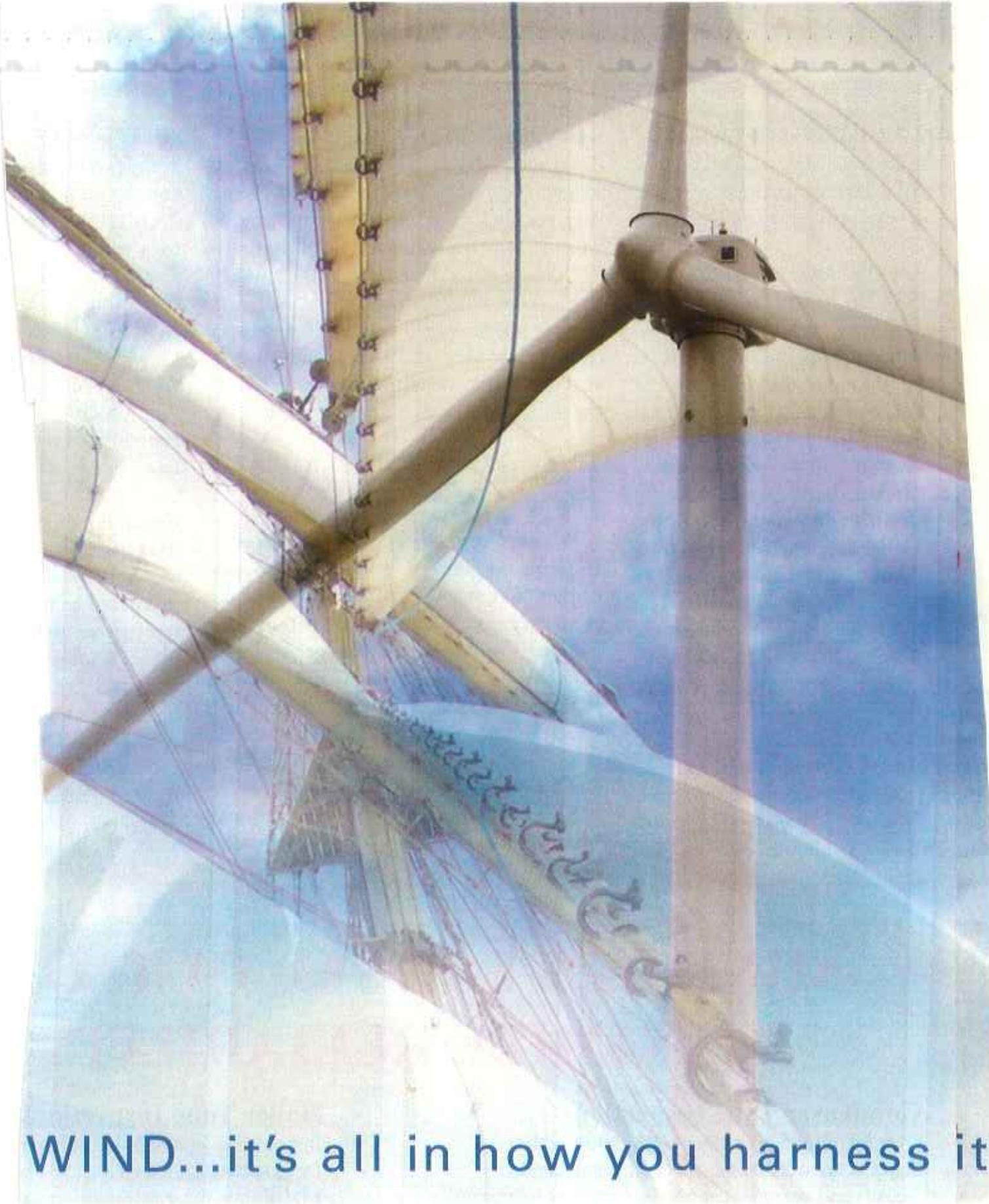


Chapter 8a

Topics:

- Alternative Energy Review
- AC Health Effects
- Measurement Review
 - Single Phase
 - Two Phase
 - Three Line Two Phase
 - Three Phase
 - Wye
- Three Phase Power



WIND...it's all in how you harness it

T. Boone Pickens

Up There

Total height:

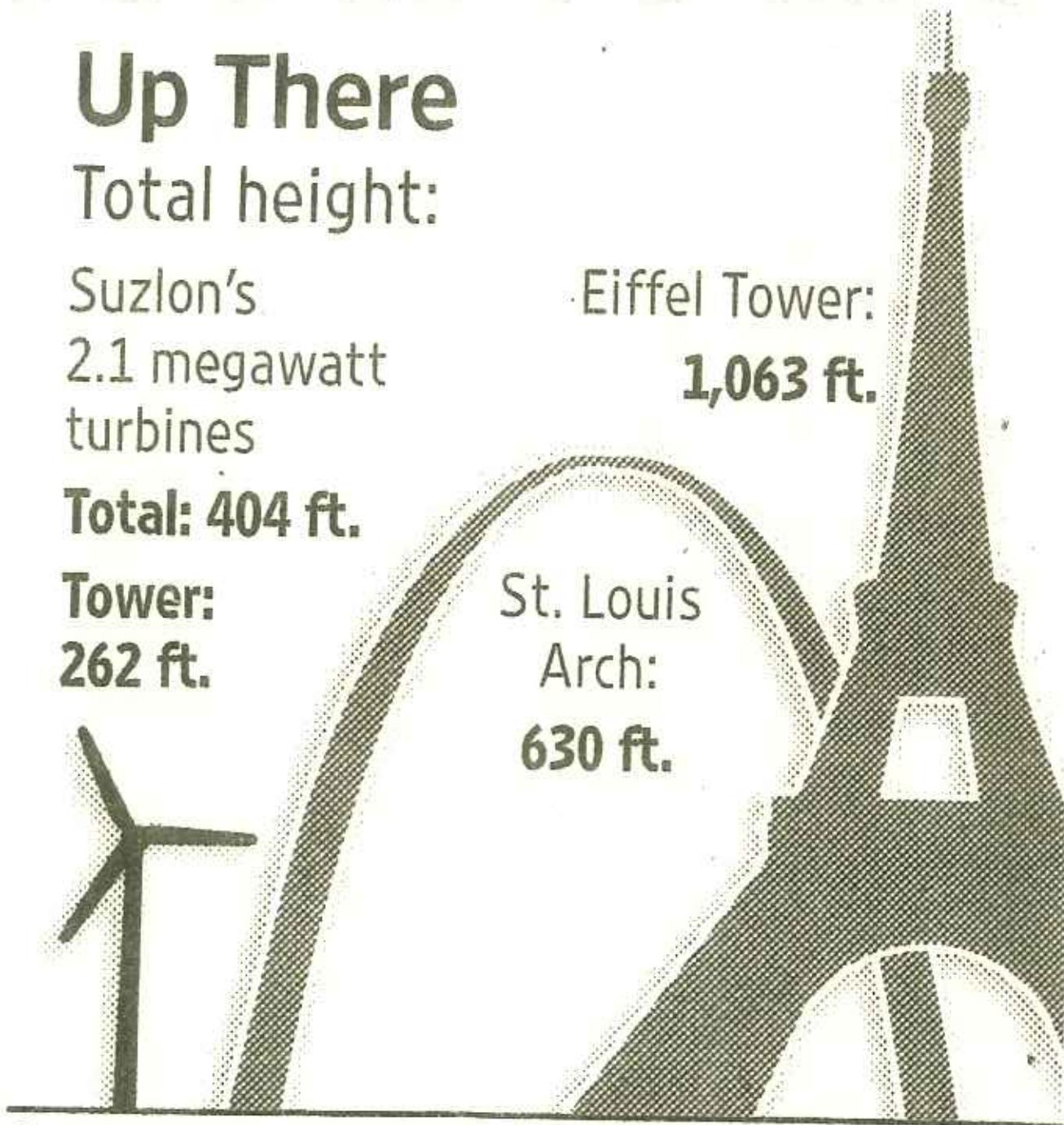
Suzlon's
2.1 megawatt
turbines

Total: 404 ft.

Tower:
262 ft.

Eiffel Tower:
1,063 ft.

St. Louis
Arch:
630 ft.



Source: the company

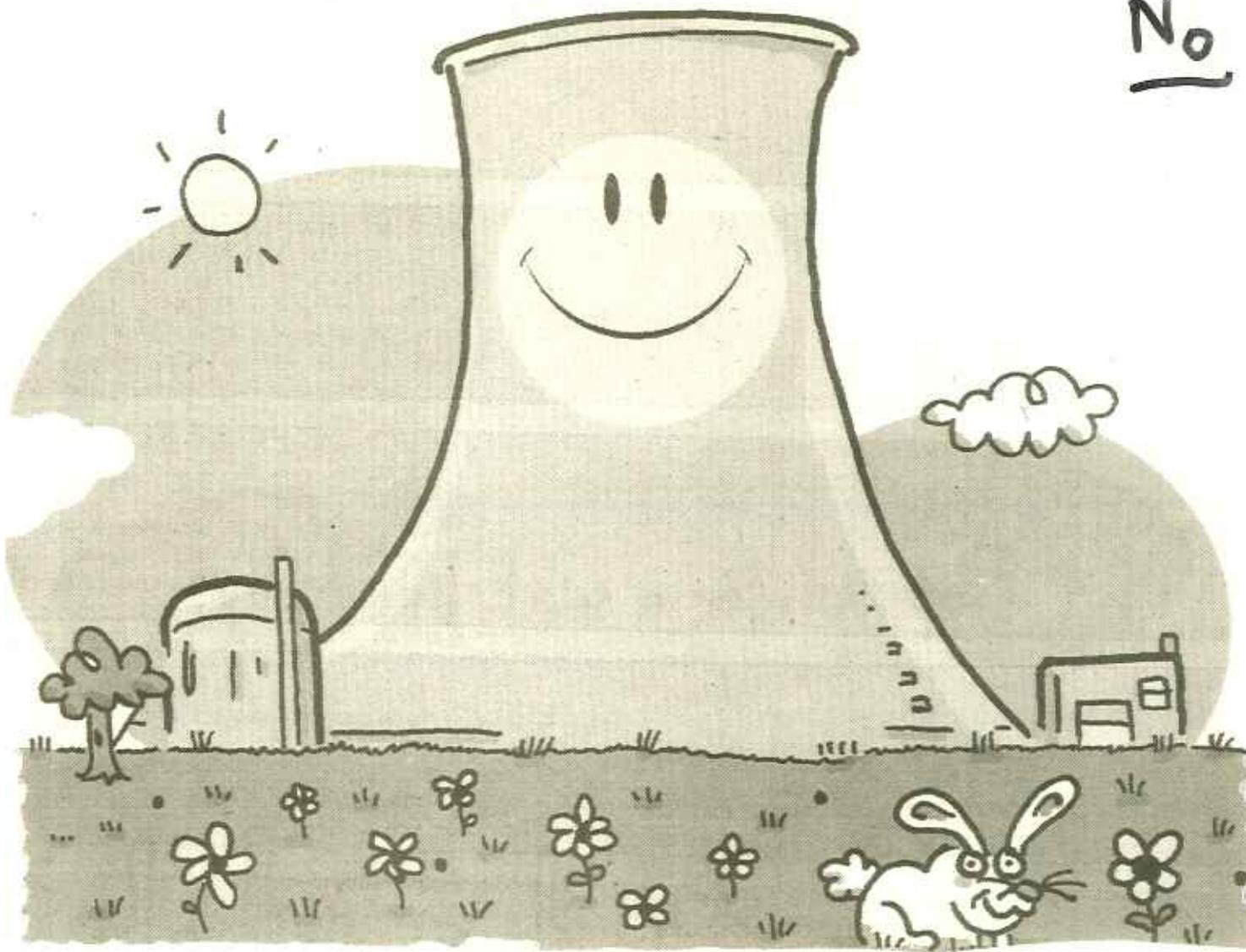
You're Blocking My View

Windjammer



From a Greenpeace ad lampooning Sen. Edward Kennedy's fight against an offshore wind farm near his summer home.

Some Love for Nuclear Power



N₂O

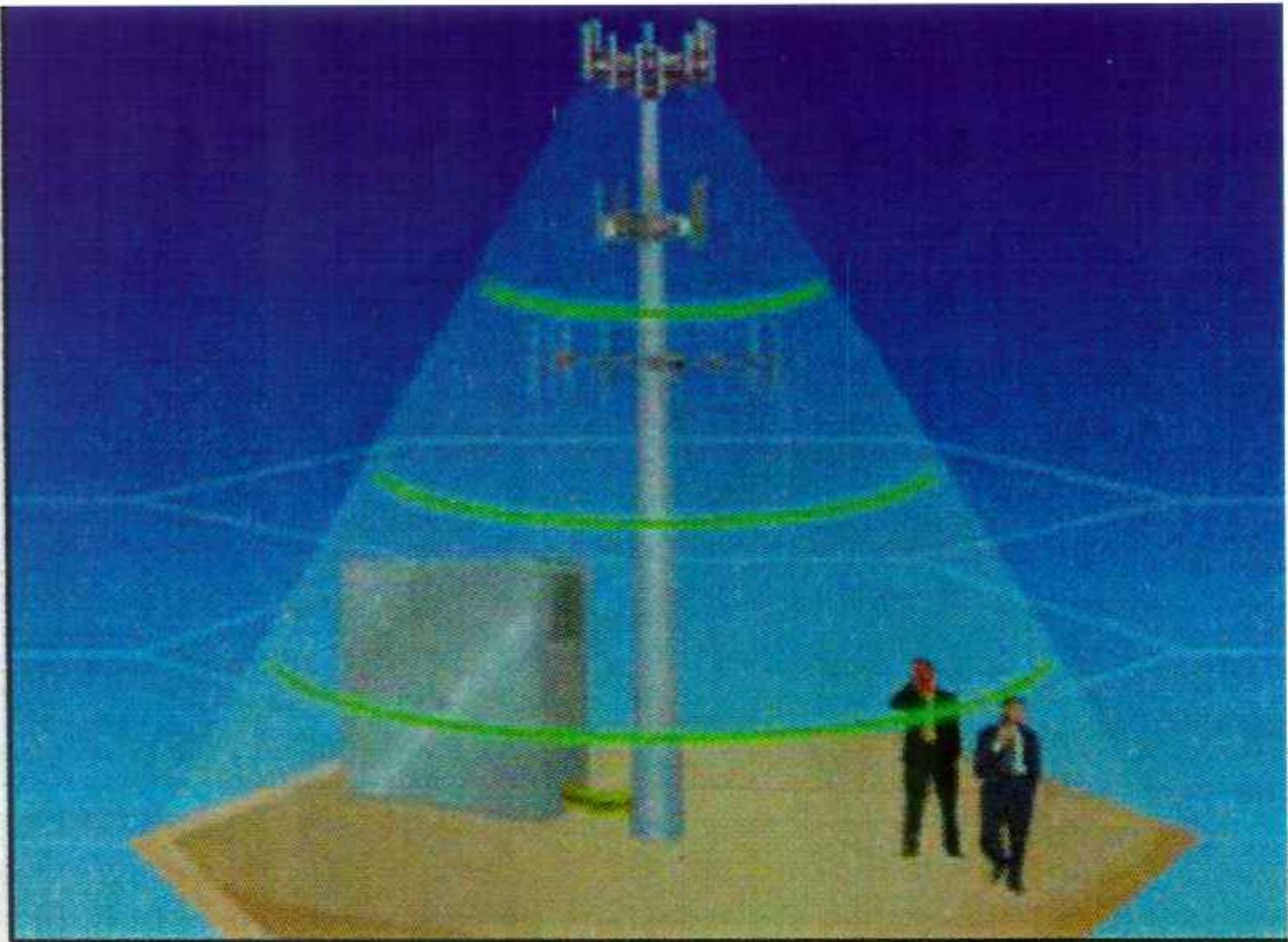
SO_x, NO_x
 CO_2

VIRTUOUS LONER

For every 1 person who bikes to work:

- 5 people walk
- 9 people take public transit
- 21 people car pool
- 154 people drive alone

(Source: Josh Margolis, CantorCO2e quoting U.S. Bureau of Census)



Flux
 $N \text{ (hr)}^{\frac{1}{2}}$
↑
intensity
↑
energy
of
radiation

Figure 3 . Exposure of humans to R energy from radio sites.

AC : MW @ 60 Hz

Cell : 0.1 W @ 6 GHz

Health of irradiated cells?

Type of mobile radio	Frequency (MHz)	Average radiated power
Cellular/PCS	824-849 MHz 1850-1990 MHz	A few hundred milliwatts
Two-way, hand-held (walkie-talkie)	30, 50, 150, 450 and 800 MHz bands	Between 2 and 5 watts
Cordless telephone	49, 915, 2450 MHz	Tens of milliwatts

Table 1 . Typical portable/mobile radio equipment.

