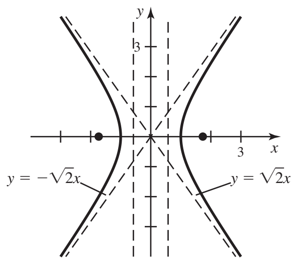
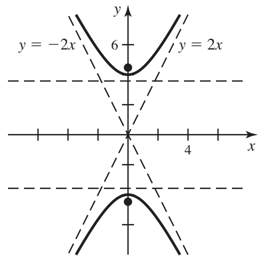
53. a. Hyperbola
b. Foci $(\pm\sqrt{3}, 0)$, vertices $(\pm 1, 0)$, directrices $x = \pm\dfrac{1}{\sqrt{3}}$
c. $e = \sqrt{3}$

d.



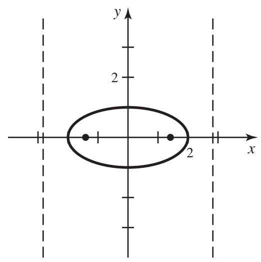
55. a. Hyperbola
b. Foci $(0, \pm 2\sqrt{5})$, vertices $(0, \pm 4)$, directrices $y = \pm\dfrac{8}{\sqrt{5}}$ **c.** $e = \dfrac{\sqrt{5}}{2}$

d.



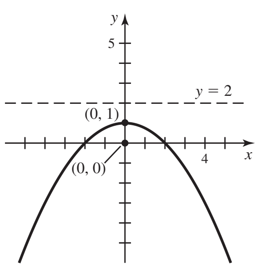
57. a. Ellipse
b. Foci $(\pm\sqrt{2}, 0)$, vertices $(\pm 2, 0)$, directrices $x = \pm 2\sqrt{2}$ **c.** $e = \dfrac{\sqrt{2}}{2}$

d.

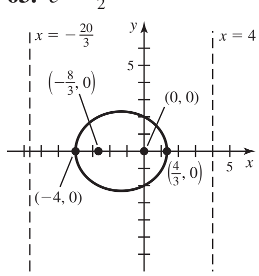


59. $y = \frac{3}{2}x - 2$

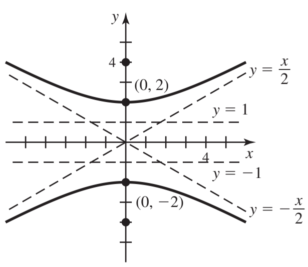
61. $e = 1$



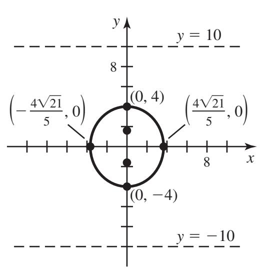
63. $e = \frac{1}{2}$



65. $\dfrac{y^2}{4} - \dfrac{x^2}{12} = 1$



67. $\dfrac{y^2}{16} + \dfrac{25x^2}{336} = 1$; foci: $\left(0, \pm\dfrac{8}{5}\right)$



69. $e = 2/3, y = \pm 9, (\pm 2\sqrt{5}, 0)$ **71.** $m = \dfrac{b}{a}$

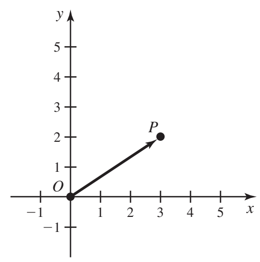
75. a. $x = \pm a\cos^{2/n} t, y = \pm b\sin^{2/n} t$
c. The curve becomes more rectangular as n increases.

CHAPTER 13

Section 13.1 Exercises, pp. 813–816

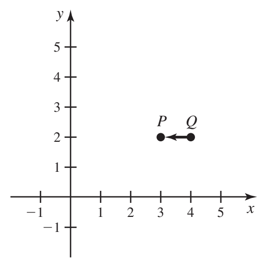
3. There are infinitely many vectors with the same direction and length as **v**. **5.** $\mathbf{u} + \mathbf{v} = \langle u_1 + v_1, u_2 + v_2 \rangle$ **7.** No **9.** $|\langle v_1, v_2 \rangle| = \sqrt{v_1^2 + v_2^2}$ **11.** If P has coordinates (x_1, y_1) and Q has coordinates (x_2, y_2), then the magnitude of $\overrightarrow{PQ}$ is given by $\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$. **13.** a, c, e **15. a.** $3\mathbf{v}$ **b.** $2\mathbf{u}$ **c.** $-3\mathbf{u}$ **d.** $-2\mathbf{u}$ **e.** $\mathbf{v}$ **17. a.** $3\mathbf{u} + 3\mathbf{v}$ **b.** $\mathbf{u} + 2\mathbf{v}$ **c.** $2\mathbf{u} + 5\mathbf{v}$ **d.** $-2\mathbf{u} + 3\mathbf{v}$ **e.** $3\mathbf{u} + 2\mathbf{v}$ **f.** $-3\mathbf{u} - 2\mathbf{v}$ **g.** $-2\mathbf{u} - 4\mathbf{v}$ **h.** $\mathbf{u} - 4\mathbf{v}$ **i.** $-\mathbf{u} - 6\mathbf{v}$

19. a.



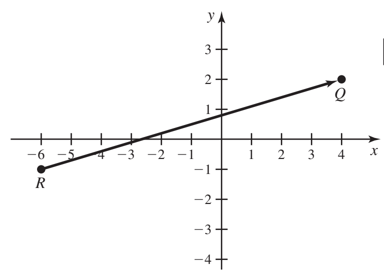
$\overrightarrow{OP} = \langle 3, 2 \rangle = 3\mathbf{i} + 2\mathbf{j}$
$|\overrightarrow{OP}| = \sqrt{13}$

b.



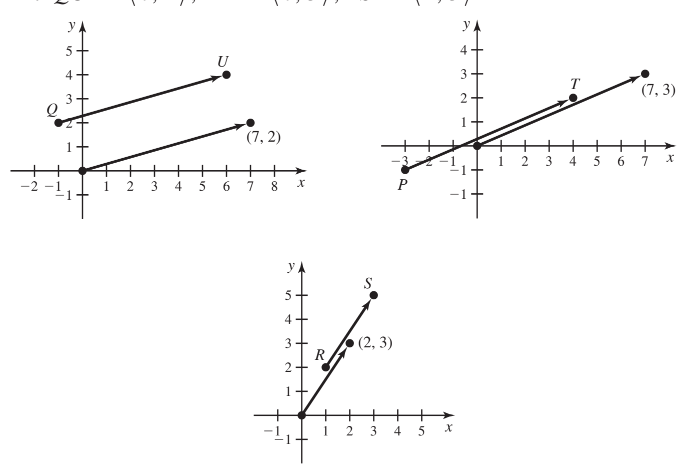
$\overrightarrow{QP} = \langle -1, 0 \rangle = -\mathbf{i}$
$|\overrightarrow{QP}| = 1$

c.



