

Module 1.0B — Three-Phase Power Masterclass

The dividing line between residential and commercial: why three phases, wye vs. delta and $\sqrt{3}$, the four systems and how to identify them in the field, power calcs, load balancing, power factor, harmonics, and rotation.

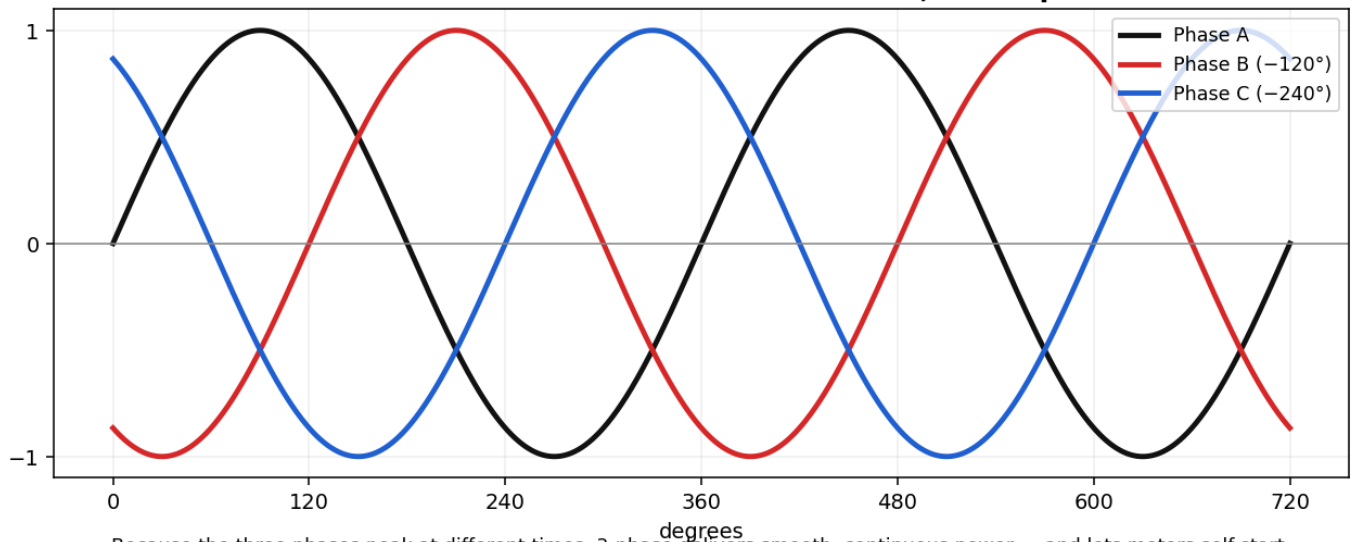
Why a masterclass on this. Three-phase power is the dividing line between residential and commercial work. Once you understand it (why there are three phases, wye vs. delta, the $\sqrt{3}$ relationship, the four voltage systems, how to identify the system you are standing in, how to calculate and balance 3-phase loads, power factor, harmonics, and phase rotation), every other commercial topic makes sense: panels, transformers, and motors all build on it. This version adds the field procedures: how to approach a live panel, take the seven readings, mark a high leg, balance a schedule, read a neutral, size power-factor capacitors, and check rotation before a motor ever turns.

Every reading in this module is taken inside live equipment. NFPA 70E (2024) treats taking voltage and current readings in an energized panel as electrical testing, where an arc flash is possible. Testing does not need an energized-work permit, but it always needs the right PPE, a rated meter, and a qualified person. If you are not yet qualified, you watch and record while a qualified electrician takes the readings. The Part C approach checklist is the order you follow every time.

Part A — Why Three Phases?

Single-phase power is one alternating voltage that rises and falls through zero. Commercial power uses **three** separate voltages, each shifted **120°** in time from the next. Each of the three is called a **phase**, and they are labeled A, B, and C.

THREE-PHASE POWER: three sine waves, 120° apart



Three sine waves, 120° apart. Because they peak at different instants, the combined power never drops to zero.

