9 $\sin\theta\vec{i} + r\cos\theta\vec{j}$

11 $\nabla z = \dfrac{1}{y}\cos\left(\dfrac{x}{y}\right)\vec{i} - \dfrac{x}{y^2}\cos\left(\dfrac{x}{y}\right)\vec{j}$

13 $\left(\dfrac{-12\beta}{(2\alpha - 3\beta)^2}\right)\vec{i} + \left(\dfrac{12\alpha}{(2\alpha - 3\beta)^2}\right)\vec{j}$

15 $60\vec{i} + 85\vec{j}$

17 $10\pi\vec{i} + 4\pi\vec{j}$

19 $(\pi/2)^{1/2}\,\vec{i}$

21 $\frac{1}{100}(2\vec{i} - 6\vec{j})$

23 $-46/5$

25 $22/5$

27 $84/5$

29 $(2x + 3e^y)dx + 3xe^y\,dy$

31 $(x+1)ye^x\vec{i} + xe^x\vec{j}$

33 Negative

35 Positive

37 Positive

39 $-\vec{j}$

41 $\vec{j}$

43 $-\vec{i} - \vec{j}$

45 $\vec{i} - \vec{j}$

47 (a) $(3.96838, 5.09487)$
   (b) 0.1052
   (c) $1/(3\sqrt{10})$

49 4.4

51 (a) $-16\vec{i} + 12\vec{j}$
   (b) $16\vec{i} - 12\vec{j}$
   (c) $12\vec{i} + 16\vec{j}$; answers may vary

53 (a) -3.268
   (b) -4.919

55 (a) Should be number
   (b) $11/5$

57 -0.5; better estimate is -1.35

59 -1.1; better estimate is -1.8

61 $4\vec{i} + 6\vec{j}$; $4(x - 2) + 6(y - 3) = 0$

63 $-4\vec{i} + \vec{j}$; $-4(x - 2) + (y - 3) = 0$

65 (a) Negative
   (b) Negative

67 (a) Negative
   (b) Positive
   (c) Positive
   (d) Negative

69 Yes

71 Yes

73 (a)

(b)
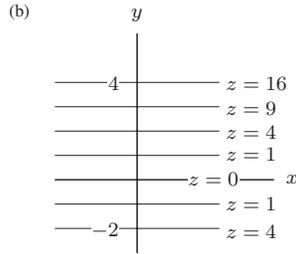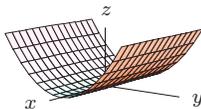
(c) $\vec{j}$

75 (a) Circles centered at P
   (b) away from P
   (c) 1

77 $(3\sqrt{5} - 2\sqrt{2})\vec{i} + (4\sqrt{2} - 3\sqrt{5})\vec{j}$

79 $4\sqrt{2}$,
    $6\vec{i} + 2\vec{j}$

81 $5/\sqrt{2}$

83 (a) P, Q
   (b)
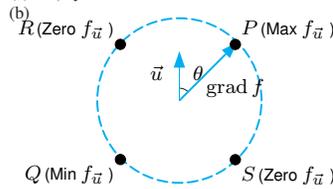
(c) $\|\operatorname{grad} f\|$
     $f_{\vec{u}} = \|\operatorname{grad} f\|\cos\theta$

89 $f_{\vec{u}}(0,0)$ is scalar, not vector

91 Closer contours give longer gradients

93
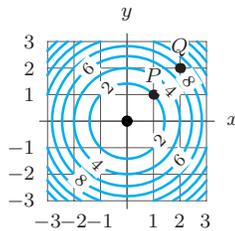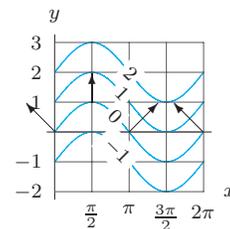

95 False

97 False

99 True

101 False

103 True

105 True

107 True

109 True

111 False

Section 14.5

1 $2x\vec{i}$

3 $e^x e^y e^z (\vec{i} + \vec{j} + \vec{k})$

5 $\dfrac{-2xyz^2}{(1+x^2)^2}\vec{i} + \dfrac{z^2}{1+x^2}\vec{j} + \dfrac{2yz}{1+x^2}\vec{k}$

7 $(x\vec{i} + y\vec{j} + z\vec{k})/\sqrt{x^2 + y^2 + z^2}$

9 $y\vec{i} + x\vec{j} + e^z\cos(e^z)\vec{k}$

11 $e^p\vec{i} + (1/q)\vec{j} + 2re^{r^2}\vec{k}$

13 $\vec{0}$

15 $6\vec{i} + 4\vec{j} - 4\vec{k}$

17 $-\pi\vec{i} - \pi\vec{k}$

19 $9/\sqrt{3}$

21 $-1/\sqrt{2}$

23 $-\sqrt{77/2}$

25 $-2\vec{i} - 2\vec{j} + 4\vec{k}$;
    $-2(x + 1) - 2(y - 1) + 4(z - 2) = 0$

27 $2\vec{j} - 4\vec{k}$; $2(y - 1) - 4(z - 2) = 0$

29 $-2\vec{i} + \vec{k}$; $-2(x + 1) + (z - 2) = 0$

31 (a) 0
   (b) $24/\sqrt{19}$

33 (a) $(2x - yz)\vec{i} + (2y - xz)\vec{j} - xy\vec{k}$
   (b) $x + 4y + 6z = 20$

35 $z = 12 - 4x - 2y$

37 $6(x - 1) + 3(y - 2) + 2(z - 1) = 0$

39 $2x + 3y + 2z = 17$

41 $z = 2x + y + 3$

43 $x + 4y + 10z = 18$

45 (a) is (III); (b) is (I); (c) is (IV); (d) is (II)

47 $22/\sqrt{14}$

49 (a) Spheres centered at the origin
   (b) $2x\sin(x^2 + y^2 + z^2)\vec{i} + 2y\sin(x^2 + y^2 + z^2)\vec{j} + 2z\sin(x^2 + y^2 + z^2)\vec{k}$
   (c) $0, 180°$

51 (a) $-\vec{j}$,
        $\frac{2}{3}\vec{i} - \frac{1}{3}\vec{j} + \frac{2}{3}\vec{k}$
   (b) $y = 0$; $2x - y + 2z = 3$
   (c) $x = y = 0$ and $z \neq 0$

53 (a) $1.2x + 1.6y + 6z = 8$
   (b) Yes; $\pm(0.8, 0.6, 1)$

55 (a)

(b) Valley

57 (a) $-4\vec{i} + 4\vec{j} + 2\vec{k}$
   (b) 24 mg/cm^3/sec

59 $f_{\vec{u}\,3} < f_{\vec{u}\,2} < 0 < f_{\vec{u}\,4} < f_{\vec{u}\,1}$

61 (a) Spheres centered at origin
   (b) $(-2x\vec{i} - 2y\vec{j} - 2z\vec{k})e^{-(x^2+y^2+z^2)}$
   (c) $-3\sqrt{2}e^{-1}$ degrees/sec

63 (a) is (V); (b) is (IV); (c) is (V)

71 $f_x(0,0,0)x + f_y(0,0,0)y + f_z(0,0,0)z = 0$

73 $f(x, y, z) = 2x + 3y + 4z + 100$

75 False

77 False

79 (a) $°$C per meter
   (b) $°$C per second
   (c) $°$C per second

Section 14.6