$\overrightarrow{RQ} = \langle 10, 3 \rangle = 10\mathbf{i} + 3\mathbf{j}$
$|\overrightarrow{RQ}| = \sqrt{109}$

21. $\overrightarrow{QU} = \langle 7, 2 \rangle, \overrightarrow{PT} = \langle 7, 3 \rangle, \overrightarrow{RS} = \langle 2, 3 \rangle$



23. $\overrightarrow{QT}$ **25.** $\langle -4, 10\rangle$ **27.** $\langle 52, -30\rangle$ **29.** $2\sqrt{2}$

31. $\mathbf{w} - \mathbf{u}$ **33.** $13\left\langle -\frac{5}{13}, \frac{12}{13}\right\rangle$ **35.** $\langle 3, 3\sqrt{3}\rangle$

37. $\left\langle \frac{15}{13}, -\frac{36}{13}\right\rangle$ **39.** $\left\langle \frac{30}{\sqrt{13}}, -\frac{20}{\sqrt{13}}\right\rangle$ **41.** $-\mathbf{i} + 10\mathbf{j}$

43. $\pm\frac{1}{\sqrt{61}}\langle 6, 5\rangle$ **45.** $\left\langle -\frac{28}{\sqrt{74}}, \frac{20}{\sqrt{74}}\right\rangle, \left\langle \frac{28}{\sqrt{74}}, -\frac{20}{\sqrt{74}}\right\rangle$

47. a. $\left\langle \frac{3}{5}, -\frac{4}{5}\right\rangle, \left\langle -\frac{3}{5}, \frac{4}{5}\right\rangle$ **b.** $b = \pm\frac{2\sqrt{2}}{3}$ **c.** $a = \pm\frac{3}{\sqrt{10}}$

49. $\langle -4\sqrt{3}, 4\rangle$ **51.** $\langle 15\sqrt{3}, -15\rangle$ **53. a.** $\mathbf{v}_a = \langle -320, 0\rangle$; $\mathbf{w} = \langle -20\sqrt{2}, -20\sqrt{2}\rangle$; $\mathbf{v}_g = \langle -320 - 20\sqrt{2}, -20\sqrt{2}\rangle$
b. Approx. 349.4 mi/hr; approx. 4.6° south of west
55. Approx. 490.3 mi/hr with a heading of about 1.2° west of north
57. $5\sqrt{65}$ km/hr $\approx$ 40.3 km/hr **59.** 1 m/s in the direction 30° east of north **61. a.** $\langle 20, 20\sqrt{3}\rangle$ **b.** Yes **c.** No **63.** $250\sqrt{2}$ lb
65. a. True **b.** True **c.** False **d.** False **e.** False **f.** False **g.** False **h.** True **67.** $\mathbf{x} = \left\langle \frac{1}{5}, -\frac{3}{10}\right\rangle$ **69.** $\mathbf{x} = \left\langle \frac{4}{3}, -\frac{11}{3}\right\rangle$

71. $4\mathbf{i} - 8\mathbf{j}$ **73.** $\langle a, b\rangle = \left(\frac{a+b}{2}\right)\mathbf{u} + \left(\frac{b-a}{2}\right)\mathbf{v}$

75. a. $\mathbf{0}$ **b.** The 6:00 vector **c.** Sum any six consecutive vectors. **d.** A vector pointing from 12:00 to 6:00 with a length 12 times the radius of the clock

77.
$$\begin{aligned}\mathbf{u} + \mathbf{v} &= \langle u_1, u_2\rangle + \langle v_1, v_2\rangle = \langle u_1 + v_1, u_2 + v_2\rangle\\ &= \langle v_1 + u_1, v_2 + u_2\rangle = \langle v_1, v_2\rangle + \langle u_1, u_2\rangle\\ &= \mathbf{v} + \mathbf{u}\end{aligned}$$

79.
$$\begin{aligned}a(c\mathbf{v}) &= a(c\langle v_1, v_2\rangle) = a\langle cv_1, cv_2\rangle\\ &= \langle acv_1, acv_2\rangle = \langle (ac)v_1, (ac)v_2\rangle\\ &= ac\langle v_1, v_2\rangle = (ac)\mathbf{v}\end{aligned}$$

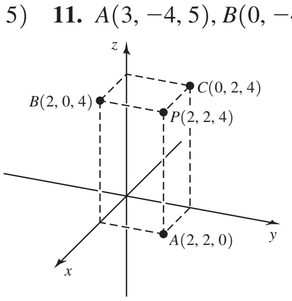
81.
$$\begin{aligned}(a + c)\mathbf{v} &= (a + c)\langle v_1, v_2\rangle\\ &= \langle (a + c)v_1, (a + c)v_2\rangle\\ &= \langle av_1 + cv_1, av_2 + cv_2\rangle\\ &= \langle av_1, av_2\rangle + \langle cv_1, cv_2\rangle\\ &= a\langle v_1, v_2\rangle + c\langle v_1, v_2\rangle\\ &= a\mathbf{v} + c\mathbf{v}\end{aligned}$$

85. a. $\{\mathbf{u}, \mathbf{v}\}$ are linearly dependent. $\{\mathbf{u}, \mathbf{w}\}$ and $\{\mathbf{v}, \mathbf{w}\}$ are linearly independent. **b.** Two linearly dependent vectors are parallel. Two linearly independent vectors are not parallel. **87. a.** $\frac{5}{3}$ **b.** -15

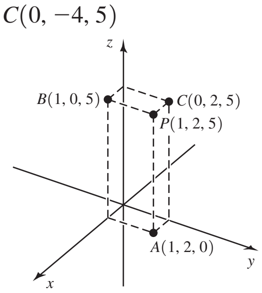
Section 13.2 Exercises, pp. 823–827

1. Move 3 units from the origin in the direction of the positive x-axis, then 2 units in the direction of the negative y-axis, and then 1 unit in the direction of the positive z-axis. **3.** It is parallel to the yz-plane and contains the point $(4, 0, 0)$. **5.** $\mathbf{u} + \mathbf{v} = \langle 9, 0, -6\rangle$; $3\mathbf{u} - \mathbf{v} = \langle 3, 20, -22\rangle$ **7.** $(0, 0, -4)$ **9.** $A(3, 0, 5), B(3, 4, 0), C(0, 4, 5)$ **11.** $A(3, -4, 5), B(0, -4, 0), C(0, -4, 5)$

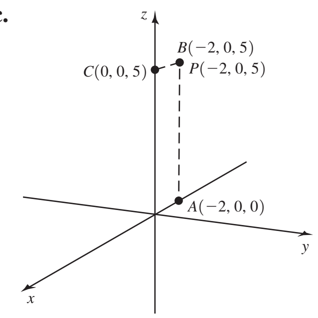
13. a.



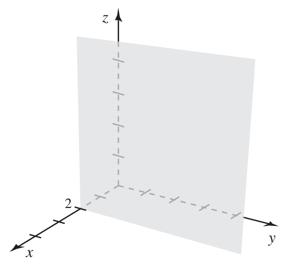
b.



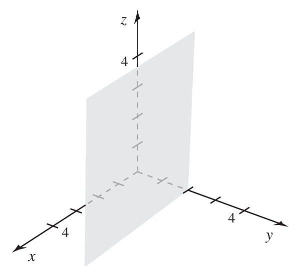
c.



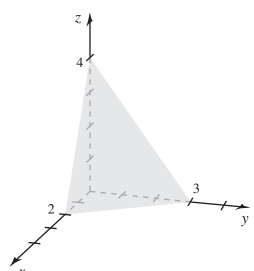
15.