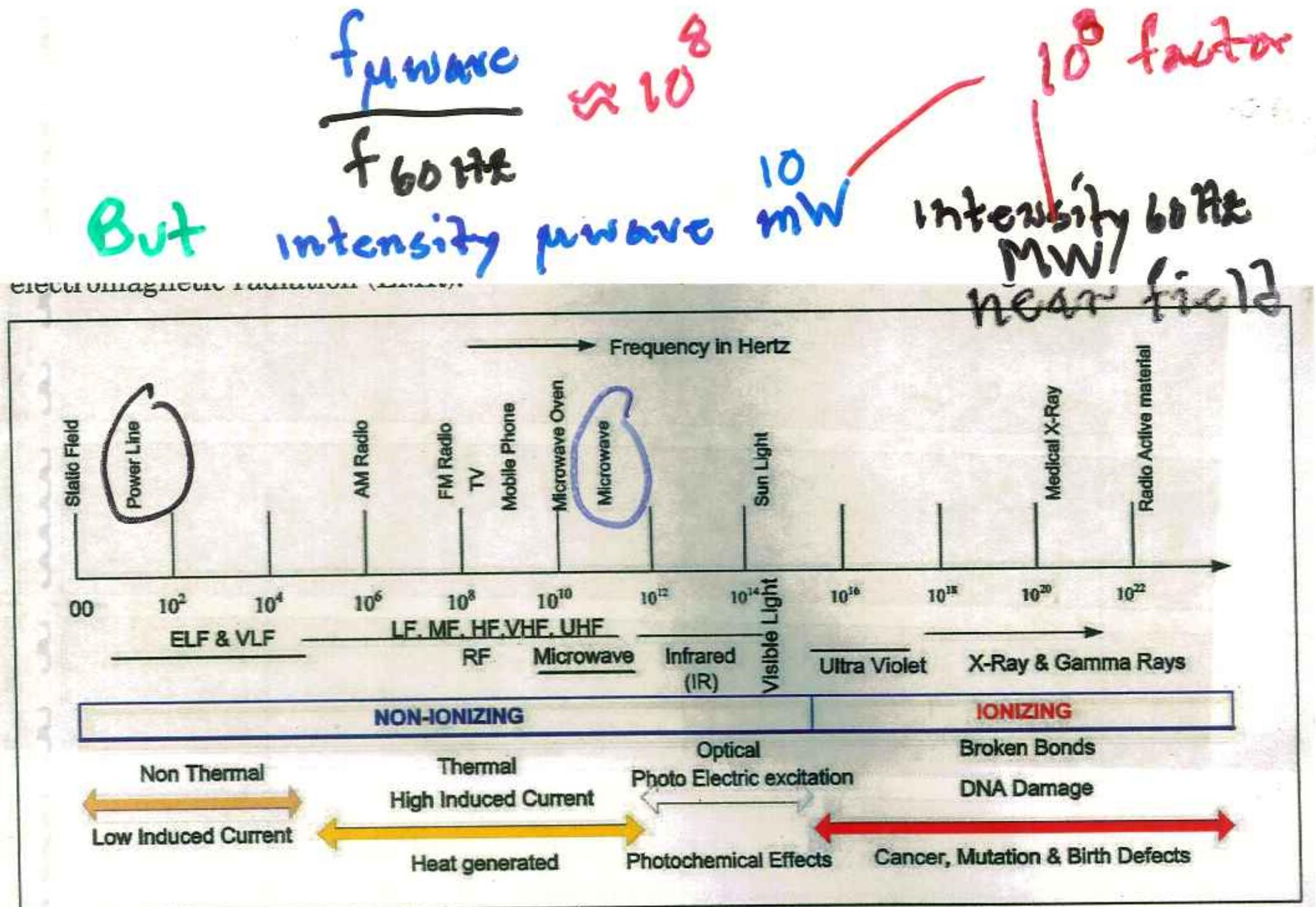
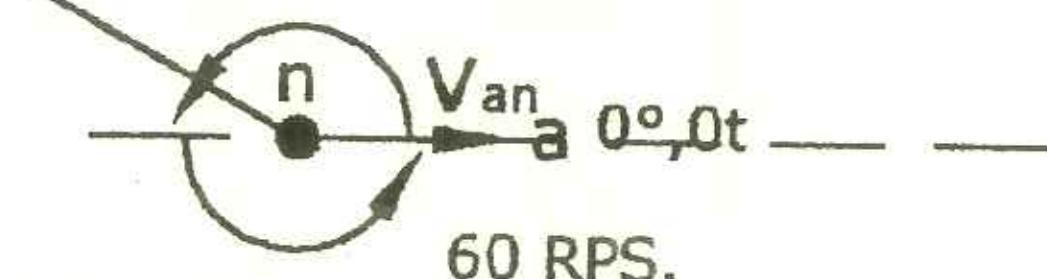


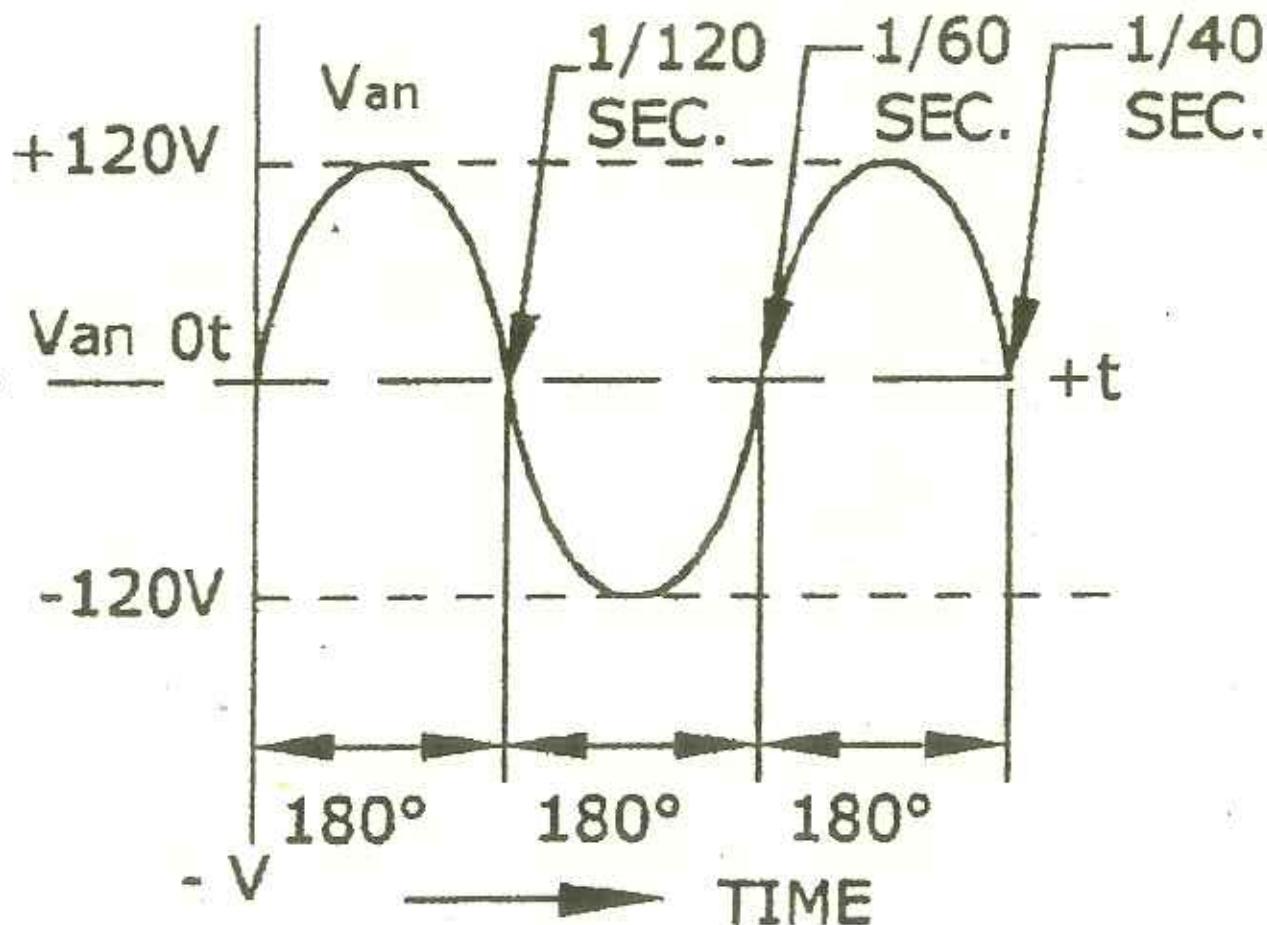
Figure 1 · Electromagnetic spectrum.

REVOLUTIONS PER SECOND (RPS.)

COMMON PROBES
REFERENCE V_{AN}, V_{BN}



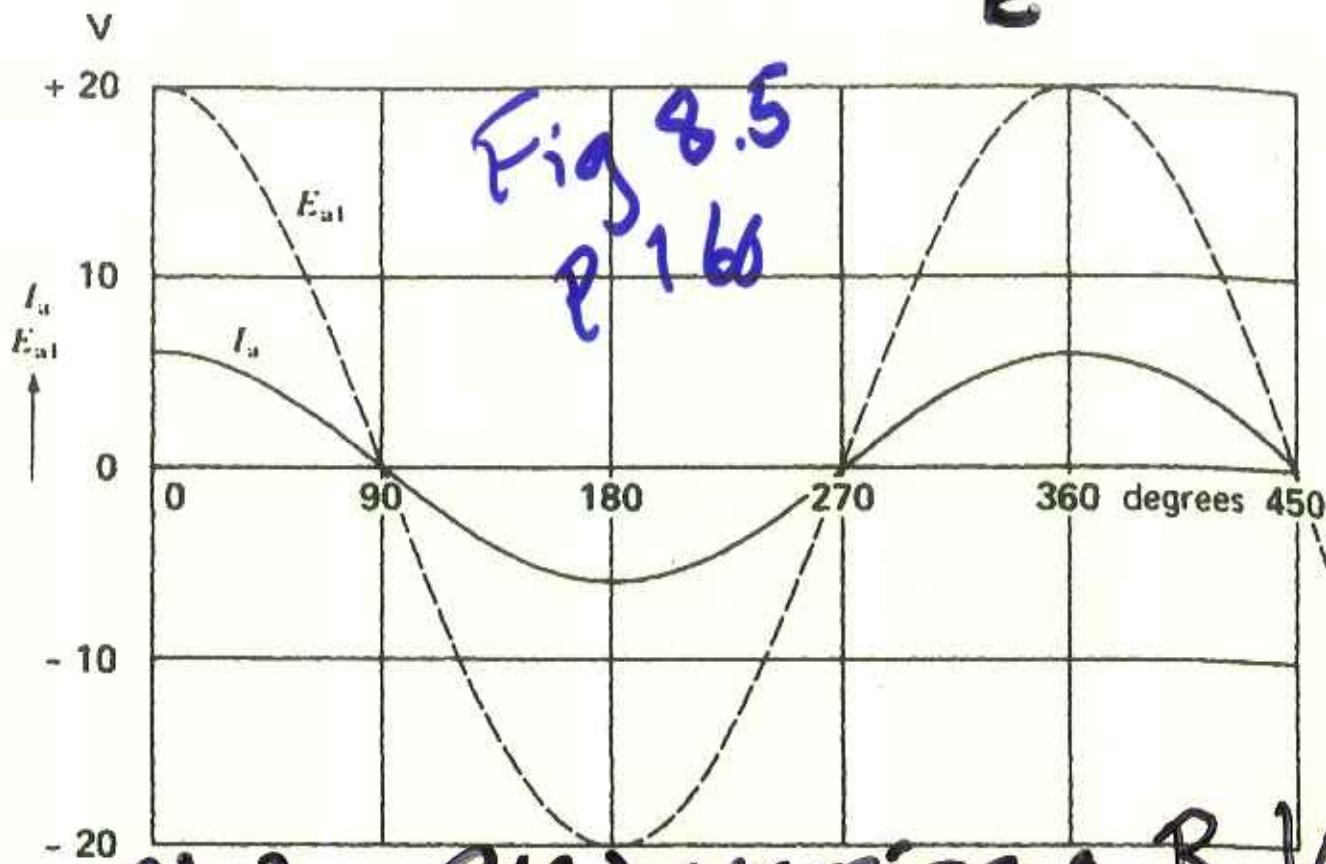
$$V_{an} = 120V \cdot \sin(W^\circ t + 0^\circ)$$



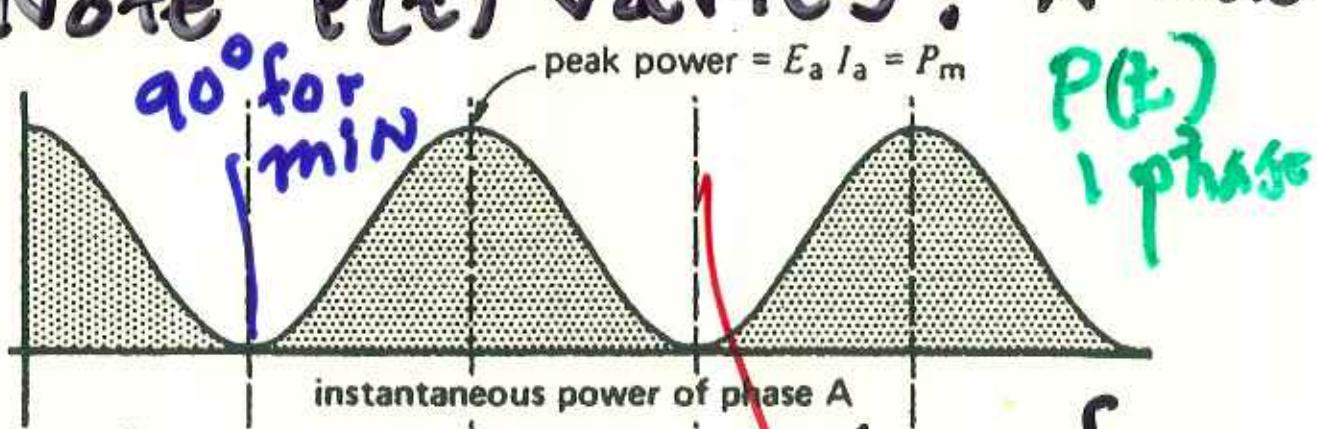
$$V_{an} = 120V \cdot \sin(W^\circ t + 0^\circ)$$

Measured a to n

2 For a resistive load



Note $P(t)$ varies: R load



\approx Power pulses at $2f_{\text{mains}}$

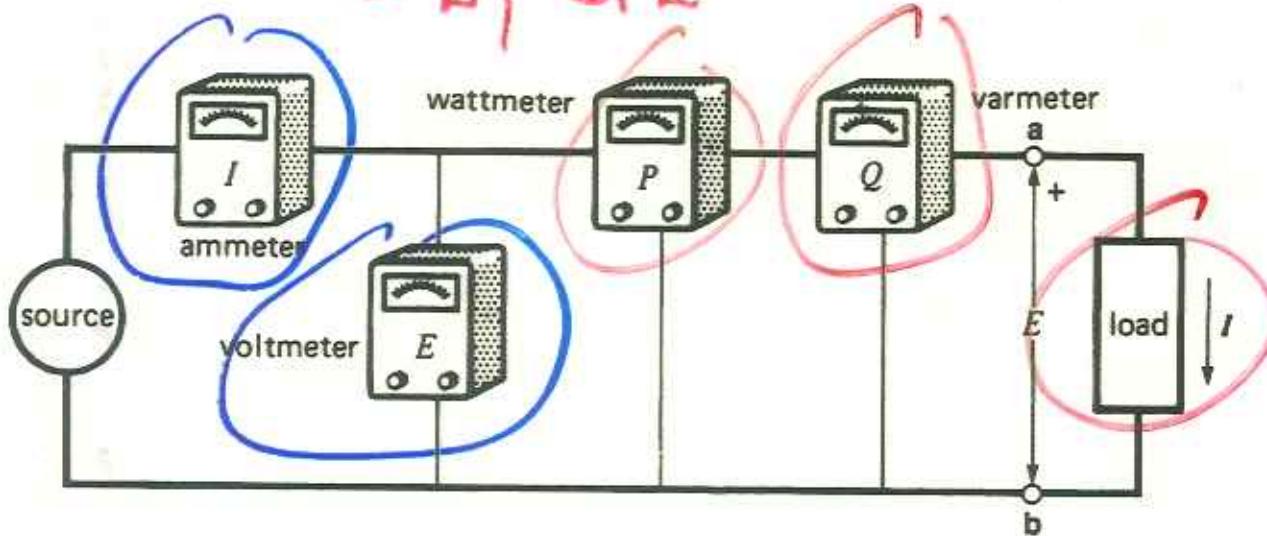
$$- P_{Av} = EI$$

$$- \textcircled{1} P_{\text{peak}} = ?$$

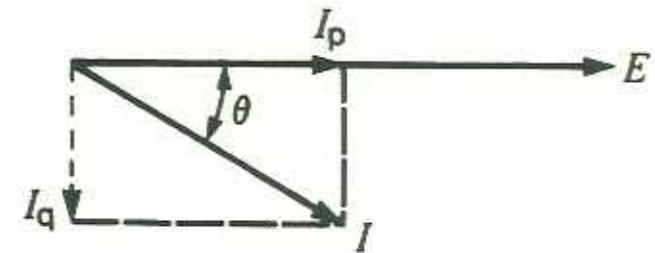
How to
eliminate
 $P(t)$?