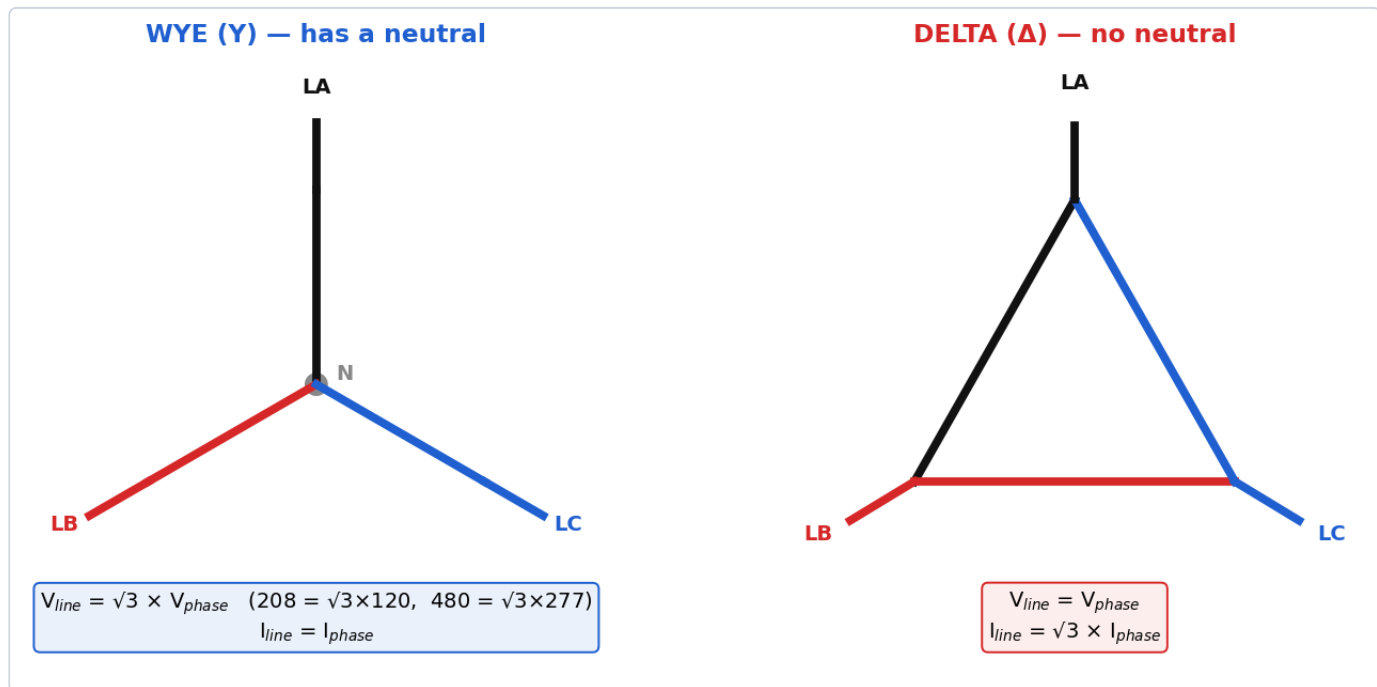
- **Constant power delivery.** Single-phase instantaneous power drops to zero twice every cycle. With three phases, the instantaneous powers, proportional to $\sin^2(\theta)$, $\sin^2(\theta-120^\circ)$, and $\sin^2(\theta-240^\circ)$, **add up to a constant**. That is why 3-phase motors run smooth and 3-phase rectifiers give cleaner DC.
- **Motors self-start.** The three phases energize the motor windings in sequence and create a **rotating magnetic field** in the stator (the stationary part). The rotor chases that field. No start capacitor or start winding is needed the way it is on a single-phase motor. Reverse any two phases and the field, and the motor, reverses (Part H).
- **Less copper for the same power.** Three-phase delivers $\sqrt{3}$ times the power of single-phase for the same line voltage and current, so you get more watts per pound of conductor.

The formula card (keep this in your wallet)

To find	Formula
Real power, watts	$P = 1.732 \times E \times I \times PF$
Apparent power, volt-amps	$VA = 1.732 \times E \times I$
Line current from watts	$I = P \div (1.732 \times E \times PF)$, the same as $0.577 \times P \div (PF \times E)$
Wye currents	$I_{\text{phase}} = I_{\text{line}}$
Delta currents	$I_{\text{line}} = 1.73 \times I_{\text{phase}}$

E is line-to-line voltage, I is line current, PF is power factor. Source: NAVEDTRA 14046, Appendix II.

Part B — Wye vs. Delta, and Where $\sqrt{3}$ Comes From



Wye ties the three windings to a common center (the neutral); delta ties them end-to-end in a triangle (no neutral).

	WYE (Y / "star")	DELTA (Δ)
How wired	Three windings joined at a common center	Three windings end-to-end in a closed triangle
Neutral?	Yes — the center point	No (3-wire)*
Voltage	$V_{line} = \sqrt{3} \times V_{phase}$	$V_{line} = V_{phase}$
Current	$I_{line} = I_{phase}$	$I_{line} = \sqrt{3} \times I_{phase}$
Gives you	Two voltages: phase-to-N and phase-to-phase	One voltage: phase-to-phase*
Typical use	The standard commercial service (208Y/120, 480Y/277)	Motor/industrial loads; legacy services

*Except the center-tapped high-leg delta, which adds a neutral — Part C.