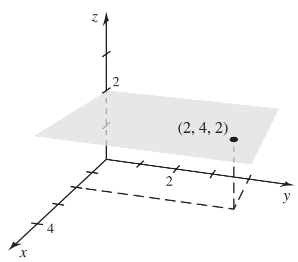
17.



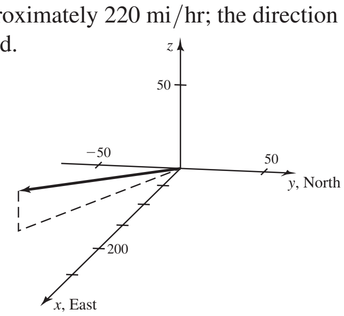
19.



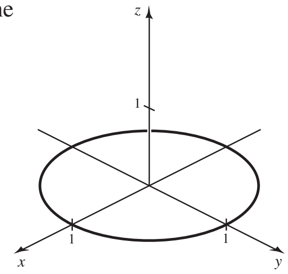
21.



23. $(x - 1)^2 + (y - 2)^2 + (z - 3)^2 = 16$
25. $(x + 2)^2 + y^2 + (z - 4)^2 \le 1$
27. $\left(x - \frac{3}{2}\right)^2 + \left(y - \frac{3}{2}\right)^2 + (z - 7)^2 = \frac{13}{2}$ **29.** A sphere centered at $(1, 0, 0)$ with radius 3 **31.** A sphere centered at $(0, 1, 2)$ with radius 3 **33.** All points on or outside the sphere with center $(0, 7, 0)$ and radius 6 **35.** The ball centered at $(4, 7, 9)$ with radius 15
37. The single point $(1, -3, 0)$ **39. a.** $\langle 12, -7, 2\rangle$ **b.** $\langle 16, -13, -1\rangle$ **c.** 5 **41. a.** $\langle -4, 5, -4\rangle$ **b.** $\langle -9, 3, -9\rangle$ **c.** $3\sqrt{2}$ **43. a.** $\langle -15, 23, 22\rangle$ **b.** $\langle -31, 49, 33\rangle$ **c.** $3\sqrt{5}$
45. a. $\overrightarrow{PQ} = \langle 2, 6, 2\rangle = 2\mathbf{i} + 6\mathbf{j} + 2\mathbf{k}$ **b.** $|\overrightarrow{PQ}| = 2\sqrt{11}$
c. $\left\langle \frac{1}{\sqrt{11}}, \frac{3}{\sqrt{11}}, \frac{1}{\sqrt{11}}\right\rangle$ and $\left\langle -\frac{1}{\sqrt{11}}, -\frac{3}{\sqrt{11}}, -\frac{1}{\sqrt{11}}\right\rangle$
47. a. $\overrightarrow{PQ} = \langle 0, -5, 1\rangle = -5\mathbf{j} + \mathbf{k}$ **b.** $|\overrightarrow{PQ}| = \sqrt{26}$
c. $\left\langle 0, -\frac{5}{\sqrt{26}}, \frac{1}{\sqrt{26}}\right\rangle$ and $\left\langle 0, \frac{5}{\sqrt{26}}, -\frac{1}{\sqrt{26}}\right\rangle$
49. a. $\overrightarrow{PQ} = \langle -2, 4, -2\rangle = -2\mathbf{i} + 4\mathbf{j} - 2\mathbf{k}$ **b.** $|\overrightarrow{PQ}| = 2\sqrt{6}$
c. $\left\langle -\frac{1}{\sqrt{6}}, \frac{2}{\sqrt{6}}, -\frac{1}{\sqrt{6}}\right\rangle$ and $\left\langle \frac{1}{\sqrt{6}}, -\frac{2}{\sqrt{6}}, \frac{1}{\sqrt{6}}\right\rangle$
51. a. $20\mathbf{i} + 20\mathbf{j} - 10\mathbf{k}$; **b.** 30 mi/hr
53. The speed of the plane is approximately 220 mi/hr; the direction is slightly south of east and upward.



55. $5\sqrt{6}$ knots to the east, $5\sqrt{6}$ knots to the north, 10 knots upward **57. a.** False **b.** False **c.** False **d.** True **59.** All points in $\mathbb{R}^3$ except those on the coordinate axes **61.** A circle of radius 1 centered at $(0, 0, 0)$ in the xy-plane



63. A circle of radius 2 centered at $(0, 0, 1)$ in the horizontal plane $z = 1$ **65.** $(x - 2)^2 + (z - 1)^2 = 9, y = 4$ **67.** $6\left\langle \frac{1}{3}, -\frac{2}{3}, \frac{2}{3} \right\rangle$

69. $\left\langle -\frac{15}{4}, \frac{5}{2}, -\frac{5\sqrt{3}}{4} \right\rangle$ **71.** $\langle 12, -16, 0 \rangle, \langle -12, 16, 0 \rangle$

73. $\langle -\sqrt{3}, -\sqrt{3}, \sqrt{3} \rangle, \langle \sqrt{3}, \sqrt{3}, -\sqrt{3} \rangle$ **75. a.** Collinear; Q is between P and R. **b.** Collinear; P is between Q and R.

c. Noncollinear **d.** Noncollinear **77.** $\left\langle \frac{500\sqrt{3}}{9}, 0, -\frac{500}{3} \right\rangle$, $\left\langle -\frac{250\sqrt{3}}{9}, -\frac{250}{3}, -\frac{500}{3} \right\rangle, \left\langle -\frac{250\sqrt{3}}{9}, \frac{250}{3}, -\frac{500}{3} \right\rangle$

79. $(3, 8, 9), (-1, 0, 3), (1, 0, -3)$

Section 13.3 Exercises, pp. 833–837

1. $\mathbf{u} \cdot \mathbf{v} = |\mathbf{u}||\mathbf{v}| \cos \theta$ **3.** -40 **5.** $\cos \theta = \frac{\mathbf{u} \cdot \mathbf{v}}{|\mathbf{u}||\mathbf{v}|}$, so $\theta = \cos^{-1}\left(\frac{\mathbf{u} \cdot \mathbf{v}}{|\mathbf{u}||\mathbf{v}|} \right)$ **7.** $\left\langle -\frac{4}{3}, \frac{2}{3}, \frac{4}{3} \right\rangle$ **9.** -1 **11.** 2

13. $\frac{\pi}{2}$; 0 **15.** 100; $\frac{\pi}{4}$ **17.** $\frac{1}{2}$ **19.** 0; $\frac{\pi}{2}$ **21.** 1; $\pi/3$

23. -2; 93.2° **25.** 2; 87.2° **27.** -4; 104° **29.** $\angle P = 78.8°$, $\angle Q = 47.2°, \angle R = 54.0°$ **31.** $\langle 3, 0 \rangle$; 3 **33.** $\langle 0, 3 \rangle$; 3

35. $\frac{6}{5}\langle -2, 1 \rangle; \frac{6}{\sqrt{5}}$ **37.** $\frac{14}{19}\langle -1, -3, 3 \rangle; -\frac{14}{\sqrt{19}}$

39. $-\mathbf{i} + \mathbf{j} - 2\mathbf{k}; \sqrt{6}$ **41.** $750\sqrt{3}$ ft-lb **43.** $25\sqrt{2}$ J