V_s, I_s

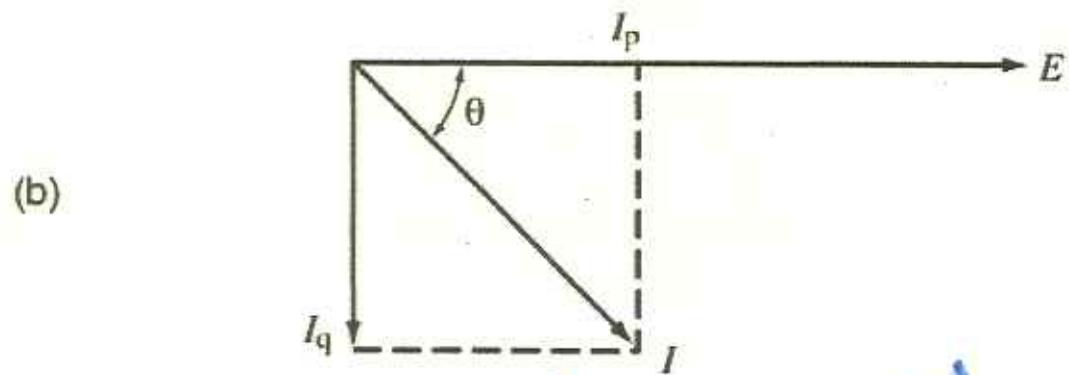
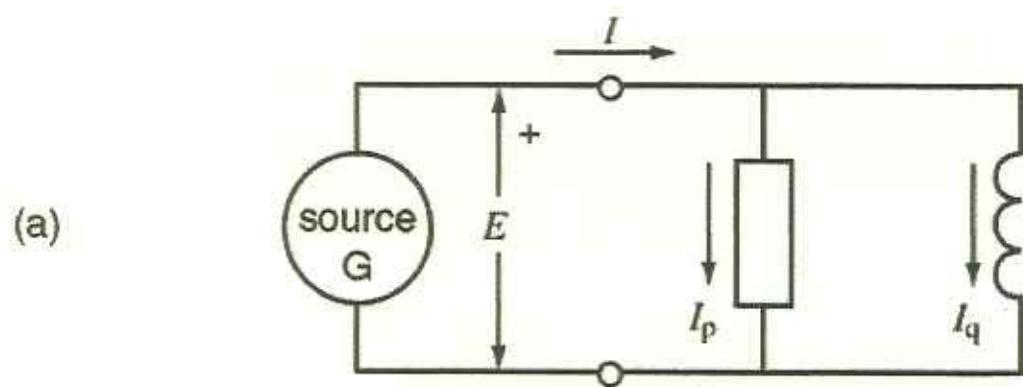
P_2, Q_2



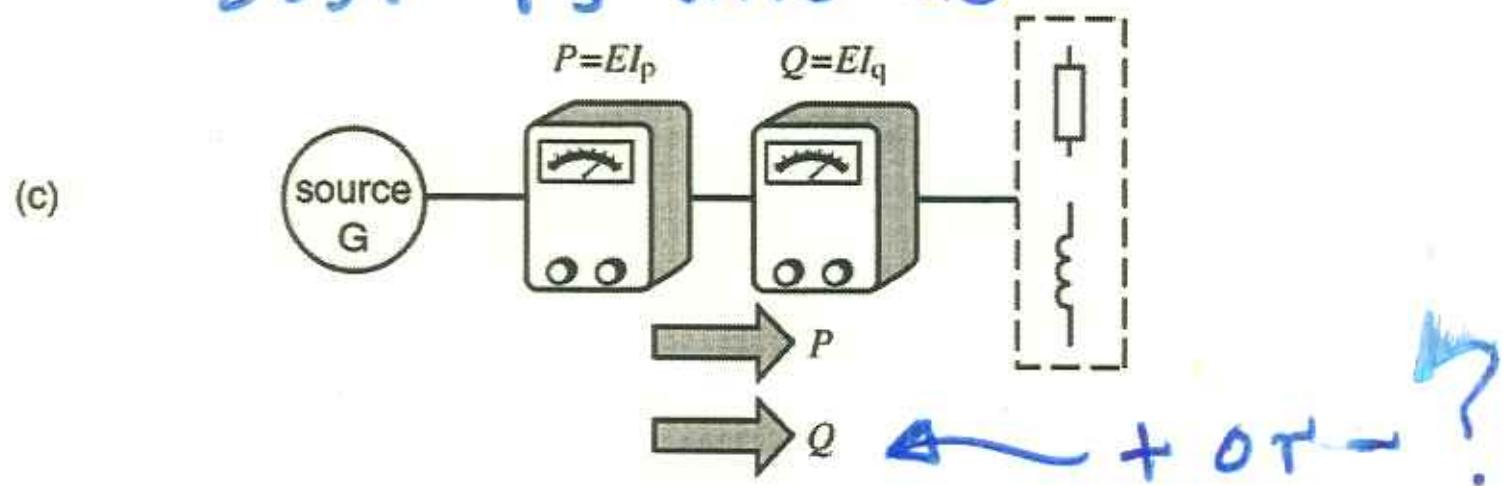
(a)

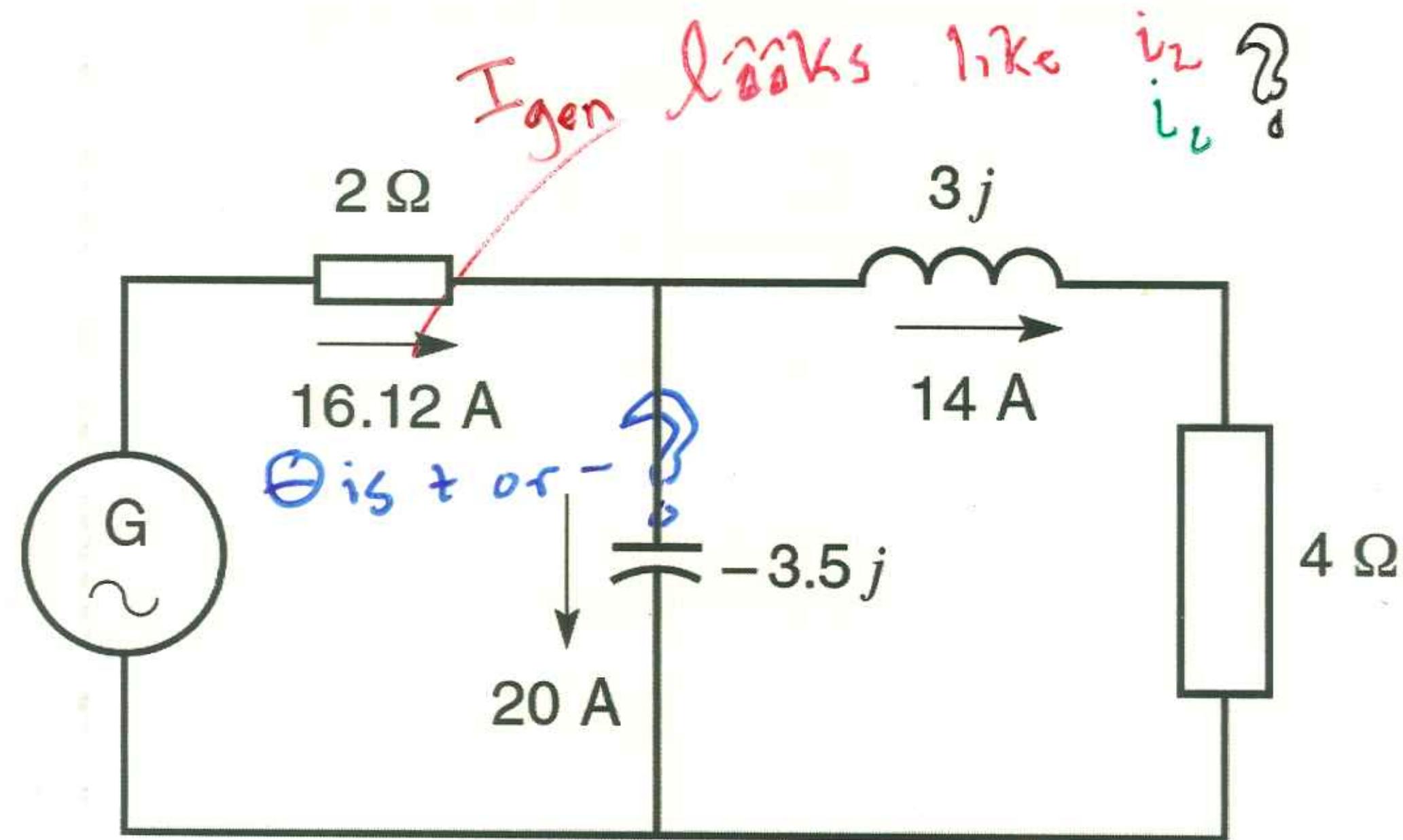


(b)

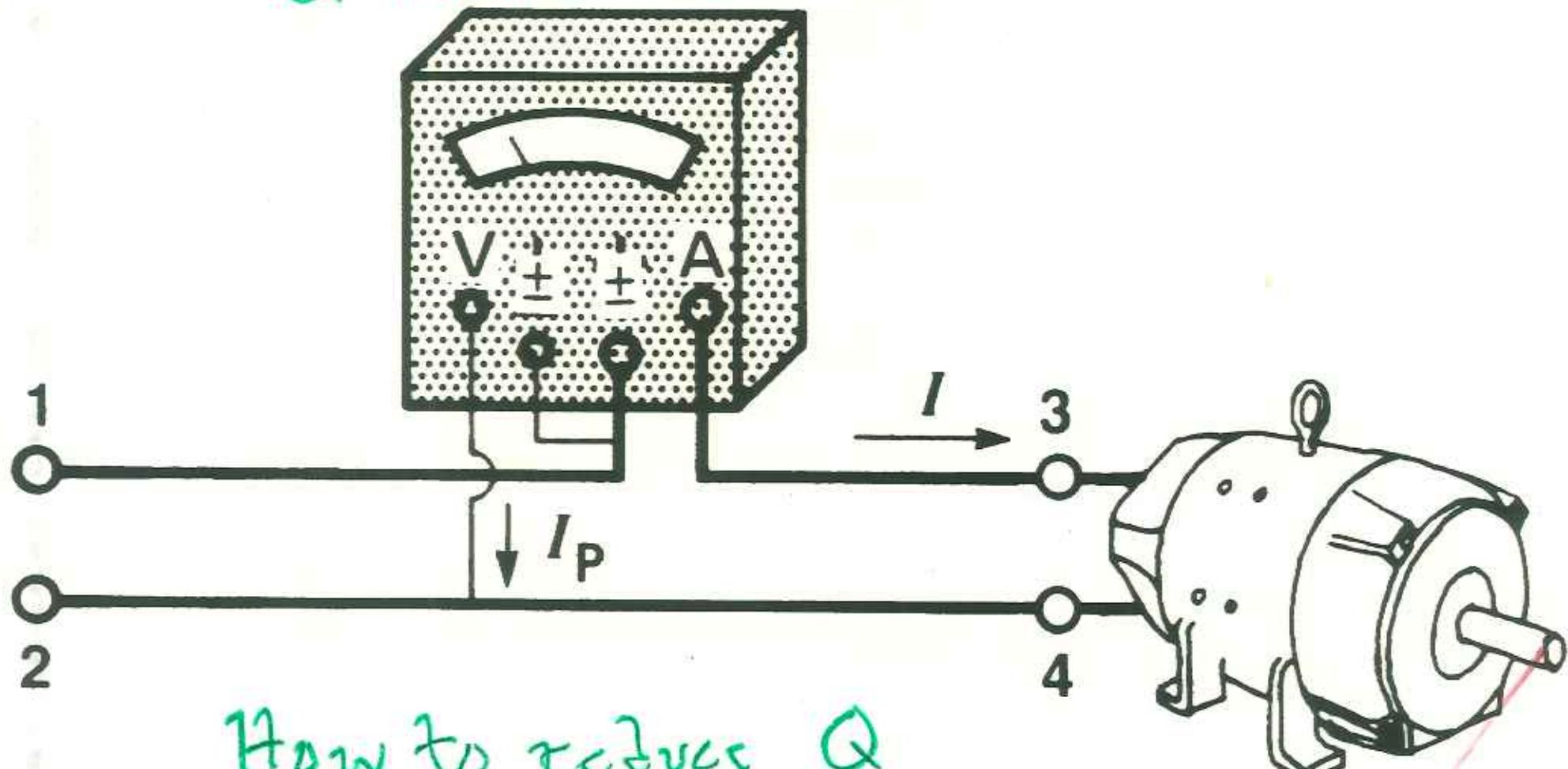


Just P's and Q's





P meter reads?
Q meter reads?

