CHAPTER 2—KINEMATICS

MULTIPLE CHOICE

1. A bee caught inside a window walks along the bottom ledge. Starting at the left corner, it walks 50 cm to the right, then 20 cm to the left, then 8 cm to the right, and 10 cm to the left. At this time how far is the bee from the corner?
   a. 28 cm
   b. 40 cm
   c. 50 cm
   d. 88 cm

   ANS: A
   RAT: Add up the bee's displacements as algebraic quantities: positive to the right and negative to the left.
   PTS: 1
   REF: p. 24
   BLM: Remember

2. A man is chased by a jaguar. The man's top speed is 20 km/hr and the jaguar's top speed is 100 km/hr. If they are 400m apart, how many seconds elapse until the man is caught?
   a. 5
   b. 14.4
   c. 18
   d. 72

   ANS: C
   RAT: Relative velocity is the difference of velocities of jaguar and man. Calculate the time, in hours, as distance apart divided by the relative speed, and convert to seconds: 1 hour = 3600 secs.
   PTS: 1
   REF: p. 25
   BLM: Higher Order

3. A boy runs around a neighbourhood block in 10 minutes: a total distance of 2 km. What are his average velocity and speed in km/s?
   a. 12, 12
   b. 0, 12
   c. 12, 0
   d. Not enough information provided

   ANS: B
   RAT: Velocity is a vector calculated from the displacement, which, in this case, is zero.
   PTS: 1
   REF: p. 25
   BLM: Higher Order

4. A migrating bird can travel non-stop at a fixed speed of 40 km/hr (in still air) a distance of 2000 kilometres due south of its present position. However, there is a west wind of 30 km/hr. What is the time required for the bird to reach its destination?
   a. 37.8 hours
   b. 53.5 hours
   c. 75.6 hours
   d. 106.9 hours

   ANS: C
   RAT: With the wind, the component of the bird's velocity in the due south direction is reduced relative to that in still air, and the bird must compensate by flying with a westerly component in its velocity. The bird still flies at 40 km/hr relative to the moving air, which forms the hypotenuse of the right-angle triangle of velocities, whose westerly component is 30 km/hr. Use Pythagoras's theorem to find the unknown south component.
   PTS: 1
   REF: p. 25
   BLM: Higher Order

5. An athlete running the 100-metre event leaves the starting block with an acceleration of 8 m/s^2, and after reaching a maximum speed of 15 km/hr maintains this speed until the end of the race. How long does the athlete take to run the race?
   a. 9.9 seconds
   b. 11.2 seconds
   c. 15.5 seconds
   d. 18.4 seconds

   ANS: D
   RAT: Calculate both the distance and time elapsed during the accelerating initial phase, using Equation 2.7 and 2.10. Determine the remaining distance to be covered and the time to cover it, using Equation 2.2.
   PTS: 1
   REF: p. 25 | p. 29-30
   BLM: Higher Order

6. How would you tell from a graph of displacement vs. time, that the velocity at point (t_2, x_2) is greater than the velocity at another point (t_1, x_1)?
   a. The vertical co-ordinate at point (t_2, x_2) is greater.
   b. The slope of the tangent is greater.
   c. The slope at (t_2, x_2) is increasing.
   d. The slope at (t_1, x_1) is decreasing.

   ANS: B
   RAT: The instantaneous velocity is given by the slope of the tangent to the curve
   PTS: 1
   REF: p. 27
   BLM: Remember

7. A bird flies north at 60 km/hr for 2 minutes, then east at 70 km/hr for 5 minutes, and finally lands after flying south at 80 km/hr for 3 minutes. What is the displacement of the landing point from the take-off point?
   a. 2.04 km, 19 degrees north of east
   b. 11.83 km, 45 degrees south of east
   c. 11.83 km, 20 degrees north of east
   d. 2.04 km, 19 degrees south of east

   ANS: D
   RAT: Add the displacements, each calculated as the given velocity times the time interval, as vectors.
   PTS: 1
   REF: p. 28
   BLM: Higher Order

8. Blood in the aorta accelerates from rest to 0.4 m/s over a distance of 2 cm. What is the average acceleration?
   a. 4 m/s^2
   b. 4 m^2/s^2
   c. 8 m^2/s
   d. 8 m/s^2

   ANS: D
   RAT: SI units of acceleration are m/s^2. Convert distance to metres, and use Equation 2.9 to find acceleration.
   PTS: 1
   REF: p. 29
   BLM: Higher Order

9. In a graph of velocity vs. time, what is the total displacement from time t_1 to time t_2?
   a. The slope of the line passing through the graph at time points t_1 and t_2.
   b. The area under the curve between t_1 and t_2.
   c. The maximum slope of the graph between t_1 and $t_{2.}$
   d. Insufficient information provided.