Where $\sqrt{3}$ comes from. Line-to-line voltage in a wye is the difference between two phase-to-neutral voltages that are 120° apart. Two equal vectors 120° apart give a result $\sqrt{3} = 1.732$ times larger. The Navy manual puts it this way: line-to-line is "equal to the phase or line to neutral voltage multiplied by 1.73." That one fact produces every commercial voltage pair:

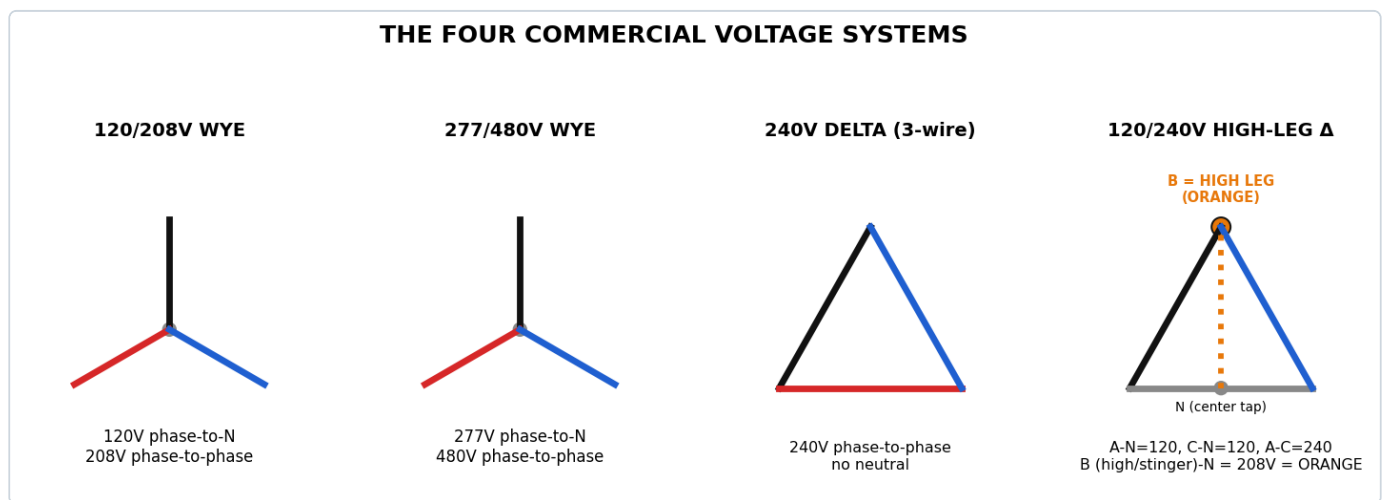
- $120 \times 1.732 = 208 \text{ V}$ • $277 \times 1.732 = 480 \text{ V}$
- backward: $208 \div 1.732 = 120$ • $480 \div 1.732 = 277$

In a **delta** the line and phase voltage are equal, but the line current carries the $\sqrt{3}$. Line current is $1.732 \times$ the current in any one winding.

Mistake to avoid: the wrong panel on a high-leg system. A panelboard or breaker marked **208Y/120 V** is built for a wye, where no leg is more than 120 V to ground. It is not suitable on a 240/120 V high-leg delta, where one leg is about 208 V to ground. Read the voltage marking on the gear before you set it.

Part C — The Four Voltage Systems (and how to tell which you're in)

You will meet four systems on commercial work. The most dangerous mistake in this trade is assuming you are on a friendly wye when you are not. So **meter every leg to ground before you energize anything or land a 120 V circuit.**



The four systems. The high-leg delta is the trap: its B phase reads 208 V to neutral and must be ORANGE.

System	Each leg to NEUTRAL	Generated by / used for
120/208 V wye	120 V (all three)	Δ-Y transformer; the workhorse: 120 V receptacles, 208 V small 3-phase.
277/480 V wye	277 V (all three)	Δ-Y transformer; big commercial: 277 V lighting, 480 V motors/HVAC, transformed down for 120 V.
240 V delta (3-wire)	no neutral present	Δ secondary; motor loads only; a separate transformer makes any 120 V.
120/240 V high-leg delta	120 / 208 / 120 V	Center-tapped Δ; the 208 V leg is the "stinger" and must be orange.

Step by step: approaching an unknown panel

Follow this order every time, even on a panel you think you know.

1. **Read the arc-flash label** before the cover comes off. NEC 2026 110.16 requires one on switchboards, panelboards, and motor control centers likely to be worked on while

energized. The label gives the voltage, the arc-flash boundary, and the PPE or incident energy. It must be a durable printed label, not handwriting (NEC 2026 110.21(B)).

