30. For the $\vec{v}$-t graph in Problem 28, create an $\vec{a}$-t graph with values.

2.3 Creating Equations

31. Below are two hypothetical equations among four variables. Derive the other equations needed to be able to solve problems when given the values of any two of the variables: $xy = p$ and $z = px$.

32. a) Derive an equation for the change in acceleration by using a graph analysis technique on an $\vec{a}$-t graph. (Note: The name given to the change in acceleration per unit time is called *jerk* by some physicists.)
    b) Write an equation for the area under the graph. What does this area represent?

2.4 Solving Problems Using Equations

Displacement, Distance, Speed, and Velocity

33. Donovan Bailey ran the 100 m dash at the Atlanta Olympics in 9.84 s. Michael Johnson ran the 200 m in 19.32 s and the 400 m in 43.49 s. Find their average speed in each case.

34. How far will the TGV train travel in 45 s if its speed is 140 m/s? Express your answer in kilometres as well.

35. A sneeze causes you to momentarily shut your eyes. If this process takes 0.5 s and you are moving at 30 km/h, how far will you travel in that time?

36. Bacteria move at 100 μm/s. How long would it take one bacterium to move 1.0 m?

37. How far would a car move in 4.8 s if its velocity changed from 14.0 m/s to 16.0 m/s?

38. What is the displacement of a car accelerating from 15 m/s forward to 10 m/s forward in 8.0 s?

39. Apollo 10's re-entry speed was 39 897 km/h. How many seconds would it take the spacecraft to stop in a distance of 3.0×10^6 m?

40. The speed of light is 3.0×10^8 m/s. The speed of sound is 344 m/s. A flash of lightning occurs in a storm 1.0×10^4 m away. How many seconds does it take for us to see the lightning and hear the thunder?

41. How long would it take a laser beam to go to the Moon and back if the distance to the Moon is 3.8×10^8 m?

42. Jules Verne wrote a book called *Around the World in Eighty Days*. What was his average speed in m/s and km/h if the radius of Earth is 6400 km?

43. What was the initial velocity of an object that moved 120 m in 5.60 s, reaching a final velocity of 15.0 m/s in that time? Was the object speeding up or slowing down?

Acceleration

44. If Donovan Bailey reaches a top speed from rest of 10.2 m/s in 2.5 s, what is his acceleration?

45. If a sprinter accelerates at 2.2 m/s^2 for 2.5 s, what is her velocity after this time, assuming initial $\vec{v} = 0$?

46. If it takes 0.08 s for an air bag to stop a person, what is the acceleration of a person moving 13.0 m/s and coming to a complete stop in that time?

47. A fastball pitcher can throw a baseball at 100 km/h. If the windup and throw take 1.5 s, what is the acceleration of the ball?

48. A car moving at 10 m/s north ends up moving 10 m/s south after a period of 12 s. What is its acceleration?

49. An asteroid moving at 3.2×10^4 km/h slams into Earth. If it takes 3.5 s to bring the asteroid to rest (what's left of it), what was its acceleration?

50. An object accelerates at 9.8 m/s^2 when falling. How long does it take an object to change its speed from 4.5 m/s to 19.4 m/s?

51. What is an object's final velocity if it accelerates at 2.0 m/s^2 for 2.3 s from a velocity of 50 km/h?

52. What is an object's final velocity if it accelerates at -2.0 m/s^2 for 2.3 s from a velocity of 50 km/h?

53. What is an object's initial velocity if it accelerates at 2.0 m/s^2 for 2.3 s, attaining a velocity of -50 km/h?

Acceleration and Displacement

54. Assuming no air resistance, how long does it take a penny to fall if it was dropped from the CN Tower (553 m)? Acceleration due to gravity is 9.8 m/s^2.

55. Assuming no air resistance, how long does it take a penny to fall if it was thrown down with an initial velocity of 5.0 m/s from the CN Tower (553 m)?

56. A car travelling at 40 km/h accelerates at 2.3 m/s^2 for 2.7 s. How far has it travelled in that time? What is its final velocity?

57. A car travelling at 40 km/h accelerates at -2.3 m/s^2 for 2.7 s. How far has it travelled in that time? What is its final velocity?

58. If 100 m sprinters accelerate from rest for 3.5 s at 2.8 m/s^2, how far have they run to this point? How long will it take them to complete the 100 m sprint, assuming they maintain their speed the rest of the way?

59. What is the average acceleration of the Blue Flame speed car if its initial velocity is 1000 km/h and it comes to a complete stop in a distance of 2.0 km? Interpret the sign of your answer.

