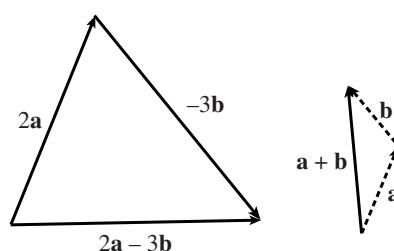
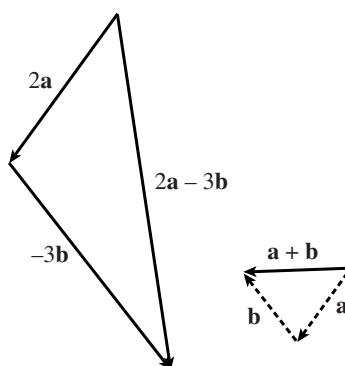


CHAPTER 10**Exercises Section 10.1**

5.



7.



9.

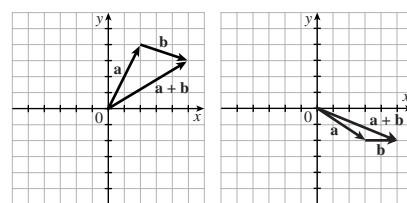
$$\langle 5, 3 \rangle, \langle -4, 6 \rangle, \langle 6, 12 \rangle, \sqrt{290}$$

$$11. 4\mathbf{i} + \mathbf{j}, -5\mathbf{i} + 4\mathbf{j}, 3\mathbf{i} + 6\mathbf{j}, 5\sqrt{10}$$

$$13. \langle -3, 3 \rangle, \langle -4, 0 \rangle, \langle -5, 9 \rangle, 4\sqrt{13}$$

$$15. -2\mathbf{i} + 3\mathbf{j}, -12\mathbf{i} + 4\mathbf{j}, 6\mathbf{i} + 5\mathbf{j}, 4\sqrt{5}$$

17.



19. parallel

21. not

23. parallel

25. not

27. $\langle 3, 1 \rangle$ 29. $\langle -3, -3 \rangle$ 31. $\langle 2, -3 \rangle$ 33. $\langle -2, -3 \rangle$ 35. (a) $\left\langle \frac{4}{5}, -\frac{3}{5} \right\rangle$ (b) $5\left\langle \frac{4}{5}, -\frac{3}{5} \right\rangle$

37. (a) $\frac{1}{\sqrt{5}}\mathbf{i} - \frac{2}{\sqrt{5}}\mathbf{j}$ (b) $2\sqrt{5}\left\langle \frac{1}{\sqrt{5}}, -\frac{2}{\sqrt{5}} \right\rangle$

39. (a) \mathbf{i} (b) $4\langle 1, 0 \rangle$ 41. (a) $\left\langle \frac{3}{\sqrt{10}}, \frac{1}{\sqrt{10}} \right\rangle$

(b) $\sqrt{10}\left\langle \frac{3}{\sqrt{10}}, \frac{1}{\sqrt{10}} \right\rangle$ 43. (a) $\left\langle -\frac{3}{5}, \frac{4}{5} \right\rangle$ (b) $5\left\langle -\frac{3}{5}, \frac{4}{5} \right\rangle$

45. $\frac{9}{5}\mathbf{i} + \frac{12}{5}\mathbf{j}$ 47. $\langle 2\sqrt{29}, 5\sqrt{29} \rangle$ 49. $\langle 4, 0 \rangle$

51. 10 pounds down, 20 pounds to the right

53. 190 pounds up, 30 pounds to the right

55. $\langle 13, 17 \rangle$; right and up

57. $\langle -80\sqrt{14}, 20 \rangle$ or 3.8° north of west

59. $\langle 20, 20\sqrt{399} \rangle$ or 2.9° east of north 61. 10 feet

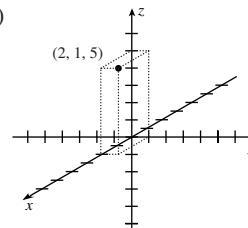
63. $20\sqrt{101}$ pounds at 5.7° 65. 7, 1, 5

69. $\|\mathbf{a} + \mathbf{b}\| = \sqrt{58} < \sqrt{13} + \sqrt{17} = \|\mathbf{a}\| + \|\mathbf{b}\|$

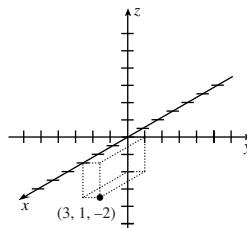
71. $\mathbf{a} = c\mathbf{b}$ ($c > 0$); $\mathbf{a} \perp \mathbf{b}$; $\|\mathbf{a} + \mathbf{b}\|^2 > \|\mathbf{a}\|^2 + \|\mathbf{b}\|^2$ when $\mathbf{a} = c\mathbf{b}$ for $c > 0$ or when the angle between \mathbf{a} and \mathbf{b} in the triangle formed by \mathbf{a} , \mathbf{b} , and $\mathbf{a} + \mathbf{b}$ is obtuse, $\|\mathbf{a} + \mathbf{b}\|^2 < \|\mathbf{a}\|^2 + \|\mathbf{b}\|^2$ when $\mathbf{a} = c\mathbf{b}$ for $c < 0$ or when the angle between \mathbf{a} and \mathbf{b} in the triangle formed by \mathbf{a} , \mathbf{b} , and $\mathbf{a} + \mathbf{b}$ is acute, $\|\mathbf{a} + \mathbf{b}\|^2 = \|\mathbf{a}\|^2 + \|\mathbf{b}\|^2$ when $\mathbf{a} \perp \mathbf{b}$.

Exercises Section 10.2

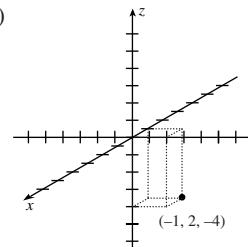
5. (a)

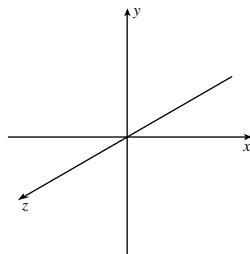


(b)



(c)



1236 Appendix B Answers to Odd-Numbered Exercises**7.**

- 9.** 5 **11.** 3 **13.** $\sqrt{38}$
15. $\langle 3, 4, -2 \rangle, \langle -1, -8, -2 \rangle, 2\sqrt{66}$
17. $\langle 3, 3, 4 \rangle, \langle -13, -9, -4 \rangle, 14$
19. $8\mathbf{i} + 4\mathbf{k}, -12\mathbf{i} - 4\mathbf{j} + 4\mathbf{k}, 2\sqrt{186}$
21. (a) $\pm \frac{1}{\sqrt{14}}\langle 3, 1, 2 \rangle$ (b) $\sqrt{14}\left\langle \frac{3}{\sqrt{14}}, \frac{1}{\sqrt{14}}, \frac{1}{\sqrt{14}} \right\rangle$
23. (a) $\pm \frac{1}{\sqrt{14}}\langle 1, -2, 3 \rangle$ (b) $2\sqrt{14}\left\langle \frac{1}{\sqrt{14}}, -\frac{2}{\sqrt{14}}, \frac{3}{\sqrt{14}} \right\rangle$
25. (a) $\pm \frac{1}{3}(2\mathbf{i} - \mathbf{j} + 2\mathbf{k})$ (b) $3\left(\frac{2}{3}\mathbf{i} - \frac{1}{3}\mathbf{j} + \frac{2}{3}\mathbf{k}\right)$
27. (a) $\pm \frac{1}{\sqrt{2}}\langle 1, 0, -1 \rangle$ (b) $2\sqrt{2}\left\langle \frac{1}{\sqrt{2}}, 0, -\frac{1}{\sqrt{2}} \right\rangle$
29. $\langle 4, 4, -2 \rangle$ **31.** $\frac{2}{\sqrt{5}}\langle 2, 0, -1 \rangle$
33. $\frac{4}{\sqrt{14}}(2\mathbf{i} - \mathbf{j} + 3\mathbf{k})$
35. $(x - 3)^2 + (y - 1)^2 + (z - 4)^2 = 4$
37. $(x - 2)^2 + y^2 + (z + 3)^2 = 9$
39. $(x - \pi)^2 + (y - 1)^2 + (z + 3)^2 = 5$
41. sphere, center $(1, 0, -2)$, radius 2
43. sphere, center $(0, 1, -2)$, radius 3
45. sphere, center $(1, 0, 2)$, radius $\sqrt{5}$
47. plane parallel to xz -plane **49.** plane parallel to xy -plane
51. plane parallel to yz -plane **53.** $y = 0$ **55.** $x = 0$
61. $\langle 2, -1, 1 \rangle, \langle 4, -2, 2 \rangle$, yes
63. 1000 pounds up, $\frac{150}{\sqrt{2}}$ pounds west, $\frac{150}{\sqrt{2}}$ pounds south

Exercises Section 10.3

- 5.** 10 **7.** -8 **9.** -3 **11.** 10 **13.** 1
15. $\cos^{-1}\frac{1}{\sqrt{26}} \approx 1.37$ **17.** $\cos^{-1}\frac{-2}{\sqrt{10}} \approx 2.26$
19. $\cos^{-1}\frac{-8}{\sqrt{234}} \approx 2.12$ **21.** yes **23.** no **25.** yes
27. possible answer: $\langle 1, 2 \rangle$ **29.** possible answer: $\langle 1, 4, 0 \rangle$
31. possible answer: $\mathbf{j} + 2\mathbf{k}$ **33.** $2, \left\langle \frac{6}{5}, \frac{8}{5} \right\rangle$
35. $\frac{9}{5}, \frac{9}{25}(4\mathbf{i} - 3\mathbf{j})$ **37.** $2, \frac{2}{3}\langle 1, 2, 2 \rangle$
39. $-\frac{8}{5}, -\frac{8}{25}\langle 0, -3, 4 \rangle$
41. 105,600 foot-pounds **45.** 920 foot-pounds
47. (a) false (b) true (c) true (d) false (e) false
49. $\mathbf{a} = c\mathbf{b}$ **53.** $\cos^{-1}\left(-\frac{1}{3}\right) \approx 109.5^\circ$

57. $-\frac{200}{3\sqrt{14}} \simeq -17.8$ Newtons

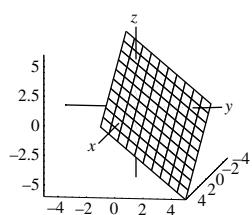
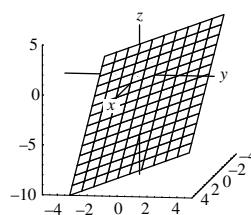
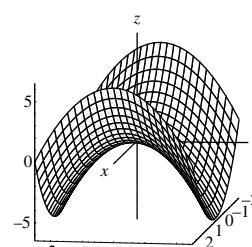
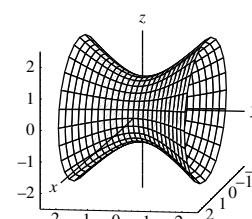
- 59.** -347 pounds **61.** $v \cdot n = 0, -w \sin \theta, w \cos \theta$
63. 45° **65.** \$190,000; monthly revenue

Exercises Section 10.4

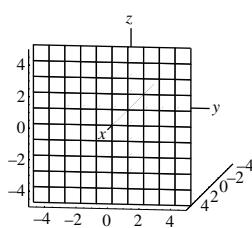
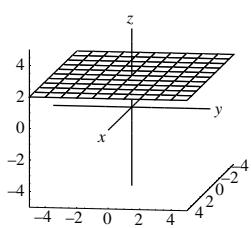
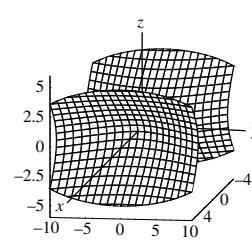
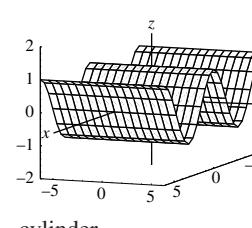
- 5.** 1 **7.** 4 **9.** $\langle 4, -3, -2 \rangle$ **11.** $\langle -9, -4, 1 \rangle$
13. $\langle 0, 4, 1 \rangle$ **15.** $\langle 4, -2, 8 \rangle$ **17.** $\pm \frac{1}{\sqrt{69}}\langle 8, 1, -2 \rangle$
19. $\pm \frac{1}{\sqrt{46}}\langle -3, -6, 1 \rangle$ **21.** $\pm \frac{1}{\sqrt{154}}\langle -1, -3, 12 \rangle$
23. $\sin^{-1}\frac{7}{\sqrt{85}} \approx 0.86$ **25.** $\sin^{-1}\frac{13}{\sqrt{170}} \approx 1.49$
27. $\sqrt{\frac{7}{2}} \approx 1.87$ **29.** $\sqrt{\frac{61}{5}} \approx 3.49$
31. 9.4 foot-pounds **33.** 10 foot-pounds **35.** up
37. left **39.** down, left **41.** down **43.** ball rises
45. ball drops, moves left **47.** ball drops **49.** no effect
51. ball rises **53.** ball rises, lands softly
55. ball rises, curves right **57.** false **59.** false
61. true **63.** 5 **65.** $\frac{11\sqrt{3}}{2}$ **67.** 10 **69.** 0
71. $-\mathbf{i}$ **73.** $-3\mathbf{j}$ **75.** yes **77.** no