2. **Put on the PPE the label calls for**, before you open anything. For panelboards in the 240 to 600 V range this is usually arc-flash PPE Category 2: arc-rated shirt and pants or coverall rated at least 8 cal/cm², arc-rated face shield with balaclava or a hood, hard hat, safety glasses, hearing protection, and leather footwear. The label on the gear in front of you governs.
3. **Inspect your voltage-rated gloves** (class 00 or 0 for low voltage) and their leather protectors. Roll each glove to look for pinholes. Gloves go on before your hands get near live parts.
4. **Check your meter's rating**. OSHA 1910.334(c) says test instruments must be "rated for the circuits and equipment." That means **CAT III 600 V minimum at a panelboard** and **CAT IV at the service**. Inspect the leads for cracks and exposed metal.
5. **Prove your meter on a known live source** (live-dead-live). NFPA 70E 110.6(E) says an absence-of-voltage instrument must be verified on a known voltage source **before and after** the test. A proving unit such as a Fluke PRV240 gives you a known 240 V source anywhere. A non-contact "tick" tester is **not** an absence-of-voltage test.
6. **Open the cover and take the seven readings** (below). Write every number down.
7. **Prove the meter again** on the known source when you are done.

The seven readings

1. Black lead on the ground bar. Red lead to A, then B, then C. That is three readings to ground.
2. Then phase to phase: A-B, B-C, C-A. That is three more.
3. Then neutral to ground (N-G). Under load, 2 V or less is normal.

A-G / B-G / C-G	A-B / B-C / C-A	System
120 / 120 / 120	208, 208, 208	208Y/120 V wye
277 / 277 / 277	480, 480, 480	480Y/277 V wye
120 / ~208 / 120	240, 240, 240	240/120 V high-leg delta ($120 \times 1.73 = 207.8$ V)
240 / 240 / 0 on one leg	240, 240, 240	Corner-grounded delta
Unequal, drifting	240 or 480, all three	Ungrounded delta (see Legacy Masterclass)

A reading of **0 V on one phase** with the breaker closed means an open phase or a blown fuse upstream. Stop and report it before anything else gets energized.

Step by step: finding and marking the high leg

1. On a 240 V delta, the one leg that reads about **208 V to ground** is the high leg.
2. Confirm it is on the **B** bus. NEC 2026 408.10(E)(1) (408.3(E)(1) in the 2023 code): phases are "A, B, C from front to back, top to bottom, or left to right, as viewed from the front," and

"the B phase shall be that phase having the higher voltage to ground on 3-phase, 4-wire, delta-connected systems." Motor control centers follow the same rule.

3. Mark it **orange**. NEC 2026 110.15: "only the conductor or busbar having the higher phase voltage to ground shall be durably and permanently marked orange in color." Use orange tape or orange heat-shrink at every termination and splice where the neutral is also present.
4. Field-mark the panel. NEC 2026 408.10(F)(1) (408.3(F)(1) in 2023) requires a permanent label on the front: "**CAUTION ___ PHASE HAS ___ VOLTS TO GROUND.**" It must be a durable printed or engraved label per 110.21(B).
5. Check the breakers on B. Schneider's NQ panelboard guide: phases A and C must be 120 V to neutral and phase B 208 V to neutral; "Connect only circuit breakers rated 240 Vac minimum. Do not use circuit breakers rated 120 V or 120/240 V to 'B' phase."
6. Know where B sits. On a 3-phase panel the bus steps A-B-C down the panel, so positions 3/4, 9/10, 15/16 and every third pair after that are B. **No single-pole 120 V circuit ever lands there** on a high-leg delta.

The high-leg trap. On a 120/240 V high-leg (4-wire) delta, A-N and C-N read 120 V but **B-N reads about 208 V** ($= \sqrt{3} \times 120$). Land a 120 V load on B and you put 208 V on a 120 V device, which destroys it instantly. Both hot legs of a corner-grounded delta and the high leg are over 150 V to ground, which is beyond what a standard Class A GFCI is built for (NEC 2026 680.5 Informational Note).

Corner-grounded and **ungrounded** deltas are legacy variants. Both read full line voltage to ground on the hot legs and need **straight-rated** (not slash-rated) breakers (see the Legacy Masterclass). Always identify the system with your meter first.

Part C — inspection checklist

- Arc-flash label present and printed. PPE matched to the label.
- Meter is CAT III 600 V or better, leads inspected, proved live-dead-live.
- All seven readings written down, and the system named from the table.
- On a high-leg delta: high leg on B, orange at every termination, caution label on the front, no 120 V breakers on B.