   ANS: B
   RAT: By Equation 2.3, the increment Δx is $v\Delta t$, which is the area of the rectangular "bar" of width Δx and height v. Adding up all the bars between times t_1 and t_2 gives the area under the curve.
   PTS: 1
   REF: p. 29
   BLM: Higher Order

10. A basketball player needs to jump 1.00 metre into the air, in order to put the ball into the basket, attaining his maximum height when reaching the basket. He approaches the basket at 6.00 m/s. When starting to jump, at what distance must the player be from the basket?
    a. 3.67 m
    b. 5.20 m
    c. 7.35 m
    d. 10.39 m

    ANS: C
    RAT: The initial velocity of the (vertical) jump with final velocity of zero can be found from Equation 2.10. The player reaches his maximum height in a time obtained from Equation 2.6. Combine these two equations to solve for the time. Then the distance from the basket can be found from the horizontal velocity (6 m/s) multiplied by the time.
    PTS: 1
    REF: p. 29-30 | p. 34
    BLM: Higher Order

11. What is the stopping distance for a car braking at constant deceleration of 0.5 *g* from a speed of 120 km/hr?
    a. 56 m
    b. 70 m
    c. 113 m
    d. 140 m

    ANS: C
    RAT: Use Equation 2.10
    PTS: 1
    REF: p. 30
    BLM: Higher Order

12. A ball is thrown vertically upward at 10 m/s. How high does the ball rise?
    a. 2.5 m
    b. 5.1 m
    c. 10.2 m
    d. 15.3 m

    ANS: B
    RAT: Use Equation 2.10
    PTS: 1
    REF: p. 30
    BLM: Higher Order

13. A stone is dropped from a bridge, 50 m above a river. How long does it take for the stone to reach the water?
    a. 2.26 seconds
    b. 3.19 seconds
    c. 4.52 seconds
    d. 4.78 seconds

    ANS: B
    RAT: Solve Equation 2.9 for Δt, with initial velocity of zero.
    PTS: 1
    REF: p. 30
    BLM: Higher Order

14. A person on the ground wishes to throw a ball up to her friend on the 3rd floor balcony, 10.0 m above, from a position 1.0 m away from the side of the building. The friend on the balcony catches the ball when it is moving horizontally. To achieve this, with what speed must the friend on the ground throw the ball?
    a. 7.0 m/s
    b. 9.9 m/s
    c. 14.0 m/s
    d. 19.8 m/s

    ANS: C
    RAT: Time Δt to reach maximum height is found from solving Equation 2.12] for v_y. The vertical component of initial velocity is found from Equation 2.10] (with *y* in place of *x*). The horizontal component of velocity is the distance from the building (1 m) divided by the time Δt.
    PTS: 1
    REF: p. 30 | p. 34
    BLM: Higher Order

15. An owl accidentally drops a mouse it is carrying, while flying horizontally at a speed of 5.0 m/s. The mouse drops to the ground 10.0 m below. What is the impact velocity with which the mouse hits the ground?
    a. 20.0 m/s, at angle of 70.35 degrees below the horizontal
    b. 14.9 m/s, at angle of 70.35 degrees below the horizontal
    c. 14.9 m/s, at angle of 70.35 degrees above the horizontal
    d. 20.0 m/s, at angle of 70.35 degrees above the horizontal

    ANS: B
    RAT: Use Equation 2.10 for the vertical component of velocity, and the fact that the horizontal component is constant at 5 m/s.
    PTS: 1
    REF: p. 30 | p. 34
    BLM: Higher Order

16. A shot putter can throw the shot with an initial velocity of 20 m/s from a height of 1.8 m at an angle of 30 degrees to the horizontal. With what speed does the shot hit the ground?
    a. 10 m/s
    b. 11.63 m/s
    c. 20 m/s
    d. 20.86 m/s