Exercises Section 10.5

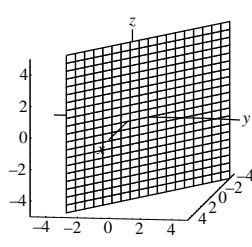
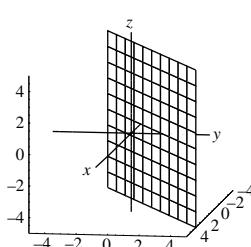
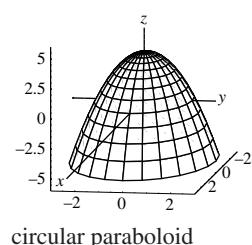
- 5.** (a) $x = 1 + 2t, y = 2 - t, z = -3 + 4t$
(b) $\frac{x - 1}{2} = \frac{y - 2}{-1} = \frac{z + 3}{4}$
7. (a) $x = 2 + 2t, y = 1 - t, z = 3 + t$
(b) $\frac{x - 2}{2} = \frac{y - 1}{-1} = \frac{z - 3}{1}$
9. (a) $x = 1 - 3t, y = 4, z = 1 + t$
(b) $\frac{x - 1}{-3} = \frac{z - 1}{1}, y = 4$
11. (a) $x = 3 + 3t, y = 1 - 4t, z = -1 + 2t$
(b) $\frac{x - 3}{3} = \frac{y - 1}{-4} = \frac{z + 1}{2}$
13. (a) $x = 2 - 4t, y = -t, z = 1 + 2t$
(b) $\frac{x - 2}{-4} = \frac{y}{-1} = \frac{z - 1}{2}$
15. (a) $x = 1 + 2t, y = 2 - t, z = -1 + 3t$
(b) $\frac{x - 1}{2} = \frac{y - 2}{-1} = \frac{z + 1}{3}$
17. $\cos^{-1}\frac{-13}{\sqrt{234}} \approx 2.59$ **19.** perpendicular **21.** parallel
23. intersect **25.** parallel
27. $2(x - 1) - (y - 3) + 5(z - 2) = 0$
29. $-3(x + 2) + 2z = 0$
31. $2(x - 2) - 7y - 3(z - 3) = 0$
33. $2(x + 2) + 6(y - 2) - 3z = 0$
35. $3(x - 2) - (y - 1) + 2(z + 1) = 0$
37. $-2x + 4(y + 2) = 0$
39. $(x - 1) - (y - 2) + (z - 1) = 0$

41.**43.****13.****15.**

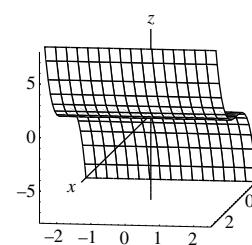
hyperboloid of 1 sheet

45.**47.****17.****19.**

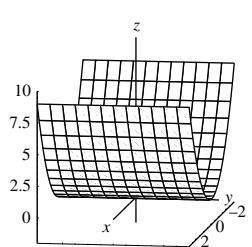
cylinder

49.**51.****21.**

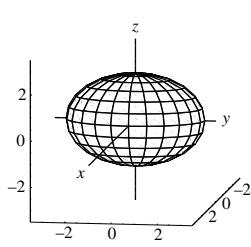
circular paraboloid

23.

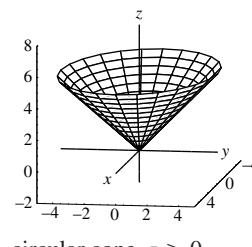
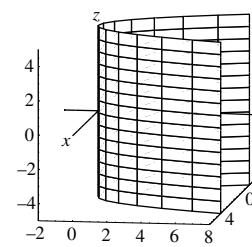
cylinder

53. $x = t, y = \frac{5}{3}t - \frac{4}{3}, z = \frac{1}{3}t - \frac{8}{3}$ **55.** $x = 4t + 11, y = -3t - 8, z = t$ **57.** $\frac{2}{3}$ **59.** $\frac{2}{\sqrt{3}}$ **61.** $\frac{3}{\sqrt{6}}$ **65.** $-4(x - 4) + 2(z - 3) = 0$ **67.** intersect at $(3, 4, 4)$, collide if $s = 1$ when $t = 1$ **Exercises Section 10.6****5.**

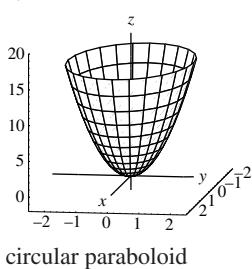
cylinder

7.

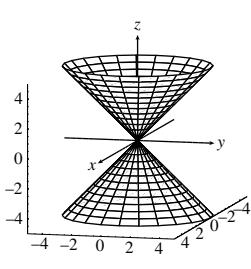
ellipsoid

25.circular cone, $z \geq 0$ **27.**

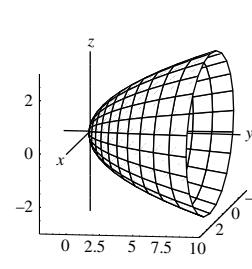
cylinder

9.

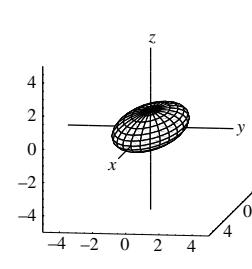
circular paraboloid

11.

elliptic cone

29.

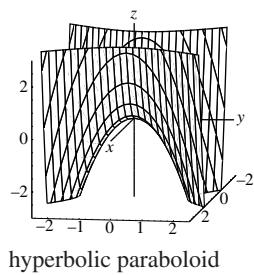
circular paraboloid

31.

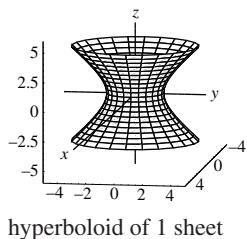
ellipsoid

1238 Appendix B Answers to Odd-Numbered Exercises

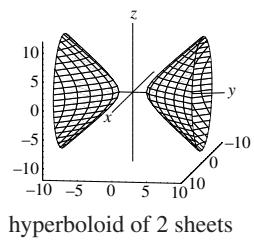
33.



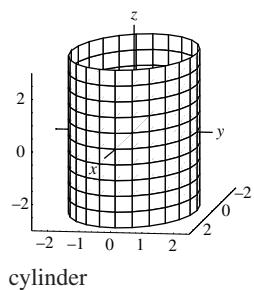
35.



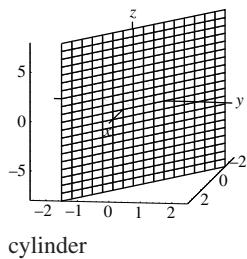
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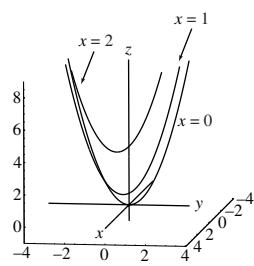
41.



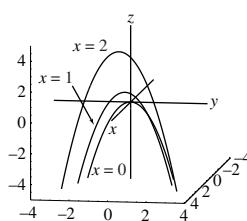
39.



45.



47.

49. $(0, 1, -1)$ and $(0, -1, -1)$

57. exercise 7: $x = \sin s \cos t, y = 3 \sin s \sin t, z = 2 \cos s$;
 exercise 9: $x = \frac{1}{2}s \cos t, y = \frac{1}{2}s \sin t, z = s^2$;
 exercise 11: $x = \frac{1}{2}\sqrt{s^2} \cos t, y = \sqrt{s^2} \sin t, z = s$
 59. possible answer: $x = s \cos t, y = s \sin t, z = 4 - s^2$

Chapter 10 Review Exercises

1. $\langle -1, 3 \rangle, \langle 4, 0 \rangle, 5$ 3. $6\mathbf{i} + 5\mathbf{j}, -16\mathbf{i} + 12\mathbf{j} + 8\mathbf{k}, 2\sqrt{94}$
 5. neither 7. parallel 9. $\langle -1, -2, 3 \rangle$

11. $\left\langle \frac{1}{\sqrt{5}}, \frac{2}{\sqrt{5}} \right\rangle$

13. $\frac{1}{3\sqrt{3}}(5\mathbf{i} + \mathbf{j} - \mathbf{k})$

15. $\left\langle -\frac{3}{5}, 0, \frac{4}{5} \right\rangle$

17. $\sqrt{46}$ 19. $\frac{2}{\sqrt{3}}(\mathbf{i} - \mathbf{j} + \mathbf{k})$

21. $\langle 20\sqrt{609}, 80 \rangle$ or 9.2° north of east

23. $x^2 + (y + 2)^2 + z^2 = 36$ 25. 0 27. -8

29. $\cos^{-1} \frac{1}{\sqrt{84}} \approx 1.46$ 31. $\frac{1}{\sqrt{6}}, \frac{1}{6}(\mathbf{i} + 2\mathbf{j} + \mathbf{k})$

33. $\langle -2, 1, 4 \rangle$ 35. $-4\mathbf{i} + 4\mathbf{j} - 8\mathbf{k}$

37. $\pm \frac{1}{\sqrt{21}} \langle -2, 1, 4 \rangle$ 39. 1700 foot-pounds 41. 3

43. $\sqrt{41}$ 45. $\frac{25}{2}$ foot-pounds

47. (a) $x = 2 - 2t, y = -1 + 3t, z = -3$

(b) $\frac{x-2}{-2} = \frac{y+1}{3}, z = -3$

49. (a) $x = 2 + 2t, y = -1 + \frac{1}{2}t, z = 1 - 3t$

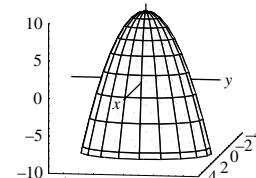
(b) $\frac{x-2}{2} = 2(y+1) = \frac{z-1}{-3}$

51. $\cos^{-1} \frac{5}{\sqrt{30}} \approx 0.42$ 53. skew

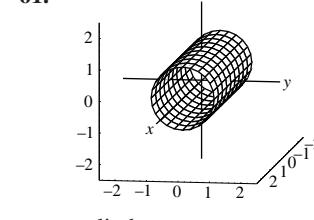
55. $4(x+5) + y - 2(z-1) = 0$

57. $4(x-2) - (y-1) + 2(z-3) = 0$

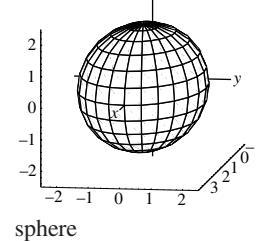
59.



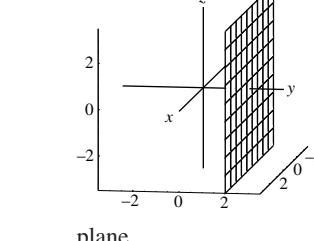
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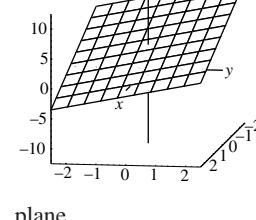
63.



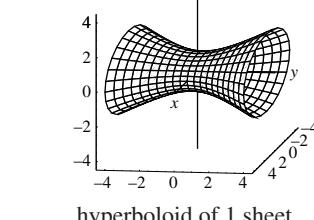
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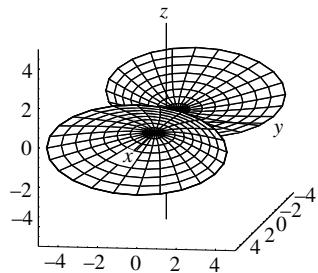


67.