Part D — Calculating 3-Phase Power (work the examples)

The formulas

$$\begin{aligned} P \text{ (W)} &= \sqrt{3} \times V_L \times I_L \times PF \quad | \quad S \text{ (VA)} = \sqrt{3} \times V_L \times I_L \quad | \quad kVA = (\sqrt{3} \times V_L \times I_L) \div 1000 \quad | \\ Q \text{ (VAR)} &= \sqrt{(S^2 - P^2)} \end{aligned}$$

Step by step: any 3-phase power problem

1. Write down what you know: line-to-line voltage, line current, and power factor if you have it.
 2. Decide what you need. Sizing a transformer or wire? You need **kVA**. Figuring the real work or the power bill? You need **kW**.
 3. If the load is single-phase on two legs of a 3-phase panel, do **not** use 1.732. Divide watts by the voltage.
 4. Do the math, then round a transformer up to the next standard size.
 5. Sanity-check against the 1.732 rule. $208\text{ V} \times 1.732 = 360$, so every kVA at 208 V is about 2.8 A. At 480 V ($480 \times 1.732 = 831$), every kVA is about 1.2 A.
- **Ex. 1, power:** 480 V load, 40 A, PF 0.9. $P = 1.732 \times 480 \times 40 \times 0.9 = 29,930\text{ W} \approx 30\text{ kW}$. $S = 1.732 \times 480 \times 40 = 33,254\text{ VA} \approx 33\text{ kVA}$.
 - **Ex. 2, size a transformer:** a 100 A, 208 V panel. $\text{kVA} = 1.732 \times 208 \times 100 \div 1000 = 36\text{ kVA}$, so pick the next size up, 45 kVA.
 - **Ex. 3, find current:** a 75 kVA, 208 V transformer's full-load secondary amps = $75,000 \div (1.732 \times 208) = 208\text{ A}$.
 - **Ex. 4, find current at 480 V:** a 112.5 kVA, 480 V transformer = $112,500 \div (1.732 \times 480) = 135\text{ A}$.
 - **Ex. 5, a single-phase load:** a 10 kW, 208 V, 1-phase load on two legs of a 3-phase panel pulls $10,000 \div 208 = 48\text{ A}$ on those two legs. No $\sqrt{3}$, because it is single-phase across two phases.

Load type	Typical power factor
Incandescent lighting, resistance heating	1.00 (100%)
Induction motor, fully loaded	about 0.80 lagging
Induction motor, lightly loaded	as low as 0.20 lagging
Neon lighting	0.30 to 0.70
When nothing else is known	0.80 lagging is the common average used in calculations

Source: NAVEDTRA 14027, Table 4-2.

Why kVA, not kW, for sizing. Transformers and conductors are sized for the **current** they carry, which is set by apparent power (kVA). Power factor only changes the real watts delivered, not the heat in the copper. Size the iron and copper in kVA. Bill and judge efficiency in kW.

Part E — Balancing the Load (and the neutral)

Spread single-phase loads evenly across A, B, and C. If all the load sits on one leg, that leg overloads while the others carry little, and you waste feeder capacity. On a 3-phase, 4-wire wye the phase currents largely cancel in the neutral, so **the neutral carries only the imbalance**.

Step by step: balancing a panel schedule

1. **Know the bus pattern.** Odd circuits are on the left, even on the right. The phase steps A-B-C down the panel: circuits 1/2 are A, 3/4 are B, 5/6 are C, 7/8 are A again, and so on (the order in NEC 2026 408.10(E)(1)).
2. **List every circuit's load** in VA from the nameplate or the load calculation. Note how many poles it uses. A 2-pole load counts half its VA on each of its two phases. A 3-pole load counts one-third on each phase.
3. **Total the VA on each phase.**
4. **Figure the imbalance:** (highest phase – lowest phase) ÷ highest phase × 100.
5. **Compare to the target.** The federal design standard UFC 3-520-01 calls for "5% or less design load imbalance" and wants the percentage shown on the panel schedule. Use 5 percent as the design goal. If you find 10 percent or more, move single-pole circuits.
6. **Move single-pole circuits** from the heavy phase to the light one until you are inside the target, then reprint the circuit directory so it matches what is in the panel (NEC 2026 408.4(A)).
7. **After energizing, clamp each phase under real load.** The phases should read about the same, which keeps the neutral current low.

Worked example. Phase totals are A = 14,200 VA, B = 11,000 VA, C = 12,800 VA. Imbalance = (14,200 – 11,000) ÷ 14,200 × 100 = **22.5 percent**. Move a 1,500 VA receptacle circuit and a 1,200 VA lighting circuit from A to B. Now A = 11,500, B = 13,700, C = 12,800. Imbalance = (13,700 – 11,500) ÷ 13,700 × 100 = **16 percent**. Swap one more 1,000 VA circuit from B to A: A = 12,500, B = 12,700, C = 12,800, and the imbalance is (12,800 – 12,500) ÷ 12,800 × 100 = **2.3 percent**. Done.