45. 400 J **47.** $\frac{1}{2}\langle 5\sqrt{3}, -15 \rangle, \frac{1}{2}\langle -5\sqrt{3}, -5 \rangle$ **49.** $\langle 490, -490 \rangle$, $\langle -490, -490 \rangle$ **51. a.** False **b.** True **c.** True **d.** False **e.** False **f.** True **53.** $c = \frac{4}{9}$ **55.** $\langle 1, a, 4a - 2 \rangle$, a real

57. a. $\operatorname{proj}_{\mathbf{k}}\mathbf{u} = |\mathbf{u}| \cos 60° \left(\frac{\mathbf{k}}{|\mathbf{k}|} \right) = \frac{1}{2}\mathbf{k}$, for all such $\mathbf{u}$ **b.** Yes

59. The heads of the vectors lie on the line $y = 3 - x$.
61. The heads of the vectors lie on the plane $z = 3$.

63. $\mathbf{u} = \left\langle -\frac{4}{5}, -\frac{2}{5} \right\rangle + \left\langle -\frac{6}{5}, \frac{12}{5} \right\rangle$

65. $\mathbf{u} = \left\langle 1, \frac{1}{2}, \frac{1}{2} \right\rangle + \left\langle -2, \frac{3}{2}, \frac{5}{2} \right\rangle$ **67.** $3x - 7y = -36$

69. $-\frac{5}{3}$ **71.** $\mathbf{I} = \frac{1}{\sqrt{2}}\mathbf{i} + \frac{1}{\sqrt{2}}\mathbf{j}, \mathbf{J} = -\frac{1}{\sqrt{2}}\mathbf{i} + \frac{1}{\sqrt{2}}\mathbf{j}$; $\mathbf{i} = \frac{1}{\sqrt{2}}(\mathbf{I} - \mathbf{J}), \mathbf{j} = \frac{1}{\sqrt{2}}(\mathbf{I} + \mathbf{J})$ **73. a.** $|\mathbf{I}| = |\mathbf{J}| = |\mathbf{K}| = 1$

b. $\mathbf{I} \cdot \mathbf{J} = 0, \mathbf{I} \cdot \mathbf{K} = 0, \mathbf{J} \cdot \mathbf{K} = 0$ **c.** $\langle 1, 0, 0 \rangle = \frac{1}{2}\mathbf{I} - \frac{1}{\sqrt{2}}\mathbf{J} + \frac{1}{2}\mathbf{K}$

75. a. The faces on $y = 0$ and $z = 0$ **b.** The faces on $y = 1$ and $z = 1$ **c.** The faces on $x = 0$ and $x = 1$ **d.** 0 **e.** 1 **f.** 2

77. a. $\left(\frac{2}{\sqrt{3}}, 0, \frac{2\sqrt{2}}{\sqrt{3}} \right)$ **b.** $\mathbf{r}_{OP} = \langle \sqrt{3}, -1, 0 \rangle, \mathbf{r}_{OQ} = \langle \sqrt{3}, 1, 0 \rangle$, $\mathbf{r}_{PQ} = \langle 0, 2, 0 \rangle, \mathbf{r}_{OR} = \left\langle \frac{2}{\sqrt{3}}, 0, \frac{2\sqrt{2}}{\sqrt{3}} \right\rangle, \mathbf{r}_{PR} = \left\langle -\frac{\sqrt{3}}{3}, 1, \frac{2\sqrt{2}}{\sqrt{3}} \right\rangle$

83. a.
$$\cos^2 \alpha + \cos^2 \beta + \cos^2 \gamma = \left(\frac{\mathbf{v} \cdot \mathbf{i}}{|\mathbf{v}||\mathbf{i}|} \right)^2 + \left(\frac{\mathbf{v} \cdot \mathbf{j}}{|\mathbf{v}||\mathbf{j}|} \right)^2 + \left(\frac{\mathbf{v} \cdot \mathbf{k}}{|\mathbf{v}||\mathbf{k}|} \right)^2 = \frac{a^2}{a^2 + b^2 + c^2} + \frac{b^2}{a^2 + b^2 + c^2} + \frac{c^2}{a^2 + b^2 + c^2} = 1$$

b. $\langle 1, 1, 0 \rangle$, 90° **c.** $\left\langle \frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}, 1 \right\rangle$, 45° **d.** No. If so, $\left(\frac{\sqrt{3}}{2} \right)^2 + \left(\frac{\sqrt{3}}{2} \right)^2 + \cos^2 \gamma = 1$, which has no solution. **e.** 54.7°

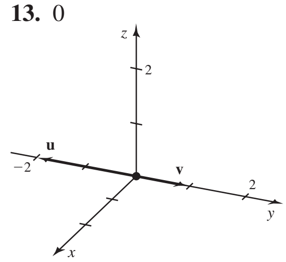
85. $|\mathbf{u} \cdot \mathbf{v}| = 33 = \sqrt{33} \cdot \sqrt{33} < \sqrt{70} \cdot \sqrt{74} = |\mathbf{u}||\mathbf{v}|$

Section 13.4 Exercises, pp. 842–844

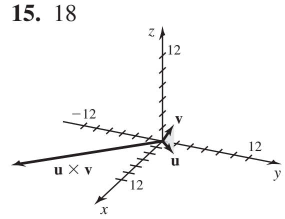
1. 0 **3. a.** $\mathbf{u}$ is orthogonal to $\mathbf{v}$. **b.** $\mathbf{u}$ is parallel to $\mathbf{v}$. **5.** $\sqrt{2}/2$

7. $-3\mathbf{i} - 2\mathbf{j} + 7\mathbf{k}$ **9.** $\mathbf{u} \times \mathbf{v} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ u_1 & u_2 & u_3 \\ v_1 & v_2 & v_3 \end{vmatrix}$ **11.** $15\mathbf{k}$

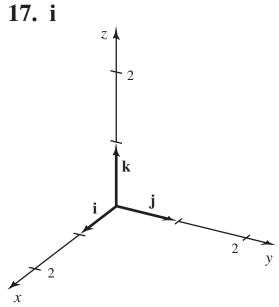
13. 0



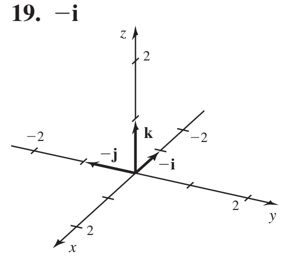
15. 18



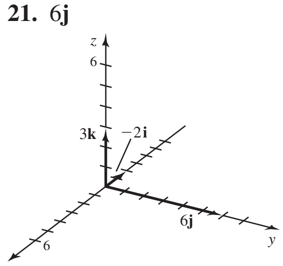
17. $\mathbf{i}$



19. $-\mathbf{i}$

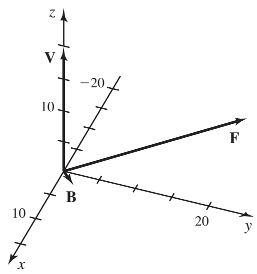


21. $6\mathbf{j}$



23. $\mathbf{u} \times \mathbf{v} = \langle -30, 18, 9 \rangle, \mathbf{v} \times \mathbf{u} = \langle 30, -18, -9 \rangle$
25. $\mathbf{u} \times \mathbf{v} = \langle 6, 11, 5 \rangle, \mathbf{v} \times \mathbf{u} = \langle -6, -11, -5 \rangle$
27. $\mathbf{u} \times \mathbf{v} = \langle 8, 4, 10 \rangle, \mathbf{v} \times \mathbf{u} = \langle -8, -4, -10 \rangle$ **29.** 11
31. $3\sqrt{10}$ **33.** $\sqrt{11}/2$ **35.** $4\sqrt{2}$ **37.** $9\sqrt{2}$ **41.** Not collinear
43. $\langle 3, -4, 2 \rangle$ **45.** $\langle 0, 20, -20 \rangle$ **47.** The force $\mathbf{F} = 5\mathbf{i} - 5\mathbf{k}$ produces the greater torque. **49.** $5/\sqrt{2}$ N-m **51.** $|\tau| = 13.2$ N-m; direction: into the page