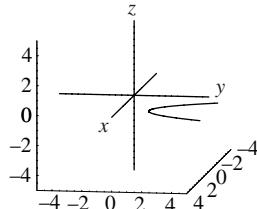
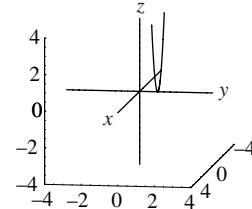
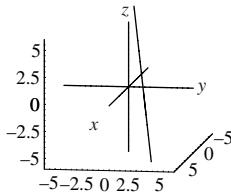
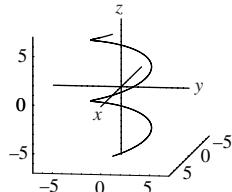
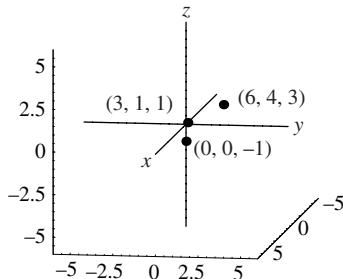
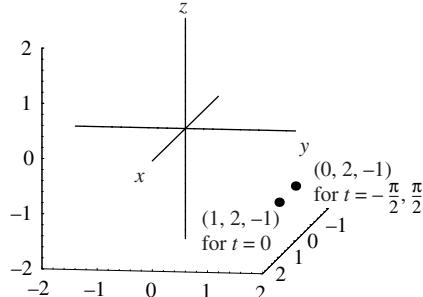
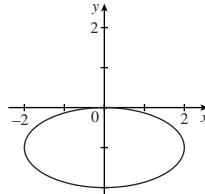
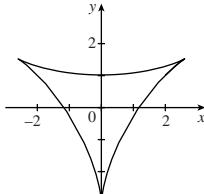
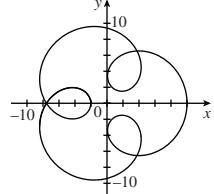
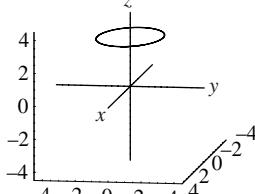
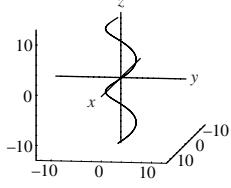
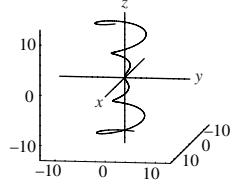
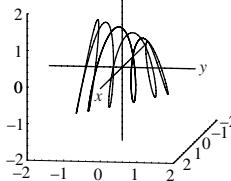
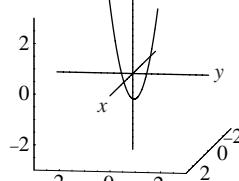
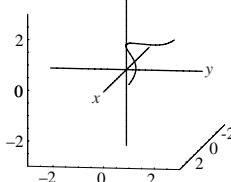


69.



71.

hyperboloid of 2 sheets

17.**19.****21.****23.****CHAPTER 11****Exercises Section 11.1****5.****7.****9.****11.****13.****15.****25.****27.****29.****31.****33.**

35. (a) F (b) C (c) E (d) A (e) B (f) D

37. 10.54 39. 21.56 41. 9.57

43. $\cos 2t = \cos^2 t - \sin^2 t$

47. same except $-\infty < x < \infty$, $-1 \leq x \leq 1$, $0 \leq x$

49. periodic, not enough points

Exercises Section 11.2

- 5.
- $\langle -1, 1, 0 \rangle$
- 7.
- $\langle 1, 1, -1 \rangle$
9. does not exist

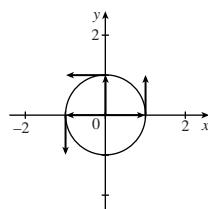
- 11.
- $t \neq 1$
- 13.
- $t \neq \frac{n\pi}{2}$
- (
- n
- odd) 15.
- $t \geq 0$

- 17.
- $\left\langle 4t^3, \frac{1}{2\sqrt{t+1}}, -\frac{6}{t^3} \right\rangle$
- 19.
- $\langle \cos t, 2t \cos t^2, -\sin t \rangle$

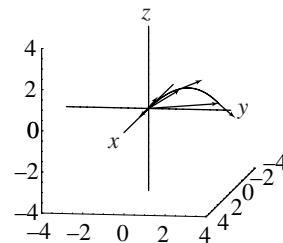
1240 Appendix B Answers to Odd-Numbered Exercises

21. $\langle 2te^{t^2}, 2t, 2 \sec 2t \tan 2t \rangle$

23.



25.



27. $\langle \frac{3}{2}t^2 - t, \frac{2}{3}t^{3/2} \rangle + \mathbf{c}$

31. $\langle \frac{1}{2}e^{t^2}, 3 \sin t - 3t \cos t, \frac{3}{2} \ln(t^2 + 1) \rangle + \mathbf{c}$

33. $\langle -\frac{2}{3}, \frac{3}{2} \rangle$

35. $\langle 4 \ln 3, 1 - e^{-2}, e^2 + 1 \rangle$

37. all t

39. $t = 0$

43. $t = 0$

45. $t = \frac{n\pi}{4}$ (n odd)

51. false

53. $\frac{1}{\sqrt{45}}, \frac{1}{\sqrt{45}}e^{-2}$

55. $\frac{25}{52} > \frac{1}{10}$

57. $\langle 1, 0 \rangle$ and $\langle 0, 1 \rangle$, $\langle 1, 2 \rangle$ and $\langle -2, 1 \rangle$

59. $\langle 0, 1 \rangle$ and $\langle -1, 0 \rangle$, $\langle -1, 0 \rangle$ and $\langle 0, -1 \rangle$

61. $\langle 0, 1, 2 \rangle$ and $\langle -1, 0, 0 \rangle$, $\langle 0, 1, -2 \rangle$ and $\langle 1, 0, 0 \rangle$

63. $\langle 1, 0, 1 \rangle$ and $\langle 0, 1, 0 \rangle$,

65. $\langle 1, 2, 1 \rangle$ and $\langle -1, 1, -1 \rangle$

67. $x^2 + (y - \frac{1}{2})^2 = \frac{1}{4}$

69. $a_T = -\frac{64}{\sqrt{5}}$ and $a_N = \frac{32}{\sqrt{5}}$, $a_T = \frac{64}{\sqrt{5}}$ and $a_N = \frac{32}{\sqrt{5}}$

71. $a_T = 0$ and $a_N = \sqrt{20}$,

73. $a_T = \frac{2\pi}{\sqrt{16 + \pi^2}}$ and $a_N = 4\sqrt{\frac{20 + \pi^2}{16 + \pi^2}}$

75. neither; increasing

77. $\langle 2, -1, 0 \rangle$, $\langle 2, -1, 0 \rangle$

79. true

81. true

83. quadruples

85. $\langle 60\sqrt{3}t, 3 + 60t - 16t^2 \rangle$, no

87. $\langle 130t, 6 - 16t^2 \rangle$, 2.59 feet

89. $\langle 120t, 8 - 16t^2 \rangle$, no

91. 3.86 sec

93. $\langle 271, 117, 0 \rangle$

95. $a = 100$, $b = -1$, $c = 10$

97. 56.57 ft/s

99. 1275.5 m

Exercises Section 11.4

5. $x = 2 \cos(\frac{s}{2})$, $y = 2 \sin(\frac{s}{2})$, $0 \leq s \leq 4\pi$

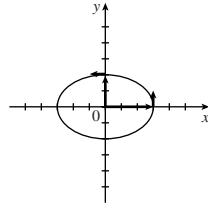
7. $x = \frac{3}{5}s$, $y = \frac{4}{5}s$, $0 \leq s \leq 5$

9. $\langle 1, 0 \rangle$, $\frac{1}{\sqrt{13}}\langle 3, -2 \rangle$, $\frac{1}{\sqrt{13}}\langle 3, 2 \rangle$

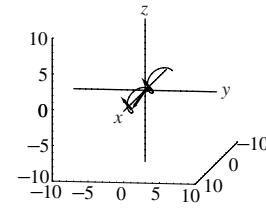
11. $\langle 0, 1 \rangle$, $\langle 1, 0 \rangle$, $\langle -1, 0 \rangle$

13. $\frac{1}{\sqrt{13}}\langle 3, 0, 2 \rangle$, $\frac{1}{\sqrt{13}}\langle 3, 0, 2 \rangle$, $\frac{1}{\sqrt{13}}\langle 3, 0, 2 \rangle$

15.



17.



19. $2^{-3/2} \approx 0.3536$

21. 0

23. $6(37)^{-3/2} \approx 0.0267$

25. 1

27. smaller

29. $\frac{8}{25}, \frac{8}{25}$

31. 1, $\frac{1}{27}$

33. max at $\langle 0, \pm 3 \rangle$, min at $\langle \pm 2, 0 \rangle$

35. max at $\langle 0, -3 \rangle$, no min

37. 0

39. 0

41. curve straightens

43. false

45. true

49. $\frac{2}{3}, 10$

51. $\frac{1}{\sqrt{45}}, \frac{1}{\sqrt{45}}e^{-2}$

53. $\frac{25}{52} > \frac{1}{10}$

Exercises Section 11.5

5. $\langle 1, 0 \rangle$ and $\langle 0, 1 \rangle$, $\frac{1}{\sqrt{5}}\langle 1, 2 \rangle$ and $\frac{1}{\sqrt{5}}\langle -2, 1 \rangle$

7. $\langle 0, 1 \rangle$ and $\langle -1, 0 \rangle$, $\langle -1, 0 \rangle$ and $\langle 0, -1 \rangle$

9. $\frac{1}{\sqrt{5}}\langle 0, 1, 2 \rangle$ and $\langle -1, 0, 0 \rangle$, $\frac{1}{\sqrt{5}}\langle 0, 1, -2 \rangle$ and $\langle 1, 0, 0 \rangle$

11. $\frac{1}{\sqrt{2}}\langle 1, 0, 1 \rangle$ and $\langle 0, 1, 0 \rangle$,

13. $x^2 + (y - \frac{1}{2})^2 = \frac{1}{4}$

15. $x^2 + y^2 = 1$

17. $a_T = -\frac{64}{\sqrt{5}}$ and $a_N = \frac{32}{\sqrt{5}}$, $a_T = \frac{64}{\sqrt{5}}$ and $a_N = \frac{32}{\sqrt{5}}$

19. $a_T = 0$ and $a_N = \sqrt{20}$,

21. neither; increasing

23. $a_T = 0$ and $a_N = a$

25. $\frac{1}{\sqrt{5}}\langle 2, -1, 0 \rangle$, $\frac{1}{\sqrt{5}}\langle 2, -1, 0 \rangle$

27. $\frac{1}{\sqrt{1+16\pi^2}}\langle 0, -1, 4\pi \rangle$, $\frac{1}{\sqrt{1+16\pi^2}}\langle 0, 1, 4\pi \rangle$

29. true

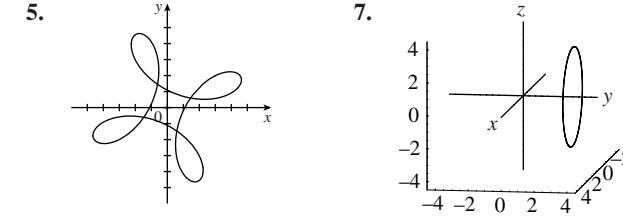
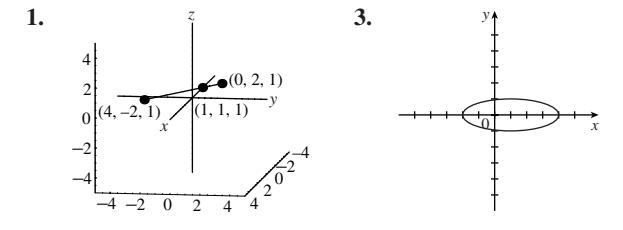
31. true

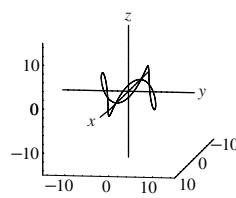
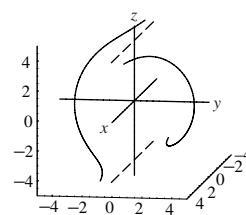
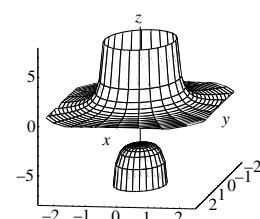
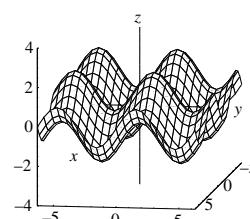
33. $10,000\pi^2 \langle -\cos \pi t, -\sin \pi t \rangle$