What the neutral current should be

For ordinary (linear) loads on a wye, the neutral current is:

$$I_N = \sqrt{(I_A^2 + I_B^2 + I_C^2 - I_A \cdot I_B - I_B \cdot I_C - I_C \cdot I_A)}$$

A / B / C amps	Neutral amps	What it means
30 / 30 / 30	0	Perfectly balanced
30 / 10 / 10	20	Unbalanced; rebalance the panel
40 / 25 / 15	21.8	Unbalanced
20 / 20 / 0	20	One phase dropped out; the neutral carries a full phase

Step by step: clamping the neutral

1. Use a **true-rms** clamp meter. An average-responding meter can read up to 50 percent low on distorted current.
2. Put **one conductor** in the jaw: the neutral alone, on the load side.

3. For loads that cycle on and off, use MIN/MAX to catch the peak.
4. Clamp each phase the same way and write the four numbers down.
5. Compare. If the neutral matches the formula above, the cause is imbalance and you fix it by moving circuits. If the neutral is as high as or higher than the highest phase while the phases are balanced, the cause is **harmonics** (Part G).

NEC 2026 120.61 (220.61 in 2023) — feeder or service neutral load

"The maximum unbalanced load shall be the maximum net calculated load between the neutral conductor and any one ungrounded conductor." There is no reduction of the neutral for a circuit made of two ungrounded conductors and the neutral of a 4-wire wye, or for nonlinear loads on a 4-wire wye. NEC 2026 310.15(E)(1) counts those neutrals as current-carrying conductors, because the neutral of a 2-hot-plus-neutral circuit from a wye "carries approximately the same current as the line-to-neutral load current of the other conductors."

Voltage unbalance and motors

Voltage unbalance (the NEMA MG 1 method) = $100 \times \frac{\text{largest deviation from the average}}{\text{average}}$. Under 1 percent is ideal. Over 2 percent is unacceptable for motors. A 1 percent voltage unbalance causes roughly 6 percent current unbalance in a motor, and the motor runs hot.

- 478 / 482 / 468 V. Average = 476. Largest deviation = 8. Unbalance = $100 \times 8 \div 476 = 1.7$ **percent**. Watch it.
- 208 / 206 / 196 V. Average = 203.3. Largest deviation = 7.3. Unbalance = **3.6 percent**. The motor must be derated or the supply fixed.
- Motor **current** unbalance should be under 10 percent. Zero amps on one phase is **single-phasing**, usually an open fuse. Shut the motor down.

Part F — Power Factor (the power triangle)

PF = real power (kW) ÷ apparent power (kVA), from 0 to 1.0. Picture a right triangle: **kW** along the bottom, **kVAR** (reactive power) going up, and **kVA** as the long side.

- **What lowers it:** inductive loads (motors, transformers, ballasts) draw lagging current. A lightly loaded motor has the worst PF.
- **Why you care:** low PF means more current, and so bigger conductors and transformers, for the same real work. Utilities **bill a penalty** on commercial accounts below about 0.9. The federal design standard expects a facility to run at 0.9 lagging or better.
- **Correction:** add **capacitors**, which draw leading current and cancel the lagging kVAR.

Step by step: sizing a capacitor bank

1. Get the load's real power in kW and its present power factor (from a power meter or the utility bill).

2. Pick the target PF, usually 0.95.
3. Find the multiplier in the table below, where the present PF row meets the target column.
4. Required kVAR = kW × multiplier. Round up to the next standard capacitor size.
5. If the capacitor is rated 240 V but used at 208 V, its output drops by $(208 \div 240)^2$, which is 0.75. A 240 V capacitor gives only 75 percent of its nameplate kVAR at 208 V.
6. Get approval from the engineer and the utility before adding capacitors. Capacitors can resonate with harmonic loads and blow fuses.

Present PF	to 0.90	to 0.95	to 1.00
0.60	0.849	1.005	1.333
0.70	0.536	0.692	1.020
0.75	0.398	0.553	0.882
0.80	0.266	0.421	0.750
0.85	0.135	0.291	0.620
0.90	0	0.156	0.484

kVAR multiplier = $\tan \phi_1 - \tan \phi_2$. Checked against Eaton's "Power factor correction: a guide for the plant engineer," Table 6.

- **Worked example:** a 100 kW load at 0.80 PF draws 125 kVA (75 kVAR). To correct to 0.95, the multiplier is 0.421, so you need $100 \times 0.421 = \mathbf{42 \text{ kVAR}}$. Afterward the load draws about **105 kVA**: less current and no penalty.
- **Eaton's example:** 400 kW at 0.87 corrected to 0.97 uses a multiplier of 0.316, so $400 \times 0.316 = 126 \text{ kVAR}$. Round up to a 140 kVAR bank.

