Single-Phase Power Calculations

100 Questions & Answers | Real Power · Reactive Power · Apparent Power · Complex Power · Power Factor

1. What is real power (P) in a single-phase AC circuit?

Answer: Real power (P) is the actual power consumed by the resistive components of a circuit, measured in watts (W). It represents the energy dissipated as heat or work per unit time. $P = V \cdot I \cdot \cos(\phi)$, where ϕ is the phase angle between voltage and current.

2. What is reactive power (Q) in a single-phase AC circuit?

Answer: Reactive power (Q) is the power exchanged between the source and the reactive elements (inductors and capacitors) of a circuit, measured in volt-amperes reactive (VAR). It does no useful work but is necessary to maintain the electromagnetic fields. $Q = V \cdot I \cdot \sin(\phi)$.

3. What is apparent power (S) in a single-phase AC circuit?

Answer: Apparent power (S) is the total power supplied by the source to the circuit, measured in volt-amperes (VA). It is the product of the RMS voltage and RMS current without considering the phase angle. $S = V \cdot I$.

4. What is complex power in a single-phase AC circuit?

Answer: Complex power S is the phasor quantity $S = P + jQ$, where P is real power and Q is reactive power. Its magnitude is the apparent power $|S| = \sqrt{P^2 + Q^2}$, and its angle is the power factor angle $\phi = \arctan(Q/P)$.

5. What is the power factor (PF) of a single-phase circuit?

Answer: Power factor (PF) is the ratio of real power to apparent power: $PF = P/S = \cos(\phi)$, where ϕ is the phase angle between voltage and current. It ranges from 0 to 1 and indicates how effectively the circuit converts apparent power into real power.

6. What are the units of real power, reactive power, apparent power, and complex power?

Answer: Real power P is measured in watts (W); reactive power Q in volt-amperes reactive (VAR); apparent power S in volt-amperes (VA); and complex power S is dimensionally in VA but expressed as a complex number $P + jQ$.

7. What is the relationship between P, Q, and S?

Answer: $S^2 = P^2 + Q^2$, so $|S| = \sqrt{P^2 + Q^2}$. This forms the 'power triangle' where S is the hypotenuse, P is the adjacent side, and Q is the opposite side relative to the power factor angle ϕ.

8. A single-phase circuit has V = 230 V (RMS) and I = 10 A (RMS) with a phase angle of 30°. Calculate P, Q, and S.

Answer: $S = V \cdot I = 230 \times 10 = 2300$ VA; $P = S \cdot \cos(30°) = 2300 \times 0.866 = 1991.8$ W; $Q = S \cdot \sin(30°) = 2300 \times 0.5 = 1150$ VAR.

9. Define lagging power factor.

Answer: A lagging power factor occurs when the current lags behind the voltage in phase, which is the case in inductive circuits. The phase angle ϕ is positive (current lags voltage), and Q is positive (inductive reactive power).

10. Define leading power factor.

Answer: A leading power factor occurs when the current leads the voltage in phase, characteristic of capacitive circuits. The phase angle ϕ is negative (current leads voltage), and Q is negative (capacitive reactive power).

11. Write the formula for real power in terms of resistance R and current I.

Answer: $P = I^2 \cdot R$, where I is the RMS current and R is the resistance. Equivalently, $P = V^2R/|Z|^2$ when the voltage across the impedance is known, but $P = I^2R$ is the simplest direct form.

12. Write the formula for reactive power in terms of reactance X and current I.

Answer: $Q = I^2 \cdot X$, where I is the RMS current and X is the net reactance ($X = X_L - X_C$). Positive X gives positive (inductive) Q; negative X gives negative (capacitive) Q.

13. How is apparent power expressed in terms of complex voltage and current phasors?

Answer: $S = V \cdot I^*$ (complex power), where V is the phasor voltage and I^* is the complex conjugate of the phasor current. The real part of S gives P and the imaginary part gives Q.

14. A resistor of 50 Ω carries a current of 4 A RMS. Find its real power.

Answer: $P = I^2 \cdot R = 4^2 \times 50 = 16 \times 50 = 800$ W. Since a pure resistor has no reactance, Q = 0 and S = 800 VA.

15. An inductor of reactance XL = 30 Ω carries 5 A RMS. Find its reactive power.

Answer: $Q = I^2 \cdot X_L = 5^2 \times 30 = 25 \times 30 = 750$ VAR (inductive, positive). The real power P = 0 since an ideal inductor has no resistance.

16. A capacitor of reactance XC = 20 Ω carries 3 A RMS. Find its reactive power.

Answer: $Q = -I^2 \cdot X_C = -3^2 \times 20 = -9 \times 20 = -180$ VAR (capacitive, negative). The real power P = 0 since an ideal capacitor has no resistance.