35. $40,000\pi^2 \langle -\cos 2\pi t, -\sin 2\pi t \rangle$

37. doubles

39. $1 < \frac{3\sqrt{3}}{2}$, $|-1| > \left| -\frac{1}{\sqrt{2}} \right|$

Chapter 11 Review Exercises

9.**11.****27.****29.**

13. (a) B (b) C (c) A (d) F (e) D (f) E
15. $2\pi\sqrt{37}$ **17.** $\langle 0, e^2, -1 \rangle$ **19.** $t \neq 0$

21. $\left\langle \frac{t}{\sqrt{t^2+1}}, 4 \cos 4t, \frac{1}{t} \right\rangle$

23. $\left\langle -\frac{1}{4}e^{-4t}, -t^{-2}, 2t^2 - t \right\rangle + \mathbf{c}$ **25.** $\langle 0, 2, 2 \rangle$
27. $\langle -8 \sin 2t, 8 \cos 2t, 4 \rangle, \langle -16 \cos 2t, -16 \sin 2t, 0 \rangle$

29. $\langle t^2 + 4t + 2, -16t^2 + 1 \rangle$

31. $\langle 4t + 2, -16t^2 + 3t + 6 \rangle$

33. $\langle 0, -128 \rangle$

35. $25(2 - \sqrt{3}) \approx 6.70$ feet, 100 feet, 80 ft/s

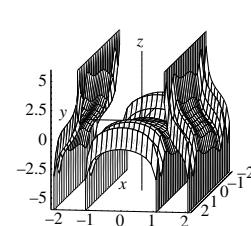
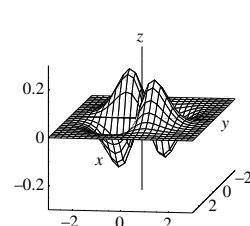
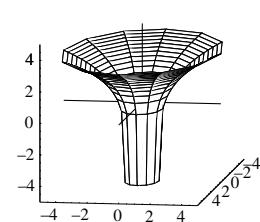
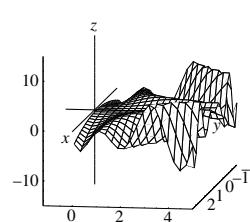
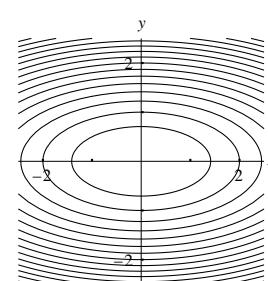
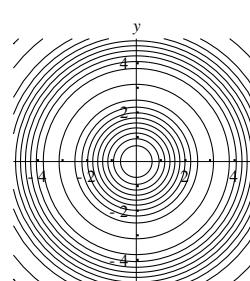
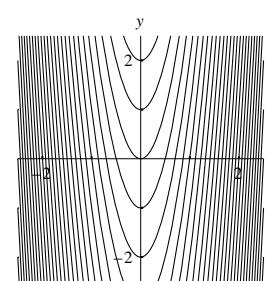
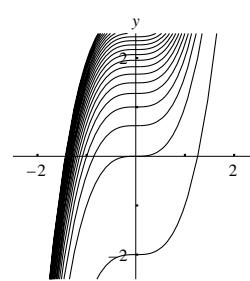
37. $\frac{1}{\sqrt{2}}\langle -1, 1, 0 \rangle, \frac{1}{\sqrt{e^{-4} + 1}}\langle -e^{-2}, 1, 0 \rangle$

39. $\frac{1}{2}, \frac{4}{3\sqrt{3}}$ **41.** 0, 0

43. $\frac{1}{\sqrt{2}}\langle 0, 1, 1 \rangle, \langle -1, 0, 0 \rangle$

45. $a_T = 0, a_N = 2; a_T = \sqrt{2}, a_N = \sqrt{2}$

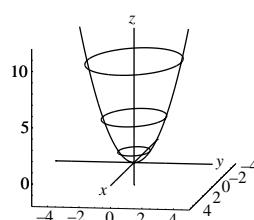
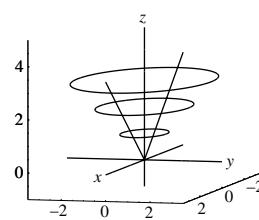
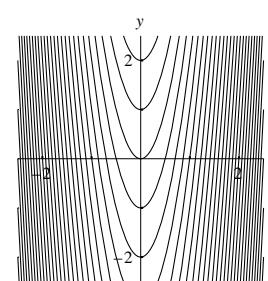
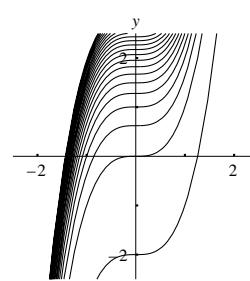
47. 345,600 $\langle -\cos 6t, -\sin 6t \rangle$

31.**33.****35.****37.****39.****41.****43.****45.**

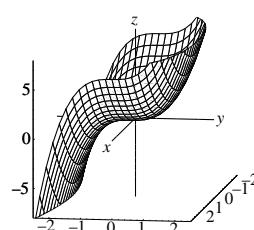
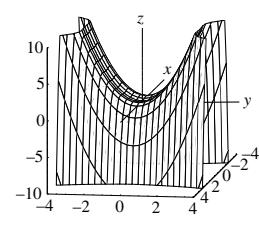
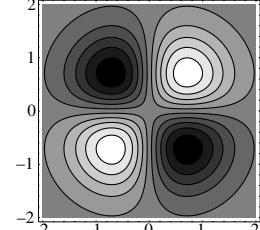
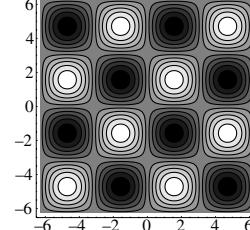
CHAPTER 12

Exercises Section 12.1

- 5.** $y \neq -x$ **7.** $x + y + 2 > 0$ **9.** $f \geq 0$
11. $-1 \leq f \leq 1$ **13.** $f \geq -1$ **15.** 3, 3
17. (a) 312 (b) 333 (c) 350 (d) 19 feet

19.**21.****43.****45.**

For 23–37, one view is shown.

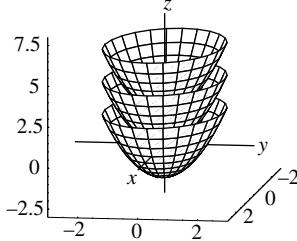
23.**25.****47.****49.**

1242 Appendix B Answers to Odd-Numbered Exercises

51. (a) B (b) D (c) A (d) F (e) C (f) E

53. (a) A (b) D (c) C (d) B

55.



57. (a) B (b) A

59. no height visible 63. any point on the line $(x, \sqrt{3}x, 0)$

65. upper left, restaurants, roads

67. left of center, power is increasing away from frame

69. max = 3.942, min = -0.57, HS

71. 60 mph, impossible

Exercises Section 12.2

5. 3 7. $-\frac{1}{2}$ 9. 2

11. Along $x = 0, L_1 = 0$; along $y = 0, L_2 = 3$, therefore L does not exist.13. Along $x = 0, L_1 = 0$; along $y = x, L_2 = 2$, therefore L does not exist.15. Along $x = 0, L_1 = 0$; along $x = y^2, L_2 = 1$, therefore L does not exist.17. Along $x = 0, L_1 = 0$; along $y^3 = x, L_2 = \frac{1}{2}$, therefore L does not exist.19. Along $x = 0, L_1 = 0$; along $y = x, L_2 = \frac{1}{2}$, therefore L does not exist.21. Along $x = 1, L_1 = 0$; along $y = x + 1, L_2 = \frac{1}{2}$, therefore L does not exist.23. Along $x = 0, L_1 = 0$; along $x^2 = y^2 + z^2, L_2 = \frac{3}{2}$, therefore L does not exist.25. Along $y = -x, L_1$ does not exist, therefore L does not exist.

27. 0 29. 0 31. 2 33. 0

39. all x, y 41. $x^2 + y^2 \leq 9$ 43. $x^2 - y < 3$ 45. $y \neq 0$ 47. $x^2 + y^2 + z^2 \geq 4$ 49. $\frac{1}{2}$ 51. true

53. false 57. 1 59. 0

Exercises Section 12.3

5. $f_x = 3x^2 - 4y^2, f_y = -8xy + 4y^3$

7. $f_x = 2xe^y, f_y = x^2e^y - 4$

9. $f_x = 2x \sin xy + x^2y \cos xy, f_y = x^3 \cos xy - 9y^2$

11. $f_x = \frac{4}{y}e^{x/y} + \frac{y}{x^2}, f_y = -\frac{4x}{y^2}e^{x/y} - \frac{1}{x}$

13. $f_x = 3 \sin y + 12x^2y^2z, f_y = 3x \cos y + 8x^3yz, f_z = 4x^3y^2$

15. $f_x = \frac{-2x}{(x^2 + y^2 + z^2)^{3/2}}, f_y = \frac{-2y}{(x^2 + y^2 + z^2)^{3/2}},$

$$f_z = \frac{-2z}{(x^2 + y^2 + z^2)^{3/2}}$$

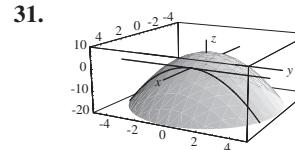
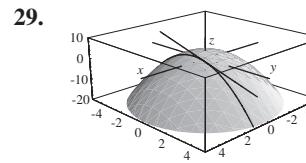
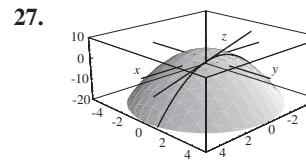
17. $\frac{\partial^2 f}{\partial x^2} = 6x, \frac{\partial^2 f}{\partial y^2} = -8x, \frac{\partial^2 f}{\partial y \partial x} = -8y$

19. $f_{xx} = 12x^2 - 6y^3, f_{xy} = -18xy^2, f_{xxy} = -36xy$

21. $f_{xx} = 6xy^2, f_{yz} = -\cos yz + yz \sin yz, f_{xyz} = 0$

23. $f_{xx} = 4y^2 e^{2xy}, f_{yy} = 4x^2 e^{2xy} - \frac{2z^2}{y^3} - xz \sin y, f_{yyzz} = -\frac{4}{y^3}$

25. $f_{ww} = 2xy - z^2 e^{wz}, f_{wxy} = 2w, f_{wwxyz} = 0$



33. $\frac{nRV^3}{PV^3 - n^2aV + 2n^3ab}$ Hint: Hold pressure constant.

37. h 39. $(0, 0, 0) = \min$

41. $\left(\frac{m\pi}{2}, \frac{n\pi}{2}, 1\right) = \max$ for m, n odd;

$\left(\frac{m\pi}{2}, \frac{n\pi}{2}, -1\right) = \min$ for m, n odd;

 $(m\pi, n\pi, 0)$ neither max nor min

43. 4, 2 45. $1, -\frac{2}{3}$ 47. 1.4, -2.4

49. 2.2, 0.0195

53. $\frac{\partial^2 f}{\partial x^2} = -n^2\pi^2 \sin n\pi x \cos n\pi ct,$

$$\frac{\partial^2 f}{\partial t^2} = -c^2 n^2 \pi^2 \sin n\pi x \cos n\pi ct$$

55. $-\frac{5}{1+I}V, -\frac{0.5}{1+0.1(1-T)}V$, inflation

57. $\cos x \cos t, -\sin x \sin t$ 61. $\left(\frac{R}{R_1}\right)^2$

63. 400, $\frac{1}{4}$, decrease by 27

67. concavity of intersection of $z = f(x, y)$ with $y = y_0$ at $x = x_0$ **Exercises Section 12.4**

5. $4(x - 2) + 2(y - 1) - (z - 4) = 0$ 7. $z = 1$

9. $-x - z = 0$ 11. $6(x + 2) + 4(y - 3) - (z - 4) = 0$

13. $-\frac{3}{5}(x + 3) + \frac{4}{5}(y - 4) - (z - 5) = 0$

15. $2(x - 1) - (y - 2) - (z - 2) = 0$ 17. x
 19. $-x$ 21. $-3x$ 23. $-8 + 12(x + 2) + y - 8(z - 1)$
 25. $11 - 12(w + 2) + 4(x - 3) + 12(y - 1) + 2z$
 27. 3 vs. 3.0017, 3.1 vs. 3.1, 3.1 vs. 3.1016
 29. 0 vs. 0, -0.1 vs. -0.0998, -0.1 vs. -0.0988
 31. 1.5552 ± 0.6307 33. 3.85 35. 4.03
 37. $2y\Delta x + (2x + 2y)\Delta y + (2\Delta y)\Delta x + (\Delta y)\Delta y$
 39. $2x\Delta x + 2y\Delta y + (\Delta x)\Delta x + (\Delta y)\Delta y$
 41. yes 43. $(ye^x + \cos x)dx + e^x dy$
 45. $f_x(0, 0) = f_y(0, 0) = 0$ 49. $6 + 4x + 2y$
 51. $3 + x - \frac{2}{3}y$
 53. $-9 + 1.4(t - 10) - 2.4(s - 10); -13.4$