    ANS: D
    RAT: The horizontal velocity is constant throughout the flight of the putt. The vertical component of velocity at a height of 1.8 m on its downward motion is equal and opposite to that when the putt is released. The vertical component on reaching the ground is found using Equation 2.10 (with *y* in place of *x*, and v_y in place of *v*). Find the magnitude of the velocity given these *x*- and *y*-components of velocity.
    PTS: 1
    REF: p. 30 | p. 34
    BLM: Higher Order

17. A ball is thrown from a building, at an angle of 45 degrees above the horizontal. If the ball were thrown in the same way from a floor at twice the height, by what factor does the distance from the building at which the ball reaches the ground increase?
   a. 2
   b. $\sqrt{2}$
   c. $2\sqrt{2}$
   d. Insufficient information

   ANS: D
   RAT: The time to reach the ground, and hence the distance the ball lands from the building, depends in a nonlinear way on the initial velocity with which the ball is thrown, and on the height from which it is thrown.
   PTS: 1
   REF: p. 34
   BLM: Higher Order

18. A boy throws a ball at an angle of 60 degrees above the horizontal, with a speed of 12.00 m/s. After 2 seconds what is the distance of the ball from the boy?
   a. 1.18 m
   b. 10.82 m
   c. 12.06 m
   d. 24.0 m

   ANS: C
   RAT: Use Equation 2.12
   PTS: 1
   REF: p. 34
   BLM: Higher Order

19. A top with a diameter of 5.00 cm is spinning at 200.00 revolutions per minute. What is the centripetal acceleration at the rim?
   a. 1.97 m/s
   b. 3.95 m/s
   c. 5.59 m/s
   d. 7.90 m/s^2

   ANS: B
   RAT: Use Equation 2.15
   PTS: 1
   REF: p. 37
   BLM: Higher Order

20. The Moon orbits the Earth in an approximately circular orbit, at a distance of 380,000 km in 27.3216 days. What is the centripetal acceleration of the Moon?
    a. 0.0272 m/s^2
    b. 0.0068 m/s^2
    c. 0.0027 m/s^2
    d. 0.0014 m/s^2

    ANS: C
    RAT: Use Equation 2.16 for centripetal acceleration in circular motion.
    PTS: 1
    REF: p. 37
    BLM: Higher Order

TRUE/FALSE

1. A fly crawls in zigzag pattern along a line, where the angle that successive straight-line segments of its path make with the general direction of motion is 60 degrees. The total distance the fly crawls is twice the distance between the end points of its path.

   ANS: T
   RAT: For each straight-line segment of path, only the component of displacement parallel to the direction of crawling contributes to displacement along the general direction. This component is given by cos 60° multiplied by the length of each segment.
   PTS: 1
   REF: p. 24
   BLM: Higher Order

2. At some point on the graph of displacement vs. time between two points, the instantaneous velocity equals the average velocity between those points.

   ANS: T
   RAT: The average velocity is the slope of the line joining the two points on the graph. Since the displacement vs. time curve passes through these points, at some point along that segment of the curve the slope of the tangent equals that of the line.
   PTS: 1
   REF: p. 27
   BLM: Higher Order

3. For an object moving along a straight line, in order to return to its starting point it does not necessarily have a speed of zero during the time lapse of its motion.

   ANS: F
   RAT: The graph of displacement vs. time starts and ends on the t-axis, i.e., at $x = 0$. In order for this to occur, the slope of the curve must be zero at some point in between.
   PTS: 1
   REF: p. 28
   BLM: Higher Order

4. For a car braking with constant deceleration, the time to stop is doubled when the speed of the car before braking is doubled.

ANS: T
RAT: By Equation 2.6, the time to reach zero velocity is proportional to the initial velocity.
PTS: 1
REF: p. 29
BLM: Remember

5. A train travelling at 200 km/hr has to brake due to an obstruction on the track 1 km ahead. The maximum braking deceleration that can be applied is 0.2 *g*. The train will be able to stop before hitting the obstruction.