17. A single-phase load draws P = 3000 W at a power factor of 0.75 lagging. Find S and Q.

Answer: $S = P/PF = 3000/0.75 = 4000$ VA; $Q = \sqrt{S^2 - P^2} = \sqrt{4000^2 - 3000^2} = \sqrt{16{,}000{,}000 - 9{,}000{,}000} = \sqrt{7{,}000{,}000} \approx 2645.8$ VAR (lagging).

18. A load has S = 5000 VA and Q = 3000 VAR (inductive). Find P and PF.

Answer: $P = \sqrt{S^2 - Q^2} = \sqrt{5000^2 - 3000^2} = \sqrt{25{,}000{,}000 - 9{,}000{,}000} = \sqrt{16{,}000{,}000} = 4000$ W; $PF = P/S = 4000/5000 = 0.8$ lagging.

19. What is unity power factor and when does it occur?

Answer: Unity power factor (PF = 1) occurs when the phase angle $\phi = 0°$, meaning voltage and current are in phase. This happens in purely resistive circuits where P = S and Q = 0.

20. What is zero power factor and what does it indicate?

Answer: Zero power factor (PF = 0) occurs when $\phi = \pm 90°$, meaning all power is reactive (Q = S) and P = 0. This is the case for purely inductive or capacitive loads, which store and release energy without consuming any real power.

21. Express complex power S in terms of impedance Z and current I.

Answer: $S = I^2 \cdot Z^*$ (using complex conjugate of impedance). If $Z = R + jX$, then $S = I^2(R - jX)$, giving $P = I^2R$ and $Q = -I^2X$. Alternatively, $S = |I|^2 Z^*$ where $Z^* = R - jX$.

22. A series RL circuit has R = 6 Ω and XL = 8 Ω connected to 120 V RMS. Calculate I, P, Q, S, and PF.

Answer: $|Z| = \sqrt{6^2 + 8^2} = \sqrt{36+64} = \sqrt{100} = 10$ Ω; $I = 120/10 = 12$ A; $P = I^2R = 144 \times 6 = 864$ W; $Q = I^2X_L = 144 \times 8 = 1152$ VAR; $S = V \cdot I = 120 \times 12 = 1440$ VA; $PF = P/S = 864/1440 = 0.6$ lagging.

23. A series RC circuit has R = 8 Ω and XC = 6 Ω connected to 100 V RMS. Find P, Q, S, and PF.

Answer: $|Z| = \sqrt{8^2+6^2} = 10$ Ω; $I = 100/10 = 10$ A; $P = 10^2 \times 8 = 800$ W; $Q = -10^2 \times 6 = -600$ VAR; $S = 100 \times 10 = 1000$ VA; $PF = 800/1000 = 0.8$ leading.

24. What is the power angle (ϕ) and how is it related to power factor?

Answer: The power angle ϕ is the phase difference between the voltage phasor and the current phasor. Power factor $PF = \cos(\phi)$. For a lagging load, $\phi > 0°$; for a leading load, $\phi < 0°$; for unity PF, $\phi = 0°$.

25. Two loads in parallel: Load A draws 1000 W at 0.8 PF lagging; Load B draws 2000 W at 0.6 PF leading. Find total P, Q, and S.

Answer: Load A: $S_A = 1000/0.8 = 1250$ VA, $Q_A = +\sqrt{1250^2 - 1000^2} = +750$ VAR; Load B: $S_B = 2000/0.6 = 3333.3$ VA, $Q_B = -\sqrt{3333.3^2 - 2000^2} = -2666.7$ VAR; Total: P = 3000 W, $Q = 750 - 2666.7 = -1916.7$ VAR; $S = \sqrt{3000^2 + 1916.7^2} \approx 3558$ VA; $PF = 3000/3558 \approx 0.843$ leading.

26. How does adding an inductive load affect the overall power factor?

Answer: Adding an inductive load increases the total inductive reactive power Q (making it more positive), which increases the phase angle ϕ and decreases the overall power factor toward lagging values (PF moves away from unity in the lagging direction).

27. How does adding a capacitive load affect the overall power factor?

Answer: Adding a capacitive load introduces negative reactive power Q, which partially offsets inductive Q, reducing the net phase angle and moving the power factor toward unity or into the leading region.

28. A 240 V RMS source supplies a load. The ammeter reads 15 A and the wattmeter reads 2700 W. Find PF, Q, and S.

Answer: $S = V \cdot I = 240 \times 15 = 3600$ VA; $PF = P/S = 2700/3600 = 0.75$; $Q = \sqrt{(S^2 - P^2)} = \sqrt{(3600^2 - 2700^2)} = \sqrt{(12{,}960{,}000 - 7{,}290{,}000)} = \sqrt{5{,}670{,}000} \approx 2381.2$ VAR.