Exercises Section 12.5

5. $(2t + t^2 + 1 - \cos e^t)e^t$
 7. $\frac{\partial g}{\partial u} = 512u^6(3u^2 - v \cos u)(u^3 - v \sin u)$
 $+ 1536u^5(u^3 - v \sin u)^2;$
 $\frac{\partial g}{\partial v} = 512u^6 \sin u(v \sin u - u^3)$
 9. $g'(t) = \frac{\partial f}{\partial x}x'(t) + \frac{\partial f}{\partial y}y'(t) + \frac{\partial f}{\partial z}z'(t)$
 11. $\frac{\partial g}{\partial u} = \frac{\partial f}{\partial x}\frac{\partial x}{\partial u} + \frac{\partial f}{\partial y}\frac{\partial y}{\partial u}, \frac{\partial g}{\partial v} = \frac{\partial f}{\partial x}\frac{\partial x}{\partial v} + \frac{\partial f}{\partial y}\frac{\partial y}{\partial v},$
 $\frac{\partial g}{\partial w} = \frac{\partial f}{\partial x}\frac{\partial x}{\partial w} + \frac{\partial f}{\partial y}\frac{\partial y}{\partial w}$
 13. -0.6271 15. 0.0587
 19. $\frac{\partial^2 f}{\partial x^2}[x'(t)]^2 + 2\frac{\partial^2 f}{\partial y \partial x}x'(t)y'(t) + \frac{\partial^2 f}{\partial y^2}[y'(t)]^2$
 $+ \frac{\partial f}{\partial x}x''(t) + \frac{\partial f}{\partial y}y''(t)$
 21. $\frac{\partial^2 f}{\partial x^2}\left(\frac{\partial x}{\partial u}\right)^2 + \frac{\partial^2 f}{\partial y \partial x}\frac{\partial y}{\partial u}\frac{\partial x}{\partial u} + \frac{\partial f}{\partial x}\frac{\partial^2 x}{\partial u^2}$
 $+ \frac{\partial^2 f}{\partial x \partial y}\frac{\partial x}{\partial u}\frac{\partial y}{\partial u} + \frac{\partial^2 f}{\partial y^2}\left(\frac{\partial y}{\partial u}\right)^2 + \frac{\partial f}{\partial y}\frac{\partial^2 y}{\partial u^2}$
 23. $\frac{\partial z}{\partial x} = \frac{-6xz}{3x^2 + 6z^2 - 3y}, \frac{\partial z}{\partial y} = \frac{3z}{3x^2 + 6z^2 - 3y}$
 25. $\frac{\partial z}{\partial x} = \frac{3yze^{xyz} - 4z^2 + \cos y}{8xz - 3xye^{xyz}}, \frac{\partial z}{\partial y} = \frac{3xze^{xyz} - x \sin y}{8xz - 3xye^{xyz}}$
 31. 2 points; halved

Exercises Section 12.6

5. $\langle 2x + 4y^2, 8xy - 5y^4 \rangle$
 7. $\langle e^{xy^2} + xy^2e^{xy^2}, 2x^2ye^{xy^2} - 2y \sin y^2 \rangle$
 9. $\langle -8e^{-8} - 2, -16e^{-8} \rangle$ 11. $\langle \frac{4}{5}, -\frac{3}{5} \rangle$ 13. $\langle 0, 0, -1 \rangle$
 15. $2 + 6\sqrt{3}$ 17. $2 - 6\sqrt{3}$ 19. $\frac{17}{5\sqrt{13}}$ 21. $-3\sqrt{5}$

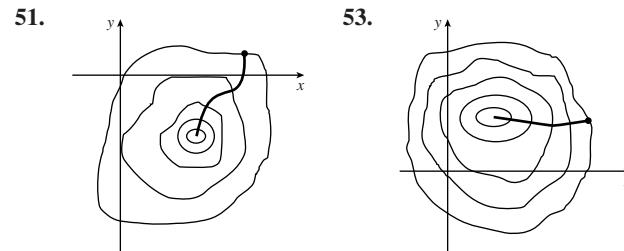
23. 0 25. $-\frac{6}{\sqrt{5}}$ 27. $-\frac{12}{\sqrt{5}}$ 29. $-\frac{3}{\sqrt{29}}$

31. $\langle 4, -3 \rangle, \langle -4, 3 \rangle, 5, -5$
 33. $\langle 16, -4 \rangle, \langle -16, 4 \rangle, \sqrt{272}, -\sqrt{272}$
 35. $\langle 1, 0 \rangle, \langle -1, 0 \rangle, 1, -1$
 37. $\langle \frac{3}{2}, -\frac{1}{8} \rangle, \langle -\frac{3}{2}, \frac{1}{8} \rangle, \frac{\sqrt{145}}{8}, -\frac{\sqrt{145}}{8}$
 39. $\langle 16, 4, 24 \rangle, \langle -16, -4, -24 \rangle, \sqrt{848}, -\sqrt{848}$

41. parallel
 45. $2(x - 1) + 3(y + 1) - z = 0,$
 The equation of the normal line is $x = 1 + 2t$
 $y = -1 + 3t$
 $z = -t$

47. $-2(x + 1) + 4(y - 2) + 2(z - 1) = 0,$
 The equation of the normal line is $x = -1 - 2t$
 $y = 2 + 4t$
 $z = 1 + 2t$

49. $(0, 0, 0), (1, 1, -1), (-1, -1, -1)$



55. possible answer: $\langle -\frac{4}{3}, -2 \rangle$ 57. $\langle 2, -2 \rangle$
 59. $\langle -\tan 10^\circ, \tan 6^\circ \rangle \approx \langle -0.176, 0.105 \rangle, 11.6^\circ$ 61. $\langle 8, 4 \rangle$
 63. $\langle 10e^{-8}, \frac{5}{16}e^{-8}, \frac{25}{4}e^{-8} \rangle$ 65. $\langle 0.8, 0.3, -0.004 \rangle$
 67. $6x + 2$

Exercises Section 12.7

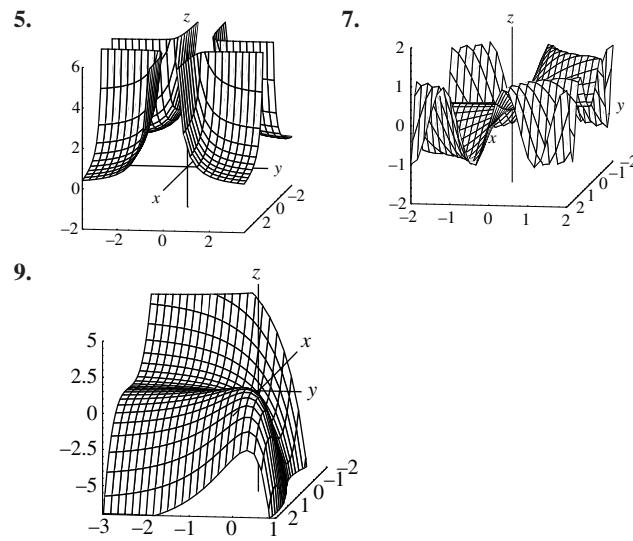
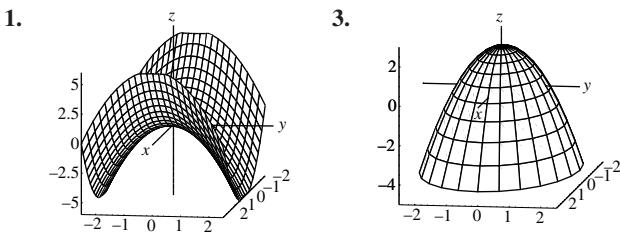
5. $(0, 0)$ saddle 7. $(0, 0)$ saddle, $(1, 1)$ relative min
 9. $(0, 1)$ relative min, $(\pm 2, -1)$ saddle
 11. $(0, 0)$ max
 13. $(0, 0)$ saddle, $(1, 1)$ and $(-1, -1)$ relative min
 15. $\left(\frac{1}{\sqrt{2}}, 0\right)$ local max, $\left(-\frac{1}{\sqrt{2}}, 0\right)$ local min
 17. $(0, 0)$ saddle, $\pm\left(\sqrt{\frac{1}{2}}, \sqrt{\frac{1}{2}}\right)$ relative max,
 $\pm\left(\sqrt{\frac{1}{2}}, -\sqrt{\frac{1}{2}}\right)$ relative min
 19. $(2.82, 0.17)$ relative min, $(-2.84, -0.18)$ saddle,
 $(0.51, 0.99)$ saddle
 21. $(\pm 1, 0)$ relative max, $\left(0, -\sqrt{\frac{3}{2}}\right)$ relative max, $\left(0, \sqrt{\frac{3}{2}}\right)$
 relative min, $(0, 0)$ saddle, $\left(\pm\frac{\sqrt{19}}{3\sqrt{3}}, -\frac{2}{3}\right)$ saddle
 23. $1.37x - 2.80$ 25. 9176 27. 247, 104

1244 Appendix B Answers to Odd-Numbered Exercises

29. (a) 1.29 (b) 2.75
 31. $(-0.3210, -0.5185), (-0.1835, -0.4269)$
 33. $(0.9044, 0.8087), (3.2924, -0.3853)$
 35. $(0, 0)$ is a saddle point
 37. $f(2, 0) = 4, f(2, 2) = -2$
 39. $f(3, 0) = 9, f(0, 0) = 0$
 41. $f(0, y) = f(x, 0) = 0$ min
 43. $f(-1, 2) = -4$ min 51. false 53. false
 55. extrema at $\left(\pm\frac{\pi}{2}, \pm\frac{\pi}{2}\right)$, saddles at $(\pm n\pi, \pm n\pi)$
 57. extrema at $\pm(1, 1)$, saddle $(0, 0)$
 59. extrema $(\pm 0.1, 0.1)$, saddle $(0, 0)$
 61. $d(x, y) = \sqrt{(x-3)^2 + (y+2)^2 + (3-x^2-y^2)^2}$,
 $(1.55, -1.03)$
 63. $(1.6, 0.8, -2.4)$ 65. $(1, 0), f(1, 0) < f(-10, 0)$

Exercises Section 12.8

5. $x = \frac{6}{5}, y = -\frac{2}{5}$ 7. $x = 2, y = -1$
 9. $x = 1, y = 1$ 11. $x = 1, y = 1$
 13. max $= f(2, 2) = f(-2, -2) = 16$,
 min $= f(2, -2) = f(-2, 2) = -16$
 15. max $= f(\pm\sqrt{2}, 1) = 8$, min $= f(\pm\sqrt{2}, -1) = -8$
 17. max $= f(1, 1) = e$, min $= f(-1, 1) = -e$
 19. max $= f(\pm\sqrt{2}, 1) = 2e$, min $= f(0, \pm\sqrt{3}) = 0$
 21. max $= f(2, 2) = f(-2, -2) = 16$
 min $= f(2, -2) = f(-2, 2) = -16$
 23. max $= f(\pm\sqrt{2}, 1) = 8$, min $= f(\pm\sqrt{2}, -1) = -8$
 25. $u = \frac{128}{3}$, $z = 195$ feet 27. $P(20, 80, 20) = 660$
 29. $P\left(\sqrt{\frac{8801}{22}}, 4\sqrt{\frac{8801}{22}}, \sqrt{\frac{8801}{22}}\right) \approx 660.0374989$
 $660 + \lambda = 660.0375$
 31. $x = y$ 33. $f\left(-\frac{\sqrt{2}}{2}, \frac{\sqrt{2}}{2}\right) = \sqrt{2}$
 35. $\alpha = \beta = \theta = \frac{\pi}{6}$; $f\left(\frac{\pi}{6}, \frac{\pi}{6}, \frac{\pi}{6}\right) = \frac{1}{8}$
 39. $L = 50, K = 10$ 41. $C(L, K) = C(64, 8) = 2400$
 43. $f(4, -2, 2) = 24$ 45. $f(1, 1, 2) = 2$
 47. (a) $(\pm 1, 0, 0)$ (b) $(0, \pm 1, \pm 1)$

