

Roots Of Unity Answers

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Answer 1 (3)

Find all the cube roots of unity ($z^3 = 1$).

Step 1. General formula for n th roots of unity:

$$z_k = e^{2\pi i k/n}, \quad k = 0, 1, \dots, n-1$$

Step 2. For $n = 3$:

$$z_0 = e^{2\pi i \cdot 0/3} = 1$$

$$z_1 = e^{2\pi i \cdot 1/3} = \cos \frac{2\pi}{3} + i \sin \frac{2\pi}{3} = -\frac{1}{2} + \frac{\sqrt{3}}{2}i$$

$$z_2 = e^{2\pi i \cdot 2/3} = \cos \frac{4\pi}{3} + i \sin \frac{4\pi}{3} = -\frac{1}{2} - \frac{\sqrt{3}}{2}i$$

$$z = 1, -\frac{1}{2} + \frac{\sqrt{3}}{2}i, -\frac{1}{2} - \frac{\sqrt{3}}{2}i$$

Answer 2 (3)

Find all the fourth roots of unity ($z^4 = 1$).

Step 1. Using $z_k = e^{2\pi i k/4}$, $k = 0, 1, 2, 3$:

$$z_0 = e^0 = 1$$

$$z_1 = e^{2\pi i/4} = e^{i\pi/2} = i$$

$$z_2 = e^{4\pi i/4} = e^{i\pi} = -1$$

$$z_3 = e^{6\pi i/4} = e^{3i\pi/2} = -i$$

Step 2. Plot on the complex plane: The points are on the unit circle at $0^\circ, 90^\circ, 180^\circ, 270^\circ$.

$$\boxed{z = 1, i, -1, -i}$$

Answer 3 (4)

Find all the sixth roots of unity ($z^6 = 1$).

Step 1. Use the general formula:

$$z_k = e^{2\pi i k/6}, \quad k = 0, 1, 2, 3, 4, 5$$

Step 2. Compute each root:

$$z_0 = e^0 = 1$$

$$z_1 = e^{i\pi/3} = \frac{1}{2} + \frac{\sqrt{3}}{2}i$$

$$z_2 = e^{i2\pi/3} = -\frac{1}{2} + \frac{\sqrt{3}}{2}i$$

$$z_3 = e^{i\pi} = -1$$

$$z_4 = e^{i4\pi/3} = -\frac{1}{2} - \frac{\sqrt{3}}{2}i$$

$$z_5 = e^{i5\pi/3} = \frac{1}{2} - \frac{\sqrt{3}}{2}i$$

$z = 1, \frac{1}{2} + \frac{\sqrt{3}}{2}i, -\frac{1}{2} + \frac{\sqrt{3}}{2}i, -1, -\frac{1}{2} - \frac{\sqrt{3}}{2}i, \frac{1}{2} - \frac{\sqrt{3}}{2}i$

Answer 4 (4)

Show that the sum of all fifth roots of unity ($z^5 = 1$) is zero.

Step 1. Let $z_k = e^{2\pi i k/5}$, $k = 0, 1, 2, 3, 4$.

Step 2. The sum:

$$\sum_{k=0}^4 z_k = 1 + e^{2\pi i/5} + e^{4\pi i/5} + e^{6\pi i/5} + e^{8\pi i/5}$$

Step 3. This is a geometric series with ratio $r = e^{2\pi i/5}$, number of terms $n = 5$:

$$\sum_{k=0}^4 z_k = \frac{1 - r^5}{1 - r} = \frac{1 - 1}{1 - r} = 0$$

$$\boxed{\sum_{k=0}^4 z_k = 0}$$

Answer 5 (5)

If z is a seventh root of unity ($z^7 = 1$), find the value of

$$1 + z + z^2 + \cdots + z^6$$

Step 1. Recognize the geometric series:

$$S = 1 + z + z^2 + \cdots + z^6$$

Step 2. Sum of geometric series:

$$S = \frac{1 - z^7}{1 - z} = \frac{1 - 1}{1 - z} = 0$$

$$\boxed{1 + z + z^2 + \cdots + z^6 = 0}$$

Answer 6 (4)

If z is a sixth root of unity ($z^6 = 1$), compute the value of

$$z + z^2 + z^4$$

Step 1. The sixth roots of unity are

$$z_k = e^{2\pi i k/6}, \quad k = 0, 1, 2, 3, 4, 5$$

Step 2. Use symmetry and pairing of roots:

$$z + z^2 + z^4 = z_1 + z_2 + z_4$$

Step 3. Sum the roots using their exponential forms:

$$z_1 = e^{i\pi/3}, \quad z_2 = e^{2i\pi/3}, \quad z_4 = e^{4i\pi/3}$$

Step 4. Convert to rectangular form and sum:

$$z_1 + z_2 + z_4 = \left(\frac{1}{2} + \frac{\sqrt{3}}{2}i\right) + \left(-\frac{1}{2} + \frac{\sqrt{3}}{2}i\right) + \left(-\frac{1}{2} - \frac{\sqrt{3}}{2}i\right) = -\frac{1}{2} + \frac{\sqrt{3}}{2}i$$

$$\boxed{z + z^2 + z^4 = -\frac{1}{2} + \frac{\sqrt{3}}{2}i}$$

Answer 7 (4)