ANS: T
RAT: Calculate the stopping distance using Equation 2.10; it is less than 1 km.
PTS: 1
REF: p. 30
BLM: Higher Order

6. If a car brakes at constant deceleration, the stopping distance is doubled when the initial speed is twice as great.

ANS: F
RAT: By Equation 2.10, the stopping distance is proportional to the square of the initial speed, and so the stopping distance is four times as great. This is why it is important to keep a large distance between cars on a highway, where cars travel at generally higher speeds than on city streets.
PTS: 1
REF: p. 30
BLM: Remember

7. Neglecting air resistance, a ball thrown horizontally with a certain velocity from the 10 floors up a building, will hit the ground at twice the distance from the building as if it were thrown from 5 floors up.

ANS: F
RAT: The horizontal velocity is constant, so the horizontal distance travelled is proportional to the time of travel to the ground. With an initial vertical velocity of zero, this time is proportional to the square root of the height.
PTS: 1
REF: p. 34
BLM: Higher Order

8. A ball thrown upwards at a given speed will reach the ground with the same speed as the initial one, regardless of the angle at which it is thrown

ANS: T
RAT: During its flight, the horizontal component of velocity of the ball is constant, while the vertical component reverses direction but has the same magnitude. Therefore, the speed is the same as that with which the ball is thrown.
PTS: 1
REF: p. 34
BLM: Higher Order

9. One centrifuge has twice the diameter of a second one, and half its number of revolutions per minute. Particles in suspension in the two centrifuges will feel the same centripetal acceleration.

   ANS: F
   RAT: The centripetal acceleration is proportional to radius (or diameter) and to the square of the number of revolutions per unit time (which equals the inverse of the revolution period). Therefore, the first centrifuge causes a centripetal acceleration half that of the second.
   PTS: 1
   REF: p. 37
   BLM: Higher Order

10. A weight is swung on the end of a string in a horizontal plane, with a certain period of revolution. If the string is shortened to half its length, and the revolution period is kept the same, the centripetal acceleration of the weight is halved.

   ANS: T
   RAT: By Equation 2.16, when the period T is fixed, the acceleration is proportional to the radius *r* of the circular path.
   PTS: 1
   REF: p. 37
   BLM: Remember

ESSAY

1. A bird flies in a straight line at 50 km/hr for 2 minutes, and after taking off again flies in a straight line at 40 km/hr for 3 minutes, before landing a second time. What are the maximum and minimum distances that the bird can be from its initial position after the second landing?

   ANS:
   Since the angle between the displacement vectors corresponding to the two successive flight paths is unknown, the total distance travelled depends on this angle. The maximum distance is the sum of the two displacements, and the minimum distance the magnitude of the difference of the displacements.
   RAT: Displacement is a vector quantity. The angle between displacement vectors must be known in order to calculate the final displacement. The maximum distance is 3.67 km, the minimum distance is 0.33 km.
   PTS: 1
   REF: p. 24-25
   BLM: Remember

2. One athlete can accelerate to a maximum speed of 15 m/s in 2 seconds, but can only maintain that speed for 20 seconds. A second athlete reaches maximum speed of 20 m/s in 2 seconds, but can only maintain it for 15 seconds. Which athlete runs the further distance? Describe your reasoning.

   ANS:
   Calculate the distance travelled during the initial acceleration phase using Equation 2.5 and 2.10, and the distance of the maximum speed phase using Equation 2.2. The first athlete runs a shorter distance than the second.
   RAT: When considering performance of an athlete, one must take into account both the acceleration and constant-speed phases, as well as the endurance of the athlete.
   PTS: 1
   REF: p. 25 | p. 29-30
   BLM: Remember

3. One athlete can accelerate to a maximum speed of 15 m/s in 2 seconds, but can only maintain that speed for 20 seconds. A second athlete reaches maximum speed of 20 m/s, but can only maintain it for 15 seconds. Which athlete will have run farther after 10 seconds?

   ANS:
   Calculate the distance travelled in the first 2 seconds using Equation 2.5 and 2.10. Then calculate the distance travelled in the remaining 8 seconds using Equation 2.2. The second athlete runs the greater distance.
   RAT: When considering performance of an athlete, one must take into account both the acceleration and constant-speed phases, as well as the endurance of the athlete.
   PTS: 1
   REF: p. 25 | p. 29-30
   BLM: Remember

4. If a car accelerates from stationary starting position, what difference would it make to the velocity of the car to gradually increase to amount of acceleration to some maximum value, rather than to maintain the acceleration at this maximum value from the beginning?

