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1. **(a)** shifted up two units
(b) two cycles of the graph where $y = \sin\theta$ has one
(c) vertically stretched by factor of 2
(d) vertically stretched by factor of 2, reflected in θ-axis

2. **(a)** vertical compression by factor of $\frac{1}{2}$
(b) horizontal expansion by factor of 2
(c) vertical shift upward by $\frac{1}{2}$
(d) vertical compression by factor of $\frac{1}{2}$ and reflection about θ-axis

3. **(a)** 120° **(b)** 1440° **(c)** 60°
(d) 72° **(e)** 240° **(f)** 1080°
(g) 90° **(h)** 360° **(i)** 540°

4. **(a)** $\frac{\pi}{2}$ **(b)** $\frac{\pi}{3}$ **(c)** $\frac{6\pi}{5}$
(d) 1 **(e)** 5π **(f)** 3π
(g) $\frac{\pi}{3}$ **(h)** $\frac{3\pi}{2}$

5. **(a)** ii **(b)** iii **(c)** i

6. **(a)** ii **(b)** iii **(c)** i

7. **(a)** 3, 180°, 30°, 1 **(b)** 5, 120°, −15°, −2
(c) 2, 1080°, −45°, 2 **(d)** $\frac{1}{2}$, 720°, 15°, −3
(e) $-4, \frac{\pi}{3}, -\frac{\pi}{18}, 1$ **(f)** $3, \frac{\pi}{2}, \frac{\pi}{2}, 2$

8. **(a)** zeros: none, min. at (90°, 1), max. at (270°, 3), axis of symmetry at $y = 2$
(b) zeros: none, min. at (270°, −2.5), max. at (90°, −1.5), axis of symmetry at $y = -2$
(c) zeros: 0 and 360°, min. at (180°, −2), axis of symmetry at $y = 0$

9. **(a)** zeros: none, min. at (0, 1) and (2π, 1), max. at (π, 3), axis of symmetry at $y = 2$
(b) zeros: none, min. at (π, −2.5), max. at (0, −1.5) and (2π, −1.5), axis of symmetry at $y = -2$
(c) zeros: π, min. at (0, −2), max. at (0, 2), axis of symmetry at $y = 0$

10. **(a)** zeros: 0, 180°, 360°, asymptotes at 90° and 270° (standard tangent curve reflected in x-axis)
(b) zeros: 0, 90°, 180°, 270°, 360°, asymptotes at 45°, 135°, 225°, and 315°
(c) zeros: 270°, y-intercept: 1, asymptotes: 180°

11. **(a)** −2.5 **(b)** −1.0 **(c)** 0.0 **(d)** −1.0

12. **(a)** −1.0 **(b)** −1.0 **(c)** −3.0 **(d)** −2.4

13. **(a)** −1.5 **(b)** −3.0 **(c)** 6.5 **(d)** 21.9

14. **(a)** alike: both sinusoidal, have 360° period, amplitude of 1, maximum value of 1, and minimum value of −1; the axis of each curve is $y = 0$. Different: they appear to start at different places.
(b) $\sin\theta = \cos\left(\theta - \frac{\pi}{2}\right)$ **(c)** $\cos\theta = \sin\left(\theta + \frac{\pi}{2}\right)$

15. zeros: $\frac{\pi}{4}, \frac{5\pi}{4}$, min. $\left(\frac{7\pi}{4}, -2\right)$, max. $\left(\frac{3\pi}{4}, 2\right)$, axis of symmetry $y = 0$, y-intercept −1

16. $y = 2\sin 3\left(\theta - \frac{\pi}{2}\right) - 2$

17. $y = -3\cos\frac{1}{2}\left(\theta + \frac{2\pi}{3}\right) + 1$

18. **(a)** axis of symmetry $y = 1$, min. (−195°, −2), (−15°, −2), (165°, −2), (345°, −2), max. (−285°, 4), (−105°, 4), (75°, 4), (255°, 4), passing through points (x, 1) where x = 330°, −240°, −150°, −60°, 30°, 120°, 210°, 300°
(b) axis of symmetry $y = -2$, min. (−315°, −7), (−195°, −7), (−−75°, −7), (45°, −7), (165°, −7), (285°, −7), max. (−255°, 3), (−135°, 3), (−15°, 3), (105°, 3), (225°, 3), (345°, 3), passing through points (x, −2) where x = −345°, −285°,−225°, −165, −105°, −45°, 15°, 75°, 135°, 195°, 255°, 315°
(c) axis of symmetry $y = 2$, min. (225°, 0), max. (−315°, 4), y-intercept 1.5
(d) axis of symmetry $y = -3$, min. (−345°, 0), max. (15°, −2.5), passing through (180°, −3) and (−180°, −3)