29. Define the power triangle and label its sides.

Answer: The power triangle is a right triangle where: the horizontal side represents real power P (W); the vertical side represents reactive power Q (VAR); the hypotenuse represents apparent power S (VA); and the angle between S and P is the power factor angle ϕ.

30. A circuit has PF = 0.866 lagging with S = 2000 VA. Find P and Q.

Answer: $P = S \cdot PF = 2000 \times 0.866 = 1732$ W; $\phi = \arccos(0.866) = 30°$; $Q = S \cdot \sin(30°) = 2000 \times 0.5 = 1000$ VAR (inductive/lagging).

31. What happens to apparent power if both P and Q double?

Answer: $S = \sqrt{(P^2+Q^2)}$. If both P and Q double, $S_{new} = \sqrt{((2P)^2+(2Q)^2)} = 2\sqrt{(P^2+Q^2)} = 2S$. Apparent power also doubles.

32. A wattmeter reads 4 kW and a varmeter reads 3 kVAR (inductive). Find S and PF.

Answer: $S = \sqrt{(4000^2+3000^2)} = \sqrt{(16{,}000{,}000+9{,}000{,}000)} = \sqrt{25{,}000{,}000} = 5000$ VA = 5 kVA; $PF = P/S = 4000/5000 = 0.8$ lagging.

33. Explain why reactive power does no useful work.

Answer: Reactive power oscillates between the source and the reactive elements (inductors/capacitors) at twice the supply frequency. It is stored in electromagnetic or electric fields during one half-cycle and returned to the source in the next, resulting in zero net energy transfer over a complete cycle.

34. A 120 V RMS, 60 Hz source is connected to a 10 Ω resistor in series with a 26.5 mH inductor. Find XL, Z, I, P, Q, and S.

Answer: $X_L = 2\pi \times 60 \times 0.0265 \approx 10\ \Omega$; $Z = \sqrt{(10^2+10^2)} = 10\sqrt{2} \approx 14.14\ \Omega$; $I = 120/14.14 \approx 8.49$ A; $P = 8.49^2 \times 10 \approx 720$ W; $Q = 8.49^2 \times 10 \approx 720$ VAR; $S = 120 \times 8.49 \approx 1018.8$ VA; $PF = \cos(45°) \approx 0.707$ lagging.

35. What is the significance of the sign of Q in complex power analysis?

Answer: A positive Q indicates inductive (lagging) reactive power, meaning the load absorbs reactive power. A negative Q indicates capacitive (leading) reactive power, meaning the load generates (supplies) reactive power back to the system.

36. A motor draws 5 kVA at 0.7 PF lagging from a 230 V supply. Find the line current.

Answer: $I = S/V = 5000/230 \approx 21.74$ A. (Using $S = V \cdot I$.)

37. Calculate the reactive power for a load with S = 10 kVA and PF = 0.9 lagging.

Answer: $P = S \cdot PF = 10{,}000 \times 0.9 = 9000$ W; $Q = S \cdot \sin(\arccos(0.9)) = 10{,}000 \times 0.436 \approx 4359$ VAR (inductive).

38. Two impedances Z1 = 3+j4 Ω and Z2 = 5–j5 Ω are in series, connected to 100 V RMS. Find total P, Q, and S.

Answer: $Z_{total} = (3+5)+j(4-5) = 8-j1\ \Omega$; $|Z| = \sqrt{(64+1)} = \sqrt{65} \approx 8.062\ \Omega$; $I = 100/8.062 \approx 12.4$ A; $P = I^2 \times 8 = 153.76 \times 8 \approx 1230$ W; $Q = I^2 \times (-1) \approx -153.76$ VAR; $S = 100 \times 12.4 = 1240$ VA.

39. What is the effect of purely resistive load on Q and PF?

Answer: A purely resistive load has $Q = 0$ (no reactive power) and $PF = 1$ (unity power factor). All apparent power equals real power: $S = P$.

40. Derive the relationship PF = R/|Z| for a series RL or RC circuit.

Answer: For a series circuit, $P = I^2R$ and $S = I^2|Z|$. Therefore $PF = P/S = I^2R/(I^2|Z|) = R/|Z|$. This shows PF equals the ratio of resistance to total impedance magnitude.

41. A single-phase 240 V load consumes 3.6 kW at 0.9 PF lagging. Find the current.

Answer: $S = P/PF = 3600/0.9 = 4000$ VA; $I = S/V = 4000/240 \approx 16.67$ A.

42. Find the impedance angle (ϕ) for a load with R = 5 Ω and X = 5 Ω (inductive).

Answer: $\phi = \arctan(X/R) = \arctan(5/5) = \arctan(1) = 45°$. Power factor $= \cos(45°) \approx 0.707$ lagging.