Chapter 12 Review Exercises

11. (a) D (b) B (c) C (d) A (e) F (f) E
 13. (a) C (b) A (c) D (d) B 21. $x \neq 0$
 23. $f_x = \frac{4}{y} + (1+xy)e^{xy}$, $f_y = -\frac{4x}{y^2} + x^2e^{xy}$
 25. $f_x = 6xy \cos y - \frac{1}{2\sqrt{x}}$, $f_y = 3x^2 \cos y - 3x^2y \sin y$
 29. $-0.04, 0.06$ 31. $45 - 10(x+2) + 9(y-5)$
 33. $(x-\pi) + 2\left(y - \frac{\pi}{2}\right)$
 35. $f_{xx} = 24x^2y + 6y^2$, $f_{yy} = 6x^2$, $f_{xy} = 8x^3 + 12xy$
 37. $3(y+1) - z = 0$
 39. $4x + 4(y-2) + 2(z-1) = 0$
 41. $8e^{8t} \sin t + (e^{8t} + 2 \sin t) \cos t$
 43. $g'(t) = \frac{\partial f}{\partial x}x'(t) + \frac{\partial f}{\partial y}y'(t) + \frac{\partial f}{\partial z}z'(t) + \frac{\partial f}{\partial w}w'(t)$
 45. $\frac{\partial z}{\partial x} = -\frac{x+y}{z}$, $\frac{\partial z}{\partial y} = -\frac{x+y}{z}$ 47. $\left(-\frac{1}{2}, 12\pi - \frac{1}{2}\right)$
 49. -4 51. $-\frac{7}{\sqrt{5}}$ 53. $\pm\frac{1}{\sqrt{145}}(9, -8), \pm 4\sqrt{145}$
 55. $\pm(1, 0), \pm 4$ 57. $(16, 2)$
 59. $(0, 0)$ relative minimum, $(2, \pm 8)$ saddles
 61. $(\frac{4}{3}, \frac{4}{3})$ relative max, $(0, 0)$ saddle 63. 212, 112
 65. $f(4, 0) = 512$, $f(0, 0) = 0$
 67. $f(1, 2) = 5$, $f(-1, -2) = -5$
 69. $f\left(\sqrt{\frac{1}{2}}, \sqrt{\frac{1}{2}}\right) = f\left(-\sqrt{\frac{1}{2}}, -\sqrt{\frac{1}{2}}\right) = \frac{1}{2}$,
 $f\left(\sqrt{\frac{1}{2}}, -\sqrt{\frac{1}{2}}\right) = f\left(-\sqrt{\frac{1}{2}}, \sqrt{\frac{1}{2}}\right) = -\frac{1}{2}$
 71. $(1, 1)$ 73. decreases, increases

CHAPTER 13

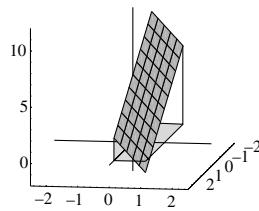
Exercises Section 13.1

5. 6 7. $\frac{13}{2}$ 9. -12 11. 40 13. $\frac{16}{3}$

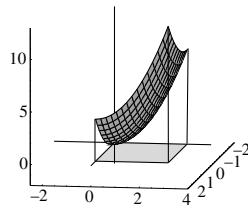
15. $12(e^2 - 1)$

17. $\frac{19}{2} - \frac{1}{2}e^6$

19.



21.



23. 2

31.

35.

37.

39.

41.

47.

51.

55.

59.

63.

25. $\frac{128}{3}$ 33. $\frac{1}{2} \neq \frac{2}{3}$ $\int_0^3 \int_1^4 (x^2 + y^2) dy dx = 90$ $\int_{-1}^1 \int_{x^2}^1 (x^2 + y^2) dy dx = \frac{88}{105}$ $\int_{-2}^2 \int_0^{4-y^2} (6 - x - y) dx dy = \frac{704}{15}$ $\int_0^2 \int_0^x y^2 dy dx = \frac{4}{3}$

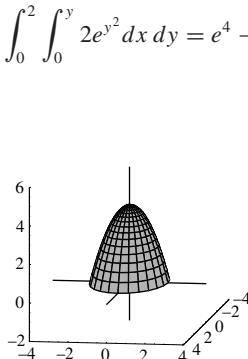
43. -1.5945

45. 1.6697

 $\int_0^2 \int_{y/2}^1 f(x, y) dx dy$ 49. $\int_0^4 \int_0^{x/2} f(x, y) dy dx$ 53. $\int_0^2 \int_0^y 2e^{y^2} dx dy = e^4 - 1$ 55. $\int_0^1 \int_0^x 3xe^{x^3} dy dx = e - 1$

59. different domains

61.

**Exercises Section 13.2**

5. $\int_{-2}^2 \int_{x^2}^{8-x^2} 1 dy dx = \frac{64}{3}$

7. $\int_0^2 \int_{y/2}^{3-y} 1 dx dy = 3$

9. $\int_0^1 \int_{x^2}^{\sqrt{x}} 1 dy dx = \frac{1}{3}$

11. 6

13. $\frac{40}{3}$

15. $\frac{1}{2}$ 17. $\frac{5}{12}$ 19. $\frac{8576}{105}$ 21. $\frac{36}{5}$

23. $\int_0^2 \int_0^{4-x^2} \sqrt{x^2 + y^2} dy dx = 10.275$

25. $\int_0^4 \int_0^{2-x/2} e^{xy} dy dx = 9.003$

27. $m = \frac{1}{3}, \bar{x} = \frac{3}{5}, \bar{y} = \frac{12}{35}$

29. $m = \frac{12}{5}, \bar{x} = \frac{41}{63}, \bar{y} = 0$

31. $m = 4, \bar{x} = \frac{16}{15}, \bar{y} = \frac{8}{3}$

33. In exercise 30, $\rho(x, y)$ is not x -axis symmetric.

35. $\rho(-x, y) = \rho(x, y)$

37. 1164

39. $1200(1 - e^{-2/3}) \approx 583.899$

41. $m = \frac{32}{3}, I_y = \frac{128}{15}, I_x = \frac{512}{7}$

43. $I_y = \frac{68}{3}, \frac{5}{3}$; second spin rate 13.6 times faster

45. 100.531, 508.938

47. $\frac{12}{5}$ 49. same 51. 3.792 53. 50.113

55. (a) total rainfall in region

(b) average rainfall per unit area in region

57. $\bar{y} = \frac{1}{3}$

Exercises Section 13.3

5. 11π 7. π 9. $\frac{\pi}{12}$ 11. $\frac{\pi}{9} + \frac{\sqrt{3}}{6}$ 13. 18π

15. $\pi - \pi e^{-4}$ 17. 0 19. $\frac{81\pi}{2}$ 21. $\frac{16}{3}$

23. $\frac{81\pi}{2}$ 25. $\frac{16\pi}{3}$ 27. $\frac{8 - 3\sqrt{3}}{12}\pi$ 29. 36

31. π 33. $\int_0^{2\pi} \int_0^2 r^2 dr d\theta = \frac{16\pi}{3}$

35. $\int_{-\pi/2}^{\pi/2} \int_0^2 r e^{-r^2} dr d\theta = \frac{\pi}{2}(1 - e^{-4})$

37. $\int_{\pi/4}^{\pi/2} \int_0^{2\sqrt{2}} r^4 dr d\theta = \frac{32\pi\sqrt{2}}{5}$ 39. $1 - e^{-1/16} \approx 0.06$

41. $\frac{1}{20}(e^{-225/16} - e^{-16}) \approx 0.000000033$ 43. $\frac{31\pi}{320}$

45. $\bar{x} = 0, \bar{y} = \frac{2}{3}$ 47. $20,000\pi(1 - e^{-1}) \approx 39,717$

49. $\frac{\pi r^4}{4}$ 51. $V = 2 \int_0^{2\pi} \int_0^a \sqrt{a^2 - r^2} dr d\theta = \frac{4\pi a^3}{3}$

Exercises Section 13.4

3. 46.831 5. 36.177 7. $4\sqrt{2}\pi$ 9. 583.769

11. $6\sqrt{11}$ 13. $4\sqrt{6}$ 15. 0.931 17. 37.174

19. 25.133 21. $\sqrt{2}A$ 23. $\frac{A}{|\cos \theta|}$ 25. 4L

Exercises Section 13.5

5. $\frac{16}{128\pi}$ 7. $-\frac{2}{3}$ 9. $\frac{4}{15}$ 11. $\frac{171}{5}$ 13. 0

15. $\int_0^2 \int_{-1}^1 \int_{x^2}^1 dz dx dy = \frac{8}{3}$ symmetry, yes

21. $\int_0^2 \int_{-1}^1 \int_{x^2}^1 dz dx dy = \frac{8}{3}$

23. $\int_{-1}^1 \int_0^{1-y^2} \int_{2-z/2}^4 dx dz dy = \frac{44}{15}$

25. $\int_{-2}^2 \int_{-\sqrt{4-y^2}}^{\sqrt{4-y^2}} \int_{y^2+z^2}^4 dx dz dy = 8\pi$

27. $\int_{-3}^3 \int_{-\sqrt{9-x^2}}^{\sqrt{9-x^2}} \int_{\sqrt{x^2+z^2}}^3 dy dz dx = 9\pi$

1246 Appendix B Answers to Odd-Numbered Exercises

29. $\int_{-\sqrt{10}}^{\sqrt{10}} \int_{-6}^{4-x^2} \int_0^{y+6} dz dy dx = \frac{160\sqrt{3}}{10}$

31. $\int_{-1}^1 \int_{x^2}^1 \int_0^{3-x} dy dz dx = 4$

33. $m = 32\pi, \bar{x} = \bar{y} = 0, \bar{z} = \frac{8}{3}$

35. $m = 138, \bar{x} = \frac{186}{115}, \bar{y} = \frac{56}{115}, \bar{z} = \frac{168}{115}$

37. right side is heavier in #34

$$\begin{aligned} 39. & \int_0^1 \int_0^{2-2y} \int_0^{2-x-2y} 4yz dz dx dy \\ &= \int_0^1 \int_0^{2-2y} \int_0^{2-2y-z} 4yz dx dz dy \\ &= \int_0^2 \int_0^{2-x} \int_0^{1-x/2-z/2} 4yz dy dz dx \end{aligned}$$

41. $\int_0^2 \int_0^{4-2y} \int_0^{4-2y-x} dz dx dy$

43. $\int_0^1 \int_0^{\sqrt{1-x^2}} \int_0^{\sqrt{1-x^2-z^2}} dy dz dx$

45. $\int_0^2 \int_{x^2}^4 \int_0^{\sqrt{y-x^2}} dz dy dx$

Exercises Section 13.6

5. $r = 4$ 7. $r = 4 \cos \theta$ 9. $z = r^2$

11. $z = \cos(r^2)$ 13. $\theta = \frac{\pi}{4}$

15. $\int_0^{2\pi} \int_0^2 \int_r^{\sqrt{8-r^2}} rf(r \cos \theta, r \sin \theta, z) dz dr d\theta$

17. $\int_0^{2\pi} \int_0^3 \int_0^{9-r^2} rf(r \cos \theta, r \sin \theta, z) dz dr d\theta$

19. $\int_0^{2\pi} \int_0^2 \int_{r^2}^4 rf(r \cos \theta, r \sin \theta, z) dz dr d\theta$

21. $\int_0^{2\pi} \int_0^2 \int_0^{4-r^2} rf(r \cos \theta, y, r \sin \theta) dy dr d\theta$

23. $\int_0^{2\pi} \int_0^1 \int_{r^2}^{2-r^2} rf(x, r \cos \theta, r \sin \theta) dx dr d\theta$

25. $\int_0^{2\pi} \int_0^2 \int_1^2 re^{r^2} dz dr d\theta = \pi(e^4 - 1)$

27. $\int_0^2 \int_0^{3-3z/2} \int_0^{6-2y-3z} (x+z) dx dy dz = 12$

29. $\int_0^{2\pi} \int_0^{\sqrt{2}} \int_r^{\sqrt{4-r^2}} zr dz dr d\theta = 2\pi$

31. $\int_0^2 \int_0^{4-2y} \int_0^{4-x-2y} (x+y) dz dx dy = 8$

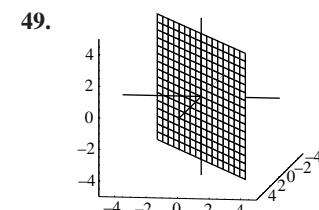
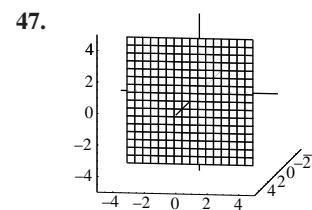
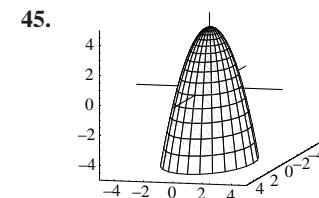
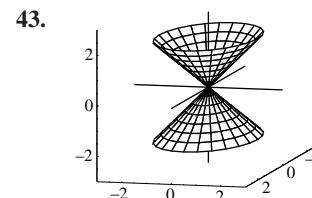
33. $\int_0^{2\pi} \int_0^3 \int_0^{r^2} re^z dz dr d\theta = \pi(e^9 - 10)$