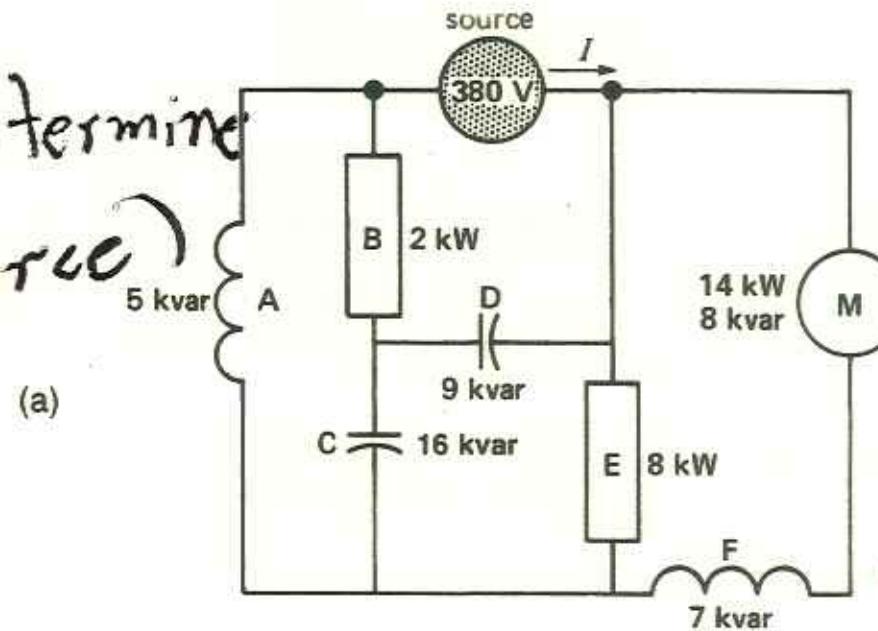


How to reduce Q

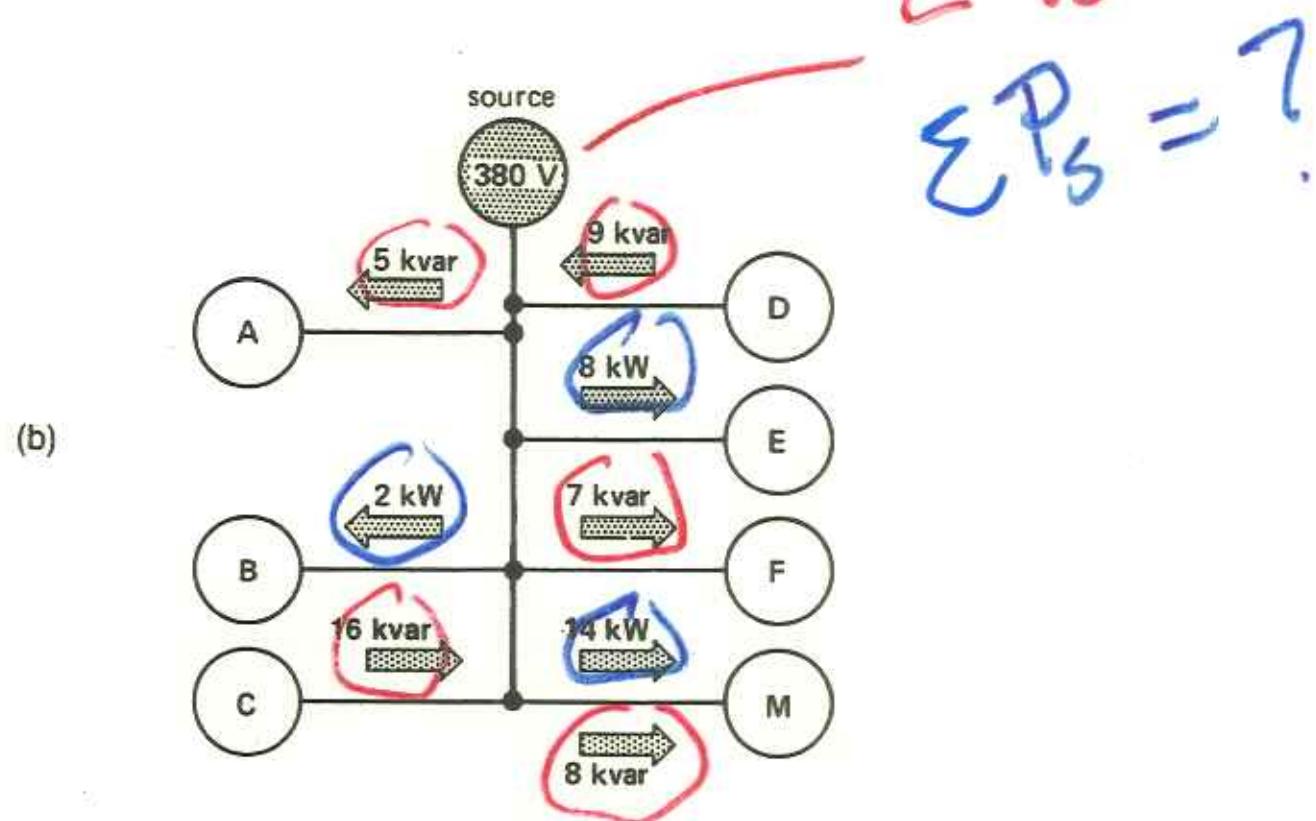
P_{mech}

Can you determine
 $I_{380\text{ source}}$

$$I = ?$$

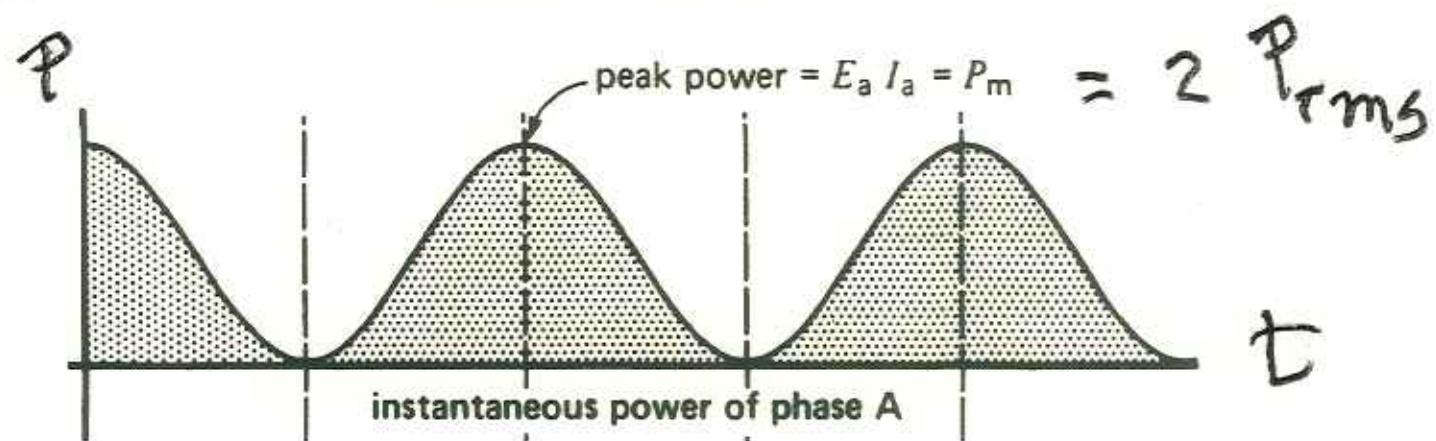
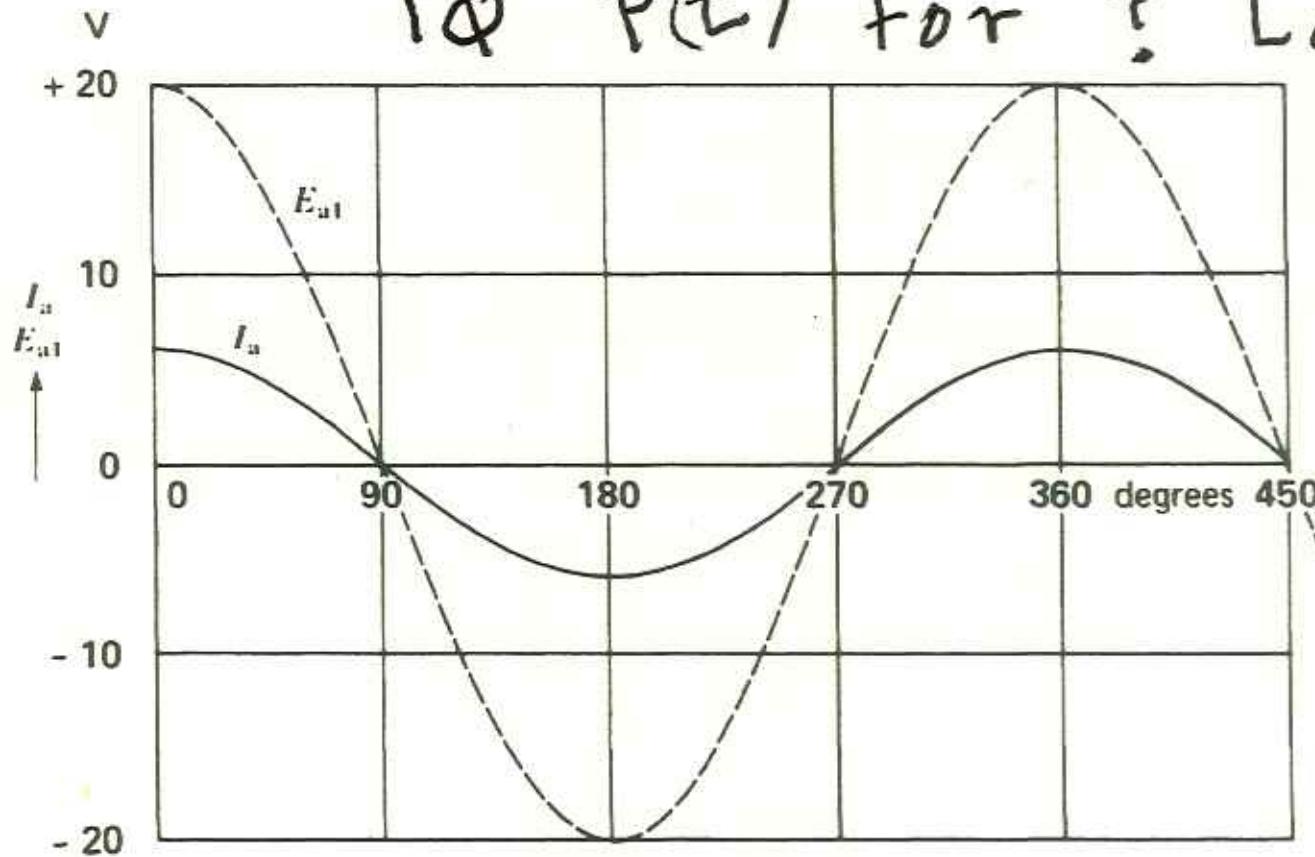


$$\sum Q_s = ?$$



$$\sum P_s = ?$$

1ϕ $P(t)$ for ? Load



~~Two~~ Single Phase Generator
is shown below

① ? When rotor as
shown is e_{coil(a)}
max or min?

P from a & b coils

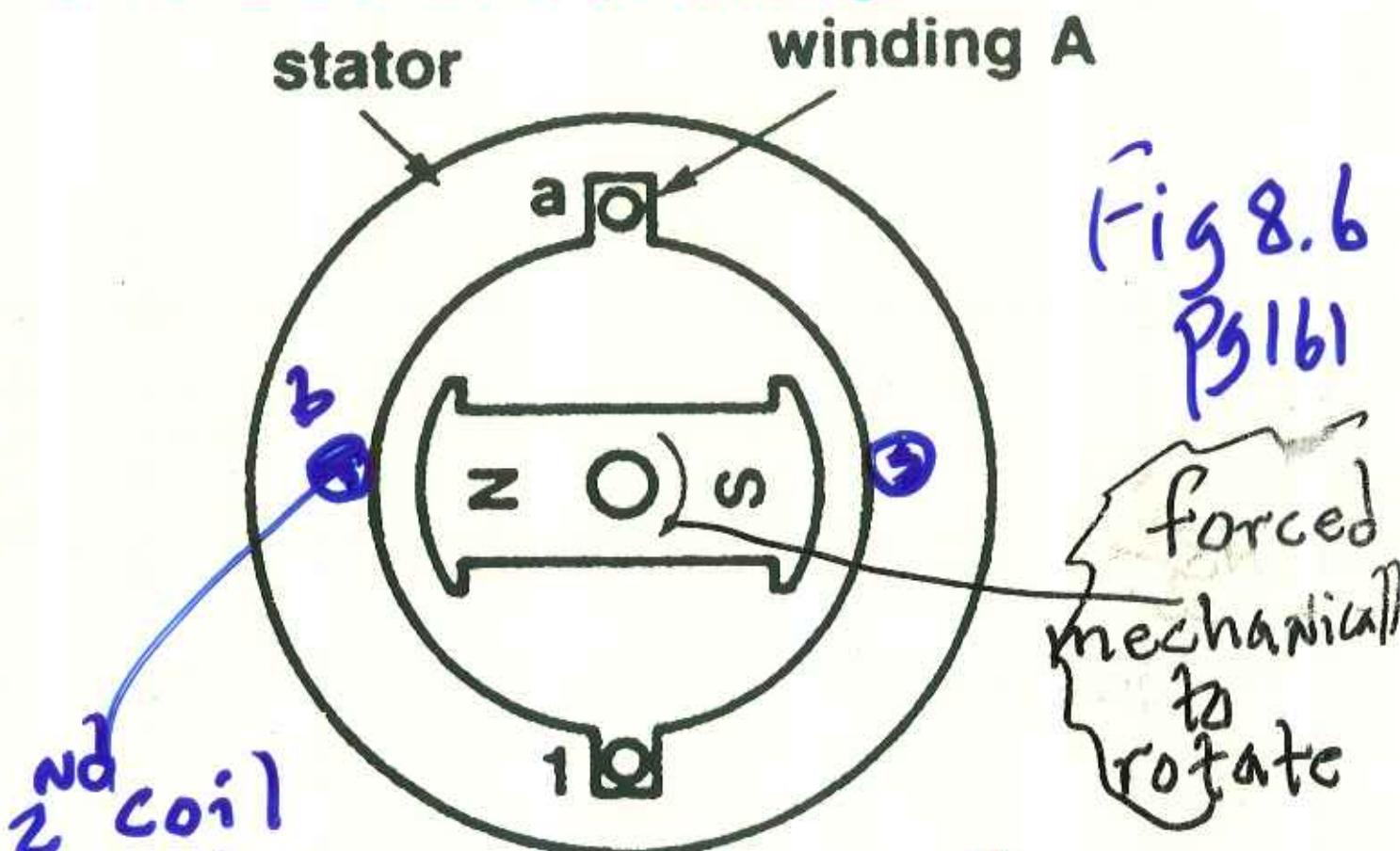
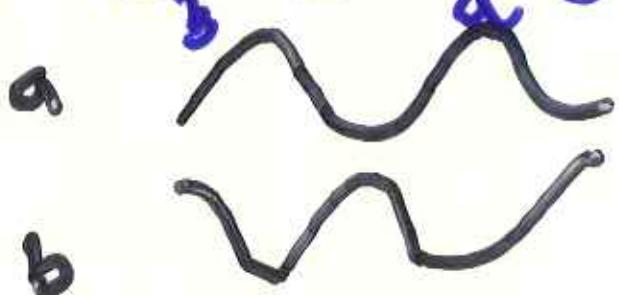


Fig 8.6
Pg 161

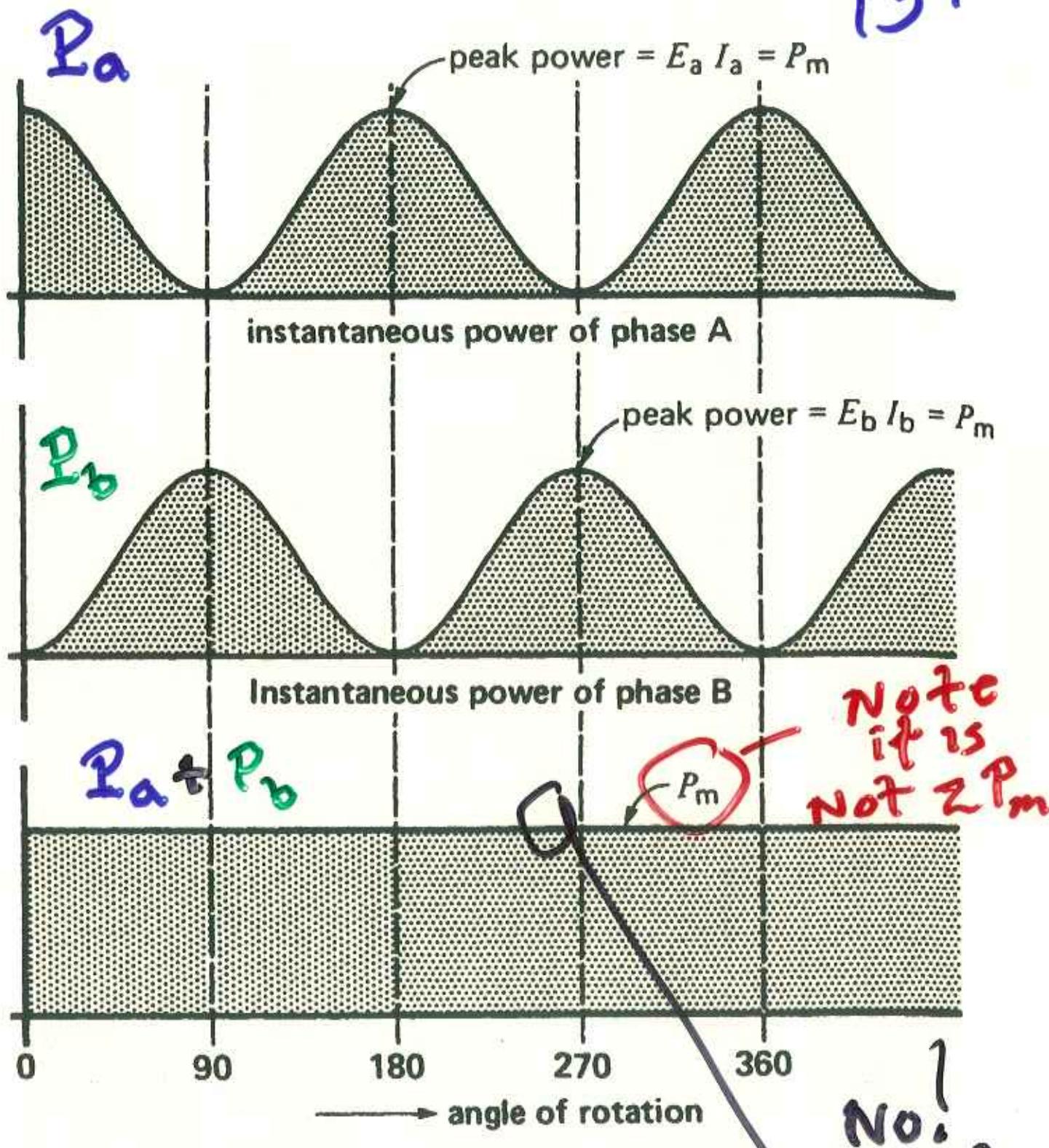
forced
mechanical
to
rotate

2nd coil creates
 $e_2 = e_a (\pm 90^\circ)$ from e_a



Add $P_a + P_b$

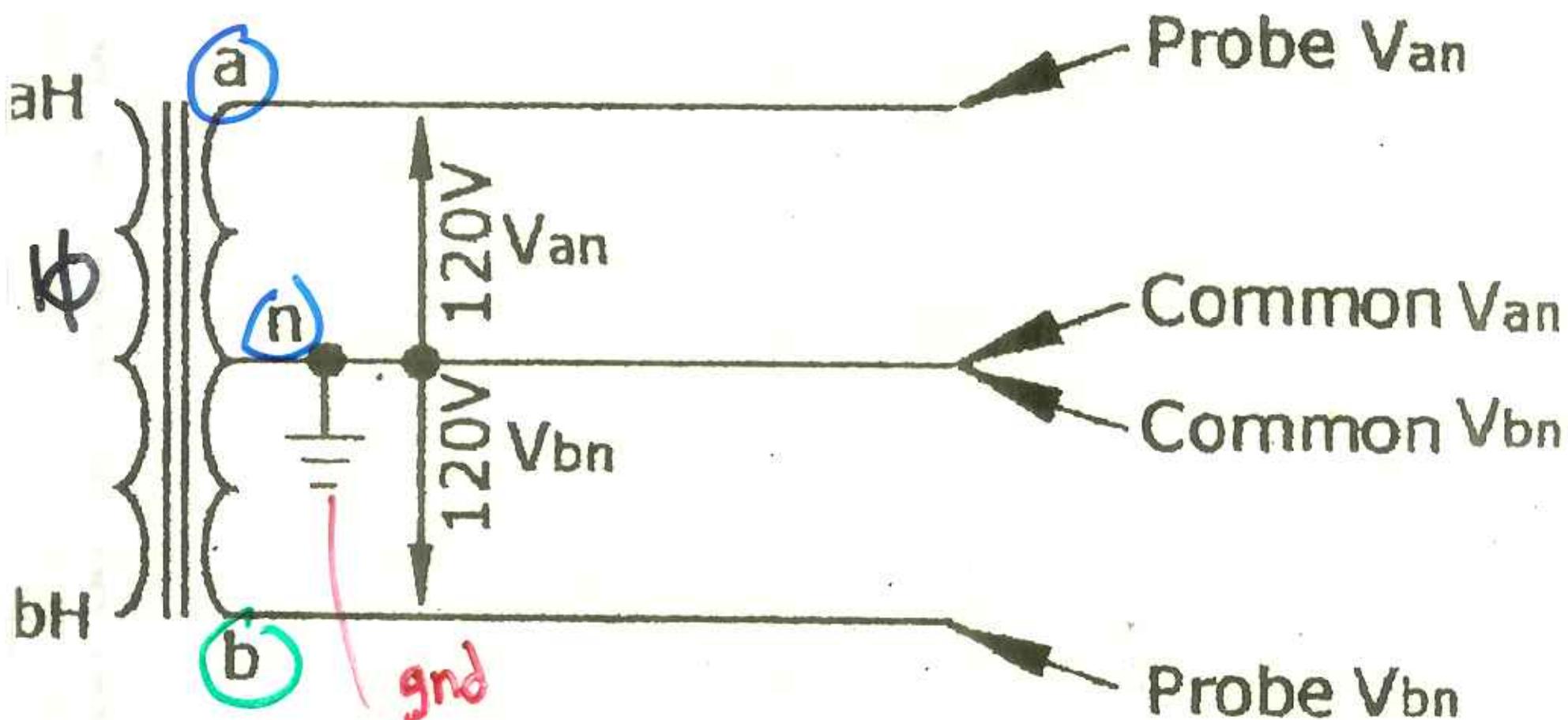
② $P_{ab} \neq f(1)$ ✎
Agree?



$2\phi AE$ Products

@ $\frac{1}{2}$ mHz

No. pulsations of $p(t)$



Power co. service transformer.

TRANSFORMER PHASE VOLTAGE

$$V_{an} = 120V + 0VJ = 120V < 0^\circ$$

$$V_{bn} = -120V + 0VJ = 120V < 180^\circ$$

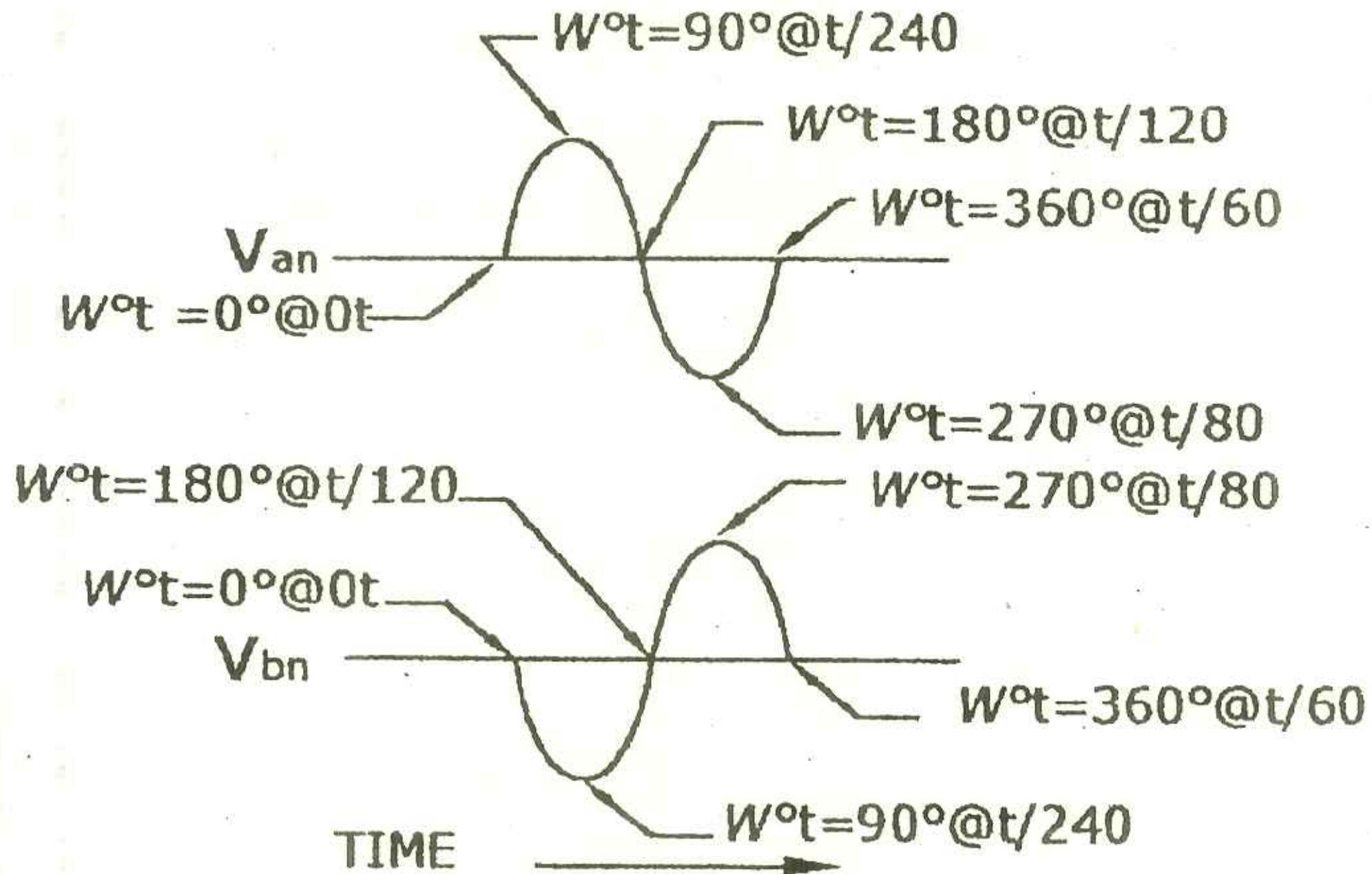
$$V_{nb} = V_{bn} + < 180^\circ$$

$$V_{nb} = 120V < (180^\circ + 180^\circ) = 120V < 0^\circ$$

$$V_{ab} = V_{an} + V_{nb}$$

$$V_{ab} = 240V + 0VJ = 240V < 0^\circ$$

Assumption: All phase currents flow into the transformer and the neutral current flows out of the transformer.