NEC 2026 Article 460 — capacitor rules you will install to

- **460.6 Discharge:** capacitors "shall be provided with a means of discharging stored energy." The voltage must drop to 50 V or less within 1 minute after disconnecting. The discharge circuit is permanently connected or automatic. Manual discharge is not allowed as the means.
- **460.8 Conductors:** ampacity at least **135 percent** of the capacitor's rated current. Worked: a 50 kVAR, 480 V capacitor draws $50,000 \div (1.732 \times 480) = 60.1 \text{ A}$, so the conductors need $60.1 \times 1.35 = \mathbf{81.2 \text{ A}}$ minimum ampacity.
- **460.9 and 460.10:** overcurrent protection in each ungrounded conductor, and a disconnect that opens all ungrounded conductors at once, rated at least 135 percent of the capacitor current.
- **460.12 and 460.13:** the capacitor case is grounded, and it carries a nameplate with kVAR, voltage, phases, and the discharge device.

Capacitors bite after the power is off. OSHA 1910.333(b)(2)(ii)(C): "Capacitors shall be discharged and high capacitance elements shall be short-circuited and grounded" before you work on them. Lock out, wait for the discharge time, verify zero volts with a proved meter, then ground the terminals before you touch them.

Part G — Harmonics on 3-Phase, 4-Wire Systems

Nonlinear loads (computers, LED drivers, VFDs) draw current in short pulses instead of a smooth sine wave. Those pulses contain **harmonics**, which are currents at multiples of 60 Hz. The **3rd harmonic (180 Hz) and its odd multiples, called "triplens,"** do NOT cancel in the neutral. They **add**, so a shared neutral can carry more current than any phase conductor, and no breaker protects the neutral.

Step by step: a harmonics survey

1. **Inventory the loads.** Count PCs, printers, VFDs, LED drivers, electronic ballasts.
 2. **Feel for heat at the transformer.** Check that the vents are clear. A hot transformer on a light load is a warning.
 3. **At the transformer secondary,** clamp each phase and the neutral with a true-rms meter. If the neutral current is mostly at 180 Hz, it is mostly 3rd harmonic.
 4. **At the sub-panel,** compare each branch neutral to its conductor rating. Look for a discolored neutral bar. Scan with an infrared thermometer.
 5. **At a receptacle,** measure neutral-to-ground under load. 2 V or less is normal. Higher at 180 Hz points to harmonics; higher at 60 Hz points to imbalance.
- **Field case (Fluke):** phases read 410, 445, and 435 A true-rms, and the **neutral read 548 A**, higher than any phase. An average-responding meter read the phases about 20 percent low.
 - **Crest factor** = peak ÷ rms. A clean sine wave is 1.414. Anything else means harmonics.
 - **Transformer derating:** harmonic derating factor = $1.414 \times \text{rms current} \div \text{peak current}$. A transformer reading 430 A rms and 841 A peak gives $1.414 \times 430 \div 841 = 0.723$, so a 225 kVA transformer is good for only $225 \times 0.723 = \mathbf{162.7 \text{ kVA}}$ on that load.
 - **Fixes:** don't undersize the neutral on feeders with heavy electronic load, and upsize it where needed. Give each phase its own neutral instead of sharing one. Use **K-rated** or harmonic-mitigating transformers (Module 1.5C) or filters. Balancing the phases fixes only the 60 Hz part of the neutral current.

Part H — Phase Rotation (Sequence)

- Rotation, normally **A-B-C**, sets which way 3-phase motors turn. **Swap any two** line conductors and the motor reverses. Swapping all three changes nothing.

- **Verify before energizing rotating equipment.** A pump or compressor run backward can be destroyed in seconds, and equipment turning the wrong way is dangerous to people. Keep rotation consistent A-B-C through the building.

Step by step: rotation check at a panel or starter (Fluke 9040 type tester)

1. Use the same PPE, gloves, and approach as Part C. Confirm voltage is present with your meter first.
2. If you can, de-energize before connecting the leads, then re-energize to read.
3. Connect the three leads to L1, L2, L3. **Confirm with your voltmeter that all three leads are on phases.** The tester's manual warns that the rotation light comes on even if one lead is on the neutral instead of a phase.
4. Read the clockwise or counterclockwise indicator. Clockwise = A-B-C.
5. De-energize to remove the leads if the setup allows it. Put covers back on with every screw.