43. A capacitor with XC = 40 Ω is connected to 200 V RMS. Calculate its reactive power.

Answer: $I = V/X_C = 200/40 = 5$ A; $Q = -I^2 \cdot X_C = -5^2 \times 40 = -1000$ VAR. (Capacitive, so Q is negative/leading.)

44. How is power factor expressed as a percentage?

Answer: Power factor as a percentage = PF × 100%. For example, PF = 0.85 lagging is expressed as 85% lagging. Some industries specify PF in percent rather than as a decimal.

45. A load has P = 2 kW and Q = 1.5 kVAR (capacitive). Find S and PF.

Answer: $S = \sqrt{(P^2+Q^2)} = \sqrt{(2000^2+1500^2)} = \sqrt{(4{,}000{,}000+2{,}250{,}000)} = \sqrt{6{,}250{,}000} = 2500$ VA = 2.5 kVA; $PF = P/S = 2000/2500 = 0.8$ leading.

46. Why is it important to know the power factor of a load?

Answer: Power factor determines how much current must be supplied for a given real power delivery. A low PF means higher current for the same P, increasing resistive losses in transmission lines (I^2R losses), requiring larger conductors and transformers, and increasing utility costs.

47. A 415 V single-phase supply delivers 8 A at a PF of 0.65 lagging. Calculate P, Q, and S.

Answer: $S = 415\times8 = 3320$ VA; $P = 3320\times0.65 = 2158$ W; $Q = 3320\times\sin(\arccos(0.65)) = 3320\times0.76 \approx 2523.2$ VAR (lagging).

48. What formula gives real power in terms of voltage, current, and phase angle?

Answer: $P = V\cdot I\cdot\cos(\phi)$, where V and I are RMS magnitudes and ϕ is the phase angle between them. $\cos(\phi)$ is the power factor.

49. What formula gives reactive power in terms of voltage, current, and phase angle?

Answer: $Q = V\cdot I\cdot\sin(\phi)$, where V and I are RMS magnitudes and ϕ is the phase angle. Positive ϕ (lagging) gives positive Q (inductive); negative ϕ (leading) gives negative Q (capacitive).

50. Three loads are connected in parallel to a 230 V single-phase source: Load 1: 500 W, PF = 1.0 Load 2: 800 W, PF = 0.8 lagging Load 3: 200 W, PF = 0.6 leading Find total P, Q, S, and PF.

Answer: Load 1: $P_1=500$W, $Q_1=0$ VAR; Load 2: $S_2=800/0.8=1000$VA, $Q_2=+600$ VAR; Load 3: $S_3=200/0.6=333.3$VA, $Q_3=-\sqrt{(333.3^2-200^2)}=-\sqrt{(111{,}089-40{,}000)}=-\sqrt{71{,}089}\approx-266.6$ VAR; Total $P=500+800+200=1500$W; Total $Q=0+600-266.6=333.4$ VAR; $S=\sqrt{(1500^2+333.4^2)}=\sqrt{(2{,}250{,}000+111{,}155)}\approx\sqrt{2{,}361{,}155}\approx1536.5$ VA; $PF=1500/1536.5\approx0.976$ lagging.

51. What is the instantaneous power p(t) in a single-phase AC circuit?

Answer: $p(t) = v(t)\cdot i(t) = V_m\cdot I_m\cdot\cos(\omega t)\cdot\cos(\omega t-\phi) = (V_m\cdot I_m/2)[\cos(\phi) + \cos(2\omega t-\phi)]$. The average of p(t) over a full cycle equals the real power $P = (V_m\cdot I_m/2)\cdot\cos(\phi) = V_{rms}\cdot I_{rms}\cdot\cos(\phi)$.

52. How does the instantaneous power relate to P and Q?

Answer: $p(t) = P(1+\cos(2\omega t)) - Q\cdot\sin(2\omega t)$. The P term oscillates between 0 and 2P (always non-negative for resistive part), while the Q term oscillates between +Q and –Q representing stored/returned reactive energy.

53. A single-phase load is represented by impedance Z = 10∠36.87° Ω. Find R, X, and PF.

Answer: $R = |Z|\cos(36.87°) = 10×0.8 = 8\ \Omega$; $X = |Z|\sin(36.87°) = 10×0.6 = 6\ \Omega$ (inductive); PF = cos(36.87°) = 0.8 lagging.

54. Calculate complex power S if V = 120∠0° V and I = 10∠–36.87° A.

Answer: $S = V·I^* = 120∠0° × 10∠+36.87° = 1200∠36.87° = 1200(\cos36.87°+j\sin36.87°) = 960+j720$ VA. So P=960 W, Q=720 VAR (lagging).