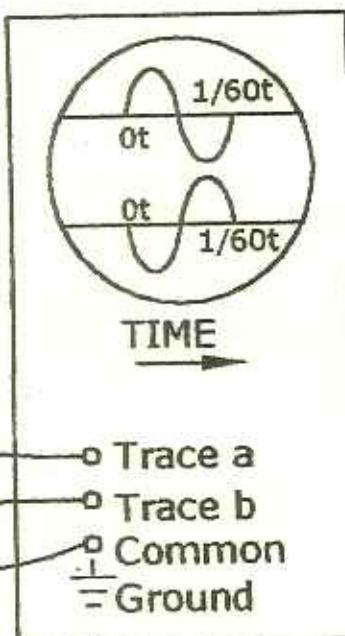
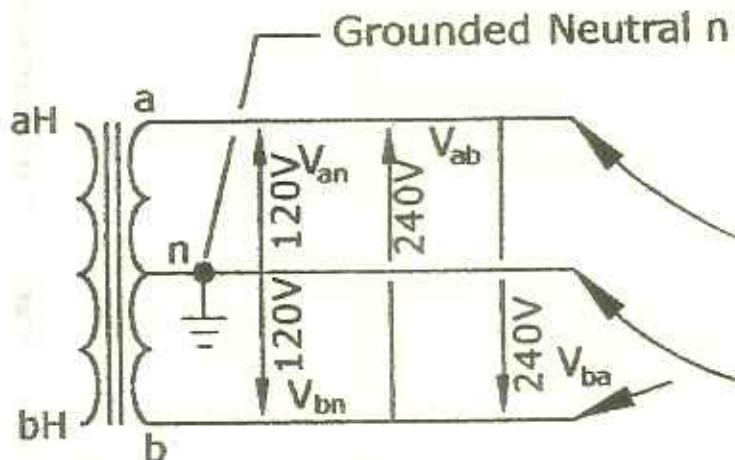
Only phase to ground voltages should be measured with an oscilloscope. Never attempt to measure phase to phase voltage with an oscilloscope.

Proper high voltage probes must be used to measure all phase wires.

All measurements with an oscilloscope are dangerous and could be lethal or short circuit the test equipment and should only be performed by a professional electrical engineer or a master electrician with the proper probes. Voltages above 300V should not be measured with an oscilloscope.

Real world application

Service 240/120V, 1PH, 3W, GN



Trace a V_{an} Sync on a

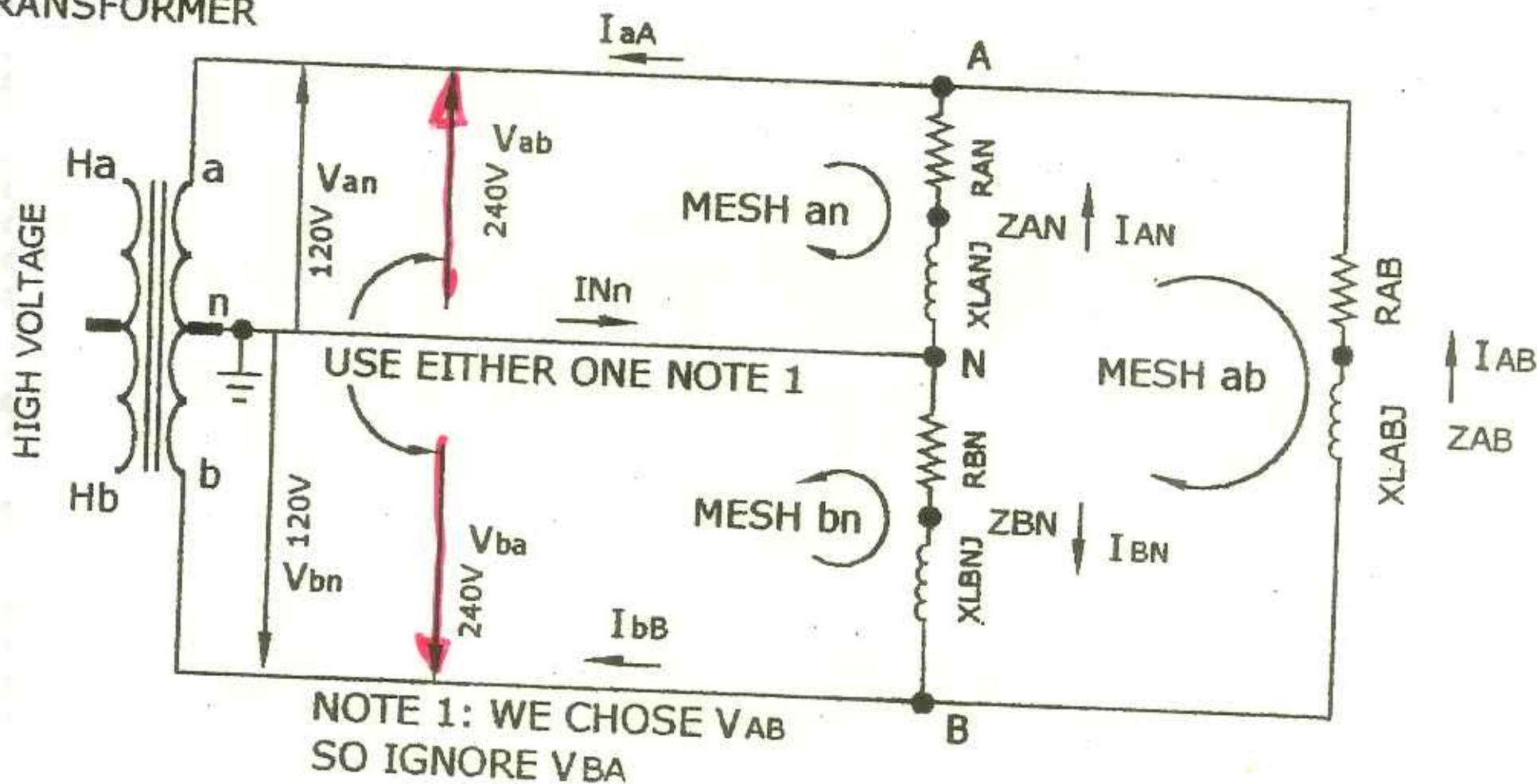
Trace b V_{bn}

Dual trace oscilloscope

Three Mesh Circuit for home Apt

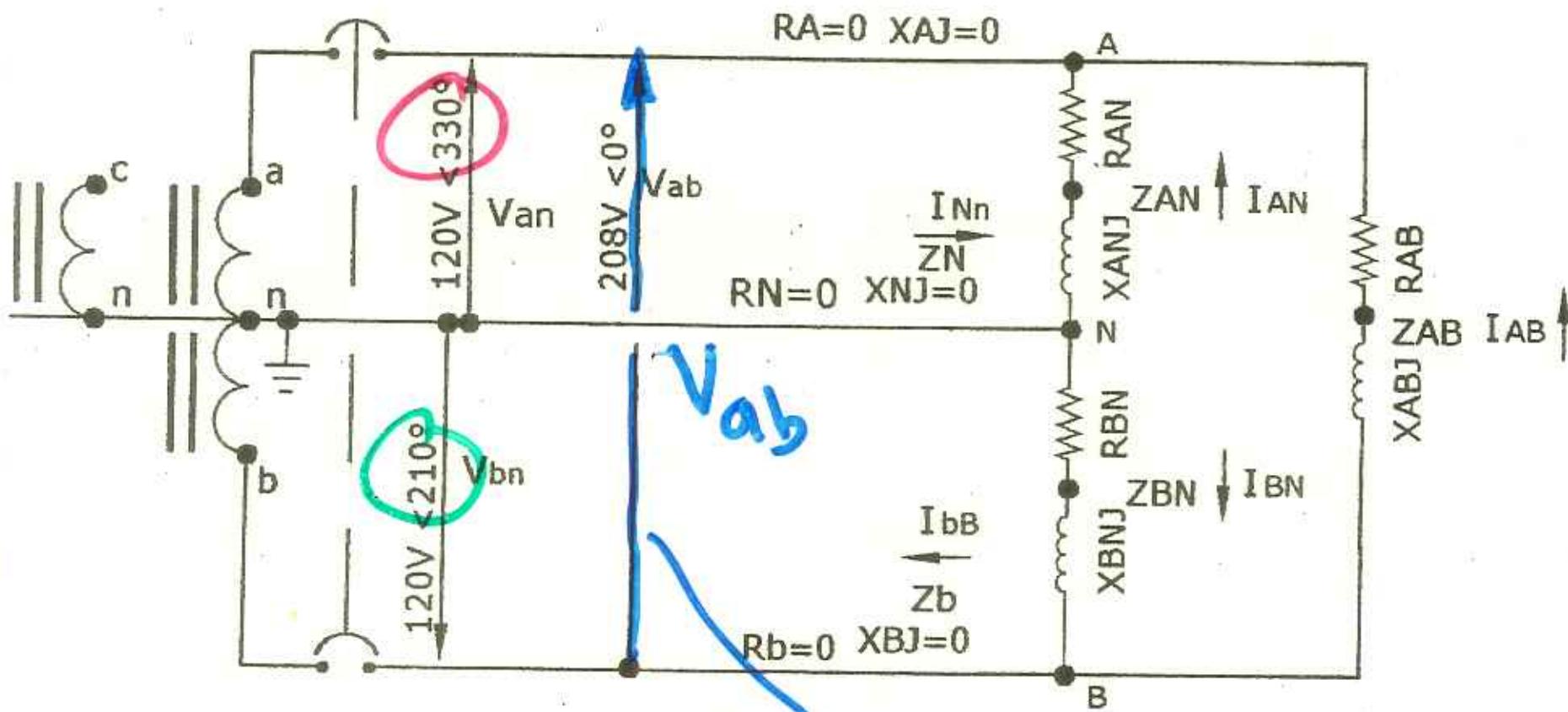
EXAMPLES OF 240/120V, 1PH., 3W.,GN.

240/120V, 1PH., 3W.,
TRANSFORMER



Special Case

2 Pole Sub Feed
Breaker In Main
Panel



VL₂₁₀ VL₃₃₀

Tricks

120° from 30°

TRANSFORMER PHASE VOLTAGE

$$V_{an} = 103.923 - 60J = 120 < -30^\circ$$

$$V_{bn} = -103.923 - 60J = 120 < 210^\circ$$

$$V_{cn} = 0 + 120J = 120 < 90^\circ$$

$$V_{ab} = V_{an} + V_{nb}$$

$$V_{ab} = 208 + 0J = 208 < 0^\circ$$

$$V_{bc} = V_{bn} + V_{nc}$$

$$V_{bc} = -104 - 180.133J = 208 < -60^\circ$$

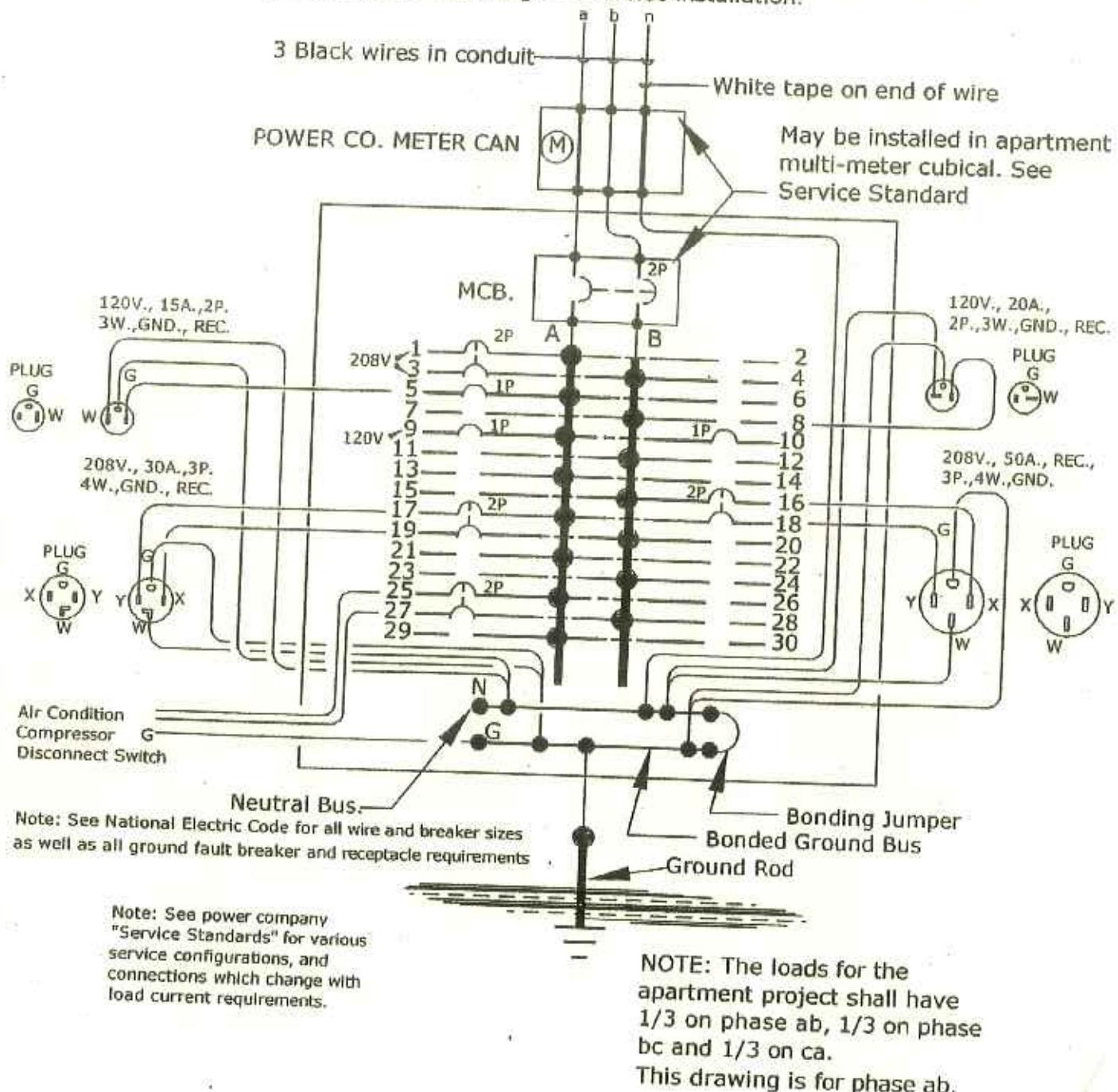
$$V_{ca} = V_{cn} + V_{na}$$

$$V_{ca} = -104 + 180.133J = 208 < 120^\circ$$

ASSUMPTION: ALL PHASE CURRENTS FLOW INTO THE TRANSFORMER AND NEUTRAL CURRENT FLOWS OUT OF THE TRANSFORMER

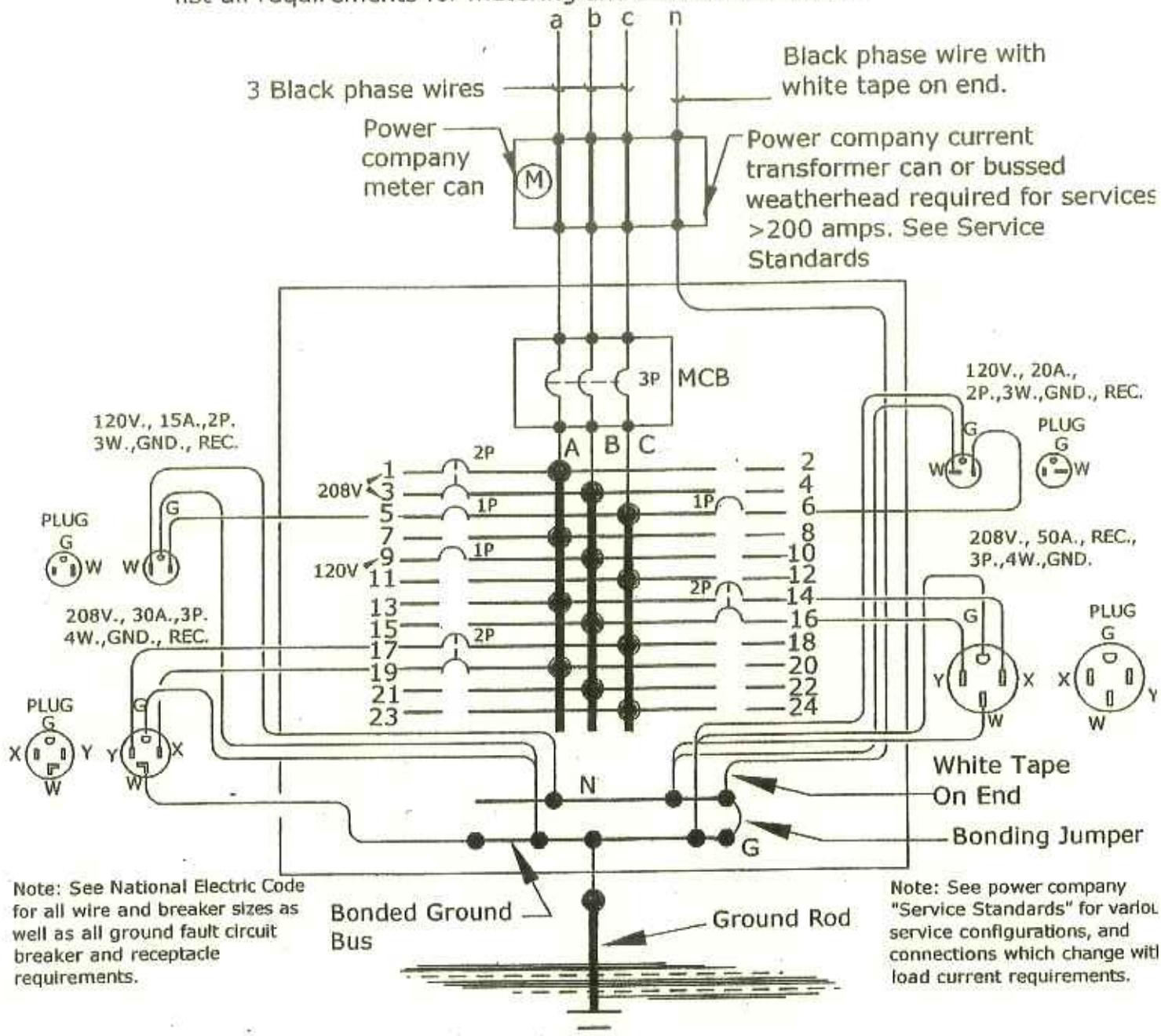
**SCHEMATIC FOR 208/120V., 1PH., 3W., GN., PHASE AB
APARTMENT SERVICE**

Service Standards are available from the local power company and list all requirements for metering and service installation.



