-group class work: Conceptual questions 1, 7, 9; Problems 3 and 4 (together), 13 and 14 (together), 26 and 27 (together), 32, 40 and 41 (together), 56, 60.

2. End-of-chapter questions suitable for online pretests: Conceptual questions 3, 4, 5, 6; Problems 3, 6, 8, 15, 24, 34, 44.

3. Graphs, graphs, graphs. If you are going to ask the students to use and interpret graphs, they are going to need a lot of practice. Graphs of the position versus time of an object moving with constant velocity are the easiest for students to understand. Anything else will give many students trouble. Impossible graphs (those which cannot depict a real physical situation, such as having multiple values of position or velocity for a single time) can be very useful pedagogically. Have the students pick the impossible graphs from a selection which includes both possible and impossible ones, and explain what is wrong with the impossible ones. Often an impossible graph can be constructed from a possible one by rotating it by 90º.

4. Show the students examples of objects moving under various circumstances (falling, going up and then down, moving at a constant speed, going back and forth, and so on) and have them draw sketches of the velocity versus time. Advanced: Have them use those sketches to find the acceleration.