35. $\int_0^\pi \int_0^{2 \sin \theta} \int_0^r 2r^2 \cos \theta dz dr d\theta = 0$

37. $\int_0^{2\pi} \int_0^1 \int_0^r 3z^2 r dz dr d\theta = \frac{2\pi}{5}$

39. $\int_0^\pi \int_0^2 \int_r^{\sqrt{8-r^2}} 2r dz dr d\theta = \frac{32\pi}{3}(\sqrt{2} - 1)$

41. $\int_0^{2\pi} \int_0^3 \int_0^{r^2} r^3 dy dr d\theta = 243\pi$



51. $m = \frac{128\pi}{3}, \bar{x} = \bar{y} = 0, \bar{z} = \frac{16}{5}$

53. $m = 10\pi, \bar{x} = 0, \bar{y} = \frac{4}{5}, \bar{z} = \frac{38}{15}$

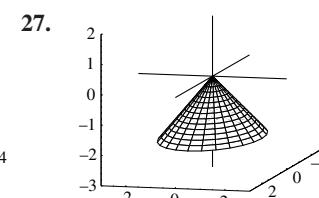
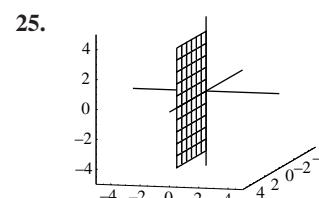
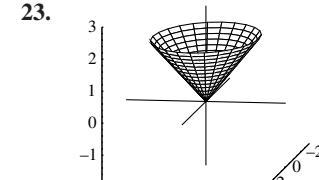
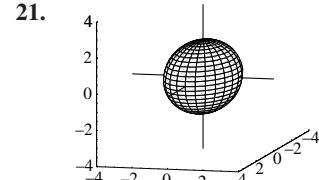
Exercises Section 13.7

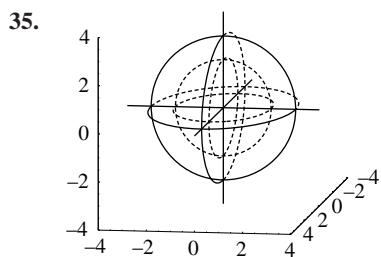
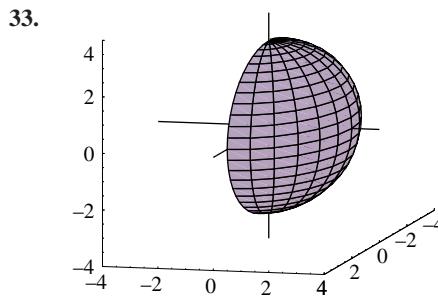
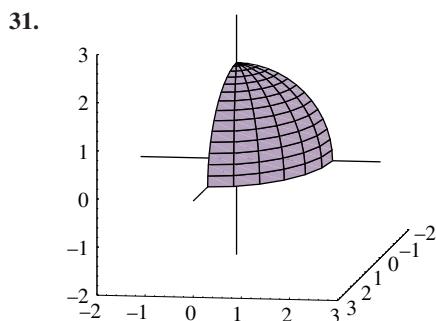
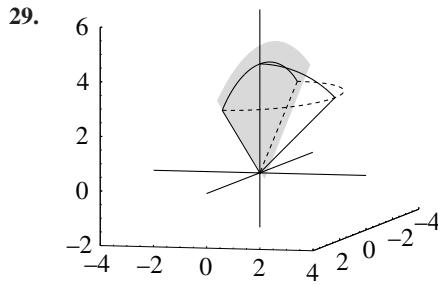
5. $(0, 0, 4)$ 7. $(4, 0, 0)$ 9. $(\sqrt{2}, 0, \sqrt{2})$

11. $\left(\frac{\sqrt{2}}{2}, \frac{\sqrt{2}}{2}, 1\right)$ 13. $\rho = 3$

15. $\theta = \frac{\pi}{4}$ or $\frac{5\pi}{4}$

17. $\rho \cos \phi = 2$ 19. $\phi = \frac{\pi}{6}$





37. $\int_0^{2\pi} \int_0^{\pi/2} \int_0^2 e^{\rho^3} \rho^2 \sin \phi d\rho d\phi d\theta = \frac{2}{3}\pi(e^8 - 1)$

39. $\int_0^{2\pi} \int_0^{\pi/2} \int_0^{\sqrt{2}} \rho^7 \sin \phi d\rho d\phi d\theta = 4\pi$

41. $\int_0^1 \int_1^2 \int_3^4 (x^2 + y^2 + z^2) dz dy dx = 15$

43. $\int_0^{2\pi} \int_0^2 \int_0^{4-r^2} r^3 dz dr d\theta = \frac{32\pi}{3}$

45. $\int_0^{2\pi} \int_0^{\pi/4} \int_0^{\sqrt{2}} \rho^3 \sin \phi d\rho d\phi d\theta = (2 - \sqrt{2})\pi$

47. $\int_0^{2\pi} \int_0^{\pi/4} \int_0^{4 \cos \phi} \rho^2 \sin \phi d\rho d\phi d\theta = 8\pi$

49. $\int_0^{2\pi} \int_0^4 \int_r^4 r dz dr d\theta = \frac{64\pi}{3}$

51. $\int_{-1}^1 \int_{-1}^1 \int_0^{\sqrt{x^2+y^2}} dz dy dx = 3.061$

53. $\int_0^{\pi/2} \int_0^{\pi/4} \int_0^2 \rho^2 \sin \phi d\rho d\phi d\theta = \frac{4 - 2\sqrt{2}}{3}\pi$

55. $\int_0^{2\pi} \int_0^2 \int_0^r r dz dr d\theta = \frac{16\pi}{3}$

57. $\int_{-\pi/2}^{\pi/2} \int_0^\pi \int_0^1 \rho^3 \sin \phi d\rho d\phi d\theta = \frac{\pi}{2}$

59. $\int_0^\pi \int_0^{\pi/4} \int_0^{\sqrt{2}} \rho^5 \sin \phi d\rho d\phi d\theta = \frac{256 - 128\sqrt{2}}{3}\pi$

61. $\bar{x} = \bar{y} = 0, \bar{z} = \frac{3}{4} + \frac{3\sqrt{2}}{8}$

Exercises Section 13.8

3. $x = \frac{1}{6}(v - u), y = \frac{1}{3}(u + 2v), 2 \leq u \leq 5, 1 \leq v \leq 3$

5. $x = \frac{1}{4}(u - v), y = \frac{1}{4}(u + 3v), 1 \leq u \leq 3, -3 \leq v \leq -1$

7. $x = r \cos \theta, y = r \sin \theta, 1 \leq r \leq 2, 0 \leq \theta \leq \frac{\pi}{2}$

9. $x = r \cos \theta, y = r \sin \theta, 2 \leq r \leq 3, \frac{\pi}{4} \leq \theta \leq \frac{3\pi}{4}$

11. $x = \sqrt{\frac{1}{2}(v - u)}, y = \frac{1}{2}(u + v), 0 \leq u \leq 2, 2 \leq v \leq 4$

13. $x = \ln\left(\frac{1}{2}(v - u)\right), y = \frac{1}{2}(u + v), 0 \leq u \leq 1, 3 \leq v \leq 5$

15. $\frac{7}{2}$ **17.** $\frac{13}{3}$ **19.** $\frac{7}{3}$ **21.** $\frac{1}{6}(e^5 - e^2) \ln 3$

23. $\frac{9}{4}$ **25.** $-2u$ **27.** 2

29. $x = u - w, y = \frac{1}{2}(-u + v + w), z = \frac{1}{2}(u - v + w), 1 \leq u \leq 2, 0 \leq v \leq 1, 2 \leq w \leq 4$ **31.** 1

Chapter 13 Review Exercises

1. 18 **3.** 207 **5.** $(e^{-1} - e^{-4})\pi$ **7.** $\frac{2}{3}$ **9.** 0

11. -19.92 **13.** $\frac{4}{3}$ **15.** 16π **17.** $\frac{128}{3}$

19. $\frac{64\pi}{3}$ **21.** $\frac{1}{3}(16 - 8\sqrt{2})\pi$ **23.** $\frac{11\pi}{2}$

25. $\int_0^4 \int_{\sqrt{y}}^2 f(x, y) dx dy$

27. $\int_{-\pi/2}^{\pi/2} \int_0^2 2r^2 \cos \theta dr d\theta = \frac{32}{3}$

29. $m = \frac{16}{3}, \bar{x} = \frac{3}{2}, \bar{y} = \frac{9}{4}$

1248 Appendix B Answers to Odd-Numbered Exercises

31. $m = \frac{64}{15}$, $\bar{x} = 0$, $\bar{y} = \frac{23}{28}$, $\bar{z} = \frac{5}{14}$

33. $\int_0^1 \int_{\sqrt{y}}^{2-y} dx dy = \frac{5}{6}$

35. $\frac{1}{2}$ 37. $2\sqrt{21}$ 39. $\frac{13\pi}{3}$ 41. $16\pi\sqrt{2}$

43. $\int_0^2 \int_{-1}^1 \int_{-1}^1 z(x+y) dz dy dx = 0$

45. $\int_0^{2\pi} \int_0^{\pi/4} \int_0^2 \rho^3 \sin \phi d\rho d\phi d\theta = (8 - 4\sqrt{2})\pi$

47. $\int_0^2 \int_x^2 \int_0^{6-x-y} f(x, y, z) dz dy dx$

49. $\int_0^{2\pi} \int_0^{\pi/2} \int_0^2 f(\rho \sin \phi \cos \theta, \rho \sin \phi \sin \theta, \rho \cos \phi) \cdot \rho^2 \sin \phi d\rho d\phi d\theta$

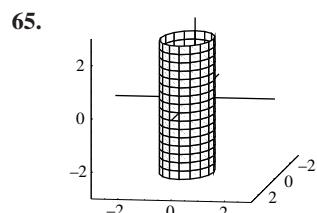
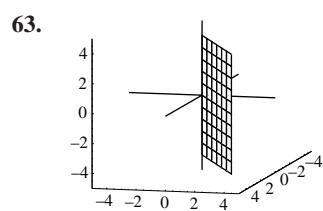
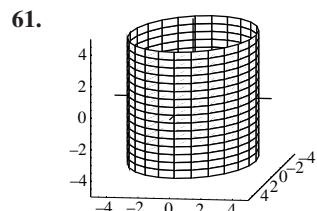
51. $\int_{\pi/4}^{\pi/2} \int_0^{\sqrt{2}} \int_0^r e^z r dz dr d\theta = \frac{e^{\sqrt{2}}(\sqrt{2}-1)\pi}{4}$

53. $\int_0^\pi \int_0^{\pi/4} \int_0^{\sqrt{2}} \rho^3 \sin \phi d\rho d\phi d\theta = \left(1 - \frac{\sqrt{2}}{2}\right)\pi$

55. (a) $r \sin \theta = 3$ (b) $\rho \sin \phi \sin \theta = 3$

57. (a) $r^2 + z^2 = 4$ (b) $\rho = 2$

59. (a) $z = r$ (b) $\phi = \frac{\pi}{4}$

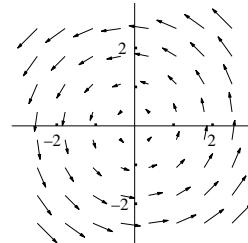


67. $x = \frac{1}{4}(v-u)$, $y = \frac{1}{2}(u+v)$, $-1 \leq u \leq 1$, $2 \leq v \leq 4$

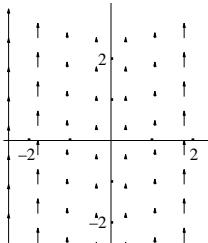
69. $\frac{1}{2}(e - e^{-1})$ 71. $4uv^2 - 4u^2$

CHAPTER 14**Exercises Section 14.1**

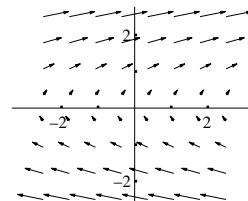
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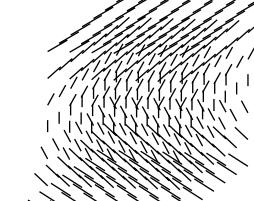
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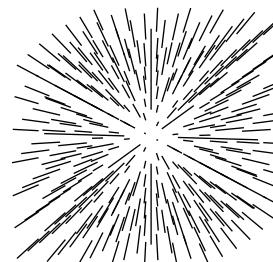
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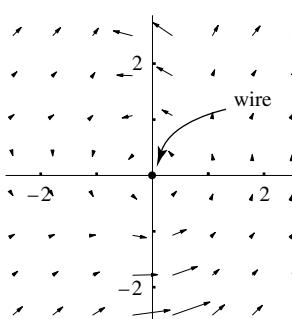
11.