53. The magnitude is $20\sqrt{2}$ at a 135° angle with the positive x-axis in the xy-plane.



55. 4.53×10^{-14} kg-m/s^2 **57. a.** False **b.** False **c.** False **d.** True **e.** False **59.** $\langle u_1, u_1 + 2, u_1 + 1 \rangle$, u_1 real

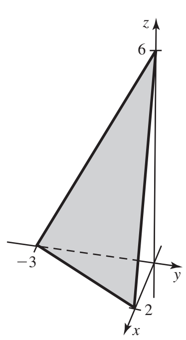
61. $\dfrac{\sqrt{(ab)^2 + (ac)^2 + (bc)^2}}{2}$

63. $|\mathbf{u} \cdot (\mathbf{v} \times \mathbf{w})| = |\mathbf{u}||\mathbf{v} \times \mathbf{w}||\cos\theta|$, where $|\mathbf{v} \times \mathbf{w}|$ is the area of the base of the parallelepiped and $|\mathbf{u}||\cos\theta|$ is its height.
67. 1.76×10^7 m/s

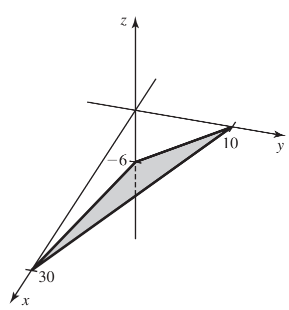
Section 13.5 Exercises, pp. 852–855

1. $\langle 4, -8, 9 \rangle$ **3.** $\langle x_1 - x_0, y_1 - y_0, z_1 - z_0 \rangle$ **5.** Perpendicular
7. A point and a normal vector **9.** $(-6, 0, 0)$, $(0, -4, 0)$, $(0, 0, 3)$
11. $x = 4t, y = 7t, z = 1$; $\mathbf{r} = \langle 0, 0, 1 \rangle + t\langle 4, 7, 0 \rangle$
13. $x = 0, y = t, z = 1$; $\mathbf{r} = \langle 0, 0, 1 \rangle + t\langle 0, 1, 0 \rangle$
15. $x = t, y = 2t, z = 3t$; $\mathbf{r} = t\langle 1, 2, 3 \rangle$
17. $x = -2t, y = 8t, z = -4t$; $\mathbf{r} = t\langle -2, 8, -4 \rangle$
19. $x = -2t, y = -t, z = t$; $\mathbf{r} = t\langle -2, -1, 1 \rangle$
21. $x = -2, y = 5 - 2t, z = 3 - t$; $\mathbf{r} = \langle -2, 5, 3 \rangle + t\langle 0, -2, -1 \rangle$ **23.** $x = 1 - 4t, y = 2 + 6t, z = 3 + 14t$; $\mathbf{r} = \langle 1, 2, 3 \rangle + t\langle -4, 6, 14 \rangle$ **25.** $x = 4, y = 3 - 9t, z = 3 + 6t$; $\mathbf{r} = \langle 4, 3, 3 \rangle + t\langle 0, -9, 6 \rangle$ **27.** $x = t, y = 2t, z = 3t, 0 \le t \le 1$
29. $x = 2 + 5t, y = 4 + t, z = 8 - 5t, 0 \le t \le 1$ **31.** Intersect at $(1, 3, 2)$ **33.** Skew **35.** Same line **37.** Parallel, distinct lines
39. 13 **41. a.** Yes **b.** No **c.** $13.16° < \theta < 18.12°$
43. $x + y - z = 4$ **45.** $2x + y - 2z = -2$
47. $x + 4y + 7z = 0$ **49.** $7x + 2y + z = 10$
51. $-x + 2y - 4z = -17$ **53.** $3y - 2z = 0$
55. $8x - 7y + 2z = 0$ **57.** $x + 3y - z = -3$
59. Yes; $2x - y = -1$

61. Intercepts
$x = 2, y = -3, z = 6$;
$3x - 2y = 6, z = 0$;
$-2y + z = 6, x = 0$; and
$3x + z = 6, y = 0$

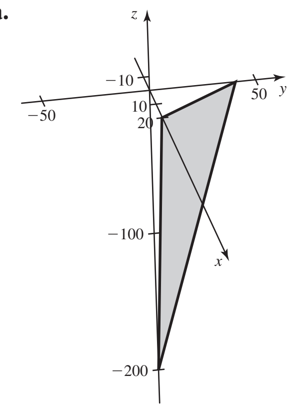


63. Intercepts
$x = 30, y = 10, z = -6$;
$x + 3y = 30, z = 0$;
$x - 5z = 30, y = 0$; and
$3y - 5z = 30, x = 0$



65. Orthogonal **67.** Neither **69.** Q and T are identical; Q, R, and T are parallel; S is orthogonal to Q, R, and T.
71. $\mathbf{r} = \langle 2 + 2t, 1 - 4t, 3 + t \rangle$
73. $x = t, y = 1 + 2t, z = -1 - 3t$

75. $x = \frac{7}{5} + 2t, y = \frac{9}{5} + t, z = -t$ **77.** $(3, 3, 3)$ **79.** $(1, 1, 2)$
81. a. True **b.** False **c.** False **d.** True **e.** False **f.** False **g.** True **83.** 6 **85.** $\dfrac{x-1}{4} = \dfrac{y-2}{7} = \dfrac{z}{2}$ **87.** Approx. 43°
89. $6x - 4y + z = d$ **91.** The planes intersect in the point $(3, 6, 0)$.
93. a.

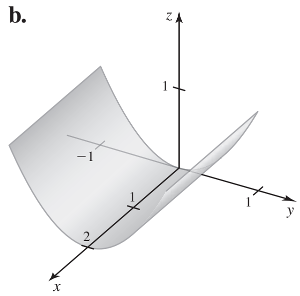


b. Positive
c. $2x + y = 40$, line in the xy-plane

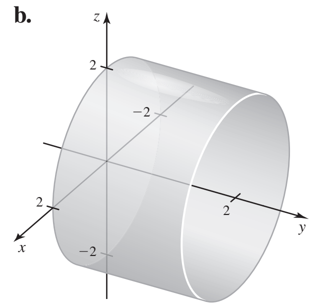
Section 13.6 Exercises, pp. 863–865

1. z-axis; x-axis; y-axis **3.** Intersection of the surface with a plane parallel to one of the coordinate planes **5.** Ellipsoid

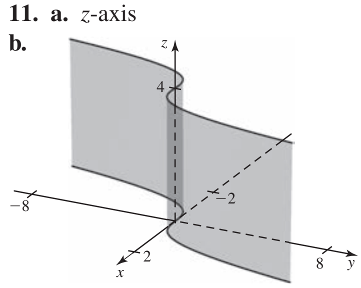
7. a. x-axis
b.