55. A load is supplied at 230∠0° V and draws I = 8∠30° A. Find S, P, Q, and PF.

Answer: $S = V·I^* = 230∠0° × 8∠–30° = 1840∠–30° = 1840(\cos(–30°)+j\sin(–30°)) = 1593.2–j920$ VA. P=1593.2 W, Q=–920 VAR (capacitive); PF=cos(30°)=0.866 leading.

56. A 100 Ω resistor and 200 VAR capacitor are in parallel across 200 V RMS. Find total P, Q, and S.

Answer: P from resistor: $P = V^2/R = 200^2/100 = 400$ W; Q from capacitor: Q = –200 VAR; $S = \sqrt{(400^2+200^2)} = \sqrt{(160{,}000+40{,}000)} = \sqrt{200{,}000} \approx 447.2$ VA; PF = 400/447.2 ≈ 0.894 leading.

57. Define power factor angle ϕ and specify its range.

Answer: The power factor angle ϕ is the angle between the voltage phasor and the current phasor (ϕ = ∠V – ∠I). For lagging loads (inductive), 0° < ϕ ≤ 90°; for leading loads (capacitive), –90° ≤ ϕ < 0°; for unity PF, ϕ = 0°.

58. How is Q related to the imaginary part of complex power S = P + jQ?

Answer: Q is directly the imaginary part of the complex power S. Positive imaginary part (Q > 0) means inductive load (lagging); negative imaginary part (Q < 0) means capacitive load (leading). |Q| = |S|·sin|ϕ|.

59. A circuit element absorbs S = 500–j300 VA. Identify the type of element and its values at 120 V RMS.

Answer: P=500 W (resistive component), Q=–300 VAR (capacitive). Current: $|I|=|S|/V=\sqrt{(500^2+300^2)}/120=\sqrt{(250000+90000)}/120=\sqrt{340000}/120\approx583.1/120\approx4.86$ A. $R=P/I^2=500/23.6\approx21.2\ \Omega$; $X_C=|Q|/I^2=300/23.6\approx12.7\ \Omega$.

60. What is the difference between volt-amperes (VA) and watts (W)?

Answer: Watts (W) measure real power — the actual energy consumed per second. Volt-amperes (VA) measure apparent power — the product of RMS voltage and current regardless of phase. VA = W only at unity power factor. In general, W ≤ VA.

61. A 50 Hz supply of 240 V drives a series RLC circuit with R=10Ω, L=50mH, C=100μF. Find XL, XC, Z, I, P, Q, and S.

Answer: $X_L=2\pi×50×0.05=15.71\Omega$; $X_C=1/(2\pi×50×0.0001)=31.83\Omega$; $X=X_L–X_C=–16.12\Omega$; $|Z|=\sqrt{(10^2+16.12^2)}=\sqrt{(100+259.9)}=\sqrt{359.9}\approx18.97\Omega$; $I=240/18.97\approx12.65$A; $P=12.65^2×10=1599.8\text{W}\approx1600\text{W}$; $Q=12.65^2×(–16.12)\approx–2579.4$VAR (capacitive); S=240×12.65=3036VA.

62. For the circuit in Q61, is the power factor leading or lagging? Why?

Answer: The power factor is leading because XC > XL (net reactance is capacitive, X < 0). The current leads the voltage, giving a negative phase angle and a leading power factor.

63. Calculate the power factor for the circuit in Q61.

Answer: PF = cos(ϕ) = R/|Z| = 10/18.97 ≈ 0.527 leading.

64. A single-phase transformer has primary voltage V1=11kV and secondary voltage V2=415V. A load of 50kVA at 0.8PF lagging is connected to the secondary. Find the primary current (ignore losses).

Answer: Secondary current $I_2 = S/V_2 = 50{,}000/415 \approx 120.5$ A. Primary current $I_1 = (V_2/V_1)×I_2 = (415/11{,}000)×120.5 \approx 4.55$ A.

65. How does a wattmeter measure real power in a single-phase circuit?

Answer: A wattmeter measures real power P = V·I·cos(ϕ) by having a current coil (carrying load current) and a voltage coil (connected across the load). The deflection is proportional to the product of instantaneous voltage and current, and the meter reads the time-average, which equals P.

66. A load requires 10 kW of real power with a power factor of 0.5 lagging. Find S, Q, and the apparent power 'wasted' compared to unity PF for the same real power.

Answer: S = P/PF = 10,000/0.5 = 20,000 VA; Q = $\sqrt{20{,}000^2 - 10{,}000^2}$ = $\sqrt{300{,}000{,}000}$ ≈ 17,320.5 VAR. At unity PF, S would equal P = 10,000 VA, so the 'excess' apparent power = 20,000–10,000 = 10,000 VA more is drawn from the supply.

67. State the principle of conservation of complex power.

Answer: In any AC network, the total complex power supplied by all sources equals the total complex power consumed by all loads. This means $\Sigma P_{sources} = \Sigma P_{loads}$ and $\Sigma Q_{sources} = \Sigma Q_{loads}$, applying separately to real and reactive components.