If z is a seventh root of unity ($z^7 = 1$), compute

$$\prod_{k=1}^6 (1 - z^k)$$

Step 1. Factorization of $z^7 - 1$:

$$z^7 - 1 = (z - 1)(1 - z)(1 - z^2)(1 - z^3) \dots (1 - z^6)$$

Step 2. Set $z = 1$:

$$1^7 - 1 = 0 = (1 - 1) \prod_{k=1}^6 (1 - z^k)$$

Step 3. Compute the product using known formula:

$$\prod_{k=1}^6 (1 - z^k) = 7$$

$$\prod_{k=1}^6 (1 - z^k) = 7$$

Answer 8 (5)

Let z_1, z_2, z_3, z_4 be the fourth roots of unity. Compute

$$z_1^2 + z_2^2 + z_3^2 + z_4^2$$

Step 1. Fourth roots of unity:

$$z_0 = 1, \quad z_1 = i, \quad z_2 = -1, \quad z_3 = -i$$

Step 2. Square each root:

$$z_0^2 = 1, \quad z_1^2 = i^2 = -1, \quad z_2^2 = (-1)^2 = 1, \quad z_3^2 = (-i)^2 = -1$$

Step 3. Sum the squares:

$$z_0^2 + z_1^2 + z_2^2 + z_3^2 = 1 + (-1) + 1 + (-1) = 0$$

$$\boxed{z_1^2 + z_2^2 + z_3^2 + z_4^2 = 0}$$

Answer 9 (5)

If z is a fifth root of unity ($z^5 = 1$), show that

$$1 + z^2 + z^4 + z^6 + z^8 = 0$$

Step 1. Reduce powers modulo 5:

$$z^5 = 1 \implies z^6 = z, \quad z^8 = z^3$$

Step 2. Rewrite the sum:

$$1 + z^2 + z^4 + z^6 + z^8 = 1 + z^2 + z^4 + z + z^3 = 1 + z + z^2 + z^3 + z^4$$

Step 3. Sum of all fifth roots of unity:

$$1 + z + z^2 + z^3 + z^4 = 0$$

$$\boxed{1 + z^2 + z^4 + z^6 + z^8 = 0}$$

Answer 10 (5)

If z is an eighth root of unity ($z^8 = 1$), compute the sum

$$S = 1 + z + z^3 + z^5 + z^7$$

Step 1. Factor out geometric series:

$$S = 1 + z + z^3 + z^5 + z^7 = (1 + z^4) + z(1 + z^4) + z^3(1 + z^4)$$

Step 2. Note $z^4 = -1$:

$$1 + z^4 = 1 + (-1) = 0$$

Step 3. Multiply terms by 0:

$$S = 0 + 0 + 0 = 0$$

$$\boxed{S = 0}$$

Answer 11 (3)

Point $P(\sqrt{3}, 1)$ is one vertex of an equilateral triangle centered at $(0, 0)$.

Step 1. Rotate P by 120° and 240° about the origin. Use rotation formula:

$$(x', y') = (x \cos \theta - y \sin \theta, x \sin \theta + y \cos \theta)$$

Step 2. Rotate by $120^\circ = 2\pi/3$:

$$x' = \sqrt{3} \cos \frac{2\pi}{3} - 1 \sin \frac{2\pi}{3} = -2, \quad y' = \sqrt{3} \sin \frac{2\pi}{3} + 1 \cos \frac{2\pi}{3} = 0$$

Step 3. Rotate by $240^\circ = 4\pi/3$:

$$x'' = \sqrt{3} \cos \frac{4\pi}{3} - 1 \sin \frac{4\pi}{3} = 1, \quad y'' = \sqrt{3} \sin \frac{4\pi}{3} + 1 \cos \frac{4\pi}{3} = -\sqrt{3}$$

Other vertices: $(-2, 0)$ and $(1, -\sqrt{3})$

Answer 12 (3)

Square centered at origin with one vertex $(2, 0)$.

Step 1. Distance from origin: $r = 2$. The square has vertices at angles $0^\circ, 90^\circ, 180^\circ, 270^\circ$.

Step 2. Convert to coordinates:

$$(2, 0), (0, 2), (-2, 0), (0, -2)$$

Vertices: $(2, 0), (0, 2), (-2, 0), (0, -2)$
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Answer 13 (4)

Rotate point $A(1, 0)$ by 120° counterclockwise.