   ANS:
   The velocity is the area under the acceleration vs. time graph. If all the acceleration is given “at the beginning”— i.e., over a short time interval — it would have to be much larger than if gradually increased from zero, in order for the areas under the respective acceleration-vs.-time graphs to be the same (and equal to the maximum velocity).
   RAT: High accelerations are undesirable, and dangerous to passengers.
   PTS: 1
   REF: p. 30
   BLM: Higher Order

5. Compare the order of magnitude of the accelerations that a human being in a crowd where the average distance apart is 3 m and the speed of walking is 4 km/hr, to those of microscopic particles, of the order of 5 μm apart, being jostled by their neighbours several hundreds of times every second.

   ANS:
   The numbers given allow an estimate of the average time between “collisions”; the average acceleration is calculated as the average speed of motion of individual people or particles, divided by the average time between “collisions.”
   RAT: The smaller the objects, in general, the larger the accelerations they experience in their environment.
   PTS: 1
   REF: p. 30
   BLM: Higher Order

6. If football is to be played on the Moon, describe what conditions that differ from those on Earth that you would need to take into consideration to design the playing field.

   ANS:
   Answers will vary
   RAT: Points that could be mentioned: Smaller gravitational acceleration; no air friction; the larger range of travel for a given velocity, longer time of flight of the ball (Equation 2.12)
   PTS: 1
   REF: p. 34
   BLM: Higher Order

7. A ball is thrown parallel to the ground at a height of 1 m. If another ball were thrown at an angle of 45 degrees above the horizontal from ground level with the same speed, which of these methods would result in the ball travelling further until its first bounce?

ANS:
Which ball travels further before the first bounce depends on the initial speed at which it is thrown. For the first case, the time to reach the ground is $t_1 = \sqrt{(2h/g)}$, where h = 1 m is the height above ground, and the distance travelled is $x_1 = v_0 t_1 = v_0\sqrt{(2h/g)}$, by Equation 2.9 (for the y-component) and Equation 2.2 (for the x-component). For the second case, the time to reach the maximum height is $t_2 = v_{0,y}/g$, where and $v_{0,y} = v_0\sin 45^o$. The time to hit the ground is $2t_2$, so the distance travelled is $x_2 = v_{0,x}t_2$, where $v_{0,x} = v_0\cos 45^o$. The ratio of these distances is $x_2/x_1 = v_0/\sqrt{(2gh)}$, which depends on the initial speed v_0.
RAT: This question is of interest in ballistics.
PTS: 1
REF: p. 34
BLM: Higher Order

8. An athlete throws a putt at an angle of 30 degrees to the horizontal. A second athlete throws a putt at 45 degrees to the horizontal, but at 95% of the initial speed of the first athlete. Which athlete threw the putt further?

ANS:
The range of each putt is given by $R = v_0^2\sin2\theta/g$. Calculate the ratio of the ranges, $R_2/R_1 = 1.04$, so the second athlete threw the putt further.
RAT: In addition to the speed, the angle at which an object is launched determines the range of the object's path.
PTS: 1
REF: p. 35
BLM: Higher Order

9. If the centripetal force on a body revolving around a centre of attraction increased when its distance from the centre decreased, describe in general terms what shape the path of the body would look like.

ANS:
Answers will vary.
RAT: From Equation 2.16, we see that the centripetal force at any point depends on the radius of curvature of the path. Whether this increases or decreases depends on the radial component of velocity, which will either increase or decrease the distance of the body from the attracting centre. In the former case, the radius of curvature decreases, and in the latter case it increases. This is precisely what happens to bodies in orbit around each other, such as the planets around the Sun, or the Moon around the Earth. The orbits are in general non-circular, resulting in increasing radius of curvature when approaching each other, and decreasing radius of curvature when receding from each other.
PTS: 1
REF: p. 37
BLM: Higher Order

10. Describe in general terms the advantages and disadvantages of building larger-diameter centrifuges spinning at a certain rate, as opposed to centrifuges of the same size but which spin faster.

ANS:
Answers will vary
RAT: By Equation 2.16, the centripetal acceleration is proportional to the diameter (or radius, r) of the path, but proportional to the square of the rate of spin (= $1/T$). Therefore, greater gains in centripetal acceleration may be achieved by spinning faster than by having a larger diameter centrifuge.
PTS: 1
REF: p. 37
BLM: Remember