60. An object thrown up from a cliff at 10 m/s reaches a velocity of 20 m/s down as it lands. If the acceleration due to gravity is 9.8 m/s^2, what is the object's displacement? How long did it take for the object to land from the time it was thrown up?

61. If you accelerate (slow down) to a stop at -0.8 m/s^2 by applying brakes, how far do you travel when your initial velocity is
a) 10 km/h? **b)** 50 km/h? **c)** 90 km/h?
d) 140 km/h?

62. The Superman roller coaster reaches a velocity of 100 km/h in 7.0 s. What is its average acceleration in m/s^2? How far has it travelled in that time? If you wish to calculate how many times faster your acceleration is than the acceleration due to the gravity (i.e., the number of *g*s you pull), divide the acceleration by 9.8 m/s^2.

63. A car is slowing down at a rate of 20 km/h per second. How far does it travel if its original velocity is 50 km/h and its final velocity is 5 m/s?

64. Use the formula $\Delta\vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2$ and the following values to create a $\vec{d}$-t chart. Then use the values you have generated to create a $\vec{d}$-t graph. From the graph, take a series of tangents and their slopes and generate a $\vec{v}$-t chart, followed by a $\vec{v}$-t graph. From the graph, find the slope and compare it to the given acceleration. Given: $\vec{v}_1 = 10$ m/s, $\vec{a} = -10$ m/s^2, and time intervals of 0.2 s starting from 0.0 s and going to 2.2 s. Comment on what happened at the end of the motion.

65. A dragster accelerates from rest for a distance of 450 m at 14 m/s^2. A parachute is then used to slow it down to a stop. If the parachute gives the dragster an acceleration of -7.0 m/s^2, how far has the dragster travelled before stopping?

66. Two rugby players are running towards each other. They are 37 m apart. If one is accelerating from rest at 0.5 m/s^2 and the other was already moving at 3.1 m/s and maintains her speed,

a) how long before they crunch together?

b) how fast was the accelerating player going?

c) how far has each player run?

67. Superwoman is hovering above the ground when a person free-falling goes by her at a terminal velocity of 140 km/h. Unfortunately, the parachute does not open. Fortunately, Superwoman is around. If it takes her 1.9 s to realize the person is in distress, what must her acceleration be if she is to catch the parachutist just before she hits the ground 1000 m below?

68. A police car stopped at a set of lights has a speeder pass it at 100 km/h. If the police car can accelerate at 3.6 m/s^2,

a) how long does it take to catch the speeder?

b) how far would the police car have to go before it catches the speeder?

c) what would its speed be when it caught up with the car? Is this speed reasonable?

Numerical Answers to End-of-chapter Problems

Chapter 1

15. a) 1200 s, **b)** 390 min, **c)** 14.4 h, **d)** 1.4×10^8 s, **e)** 0.126 h, **f)** 6.7×10^{-7} a

16. a) 2.5×10^8 µs, 250 000 000 µs, **b)** 2.50×10^5 m·s, 250 000 ms **c)** 2.50×10^{-1} ks, 0.250 ks, **d)** 2.50×10^{-4} m·s, 0.000250 Ms

17. a) 6.9 m/s, **b)** 41.7 m/s, **c)** 7.2 km/h, **d)** 180 km/h

18. a) 316 people, **b)** 1810 ft

19. a) Yes, speed of 52.9 km/h **b)** 1763 times slower

21. a) 64000 mm, **b)** 32 m, **c)** 32.005 m, **d)** 24 m

22. a) 20.5 m, **b)** 49 m, **c)** 3543.6 m, **d)** 30.9 km

23. a) 125 m [E], **b)** 75 m [N], **c)** 95 m [W], **d)** 95 m [N], **e)** 0

24. a) 28 m/s [N], **b)** 22 m/s [S], **c)** 33 m/s [E], **d)** 27 m/s [S]

25. 73 km/h, 67 km/h

27. Slope: **a)** km/h, **b)** no units, **c)** kg/m^3, **d)** kg/s^2
Area: **a)** km·h, **b)** m^2, **c)** kgm^3, **d)** kgm^2/s^2

28. A, C, F, H: standing; B, G: forward motion; D, E: backward motion

29. a) I 2.5 m/s; II 0 m/s; III −1.2 m/s **b)** I 4500 m·s; II 6000 m·s; III 6750 m·s