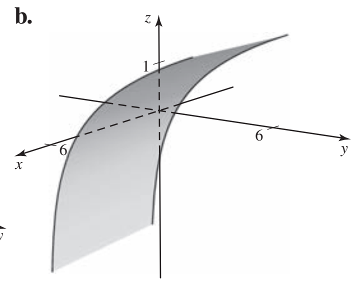
9. a. y-axis
b.



11. a. z-axis
b.



13. a. x-axis
b.

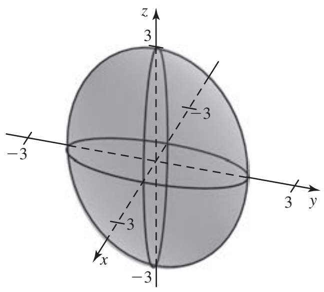


15. Ellipsoid; xy-trace: $x^2 + y^2 = 1$ (circle); xz-trace: $x^2 + \dfrac{z^2}{25} = 1$ (ellipse); yz-trace: $y^2 + \dfrac{z^2}{25} = 1$ (ellipse)
17. Paraboloid; xy-trace: $(0, 0, 0)$ (a single point); xz-trace: $z = 25x^2$ (parabola); yz-trace: $z = 25y^2$ (parabola) **19.** Hyperboloid of two sheets; xz-trace: $z^2 - 25x^2 = 25$ (hyperbola); yz-trace: $z^2 - 25y^2 = 25$ (hyperbola) **21.** Hyperbolic paraboloid
23. Elliptic paraboloid **25.** Hyperbolic cylinder
27. Elliptic paraboloid

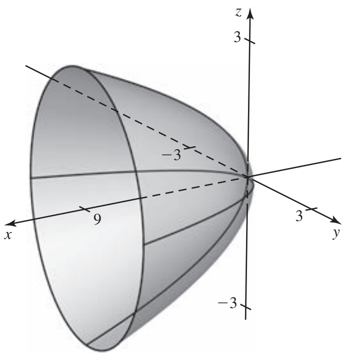
29. a. $x = \pm 1, y = \pm 2, z = \pm 3$

b. $x^2 + \frac{y^2}{4} = 1, x^2 + \frac{z^2}{9} = 1, \frac{y^2}{4} + \frac{z^2}{9} = 1$

c. Ellipsoid



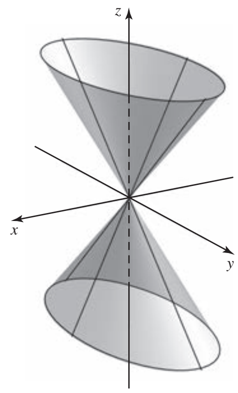
31. a. $x = y = z = 0$
b. $x = y^2, x = z^2$, origin
c. Elliptic paraboloid



37. a. $x = y = z = 0$

b. Origin, $\frac{y^2}{4} = z^2, x^2 = z^2$

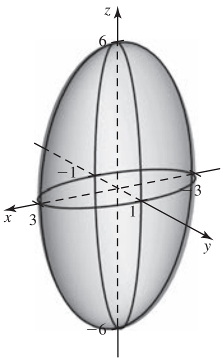
c. Elliptic cone



39. a. $x = \pm 3, y = \pm 1, z = \pm 6$

b. $\frac{x^2}{3} + 3y^2 = 3, \frac{x^2}{3} + \frac{z^2}{12} = 3, 3y^2 + \frac{z^2}{12} = 3$

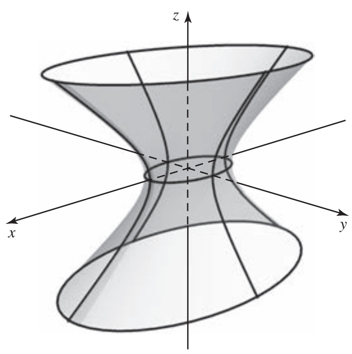
c. Ellipsoid



33. a. $x = \pm 5, y = \pm 3$, no z-intercept

b. $\frac{x^2}{25} + \frac{y^2}{9} = 1, \frac{x^2}{25} - z^2 = 1, \frac{y^2}{9} - z^2 = 1$

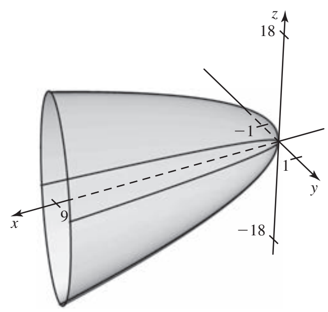
c. Hyperboloid of one sheet



41. a. $x = y = z = 0$
b. Origin,

$x - 9y^2 = 0, 9x - \frac{z^2}{4} = 0$

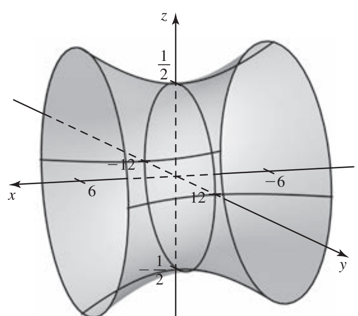
c. Elliptic paraboloid



43. a. No x-intercept, $y = \pm 12, z = \pm \frac{1}{2}$

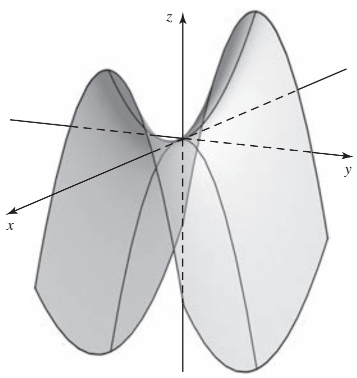
b. $-\frac{x^2}{4} + \frac{y^2}{16} = 9, -\frac{x^2}{4} + 36z^2 = 9, \frac{y^2}{16} + 36z^2 = 9$

c. Hyperboloid of one sheet



35. a. $x = y = z = 0$ **b.** $\frac{x^2}{9} - y^2 = 0, z = \frac{x^2}{9}, z = -y^2$

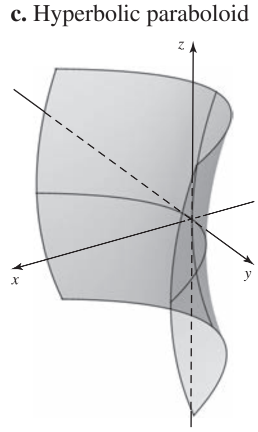
c. Hyperbolic paraboloid



45. a. $x = y = z = 0$

b. $5x - \frac{y^2}{5} = 0, 5x + \frac{z^2}{20} = 0, -\frac{y^2}{5} + \frac{z^2}{20} = 0$

