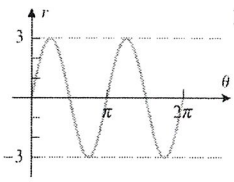
12. (a) $y = -3$ (b) $x^2 + y^2 = 5$
(c) $x^2 + y^2 + 4x = 0$ (d) $x^2(x^2 + y^2) = y^2$

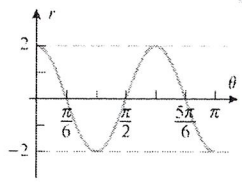
FOCUS ON CONCEPTS

13–16 A graph is given in a rectangular θr-coordinate system. Sketch the corresponding graph in polar coordinates.

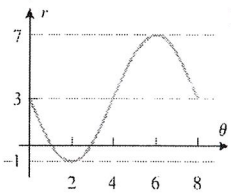
13.



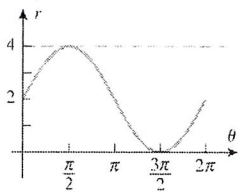
14.



15.

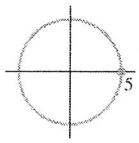


16.



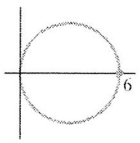
17–20 Find an equation for the given polar graph. [*Note:* Numeric labels on these graphs represent distances to the origin.]

17. (a)



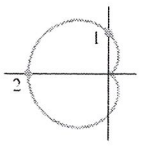
Circle

(b)



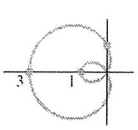
Circle

(c)



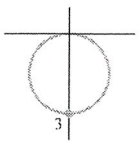
Cardioid

18. (a)



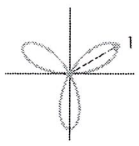
Limaçon

(b)



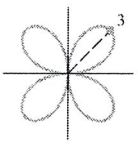
Circle

(c)



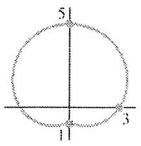
Three-petal rose

19. (a)



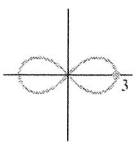
Four-petal rose

(b)



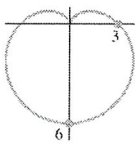
Limaçon

(c)



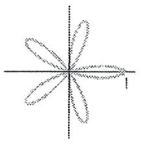
Lemniscate

20. (a)



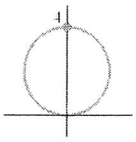
Cardioid

(b)



Five-petal rose

(c)



Circle

21–46 Sketch the curve in polar coordinates.

21. $\theta = \dfrac{\pi}{3}$ **22.** $\theta = -\dfrac{3\pi}{4}$ **23.** $r = 3$

24. $r = 4\cos\theta$ **25.** $r = 6\sin\theta$ **26.** $r - 2 = 2\cos\theta$

27. $r = 3(1 + \sin\theta)$ **28.** $r = 5 - 5\sin\theta$

29. $r = 4 - 4\cos\theta$ **30.** $r = 1 + 2\sin\theta$

31. $r = -1 - \cos\theta$ **32.** $r = 4 + 3\cos\theta$

33. $r = 3 - \sin\theta$ **34.** $r = 3 + 4\cos\theta$

35. $r - 5 = 3\sin\theta$ **36.** $r = 5 - 2\cos\theta$

37. $r = -3 - 4\sin\theta$ **38.** $r^2 = \cos 2\theta$

39. $r^2 = 16\sin 2\theta$ **40.** $r = 4\theta \quad (\theta \geq 0)$

41. $r = 4\theta \quad (\theta \leq 0)$ **42.** $r = 4\theta$

43. $r = -2\cos 2\theta$ **44.** $r = 3\sin 2\theta$

45. $r = 9\sin 4\theta$ **46.** $r = 2\cos 3\theta$

47–50 True–False Determine whether the statement is true or false. Explain your answer.

47. The polar coordinate pairs $(-1, \pi/3)$ and $(1, -2\pi/3)$ describe the same point.

48. If the graph of $r = f(\theta)$ drawn in rectangular θr-coordinates is symmetric about the r-axis, then the graph of $r = f(\theta)$ drawn in polar coordinates is symmetric about the x-axis.

49. The portion of the polar graph of $r = \sin 2\theta$ for values of θ between $\pi/2$ and π is contained in the second quadrant.

50. The graph of a dimpled limaçon passes through the polar origin.

51–55 Determine a shortest parameter interval on which a complete graph of the polar equation can be generated, and then use a graphing utility to generate the polar graph.

51. $r = \cos\dfrac{\theta}{2}$ **52.** $r = \sin\dfrac{\theta}{2}$

53. $r = 1 - 2\sin\dfrac{\theta}{4}$ **54.** $r = 0.5 + \cos\dfrac{\theta}{3}$

55. $r = \cos\dfrac{\theta}{5}$

56. The accompanying figure shows the graph of the "butterfly curve"

$$r = e^{\cos\theta} - 2\cos 4\theta + \sin^3\frac{\theta}{4}$$

Determine a shortest parameter interval on which the complete butterfly can be generated, and then check your answer using a graphing utility.

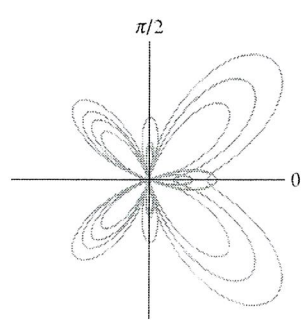


Figure Ex-56