68. A 230V source has internal impedance Zs = 1+j2 Ω and drives a load ZL = 9+j6 Ω. Find P_load, Q_load, P_source (generated), and Q_source.

Answer: Z_{total} = 10+j8 Ω; |Z| = $\sqrt{100+64}$ = 12.806 Ω; I = 230/12.806 = 17.96 A; $P_{load} = 17.96^2 \times 9$ = 2901.4 W; $Q_{load} = 17.96^2 \times 6$ = 1934.3 VAR; $P_{loss} = 17.96^2 \times 1$ = 322.4 W; $Q_{internal} = 17.96^2 \times 2$ = 644.9 VAR; P_{source} = 2901.4+322.4 = 3223.8 W; Q_{source} = 1934.3+644.9 = 2579.2 VAR.

69. What is the Thevenin equivalent as seen from a load's perspective relevant to power calculations?

Answer: The Thevenin equivalent (V_{th} in series with Z_{th}) determines the current through the load, and hence the power: $I = V_{th}/(Z_{th}+Z_L)$. $P_L = |I|^2 \cdot R_L$ and $Q_L = |I|^2 \cdot X_L$, where R_L and X_L are the load's resistance and reactance.

70. Find PF if the voltage is v(t) = 170 sin(314t+20°) V and current is i(t) = 10 sin(314t–10°) A.

Answer: Phase angle ϕ = angle of V – angle of I = 20° – (–10°) = 30°. PF = cos(30°) ≈ 0.866 lagging (current lags voltage).

71. What is the RMS value of v(t) = 170 sin(ωt) and how is it used in power calculations?

Answer: $V_{rms} = 170/\sqrt{2}$ ≈ 120.2 V. RMS values are used in power calculations because $P = V_{rms} \cdot I_{rms} \cdot \cos(\phi)$, $S = V_{rms} \cdot I_{rms}$, etc. Using peak values would give incorrect results for average power.

72. A load absorbs complex power S = 3000+j4000 VA from a 250 V RMS source. Find the load current and impedance.

Answer: |S| = $\sqrt{3000^2+4000^2}$ = 5000 VA; I = |S|/V = 5000/250 = 20 A; |Z| = V/I = 250/20 = 12.5 Ω; ϕ = arctan(4000/3000) = 53.13°; Z = 12.5∠53.13° = 7.5+j10 Ω.

73. Explain active and passive sign convention for complex power.

Answer: With the passive sign convention (current entering positive terminal), $S = V \cdot I^*$ gives positive P for power absorbed. With the active sign convention (current leaving positive terminal), $S = -V \cdot I^*$ or equivalently $S = V^* \cdot I$ gives positive P for power supplied by a source.

74. A single-phase induction motor operates at 415 V, draws 12 A, and has an efficiency of 85% and PF=0.75 lagging. Find apparent power, real power input, and mechanical output.

Answer: S = 415×12 = 4980 VA; P_{input} = S×PF = 4980×0.75 = 3735 W; $P_{output} = \eta \times P_{input}$ = 0.85×3735 ≈ 3174.75 W ≈ 3.175 kW.

75. For a parallel RLC circuit, how do you find total P, Q, and S?

Answer: In a parallel circuit, the voltage across all elements is the same (V). $P = V^2/R$; $Q_L = V^2/XL$ (inductive, positive); $Q_C = -V^2/XC$ (capacitive, negative); $Q_{total} = Q_L + Q_C$; $S = \sqrt{P^2+Q_{total}^2}$; PF = P/S.

76. A parallel circuit has R=100Ω, XL=50Ω, XC=100Ω across 200V RMS. Find P, Q_total, S, and PF.

Answer: P = $200^2/100$ = 400 W; $Q_L = 200^2/50$ = 800 VAR; $Q_C = -200^2/100$ = –400 VAR; Q_{total} = 800–400 = 400 VAR; S = $\sqrt{400^2+400^2}$ = $400\sqrt{2}$ ≈ 565.7 VA; PF = 400/565.7 ≈ 0.707 lagging.

77. Define displacement power factor.

Answer: Displacement power factor (DPF) is the cosine of the phase angle between the fundamental components of voltage and current. It is the traditional power factor for sinusoidal systems and equals PF = cos(φ■) where φ■ is the fundamental phase displacement.

78. How does Ohm's law apply to power calculations in AC circuits?

Answer: In AC circuits, Ohm's law uses phasors: $V = I \cdot Z$. Power calculations follow: $P = |I|^2R = |V|^2/R$ (for R alone); $Q = |I|^2X = |V|^2/X$ (for X alone); and $S = |I|^2|Z| = |V|^2/|Z| = |V||I|$.