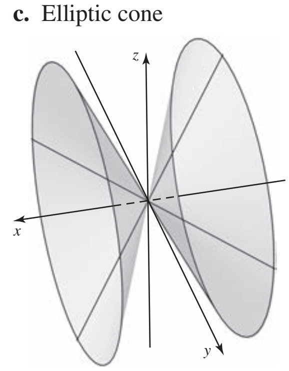
c. Hyperbolic paraboloid



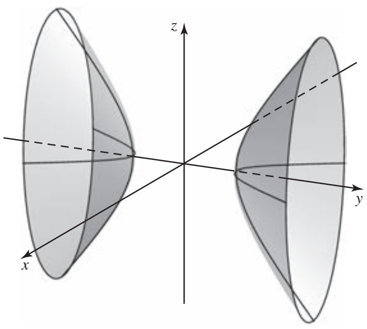
47. a. $x = y = z = 0$

b. $\frac{y^2}{18} = 2x^2, \frac{z^2}{32} = 2x^2$, origin

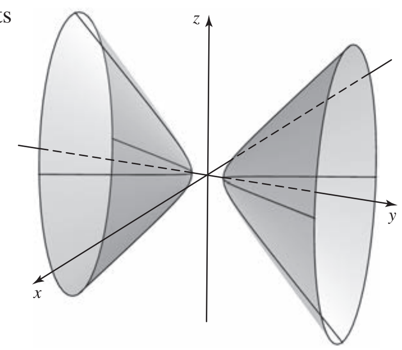
c. Elliptic cone



49. **a.** No x-intercept, $y = \pm 2$, no z-intercept
b. $-x^2 + \frac{y^2}{4} = 1$, no xz-trace, $\frac{y^2}{4} - \frac{z^2}{9} = 1$
c. Hyperboloid of two sheets



51. **a.** No x-intercept, $y = \pm\frac{\sqrt{3}}{3}$, no z-intercept
b. $-\frac{x^2}{3} + 3y^2 = 1$, no xz-trace, $3y^2 - \frac{z^2}{12} = 1$
c. Hyperboloid of two sheets

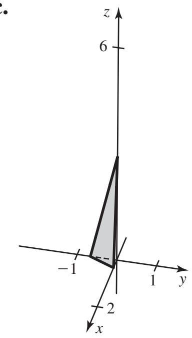


53. The graph of the ellipsoid $x^2 + 4y^2 + 9z^2 + 54z = 19$ is obtained by shifting the graph of the ellipsoid $x^2 + 4y^2 + 9z^2 = 100$ down 3 units. **55.** Hyperboloid of one sheet **57.** Hyperboloid of two sheets **59.** **a.** True **b.** True **c.** True **d.** False **e.** False **61.** All except the hyperbolic paraboloid **63.** 8 **65.** **b.** $\frac{x^2 + z^2}{(10.55/\pi)^2} + \frac{y^2}{(5.55)^2} = 1$
67. $4x^2 + 8y^2 + 4(z - 3)^2 = 9, 3 \le z \le 4.5$

Chapter 13 Review Exercises, pp. 865–867

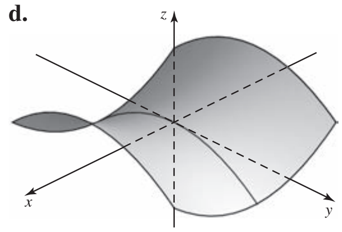
1. **a.** True **b.** False **c.** True **d.** False **e.** True **f.** True
3. $\langle 3, -6\rangle$ **5.** $\langle -5, 8\rangle$ **7.** $\sqrt{221}$ **9.** $12\left\langle \frac{1}{3}, -\frac{2}{3}, \frac{2}{3}\right\rangle$
11. $\left\langle \frac{10}{3}, -\frac{20}{3}, \frac{20}{3}\right\rangle$ **13.** $\langle 58, 26, 44\rangle$ **15.** $a = -3$
17. **a.** $\mathbf{v} = -275\sqrt{2}\mathbf{i} + 275\sqrt{2}\mathbf{j}$ **b.** $-275\sqrt{2}\mathbf{i} + (275\sqrt{2} + 40)\mathbf{j}$
19. $\{(x, y, z): (x - 1)^2 + y^2 + (z + 1)^2 = 16\}$
21. $\{(x, y, z): x^2 + (y - 1)^2 + z^2 > 4\}$ **23.** A ball centered at $\left(\frac{1}{2}, -2, 3\right)$ of radius $\frac{3}{2}$ **25.** All points outside a sphere of radius 10 centered at $(3, 0, 10)$ **27.** 50.15 m/s; 85.4° below the horizontal in the northerly horizontal direction **29.** 50 lb; 36.9° north of east
31. A circle of radius 1 centered at $(0, 2, 0)$ in the vertical plane $y = 2$
33. **a.** 0.68 radian **b.** $\frac{7}{9}\langle 1, 2, 2\rangle; \frac{7}{3}$ **c.** $\frac{7}{3}\langle -1, 2, 2\rangle; 7$
35. $250\sqrt{2}$ ft-lb **37.** $90\sqrt{3}$ lb; 90 lb **39.** 11
41. $\pm\left\langle \frac{12}{\sqrt{197}}, \frac{7}{\sqrt{197}}, \frac{2}{\sqrt{197}}\right\rangle$ **43.** $\langle -10, 10, 10\rangle$

45. $|\tau|(\theta) = 39.2 \sin\theta$ has a maximum value of 39.2 N-m (when $\theta = \pi/2$) and a minimum value of 0 N-m (when $\theta = 0$). Direction does *not* change. **47.** $\mathbf{r} = \langle 0, -3, 9\rangle + t\langle 2, -5, -8\rangle, 0 \le t \le 1$
49. $\mathbf{r} = \langle t, 1 + 6t, 1 + 2t\rangle$
51. **a.** $18x - 9y + 2z = 6$ **b.** $x = \frac{1}{3}, y = -\frac{2}{3}, z = 3$
c.

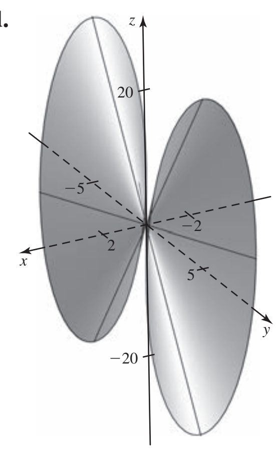


53. $x = t, y = 12 - 9t, z = -6 + 6t$ **55.** $4x + 2y + 13z = 39$
57. $3x + y + 7z = 4$ **59.** 3

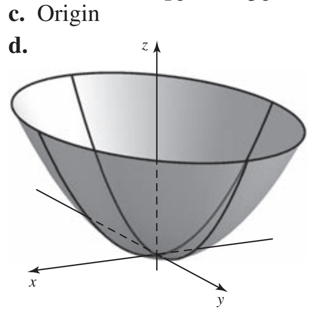
61. **a.** Hyperbolic paraboloid
b. $y^2 = 4x^2, z = \frac{x^2}{36}, z = -\frac{y^2}{144}$
c. $x = y = z = 0$
d.



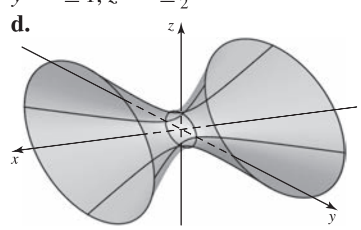
63. **a.** Elliptic cone
b. $y^2 = 4x^2$, origin, $y^2 = \frac{z^2}{25}$
c. Origin
d.



