Chapter 2

MOTION

This chapter covers the basics of the description of motion. The concepts of position, speed, velocity, and acceleration are defined and physically interpreted, with applications to falling objects, circular motion, and projectiles. A distinction is made between average values and instantaneous values. Scalar and vector quantities are also discussed. Also, an interesting Highlight on Galileo and the Leaning Tower of Pisa discusses the status of the tower.

Problem solving is difficult for most students. The authors have found it successful to assign a take-home quiz on several questions and exercises at the end of the chapter that is handed in at the beginning of class. (It may save time and be instructive to have students exchange and grade papers as you go over the quiz.) This may be followed by an in-class quiz on one of the take-home exercise, for which the numerical values have been changed. The procedure provides students with practice and helps them gain confidence.

DEMONSTRATIONS

A linear air track may be used to demonstrate both velocity and acceleration. If an air track is not available, a 2-in. × 6-in. × 12-ft wooden plank may be substituted. It will be necessary to have a V groove cut into one edge of the plank to hold a steel ball of about 1-in. diameter. The ball will roll fairly freely in the V groove.

Also, various free-fall demonstrations are commercially available.

(General references to teaching aids are given in the Teaching Aids section.)

ANSWERS TO MATCHING QUESTIONS

a. 16 b. 13 c. 1 d. 6 e. 14 f. 2 g. 3 h. 12 i. 5 j. 15 k. 18 l. 8 m. 10 n. 7 o. 17 p. 11 q. 4 r. 9

ANSWERS TO MULTIPLE-CHOICE QUESTIONS

1. d 2. c 3. d 4. d 5. d 6. b

7. c 8. d 9. d 10. d 11. c 12. c

ANSWERS TO FILL-IN-THE-BLANK QUESTIONS

1. position 2. scalar 3. vector 4. distance 5. speed 6. constant or uniform
7. time, t^2 8. gravity 9. m/s^2 10. centripetal (center-seeking) 11. 4 12. acceleration

ANSWERS TO SHORT-ANSWER QUESTIONS

1. Mechanics.
2. An origin or reference point.
3. Length per time (length/time).
4. A scalar has magnitude, and a vector has magnitude and direction.
5. Distance is the actual path length and is a scalar. Displacement is the directed, straight-line distance between two points and is a vector. Distance is associated with speed, and displacement is associated with velocity.
6. They both give averages of different quantities.
7. (a) They are equal. (b) The average speed has a finite value, but the average velocity is zero because the displacement is zero.
8. Either the magnitude or direction of the velocity, or both. An example of both is a child going down a wavy slide at a playground.
9. Yes, both (a) and (b) can affect speed and therefore velocity.
10. No. If the velocity and acceleration are both in the negative direction, the object will speed up.
11. Initial speed is zero. Initial acceleration of 9.8 m/s^2, which is constant.
12. The object would remain suspended.
13. Yes, in uniform circular motion, velocity changing direction, centripetal acceleration.
14. Center-seeking. Necessary for circular motion.
15. Yes, we are in rotational or circular motion in space.
16. Inwardly toward the Earth's axis of rotation for (a) and (b).
17. g and v_x
18. Greater range on the Moon, gravity less (slower vertical motion).
19. Initial velocity, projection angle, and air resistance.
20. No, it will always fall below a horizontal line because of the downward acceleration due to gravity.

21. Both have the same vertical acceleration.

22. Less than 45° because air resistance reduces the velocity, particularly in the horizontal direction.

ANSWERS TO VISUAL CONNECTION

a. speed, b. uniform velocity, c. acceleration (change in velocity magnitude), d. acceleration (change in velocity magnitude and direction)

ANSWERS TO APPLYING-YOUR-KNOWLEDGE QUESTIONS

1. More instantaneous. Think of having your speed measured by a radar. This is an instantaneous measurement, and you get a ticket if you exceed the speed limit.

2. (a) The orbital (tangential) acceleration is small and not detected. (b) The apparent motion of the Sun, Moon, and stars.

3. (a) toward the center of the Earth, (b) toward the axis, (c) zero

4. Yes, neglecting air resistance.

5. $d = ½\, gt^2, so\;\; t = \sqrt{2d/g} = \sqrt{\dfrac{2(11\text{ m})}{9.8\text{ m/s}^2}} =$ 1.5 s   Balloon lands in front of prof. Student gets an "F" grade.