SCHEMATIC FOR 208Y/120V., 3PH., 4W.GN.

Service Standards are available from the local power company and list all requirements for metering and service installation.



Ch 7 HW
Pbm 28
rcall?

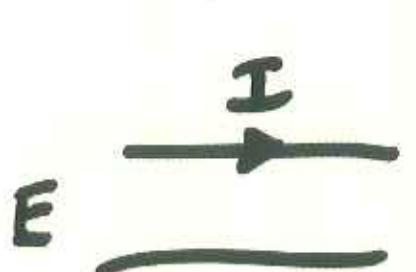
CHAPTER 8 Three-Phase Circuits

The chapter begins with a ① user-friendly introduction to 3-phase circuits and a simple method of solving them. The treatment of industrial loads is then explored together with the notion of power factor correction. The ② important topic of phase sequence is also discussed, to prepare the student for an understanding of the direction of rotation of motors and the synchronization of ac generators. As another aspect of phase sequence and phasor relationships, Section 8.21 shows how a single-phase load can be made to appear as a perfectly balanced load on a three-phase line.

Skip

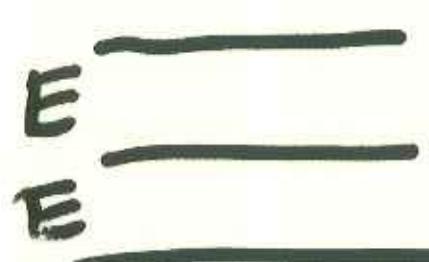
2

Ch 8 3φ System

 $P_{Av} = ?$

$$P_{Av} = EI \cos\theta$$

$P(t)$ varies at $z f_{mains}$

 $P_{Av} = \sqrt{3} EI \cos\theta$

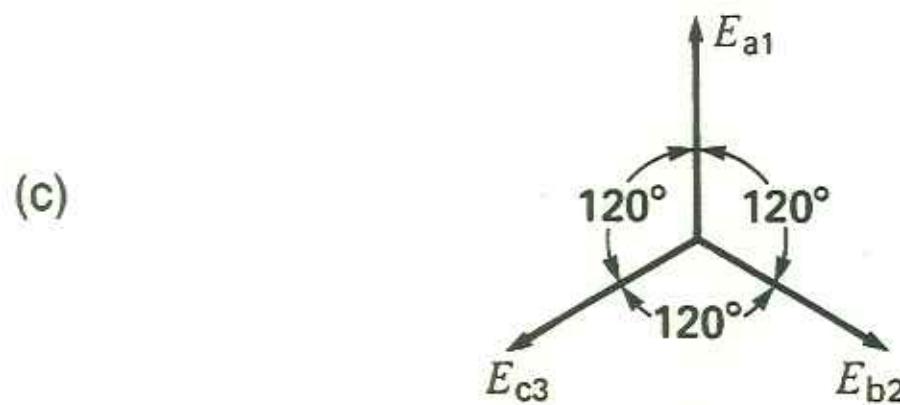
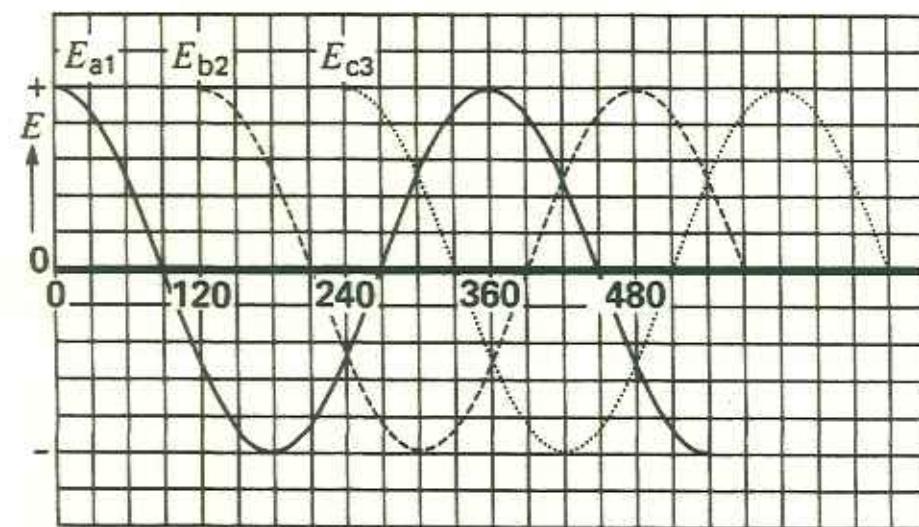
$$P_{Av} = ?$$

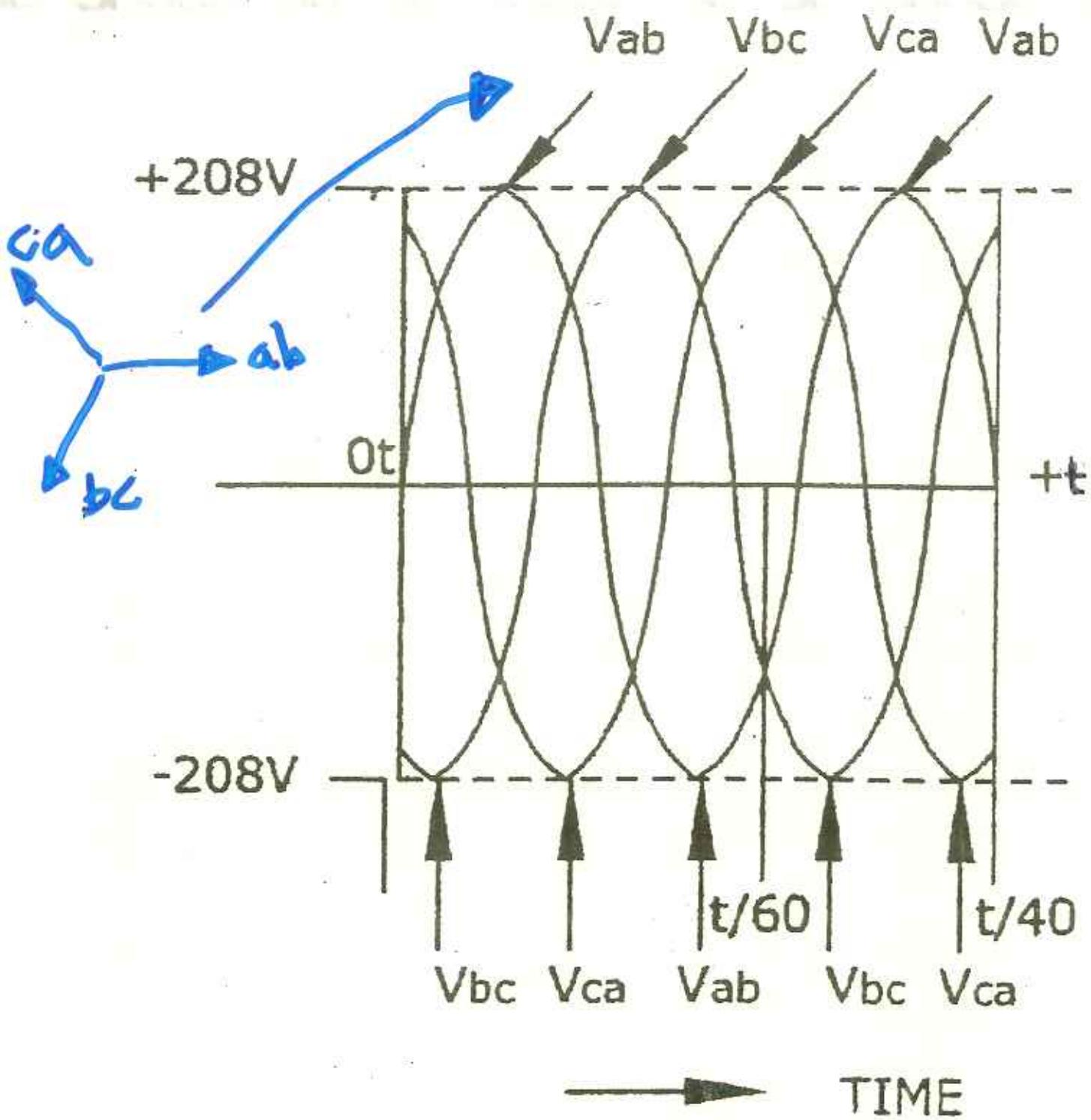
* 50% more wire but P increases by $\sqrt{3}$ *

$P_{3φ}(t) = \text{constant}$ with

∴ 3φ machinery is more mechanically robust

Rotating Machine → AC Power ^{3φ not 1φ}



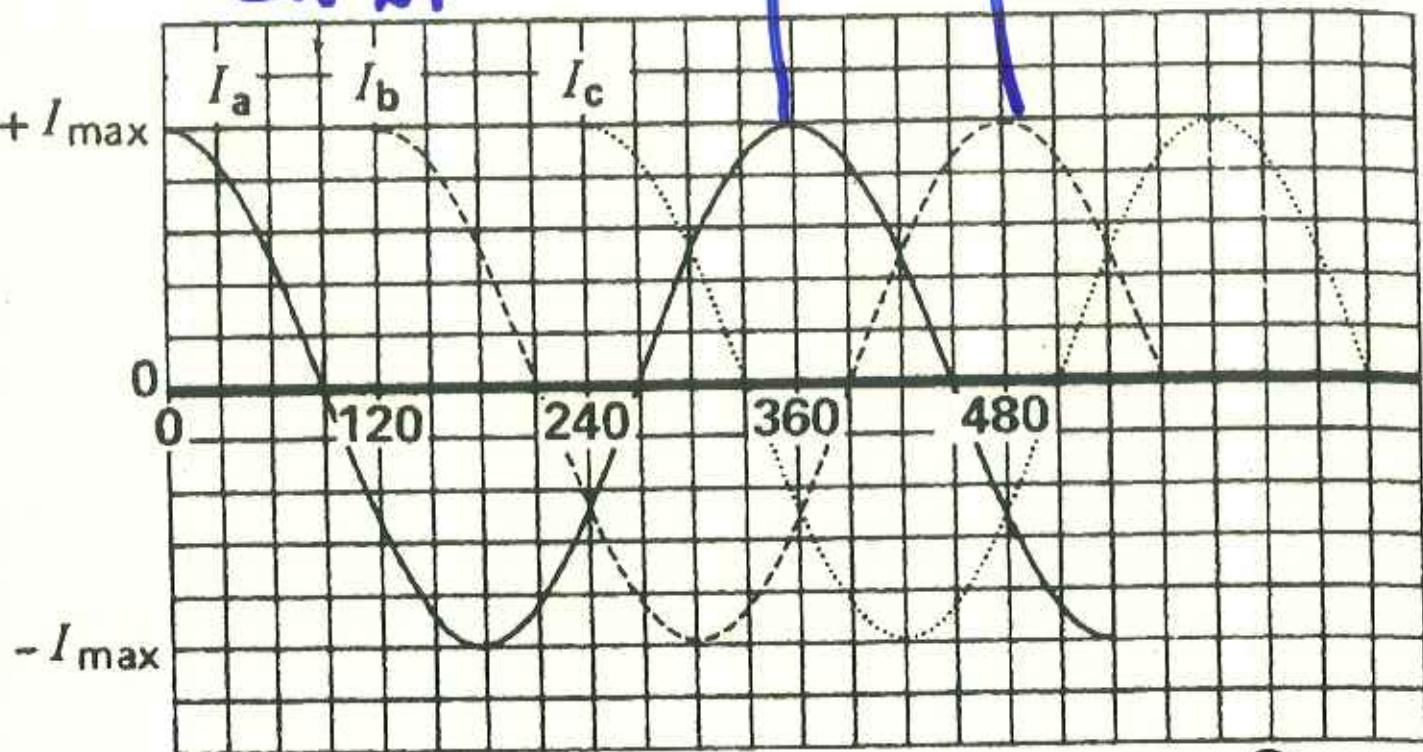


(12)

3φ i have peak is
separated in time $\Delta T = ?$ between
peaks

Combining them
get $\approx DC$

Ch 21 *



For 120° shift and 60 Hz

$$\Delta T = \frac{120^\circ}{360^\circ} \left[\frac{1}{60} \right]$$

$\underbrace{\qquad\qquad}_{1/3}$

16.6 ms

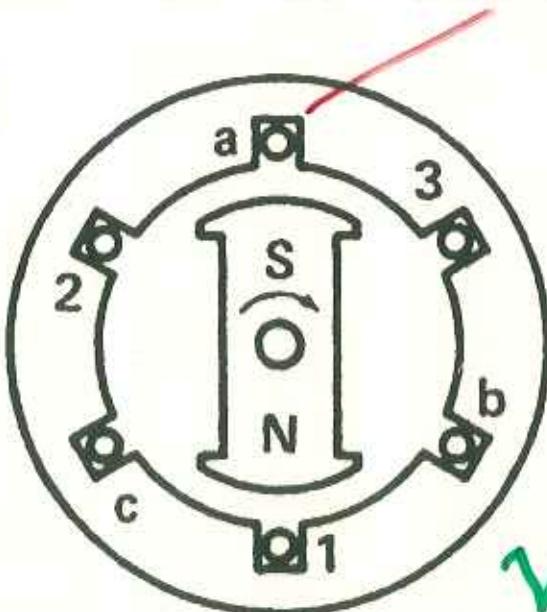
$= 5.55 \text{ ms}$ between peaks

3Φ Generator

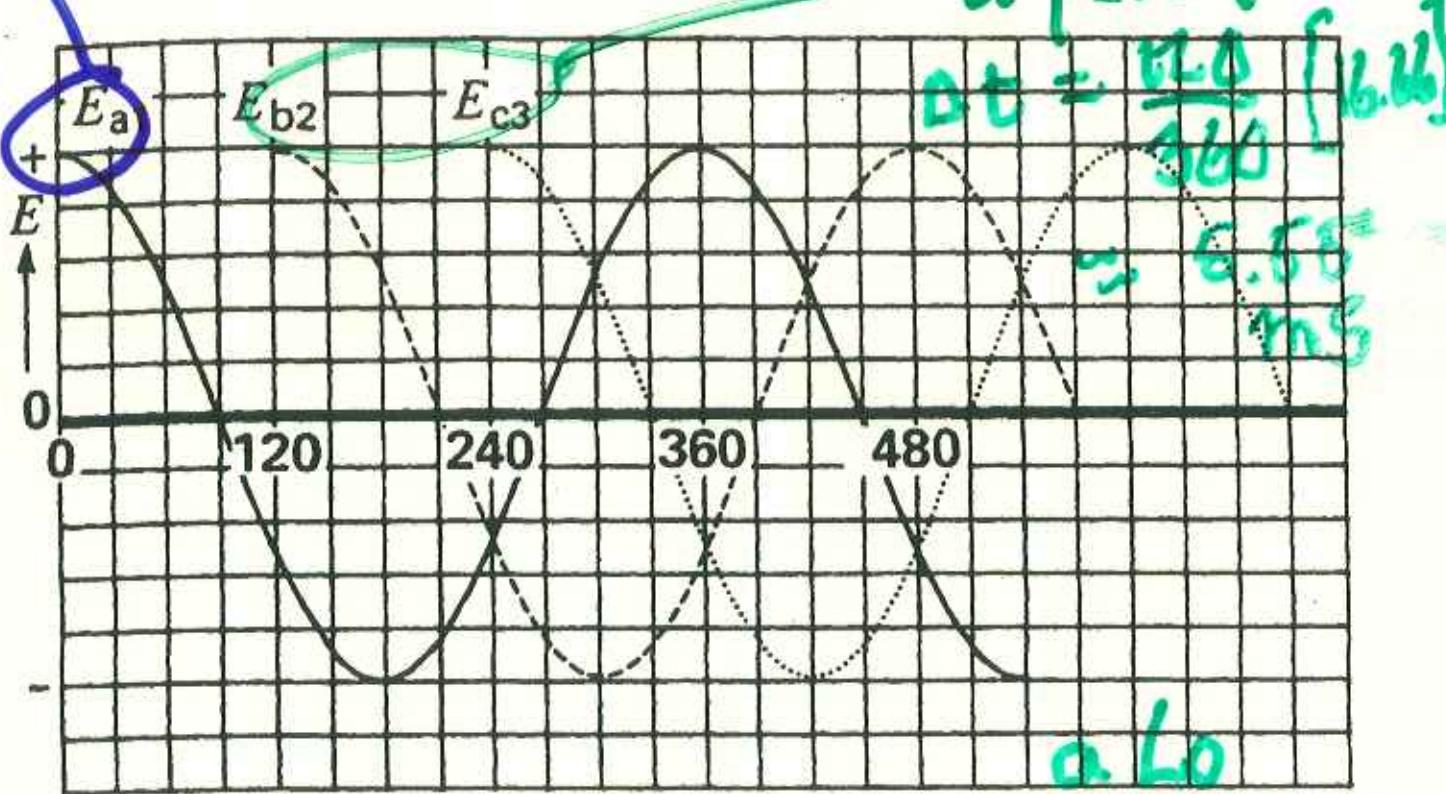
Fig 8.9
P163

a - b - c
Wire
loops
are
spatially
 120°
apart

?