65. **a.** Elliptic paraboloid
b. Origin, $z = \frac{x^2}{16}, z = \frac{y^2}{36}$
c. Origin
d.

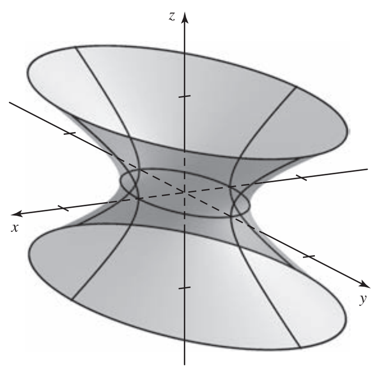


67. **a.** Hyperboloid of one sheet
b. $y^2 - 2x^2 = 1, 4z^2 - 2x^2 = 1, y^2 + 4z^2 = 1$ **c.** No x-intercept, $y = \pm 1, z = \pm\frac{1}{2}$
d.

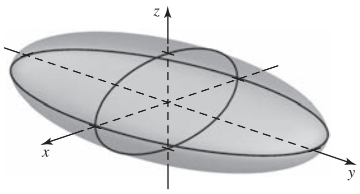


69. **a.** Hyperboloid of one sheet
b. $\frac{x^2}{4} + \frac{y^2}{16} = 4, \frac{x^2}{4} - z^2 = 4, \frac{y^2}{16} - z^2 = 4$
c. $x = \pm 4, y = \pm 8$, no z-intercept

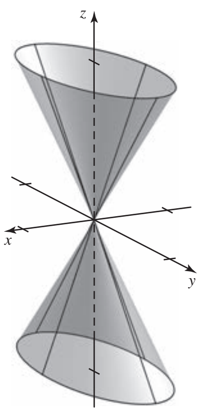
d.



71. a. Ellipsoid **b.** $\frac{x^2}{4} + \frac{y^2}{16} = 4$, $\frac{x^2}{4} + z^2 = 4$, $\frac{y^2}{16} + z^2 = 4$
c. $x = \pm 4, y = \pm 8, z = \pm 2$
d.



73. a. Elliptic cone **b.** Origin, $\frac{x^2}{9} = \frac{z^2}{64}, \frac{y^2}{49} = \frac{z^2}{64}$ **c.** Origin
d.

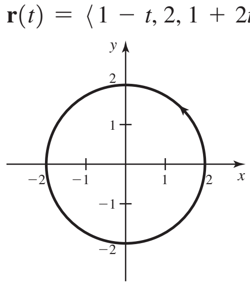


75. a. A **b.** D **c.** C **d.** B

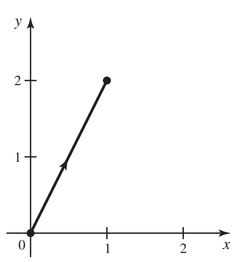
CHAPTER 14

Section 14.1 Exercises, pp. 873–875

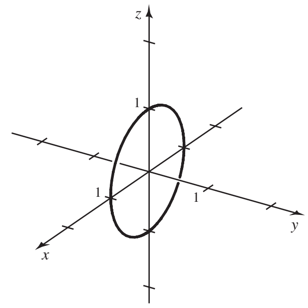
1. One **3.** Its output is a vector.
5. $\lim_{t\to a} \mathbf{r}(t) = \langle \lim_{t\to a} f(t), \lim_{t\to a} g(t), \lim_{t\to a} h(t) \rangle$
7. $\mathbf{r}(t) = t\,\mathbf{i} + 2t\,\mathbf{j} + 3t\,\mathbf{k}$
9. $\mathbf{r}(t) = \langle 2 + 2t, 3 + 3t, 7 - 4t \rangle$
11. $\mathbf{r}(t) = \langle 3 + 2t, 4, 5 - t \rangle$
13. $\mathbf{r}(t) = \langle 1 - t, 2, 1 + 2t \rangle$, for $0 \le t \le 1$
15.



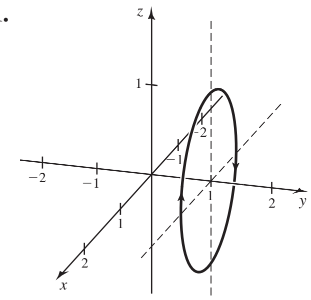
17.



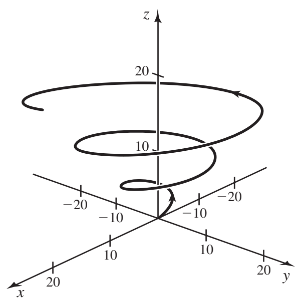
19.



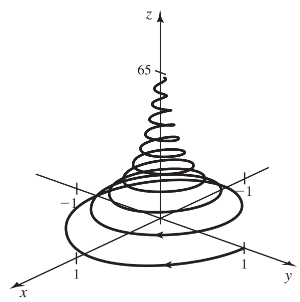
21.



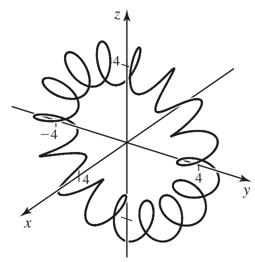
23.



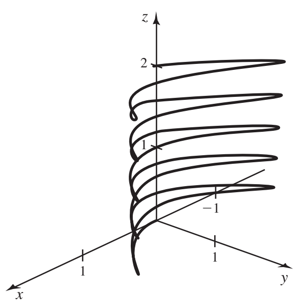
25.



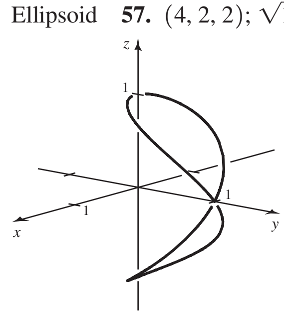
27.



29. When viewed from above, the curve is a portion of the parabola $y = x^2$.



31. $-\mathbf{i} - 4\mathbf{j} + \mathbf{k}$ **33.** $-2\mathbf{j} + \frac{\pi}{2}\mathbf{k}$ **35.** $\mathbf{i}$ **37. a.** True **b.** False
c. True **d.** True **39.** $\{t : |t| \le 2\}$ **41.** $\{t : 0 \le t \le 2\}$
43. $(4, 8, 16)$ **45. a.** E **b.** D **c.** F **d.** C **e.** A **f.** B
47. $\mathbf{r}(t) = \langle 2 \cos t, 2 \sin t, 4 \rangle$
49. $\mathbf{r}(t) = \langle 5 \cos t, 5 \sin t, 10 \cos t + 10 \sin t \rangle$
51. a. Ball has a parabolic trajectory in the *yz*-plane; 1200 ft
b. Approx. 1199.7 ft **c.** 1196 ft **53.** Hyperboloid of one sheet
55. Ellipsoid **57.** $(4, 2, 2)$; $\sqrt{179}$
59.



The curve lies on the sphere $x^2 + y^2 + z^2 = 1$.

61. $\frac{2\pi}{(m, n)}$, where (m, n) = greatest common factor of m and n