19. **(a)** axis of symmetry $y = 1$, min. $\left(\frac{5\pi}{18}, -3\right), \left(\frac{11\pi}{18}, -3\right), \left(\frac{17\pi}{18}, -3\right), \left(\frac{23\pi}{18}, -3\right), \left(\frac{29\pi}{18}, -3\right), \left(\frac{35\pi}{18}, -3\right)$, max. $\left(\frac{\pi}{9}, 5\right), \left(\frac{4\pi}{9}, 5\right), \left(\frac{7\pi}{9}, 5\right), \left(\frac{10\pi}{9}, 5\right), \left(\frac{13\pi}{9}, 5\right), \left(\frac{16\pi}{9}, 5\right)$
(b) axis of symmetry $y = 2$, min. $\left(\frac{3\pi}{8}, -1\right), \left(\frac{7\pi}{8}, -1\right), \left(\frac{11\pi}{8}, -1\right), \left(\frac{15\pi}{4}, -1\right)$, max. $\left(\frac{\pi}{8}, 5\right), \left(\frac{5\pi}{8}, 5\right), \left(\frac{9\pi}{8}, 5\right), \left(\frac{13\pi}{8}, 5\right)$

20. $\cos\theta$: stretched vertically by factor of 3, reflected in x-axis, moved up one unit on the y-axis, horizontally shifted $\frac{\pi}{8}$ units right, period: 180°; $\sin\theta$: vertically stretched by factor of 3, reflected in x-axis, moved up one unit on y-axis, period: 180°, horizontal phase shift of $\frac{\pi}{4}$ units right

21. **(a)** period: $\frac{6}{5}$, represents the time between one beat of a person's heart and the next beat
(b) 50 beats/min
(c) axis of symmetry $p(t) = 100$ mm, min. (0, 80), $\left(\frac{6}{5}, 80\right), \left(\frac{12}{5}, 80\right), \left(\frac{18}{5}, 80\right), \left(\frac{24}{5}, 80\right)$, (6, 80), max. $\left(\frac{3}{5}, 120\right), \left(\frac{9}{5}, 120\right)$, (3, 120), $\left(\frac{21}{5}, 120\right), \left(\frac{27}{5}, 120\right)$
(d) range: $80 \le P(t) \le 120$; lowest blood pressure is 80 and the highest blood pressure is 120

22. **(a)** (t, T) = (0, 32), (1, 28.9), (2, 20.5), (3, 9), (4, −2.5), (5, −10.9), (6, −14), (7, −10.9), (8, −2.5), (9, 9), (10, 20.5), (11, 28.9), (12, 32), (13, 28.9)
(b) Plot the points in (a). Let x-axis represent time and y-axis represent temperature. axis of symmetry $T = 9$, min. (6, −14), max. (0, 32) and (12, 32)
(c) maximum = axis + amplitude, minimum = axis − amplitude
(d) 12
(e) stretch vertically by factor of 23, vertical shift: 9 units up, period: 12, maximum: 32°, minimum: −14°

23. **(a)** The number of hours of daylight increases to a maximum and decreases to a minimum in a regular cycle as the Earth revolves around the sun.
(b) Mar. 21: 12 h, Sept. 21: 12 h, spring and fall equinox
(c) The sine function is shifted right 80 days.
(d) June 21: 16 h, Dec. 21: 8 h, longest and shortest day of year
(e) 12 is the axis of the curve representing half the distance between the maximum and minimum hours of daylight.
(f) Let x-axis represent the day of the year and y-axis represent the number of hours of daylight. axis of symmetry $D(t) = 12$, min. (0, 8) and (360, 8), max. (182.5, 16)
(g) maximum: 16 h in late June, minimum: 8 h in late Dec. or early Jan.

(h) Mar. 21, Sept. 21

24. **(a)** Feb. 8: $-10.5°$, May 15: 22.3°

(b) Let the x-axis represent the day of the year and the y-axis represent the angle of the sunset. axis of symmetry $P(t) = 0°$, min. $(0, -28°)$ and $(365, -28°)$, max. $(180, 28°)$

(c) maximum: 28°, minimum: $-28°$

(d) 365; 365 days in a year

(e) horizontal shift to the right 81 days, representing the spring equinox around June 22

25. **(a)** a: vertical stretch by factor of a, b: horizontal phase shift by b units, shift left for $b < 0$, shift right for $b > 0$, k: horizontal stretch by factor of $\frac{1}{k}$, d: vertical translation of d units, shift up $d > 0$, shift down $d < 0$

(b) Use sketch of $y = \sin\theta$ as starting graph. Horizontally compress by factor of $\frac{1}{2}$, shift left 45°, vertically expand by factor of 3, and shift vertically up 1.

(c) axis of symmetry $y = 1$, min. $(90°, -2)$ and $(270°, -2)$, max. $(0°, 4)$ and $(180°, 4)$ and $(360°, 4)$

26. Use graphing calculator to graph both graphs. When the rabbit population is high, the fox population increases causing a decrease in the rabbit population. The decrease in rabbits causes a corresponding decrease in fox. As the number of fox decrease there is a corresponding increase in the number of rabbits. This starts the cycle over again.