Voltages are
temporally
 120°
apart



$$\sum V = 0$$

\Rightarrow Projections
cancel

b $L - 120$
c $L + 120$

Harder to show $P_{av}(3\varphi) \neq f(t)$

3 Trfs (isolated)

Σ a

How to wire together
for 3Ø?

Σ b

Three hot lines
Two ways

Σ c

V_{L1} L0

V_{L2} L120

V_{L3} L240



Wye

?

Delta

?

Primary

Y

Δ

Δ

Y

Phase
current

VS

Line
current

Sec

Y

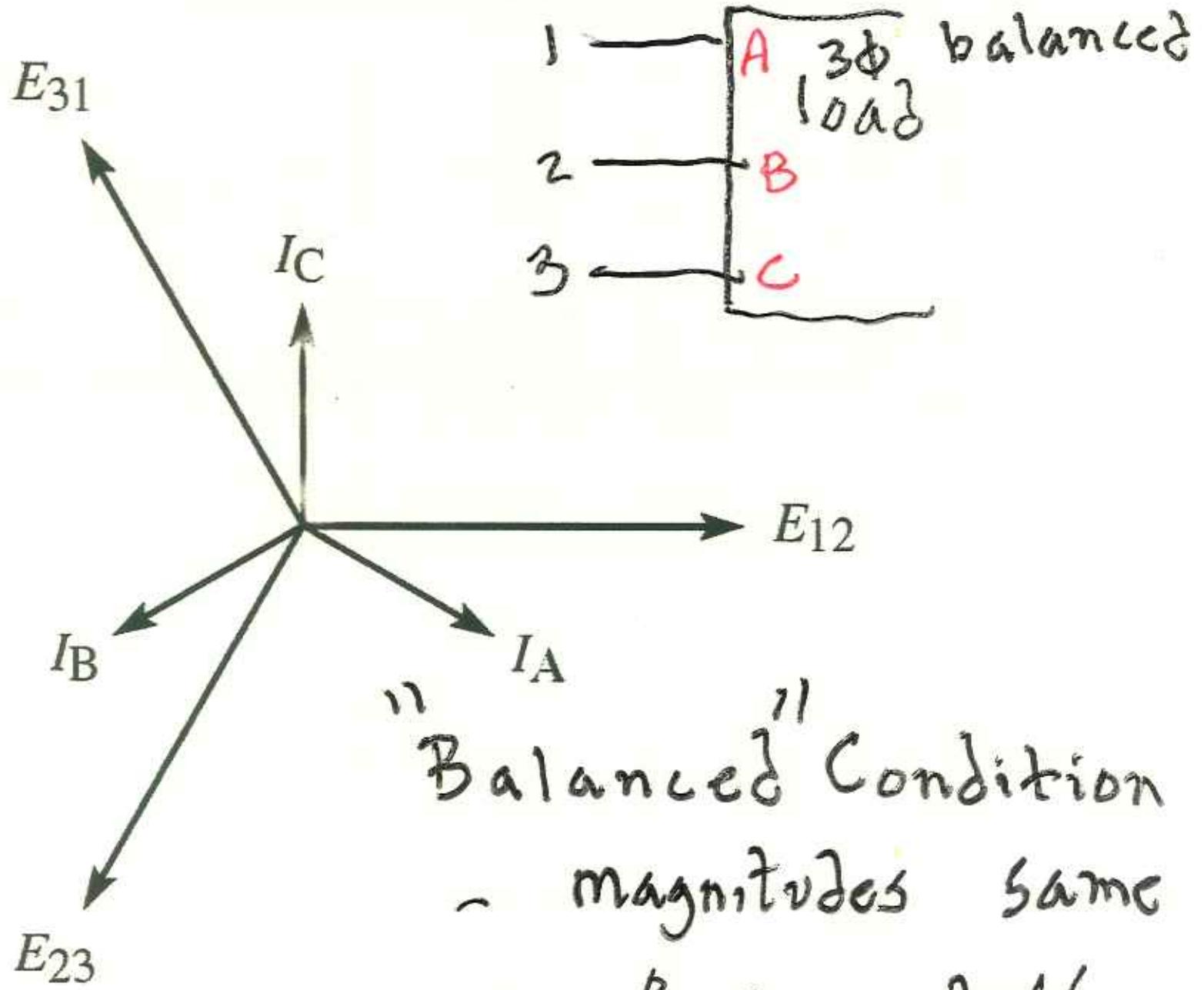
Δ

Y

Δ

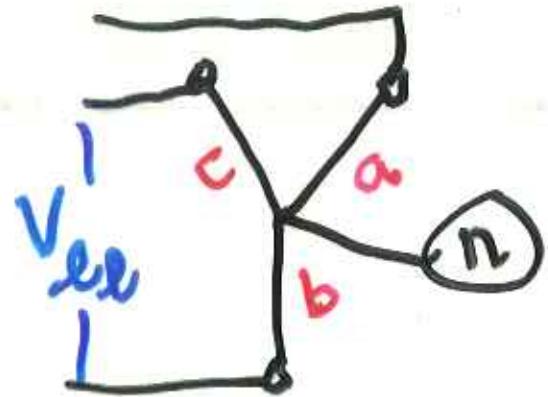
} same

} mixed



"Balanced" Condition

- magnitudes same
- 120° phase difference

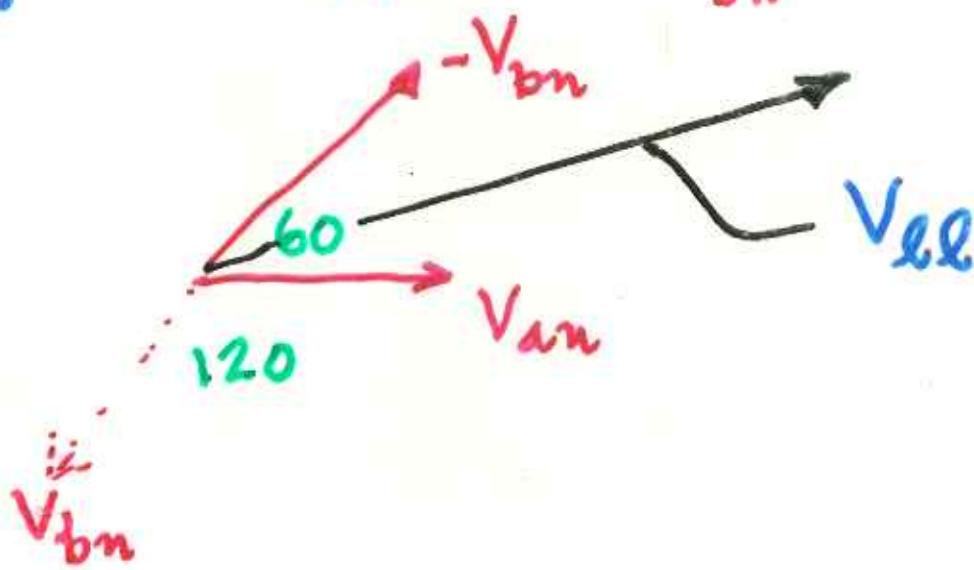


$$V_{cn} = V_{ln} + V_{nn}$$

$$V_{an} = V_{ln}$$

$$|V_{an}| = |V_{bn}| \\ = |V_{cn}|$$

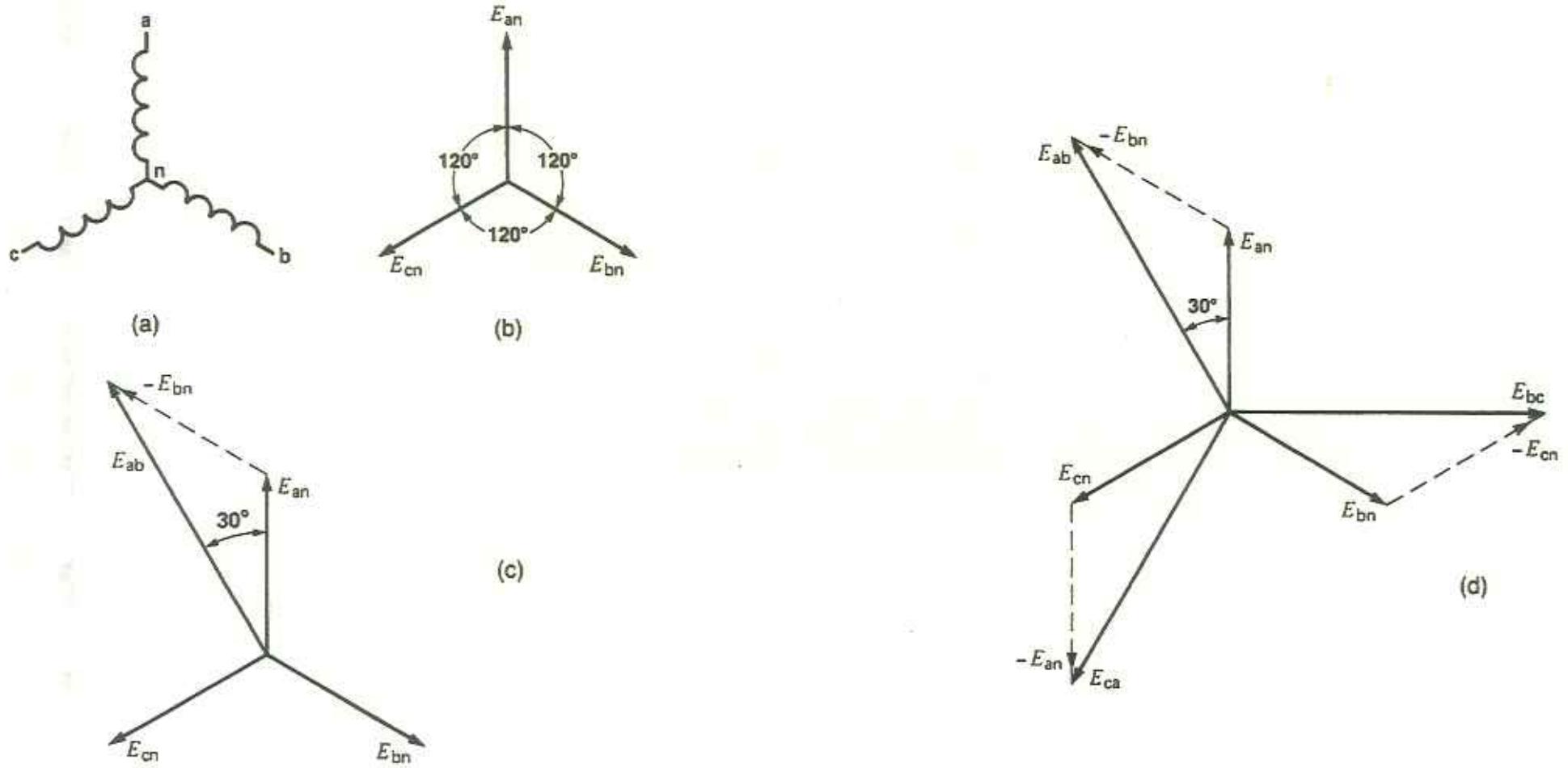
$$V_{ll} = V_{an} - V_{bn}$$

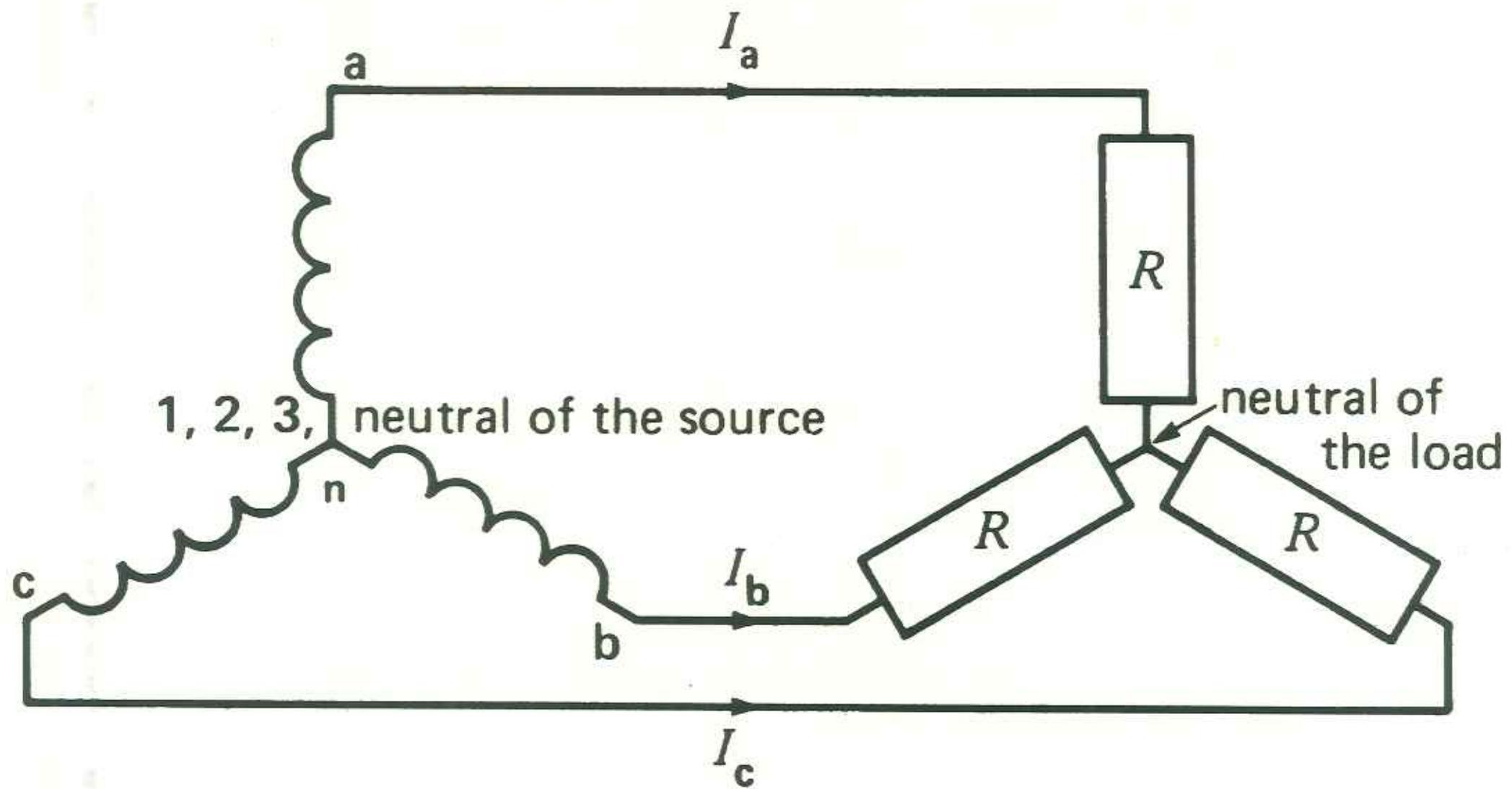


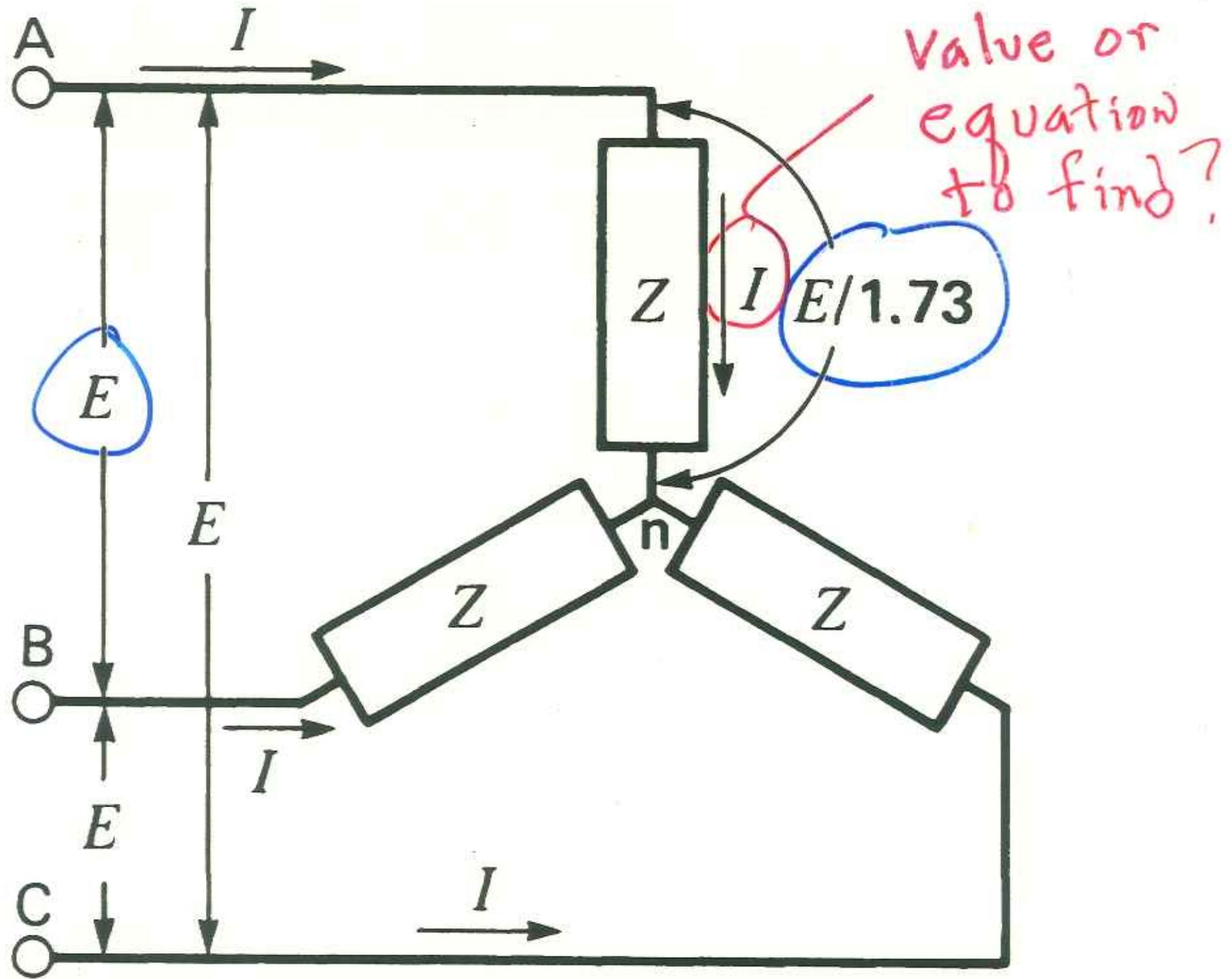
$$|V_{ll}| = \sqrt{3} V_\phi$$

$\angle V_{ll}$ leads V_{an} by 30°

I_n for balanced Δ is?