13.



15. $\mathbf{F}_1 = \mathbf{D}$, $\mathbf{F}_2 = \mathbf{B}$, $\mathbf{F}_3 = \mathbf{A}$, $\mathbf{F}_4 = \mathbf{C}$ 17. $\langle 2x, 2y \rangle$
 19. $\frac{\langle x, y \rangle}{\sqrt{x^2 + y^2}}$ 21. $\langle e^{-y}, -xe^{-y} \rangle$ 23. $\frac{\langle x, y, z \rangle}{\sqrt{x^2 + y^2 + z^2}}$
 25. $\langle 2xy, x^2 + z, y \rangle$ 27. $f(x, y) = xy + c$ 29. not
 31. $f(x, y) = \frac{1}{2}x^2 - x^2y + \frac{1}{3}y^3 + c$
 33. $f(x, y) = -\cos xy + c$
 35. $f(x, y, z) = 2x^2 - xz + \frac{3}{2}y^2 + yz + c$ 37. not
 39. $y = \frac{1}{2}\sin x + c$ 41. $y^2 = x^3 + c$
 43. $(y+1)e^{-y} = -\frac{1}{2}x^2 + c$ 45. $y^2 + 1 = ce^{2x}$
 47. $f(x, y, z) = \int_0^x f(u) du + \int_0^y g(u) du + \int_0^z h(u) du + c$

51. $3rr$ 55.

Exercises Section 14.2

5. $4\sqrt{13}$ 7. $\frac{21}{2}\sqrt{17}$ 9. 4 11. 12 13. -4
 15. 3π 17. 25.41 19. -4 21. 14 23. $\frac{9}{2}$
 25. $6\sqrt{6}$ 27. -4 29. 31 31. 0 33. $\frac{8}{3}$
 35. 26 37. 0 39. $4\pi - \frac{19}{3}$ 41. positive
 43. zero 45. negative 47. 18.67
 49. $\bar{x} = 2.227$, $\bar{y} = 5.324$
 51. 99.41 53. 359.9 55. $\frac{\pi^3}{3}\sqrt{5}$ 59. 4π
 61. $\frac{32}{3}$ 63. 12 65. (a) 22.1 (b) 15.35 (c) 3.65

Exercises Section 14.3

5. $f(x, y) = x^2y - x + c$ 7. $f(x, y) = \frac{x}{y} - x^2 + \frac{1}{2}y^2 + c$
 9. not 11. $f(x, y) = e^{xy} + \sin y + c$
 13. $f(x, y, z) = xz^2 + x^2y + y - 3z + c$
 15. $f(x, y, z) = xy^2z^2 + \frac{1}{2}x^2 + \frac{1}{2}y^2 + c$
 17. $f(x, y) = x^2y - y$; 8 19. $f(x, y) = e^{xy} - y^2$; -16
 21. $f(x, y, z) = xz^2 + x^2y$; -38 23. $\frac{152}{3}$ 25. 18
 27. $\sqrt{30} - \sqrt{14}$ 29. -2 31. $10 - e^{18}$
 33. $(x - 5)^2 + (y - 6)^2 = 16$ 35. yes 37. no 39. no
 45. false 47. true 49. $\tan^{-1}\left(\frac{y}{x}\right) + c$, $x \neq 0; 0$
 51. (a) Simply connected (b) Not simply connected

Exercises Section 14.4

5. π 7. 16 9. -54 11. $\frac{32}{3}$ 13. 6π
 15. $\frac{1}{3}$ 17. $\frac{4}{3} + \frac{1}{2}e^2 + \frac{3}{2}e^{-2}$ 19. $\frac{32}{5}$ 21. 4
 23. 0 25. 8π 27. $\frac{3}{8}\pi$ 29. $\frac{32}{3}$
 33. $\bar{x} = 0$, $\bar{y} = \frac{4}{7}$ 37. 0 39. 0
 41. $\{(x, y) \in \mathbb{R}^2 | (x, y) \neq (0, 0)\}$; No

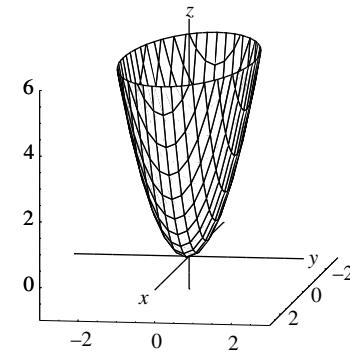
Exercises Section 14.5

5. $\langle 0, 0, -3y \rangle$, $-x$ 7. $\langle -3, 2x, 0 \rangle$, $2z$
 9. $\langle -y, -2x, -x \rangle$, $y + z$ 11. $\langle xe^y + 1, -e^y, 0 \rangle$, $2x + 1$
 13. $\langle -x \sin y, 3y - \cos y, 2x - 3z \rangle$, 0
 15. $\langle 2yz - 2z, 2x, 0 \rangle$, $2z + 1 + y^2$ 17. conservative
 19. incompressible 21. conservative
 23. neither 25. incompressible
 27. conservative 29. conservative
 31. (a) scalar (b) undefined (c) undefined
 (d) vector (e) vector
 35. positive 37. zero 39. negative
 51. $-\frac{x^2}{(x^2 + y^2 + z^2)^{3/2}} - \frac{y^2}{(x^2 + y^2 + z^2)^{3/2}}$
 $-\frac{z^2}{(x^2 + y^2 + z^2)^{3/2}} + \frac{3}{\sqrt{x^2 + y^2 + z^2}}$
 53. (a) Equal (b) Greater
 55. $\mathbf{F} = xi + y^3j + zk$, $\nabla \cdot \mathbf{F} = 3y^2 + 2$

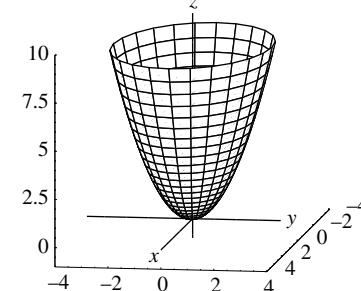
Exercises Section 14.6

5. $x = x, y = y, z = 3x + 4y$
 7. $x = \cos u \cosh v, y = \sin u \cosh v, z = \sinh v$,
 $0 \leq u \leq 2\pi$, $-\infty < v < \infty$
 9. $x = 2 \cos \theta, y = 2 \sin \theta, z = z$, $0 \leq \theta \leq 2\pi, 0 \leq z \leq 2$
 11. $x = r \cos \theta, y = r \sin \theta, z = 4 - r^2$,
 $0 \leq \theta \leq 2\pi, 0 \leq r \leq 2$

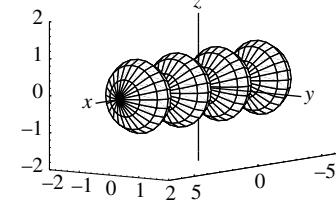
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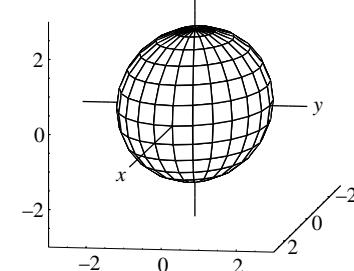
15.



17.



19.



1250 Appendix B Answers to Odd-Numbered Exercises

21. (a) A (b) C (c) B 23. $16\pi\sqrt{2}$

25. $4\pi\sqrt{14}$ 27. $\frac{1}{2}\sqrt{2}$ 29. 4π

31. $\int_1^3 \int_1^2 x\sqrt{14} dx dy = 3\sqrt{14}$

33. $\int_0^{2\pi} \int_0^r r^2 \sin\theta \sqrt{4r^2 + 1} dr d\theta = 0$

35. $\int_0^{2\pi} \int_0^r r^3 \sqrt{4r^2 + 1} dr d\theta = \frac{391\sqrt{17} + 1}{60}\pi$

37. $\int_0^{2\pi} \int_0^4 \sqrt{2}r^2 dr d\theta = \frac{128\sqrt{2}}{3}\pi$

39. $\int_0^{2\pi} \int_0^{\pi/2} 4(4\sin\phi) d\phi d\theta = 32\pi$

41. 24π 43. -18π 45. $\frac{5}{2}$ 47. $\frac{\pi}{2}$ 49. $\frac{7}{4}$

51. 0 53. $m = 8\sqrt{14}\pi$, $\bar{x} = \bar{y} = 0$, $\bar{z} = 6$

55. $m = 2\pi$, $\bar{x} = \frac{1}{3}$, $\bar{y} = 0$, $\bar{z} = \frac{1}{2}$

57. $\iint_S g(x, y, z) dS = \iint_R g(f(y, z), y, z) \sqrt{(f_y)^2 + (f_z)^2 + 1} dA$

where S is given by $x = f(y, z)$ for (y, z) in region $R: \mathbb{R}^2$.

59. $\frac{3\pi}{2}$ 61. 198.8π

63. 0.474π 65. 23.66

67. Flow lines don't cross boundary.

Exercises Section 14.7

5. $\frac{3}{2}$ 7. π 9. 0 11. 8 13. 32π

15. $\frac{64\pi}{3}$ 17. 4π 19. $\frac{6\pi}{5}$ 21. 0 23. $\frac{\pi}{2}$

25. π 27. 224π 29. $\frac{27}{5}$ 31. $\frac{512}{3}$

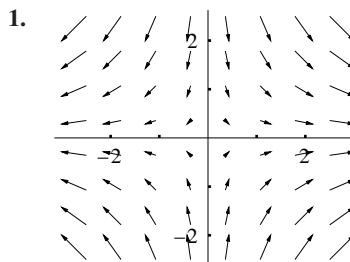
Exercises Section 14.8

5. 0 7. 4π 9. $-\frac{4}{3}$ 11. $-\pi$ 13. 0

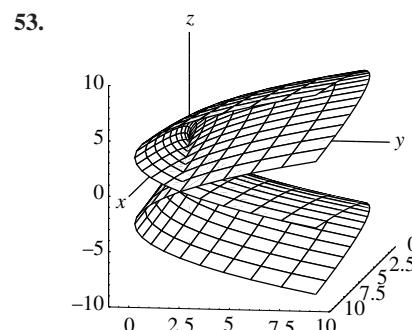
15. 1 17. 0 19. -4π

25. 0

33. Both surfaces
- S_1
- and
- S_2
- should be positively oriented, or both negatively oriented.

Chapter 14 Review Exercises

1. $\mathbf{F}_1 = D, \mathbf{F}_2 = C, \mathbf{F}_3 = B, \mathbf{F}_4 = A$
 5. $f(x, y) = xy - x^2y^2 + y + c$ 7. not
 9. $y^3 = 3x^2 + c$ 13. 18 15. 18π 17. 0
 19. 0 21. $3\pi - 4$ 23. zero 25. 40π
 27. 66 29. 3 31. 10 33. conservative 35. $\frac{1}{3}$
 37. -2 39. $\frac{32}{3}$ 41. 6π
 43. $\langle 0, 0, 0 \rangle, 3x^2 - 3y^2$ 45. $\langle 0, 0, 0 \rangle, 2 + 2z^2 + 2y^2$
 47. neither 49. both 51. positive



53. $\mathbf{F}_1 = D, \mathbf{F}_2 = C, \mathbf{F}_3 = B, \mathbf{F}_4 = A$ 55. (a) B (b) C (c) A 57. $\frac{1}{6}(17^{3/2} - 5^{3/2})\pi$
 59. $-8\sqrt{14}$ 61. $4\pi\sqrt{26}$ 63. 0
 65. $m = \frac{1}{3}(17\sqrt{17} - 1)\pi$, $\bar{x} = \bar{y} = 0$, $\bar{z} = \frac{1 + 391\sqrt{17}}{10(17\sqrt{17} - 1)}$
 67. $\frac{16}{3}$ 69. $\frac{304}{5}$ 71. $\frac{8\pi}{3}$ 73. 0 75. 0
 77. 0