79. A single-phase circuit has PF = 0.8 lagging and Q = 600 VAR. Find P and S.

Answer: $\phi = \arccos(0.8) = 36.87°$; $\tan(\phi) = Q/P \rightarrow P = Q/\tan(\phi) = 600/\tan(36.87°) = 600/0.75 = 800$ W; $S = \sqrt{(800^2+600^2)} = \sqrt{(640{,}000+360{,}000)} = \sqrt{1{,}000{,}000} = 1000$ VA.

80. What is the physical interpretation of reactive power in an inductive load?

Answer: In an inductive load, reactive power represents energy stored in the magnetic field during the positive half-cycle of current and returned to the source during the negative half-cycle. This energy oscillates at twice the supply frequency and contributes to the current drawn but not to useful work.

81. A 1 kW resistive heater and a 2 kVAR inductive motor are connected in parallel across 240 V. Find total S, I, and PF.

Answer: P=1000W, Q=2000VAR; $S=\sqrt{(1000^2+2000^2)}=\sqrt{5{,}000{,}000}\approx2236.1$VA; I=S/V=2236.1/240≈9.32A; PF=P/S=1000/2236.1≈0.447 lagging.

82. Calculate the power factor angle for a load with P = 5 kW and Q = 5 kVAR (inductive).

Answer: $\phi = \arctan(Q/P) = \arctan(5000/5000) = \arctan(1) = 45°$. PF = cos(45°) ≈ 0.707 lagging.

83. A source delivers 10 kVA. If PF = 0.9 lagging, how much real power is delivered?

Answer: P = S×PF = 10,000×0.9 = 9000 W = 9 kW.

84. What is the reactive power if P = 7 kW and S = 10 kVA?

Answer: $Q = \sqrt{(S^2–P^2)} = \sqrt{(100{,}000{,}000–49{,}000{,}000)} = \sqrt{51{,}000{,}000} \approx 7141.4$ VAR ≈ 7.14 kVAR.

85. A load has Z = 6–j8 Ω and is connected to a 120 V RMS source. Calculate P, Q, S, and PF.

Answer: $|Z|=\sqrt{(36+64)}=10Ω$; I=120/10=12A; $P=12^2×6=864$W; $Q=12^2×(–8)=–1152$VAR (capacitive); S=120×12=1440VA; PF=864/1440=0.6 leading.

86. Distinguish between kW, kVA, and kVAR in practical terms.

Answer: kW (kilowatts) is real power — what you actually pay for on electricity bills and what does useful work. kVA (kilovolt-amperes) is apparent power — the total power the supply equipment must handle. kVAR (kilovolt-amperes reactive) is reactive power — the portion that oscillates without doing work but stresses the system.

87. A generator rated at 500 kVA operates at 0.85 PF lagging. How much real power does it deliver?

Answer: P = S×PF = 500,000×0.85 = 425,000 W = 425 kW.

88. Find the reactive power of a capacitor with C = 50 μF at 230 V, 50 Hz.

Answer: XC = 1/(2π×50×50×10■■) = 1/(0.01571) ≈ 63.66 Ω; I = 230/63.66 ≈ 3.614 A; $Q = –I^2×XC = –3.614^2×63.66 \approx –831.3$ VAR. (Capacitive, leading.)

89. Two impedances Z1=5∠30°Ω and Z2=8∠–45°Ω are in parallel, supplied at 100V RMS. Find total P and Q.

Answer: I1=100/(5∠30°)=20∠–30°A → S1=V·I1*=100×20∠30°=2000∠30°=1732+j1000VA; I2=100/(8∠–45°)=12.5∠45°A → S2=100×12.5∠–45°=1250∠–45°=883.9–j883.9VA; Total: P=1732+883.9=2615.9W; Q=1000–883.9=116.1VAR.

90. A 415 V, 50 Hz single-phase supply drives a load with Z = 20∠60° Ω. Find I, P, Q, S, and PF.

Answer: I=415/20=20.75A; φ=60°; P=415×20.75×cos(60°)=415×20.75×0.5=4305.6W; Q=415×20.75×sin(60°)=415×20.75×0.866≈7457.6VAR; S=415×20.75=8611.25VA; PF=cos(60°)=0.5 lagging.

91. What is a power analyzer and what quantities does it measure?

Answer: A power analyzer is an instrument that measures electrical power quantities in AC circuits. It simultaneously measures and calculates V (RMS), I (RMS), P (real power), S (apparent power), Q (reactive power), PF (power factor), and phase angle ϕ, often displaying waveforms and harmonic content.

92. How can you verify power calculations using energy conservation in a circuit?

Answer: By applying conservation of complex power: sum all complex powers of sources (with active sign convention) and all complex powers of loads (with passive sign convention). The total must equal zero: $\Sigma S_{sources} = \Sigma S_{loads}$, which must hold separately for real (P) and reactive (Q) parts.