6. (a) updraft, slow down, reach terminal velocity later. (b) downdraft, speed up, terminal velocity sooner.

7. Escaping air stabilizes chute – prevents rocking.

8. Streamlines. Prevents air blocking.

ANSWERS TO EXERCISES

1. 7 m
2. 5 m south of east
3. $\bar{v}$ = *d/t* = 100 m/12 s = 8.3 m/s
4. 1.6 m/s
5. *t* = *d/v* = 7.86×10^{10} m/ 3.00×10^8 m/s = 2.62×10^2 s. Speed of light (constant).
6.. *t* = *d/v* = 750 mi/(55.0 mi/h) = 13.6 h
7. (a) *d* = $\bar{v}\,t$ = (52 mi/h)(1.5 h) = 78 mi (b) $\bar{v}$ = *d/t* = 22 mi/0.50 h = 44 mi/h

(c) $\bar{v}$ = *d/t* = 100 mi/2.0 h = 50 mi/h

7. $\bar{v}$ = *d/t* = 7.86×10^{10} m/ 2.62×10^2 s = 3.00×10^8 m/s. Speed of light (constant).

8. (a) *d*/150 s. (b) *d*/192 s., (c) *d*/342 s. Omission. *d* inadvertently left out. Assuming 100 m,

(a) 100 m/150 s = 0.667 m/s. (b) 100 m/192 s = 0.521 m/s. (c) 200 m/ 342 s = 0.585 m/s.

9. (a) $\bar{v} = d/t$ = 300 km/2.0 h = 150 km/h, east. (b) Same, since constant.

10. (a) $\bar{v} = d/t$ = 750 m/20.0 s = 37.5 m/s, north. (b) Zero, since displacement is zero.

11. $\bar{a} = (v_f - v_o)/t$ = (12 m/s – 0)/6.0 s = 2.0 m/s^2

12. (a) $\bar{a} = (v_f - v_o)/t$ = (0 – 8.3 m/s)/1200 s = -6.9×10^{-3} m/s^2

(b) $v = d/t$ = (5.0×10^3 m)/(1.2×10^3 s) = 4.2 m/s (Needs to start slowing in plenty of time.)

13. (a) $\bar{a} = (v_f - v_o)/t$ = (8.0 m/s – 0)/10 s = 0.08 m/s^2 in direction of motion.

(b) $\bar{a}$ = (12 m/s – 0)/15 s = 0.80 m/s^2 in direction of motion.

14. (a) (a) 44 ft/s/5.0 s = 8.8 ft/s^2, in the direction of motion. (b) 11 ft/s^2, (c) -7.3 ft/s^2

(b) $\bar{a}$ = (88 ft /s – 44 ft /s)/4.0 s = 11 ft /s^2 in direction of motion.

(c) (66 ft /s – 88 ft /s)/3.0 s = –7.3 ft /s^2 opposite direction of motion.

(d) $\bar{a}$ = (66 ft /s – 0)/12 s = 5.5 ft /s^2 in direction of motion.

15. No, $d = ½ gt^2$ = ½ (9.8 m/s^2) (4.0)^2 = 78 m in 4.0 s.

16. $v = v_o + gt$ = 0 + (9.8 m/s^2)(3.5 s) = 34 m/s

17. $d = ½ gt^2$, *t = sq.root* [2(2.71 m)/9.80 m/s^2] =7.4 s

18. $d = ½ gt^2$. *t* as in 17. 4.3 s – 2.5 s = 1.8 s.

19. (a) $a_c = v^2/r$ = (10 m/s)^2/ 70 m = 1.4 m/s^2 toward center.

(b) a_c/g = (1.4 m/s^2)/(9.8 m/s^2) = 0.14 or 14%, yes.

20. 90.0 km/h = 25.0 m/s. $a_c = v^2/r$ = (25.0 m/s)^2/500 m = 1.25 m/s^2.

21. 0.55 s. Vertical distance is the same.

22. 45º – 37º = 8º, so 45º + 8º = 57º.