30. I 2.5 m/s; II 0; III −1.2 m/s

31. 72 m/s; 260 km/h

32. 1200 km/h

33. 20 mm/s

34. −20 mm/s

38. slopes: **i)** 0.6 m/s; **ii)** 0.5 m/s, **iii)** −0.3 m/s, **iv)** −1.2 m/s

42. average velocity
AB 4.3 m/s; BC 0 m/s;
BD −3.8 m/s; AD 0 m/s;
AE −2.1 m/s; BE −5.8 m/s

43. AB: slope: 0.8 m/s
CD: slope: 0.83 m/s

Chapter 2

14. b) 43 km/h, 90 km/h, 0 km/h, −162 km/h, −497 km/h
c) 0.21 m/s^2, 0 m/s^2, −0.21 m/s^2, −0.71 m/s^2, 0 m/s^2, −0.46 m/s^2
d) 1500 m, 4500 m, 1500 m, −3900 m, −5600 m, −21 800 m
e) −23 800 m
f) 12.5 m/s, 25 m/s, 12.5 m/s, −37 m/s, −75 m/s, −180 m/s
g) −33 m/s
h) 54 m/s

15. a) 10 m/s, 47 m/s, 31 m/s, −9 m/s
b) 3.3 m/s^2, 0, −3.9 m/s^2, −4.2 m/s^2
c) 10 s–14 s
d) 0 s, 26 s
e) 10 s
f) 10 s–14 s, 30 s

16. 4.8 m/s^2

17. −3.9 m/s^2

19. b) 0.15 m/s^2; −0.87 m/s^2, 0.20 m/s^2, 0.10 m/s^2

20. a) 45.5 m, −21 m, −80 m, −20 m
b) −75 m

21. b) 3.8 s
c) no
e) yes
f) B is 28 m ahead of A

33. 10.2 m/s, 10.4 m/s, 9.20 m/s

34. 6300 m = 6.3 km

35. 4.2 m

36. 2.8 h

37. 72 m

38. 100 m

39. 540 s

40. 3.3×10^{-5} s, 29 s

41. 2.6 s

42. 5.8 m/s = 21 km/h

43. 28 m/s, slowing down

44. 4.1 m/s^2

45. 5.5 m/s

46. −162 m/s^2

47. 19 m/s^2

48. −1.7 m/s^2

49. −2500 m/s^2

50. 1.5 s

51. 19 m/s

52. 9.4 m/s

53. −19 m/s

54. 10.6 s

55. 10 s

56. 38 m, 17 m/s

57. 21 m, 4.8 m/s

58. 17 m, 12 s

59. -2.5×10^5 km/h^2

60. −15 m, 3.1 s

61. a) 4.9 m, **b)** 120 m, **c)** 390 m, **d)** 950 m

62. 4.0 m/s^2, 97 m

63. 15 m

65. 1300 m

66. a) 7.5 s, **b)** 3.8 m/s, **c)** 14 m, 23 m

67. 3.53 m/s^2

68. a) 15 s, **b)** 427 m, **c)** 55 m/s

Chapter 3

14. a) $\vec{v}_{f_{max}}$ = 10 m/s [E]; $\vec{v}_{f_{min}}$ = 2 m/s [W]

15. a) 0
b) 0.5 km [N37°E]
c) 0.5 km [W53°S]
d) 2.4 km/h
e) 2.4 km/h [E53°N]

18. a) 9.8 m/s, 20 m/s, 29 m/s, 39 m/s
b) 17 m/s [R35° D], 24 m/s [R55°D], 32 m/s [R64°D], 41 m/s [R70°D]

19. a) 0 m/s, 9.8 m/s, 20 m/s, 29 m/s
b) 9.8 m/s, 9.8 m/s, 9.8 m/s, 9.8 m/s
c) 9.8 m/s [E], 14 m/s [R45°D], 22 m/s [R64°D], 31 m/s [R71°D]

20. 150 m

21. 140 m

22. a) 0.64 s, **b)** 210 m

23. 32 m

24. 2.60 m

25. a) land at same time
b) 2.0 m

26. (22) 330 m/s [R1.1°D], (23) 45 m/s [R9.0°D] (24) 40 m/s [R10°D]

27. a) 550 m, **b)** 950 m, **c)** 100 m/s, **d)** 130 m/s [R48°D]

28. a) 14 s **b)** 1100 m **c)** 160 m/s [R60°D]

29. a) 1000 m **b)** 1100 m **c)** 230 m

30. 8.5 m

31. yes

32. yes

33. a) 24 m, **b)** 4.3 s, **c)** 27 m/s [R53°D]

35. 101.5 km/h, 98.5 km/h

36. a) −35 km/h, **b)** 35 km/h, **c)** 135 km/h, **d)** 135 km/h