Step 1. Rotation formula:

$$(x', y') = (x \cos \theta - y \sin \theta, x \sin \theta + y \cos \theta)$$

Step 2. Compute:

$$x' = 1 \cdot \cos 120^\circ - 0 \cdot \sin 120^\circ = -\frac{1}{2}, \quad y' = 1 \cdot \sin 120^\circ + 0 \cdot \cos 120^\circ = \frac{\sqrt{3}}{2}$$

Rotated point: $\left(-\frac{1}{2}, \frac{\sqrt{3}}{2}\right)$
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Answer 14 (4)

Square with vertices $A(1, 2)$ and $B(3, 4)$.

Step 1. Vector from A to B :

$$\vec{AB} = (3 - 1, 4 - 2) = (2, 2)$$

Step 2. Perpendicular vector for square sides:

$$\vec{AD} = (-2, 2), \quad \vec{BC} = (-2, 2)$$

Step 3. Remaining vertices:

$$D = A + \vec{AD} = (1 - 2, 2 + 2) = (-1, 4)$$

$$C = B + \vec{BC} = (3 - 2, 4 + 2) = (1, 6)$$

Other vertices: $C(1, 6), D(-1, 4)$

Answer 15 (4)

Regular hexagon with vertex $P(1, \sqrt{3})$, center at origin.

Step 1. Distance from center: $r = \sqrt{1^2 + (\sqrt{3})^2} = 2$

Step 2. Hexagon vertices at angles $\theta + k \cdot 60^\circ$, $k = 0..5$.

Step 3. Compute coordinates (rotating 60° each step):

$$(1, \sqrt{3}), (-1, \sqrt{3}), (-2, 0), (-1, -\sqrt{3}), (1, -\sqrt{3}), (2, 0)$$

Remaining vertices: $(-1, \sqrt{3}), (-2, 0), (-1, -\sqrt{3}), (1, -\sqrt{3}), (2, 0)$
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Answer 16 (5)

Triangle ABC with centroid at origin. $A(3, 1)$, $B(-1, 2)$, find C .

Step 1. Centroid formula:

$$G = \frac{A + B + C}{3} = (0, 0) \implies C = -(A + B)$$

Step 2. Compute:

$$C = -((3, 1) + (-1, 2)) = -(2, 3) = (-2, -3)$$

$$\boxed{C = (-2, -3)}$$

Answer 17 (5)

Regular pentagon, center at origin, vertex $P(2, 0)$.

Step 1. Pentagon vertices at angles $\theta + k \cdot 72^\circ$, $k = 0..4$.

Step 2. Compute coordinates:

$$(2, 0), (2 \cos 72^\circ, 2 \sin 72^\circ), (2 \cos 144^\circ, 2 \sin 144^\circ), \\ (2 \cos 216^\circ, 2 \sin 216^\circ), (2 \cos 288^\circ, 2 \sin 288^\circ)$$

Step 3. Approximate decimal values:

$$(2, 0), (0.618, 1.902), (-1.618, 1.176), (-1.618, -1.176), (0.618, -1.902)$$

Remaining vertices as above

Answer 18 (5)

Rotate triangle $A(0,0), B(2,0), C(1,\sqrt{3})$ 60° counterclockwise.

Step 1. Rotation formula:

$$(x', y') = (x \cos 60^\circ - y \sin 60^\circ, x \sin 60^\circ + y \cos 60^\circ)$$

Step 2. Compute each vertex:

$$A' = (0, 0)$$

$$B' = (2 \cdot 0.5 - 0 \cdot \sqrt{3}/2, 2 \cdot \sqrt{3}/2 + 0 \cdot 0.5) = (1, \sqrt{3})$$

$$C' = (1 \cdot 0.5 - \sqrt{3} \cdot \sqrt{3}/2, 1 \cdot \sqrt{3}/2 + \sqrt{3} \cdot 0.5) = (-1, \sqrt{3})$$

$$\boxed{A'(0,0), B'(1, \sqrt{3}), C'(-1, \sqrt{3})}$$

Answer 19 (5)

Square with vertices $A(1, 0)$, $B(0, 1)$, $C(-1, 0)$. Find the fourth vertex D .

Step 1. Diagonal intersection: midpoint of $AC = ((1 + -1)/2, (0 + 0)/2) = (0, 0)$

Step 2. Find D opposite B using midpoint formula:

$$\text{Midpoint of } B \text{ and } D = (0, 0) \implies D = 2 \cdot (0, 0) - B = -B = (0, -1)$$

$$\boxed{D = (0, -1)}$$

Answer 20 (5)

Regular octagon, center at origin, vertex $(1, 0)$.

Step 1. Vertices at angles $k \cdot 45^\circ$, $k = 0..7$, radius $r = 1$

Step 2. Coordinates:

$$(1, 0), (\sqrt{2}/2, \sqrt{2}/2), (0, 1), (-\sqrt{2}/2, \sqrt{2}/2), \\ (-1, 0), (-\sqrt{2}/2, -\sqrt{2}/2), (0, -1), (\sqrt{2}/2, -\sqrt{2}/2)$$

Remaining vertices as above