Step by step: rotation check at the motor (Fluke 9062 type tester)

1. **Motor disconnected, all leads off.** Clip the tester to the motor terminals: L1 to U (T1), L2 to V (T2), L3 to W (T3).
2. Press ON and turn the motor shaft half a turn to the right. The indicator shows which way the motor will turn when A-B-C is applied in that order.
3. On a running motor without a VFD, the same tester can read rotation without contact: lay it parallel to the shaft within 1 inch of the motor case.

Step by step: correcting rotation

1. Open and lock the disconnect that is in sight of the motor. Apply your own lock and tag.
2. Verify absence of voltage at the motor leads, phase to phase and phase to ground, with a meter proved live-dead-live (NFPA 70E 120.6).
3. Swap **any two** of T1, T2, T3 at the starter load terminals or in the motor's connection box.
4. Re-energize. Bump the motor uncoupled if you can, and confirm rotation with the tester or by sight.
5. Mark the conductors so the next person keeps the same order.

NEC 2026 210.5(C)(2) — phase identification

Where a building has branch circuits from more than one voltage system (for example 480Y/277 and 208Y/120), "each ungrounded conductor of a branch circuit shall be identified by phase or line and by nominal voltage system at all termination, connection, and splice points." The identification method must be posted at each panelboard.

Part H — mistakes to avoid

- Trusting a rotation light with one lead on the neutral.
- Swapping all three leads "to be sure." It changes nothing.

- Fixing rotation at the motor on one unit and at the panel on the next. Pick one place and keep the building consistent.

NEC 2026 Checkpoints (2023 number in parentheses where it moved)

- **110.15** high-leg orange marking • **110.16** arc-flash label • **110.21(B)** field-applied labels.
- **408.10(E)(1)** (408.3(E)(1)) bus phase arrangement, B = high leg • **408.10(F)(1)** (408.3(F)(1)) high-leg caution label.
- **Article 120** (Article 220) load calculations • **120.61** (220.61) neutral load • **310.15(E)(1)** neutral as a current-carrying conductor.
- **210.5(C)(2)** phase and system identification • **460.6-460.13** capacitors • **430** motors.

Hands-On Field Exercise

- With a qualified electrician, run the full approach on a live panel: label, PPE, meter rating, live-dead-live, the seven readings, live-dead-live again.
- Meter phase-to-neutral and phase-to-phase on a 120/208 V and a 277/480 V system. Confirm 1.732 with the meter.
- Identify an unknown panel from its seven readings, using the table in Part C.
- On a high-leg delta, find the orange leg, confirm about 208 V to neutral, confirm it is on B, and check the caution label and the breakers on B.
- Work all five power examples. Size a transformer for a 208 V panel.
- Balance a real panel schedule to under 5 percent on paper.
- Clamp the neutral and all three phases of a panel feeding electronics. Calculate what the neutral should be and explain any difference.
- Calculate the kVAR to correct a 100 kW, 0.80 PF load to 0.95, and the minimum conductor ampacity for that bank at 480 V.
- Check rotation at a starter with a rotation tester, then reverse a motor by swapping two leads under lockout.

Sources used in this module (public documents)

- NFPA 70, National Electrical Code 2026 (free read-only access at [nfpa.org](https://www.nfpa.org)): 110.15, 110.16, 110.21(B), 120.61, 210.5(C), 310.15(E), 408.10(E)/(F), 460.6-460.13, 680.5.
- NFPA 70E, 2024 edition: 110.6(E), 120.6, 130.2, 130.7(C)(15).
- OSHA 29 CFR 1910.333 and 1910.334: [osha.gov/laws-regs/regulations/standardnumber/1910](https://www.osha.gov/laws-regs/regulations/standardnumber/1910)
- NAVEDTRA 14027 Construction Electrician Intermediate (maritime.org/doc/pdf/conselect2.pdf) and NAVEDTRA 14046 Construction Electrician 1.
- UFC 3-520-01 Interior Electrical Systems and UFC/UFM 3-560-01 Electrical Safety, O&M: [wbdg.org/dod/ufc](https://www.wbdg.org/dod/ufc)
- Schneider Electric NQ/NQM Panelboards User Guide 80043-712-06 and Dry-Type Transformers bulletin 43006-850-01: [se.com](https://www.se.com)
- Fluke 9040 and 9062 users manuals; Fluke application notes "Troubleshooting power harmonics" and "Proper use of clamp meters."

- Eaton SA02607001E, "Power factor correction: a guide for the plant engineer": eaton.com
- Michael Johnston, "The Wild Leg," Electrical Contractor magazine, Feb. 2025: ecmag.com
- Power Monitors Inc., "Voltage Unbalance and Polyphase Induction Motors": powermonitors.com

Foundation masterclass. Applied in Modules 1.4 (panels), 1.5 (transformers), 1.6 (motors).