93. A 240 V source supplies two parallel loads: Load A: 2 kW at PF = 1; Load B: S = 3 kVA at PF = 0.7 lagging. Find total I and overall PF.

Answer: Load A: $P_A=2000W$, $Q_A=0$; Load B: $P_B=3000\times0.7=2100W$, $Q_B=3000\times\sin(\arccos 0.7)=3000\times0.714\approx2142VAR$; Total: $P=4100W$, $Q=2142VAR$; $S=\sqrt{(4100^2+2142^2)}=\sqrt{(16{,}810{,}000+4{,}588{,}164)}=\sqrt{21{,}398{,}164}\approx4626VA$; $I=S/V=4626/240\approx19.28A$; $PF=4100/4626\approx0.886$ lagging.

94. An AC circuit has v(t)=311sin(377t) V and i(t)=14.14sin(377t–53.13°) A. Calculate P, Q, and S.

Answer: $V_{rms}=311/\sqrt{2}=220V$; $I_{rms}=14.14/\sqrt{2}=10A$; $\phi=53.13°$; $S=220\times10=2200VA$; $P=2200\times\cos(53.13°)=2200\times0.6=1320W$; $Q=2200\times\sin(53.13°)=2200\times0.8=1760VAR$ (lagging).

95. Explain how impedance angle relates to power factor angle.

Answer: The impedance angle $\theta_Z = \arctan(X/R)$ equals the power factor angle ϕ for a passive load. This is because the phase difference between voltage and current across an impedance $Z = R+jX$ equals θ_Z. Thus $PF = \cos(\theta_Z) = R/|Z|$.

96. A load consumes P = 4 kW. If power factor is changed from 0.7 to 0.95 lagging (hypothetically), compare Q at both power factors.

Answer: At PF=0.7: $S_1=4000/0.7=5714.3VA$; $Q_1=\sqrt{(5714.3^2-4000^2)}=\sqrt{(32{,}653{,}469-16{,}000{,}000)}\approx4081.7VAR$; At PF=0.95: $S_2=4000/0.95=4210.5VA$; $Q_2=\sqrt{(4210.5^2-4000^2)}=\sqrt{(17{,}728{,}312-16{,}000{,}000)}\approx1314.9VAR$. Q reduced from 4081.7VAR to 1314.9VAR.

97. What is the Boucherot theorem (or Boucherot's rule)?

Answer: Boucherot's theorem states that in a network with multiple loads, the total real power P and total reactive power Q can be found by algebraically summing the individual P and Q values of each load. Total $S = \sqrt{(P_{total}^2+Q_{total}^2)}$. Real and reactive powers add independently.

98. A 120 V RMS source has a series resistance Rs=2Ω and feeds a load RL=18Ω (purely resistive). Find P_load, P_loss, efficiency, and PF.

Answer: Total $R=20\Omega$; $I=120/20=6A$; $P_{load}=6^2\times18=648W$; $P_{loss}=6^2\times2=72W$; $P_{total}=648+72=720W$; $\eta=648/720=90\%$; PF=1.0 (purely resistive, no reactive elements).

99. Summarize all four power quantities (P, Q, S, and complex S) with their formulas, units, and physical meanings.

Answer: P (real power, W): $P=V\cdot I\cdot\cos\phi=I^2R$; energy actually consumed. Q (reactive power, VAR): $Q=V\cdot I\cdot\sin\phi=I^2X$; energy oscillating with reactive elements, no net consumption. S (apparent power, VA): $S=V\cdot I=\sqrt{(P^2+Q^2)}$; total power the source must supply. Complex power (VA): $S=P+jQ=V\cdot I^*$; phasor quantity capturing all power information including phase relationship.

100. A single-phase system has the following loads on 230V RMS: Load 1: 1500W, PF=0.8 lagging Load 2: 800W, PF=1.0 Load 3: 1200W, PF=0.6 leading Find total P, Q, S, PF, and supply current.

Answer: Load1: $S_1=1500/0.8=1875VA$, $Q_1=+\sqrt{(1875^2-1500^2)}=+1125VAR$; Load2: $S_2=800VA$, $Q_2=0$; Load3: $S_3=1200/0.6=2000VA$, $Q_3=-\sqrt{(2000^2-1200^2)}=-1600VAR$; Total: $P=1500+800+1200=3500W$; $Q=1125+0-1600=-475VAR$; $S=\sqrt{(3500^2+475^2)}=\sqrt{(12{,}250{,}000+225{,}625)}=\sqrt{12{,}475{,}625}\approx3532.1VA$; $PF=3500/3532.1\approx0.991$ leading; $I=S/V=3532.1/230\approx15.36A$.