22

$$S_{3\phi} = \sqrt{3} V_{line-line} I_{phase}$$

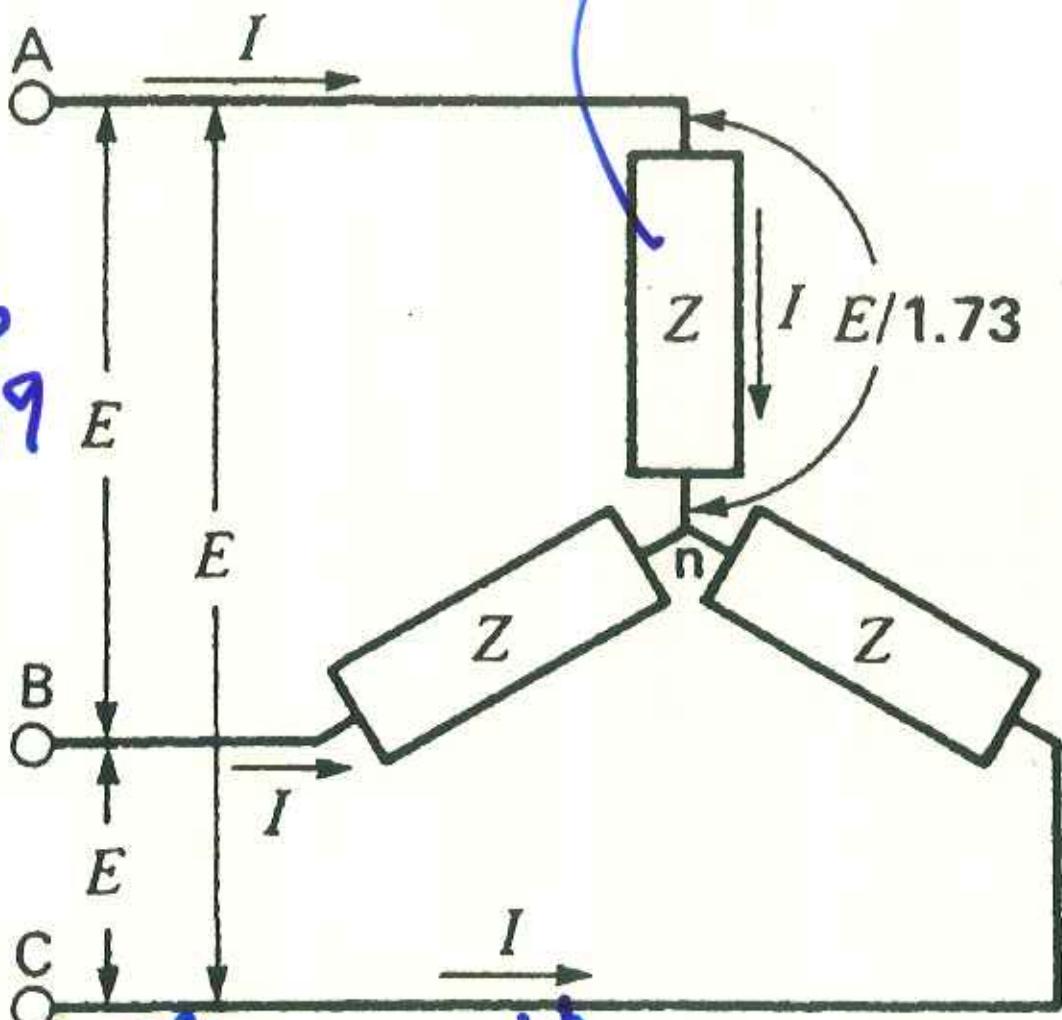
Summary

Wye connection

Each Z

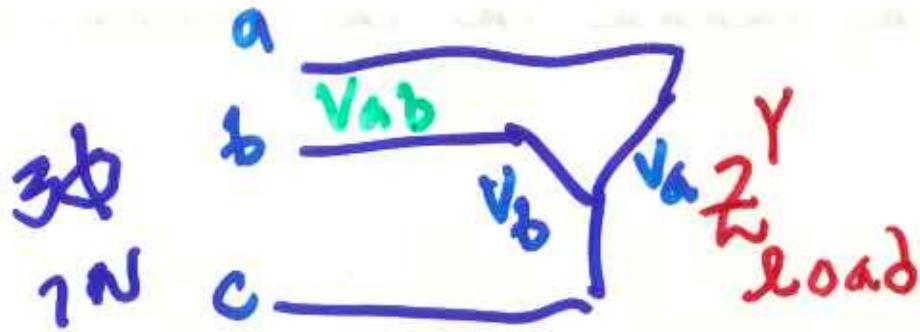
$$S_Z = \frac{E_{line}}{\sqrt{3}} I_Z$$

Fig 8.16
pg 169



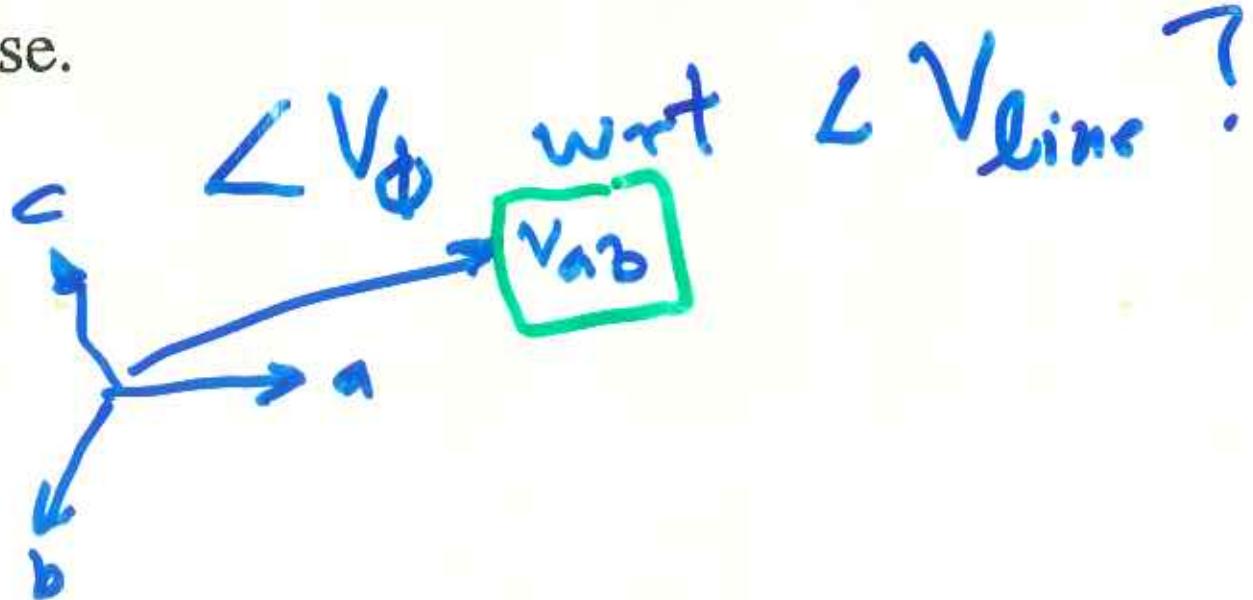
Total $S_T = 3 S_Z$

$$S_T = \frac{3}{\sqrt{3}} E_{line} I_\phi = ?$$

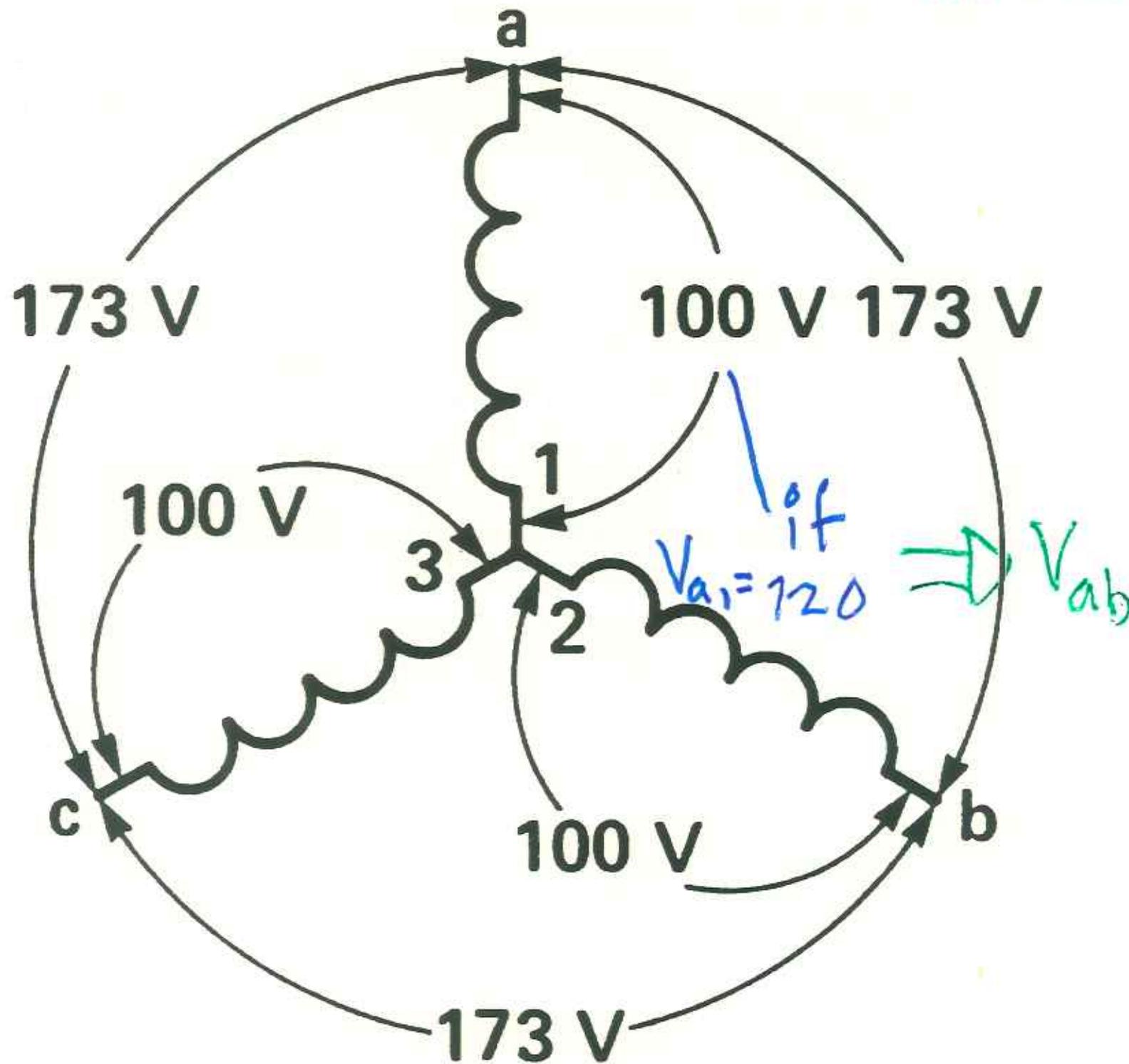


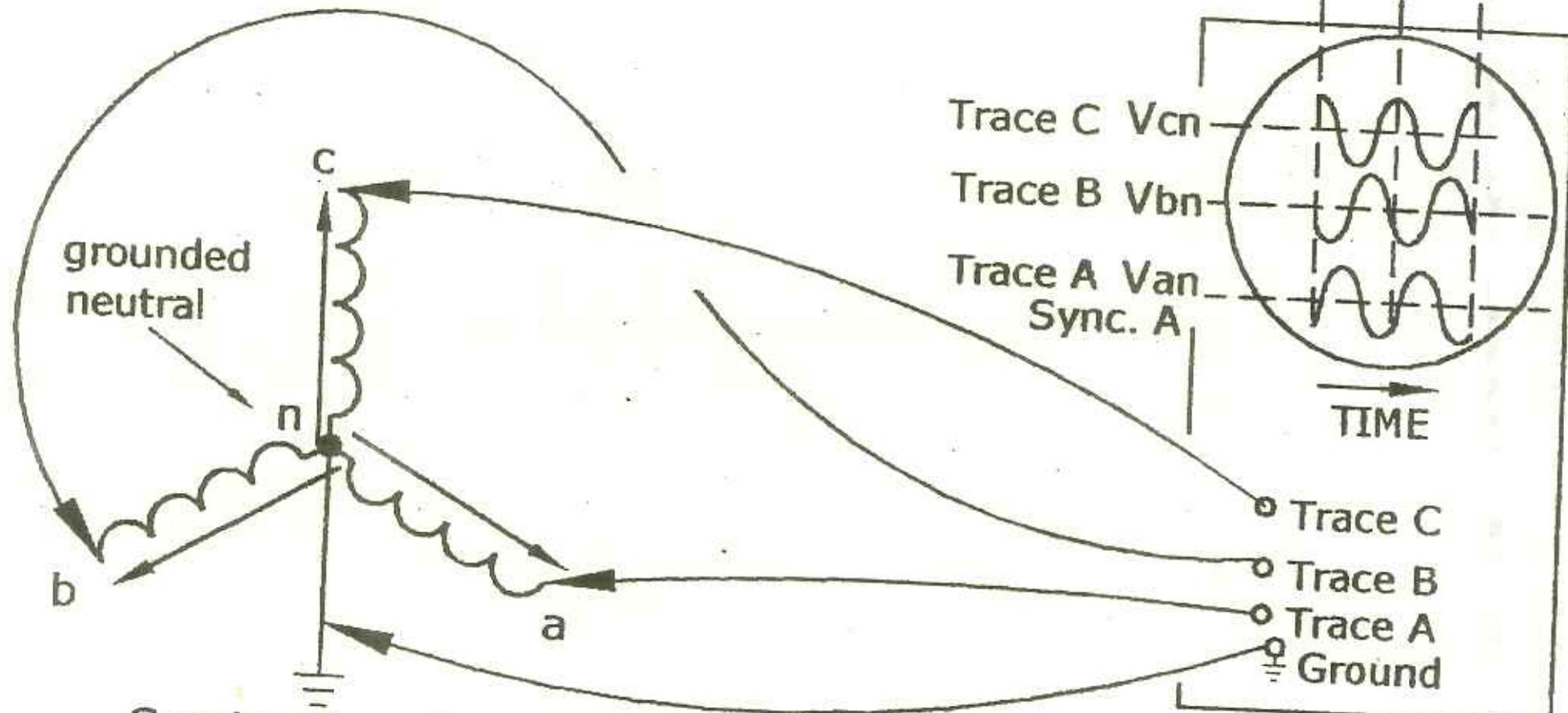
Impedances connected in wye.

- The current in each element is equal to the line current I .
- The voltage across each element is equal to the line voltage E divided by $\sqrt{3}$.
- The voltages across the elements are 120° out of phase.
- The currents in the elements are 120° out of phase.

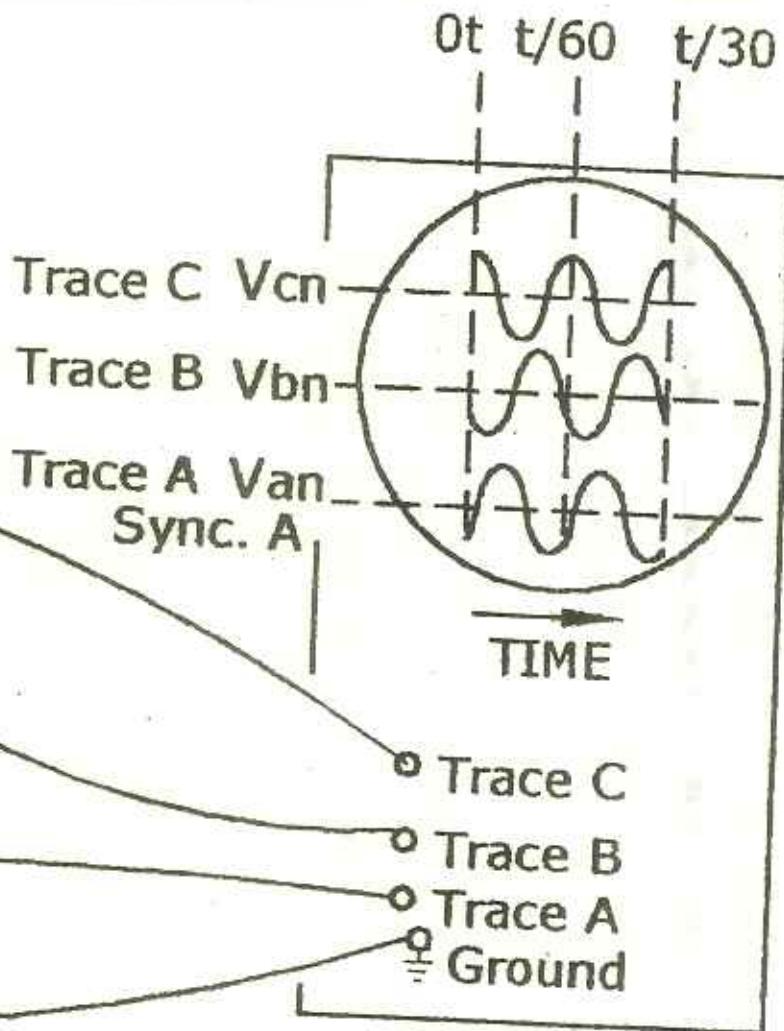


$$V_{ab} = 214$$





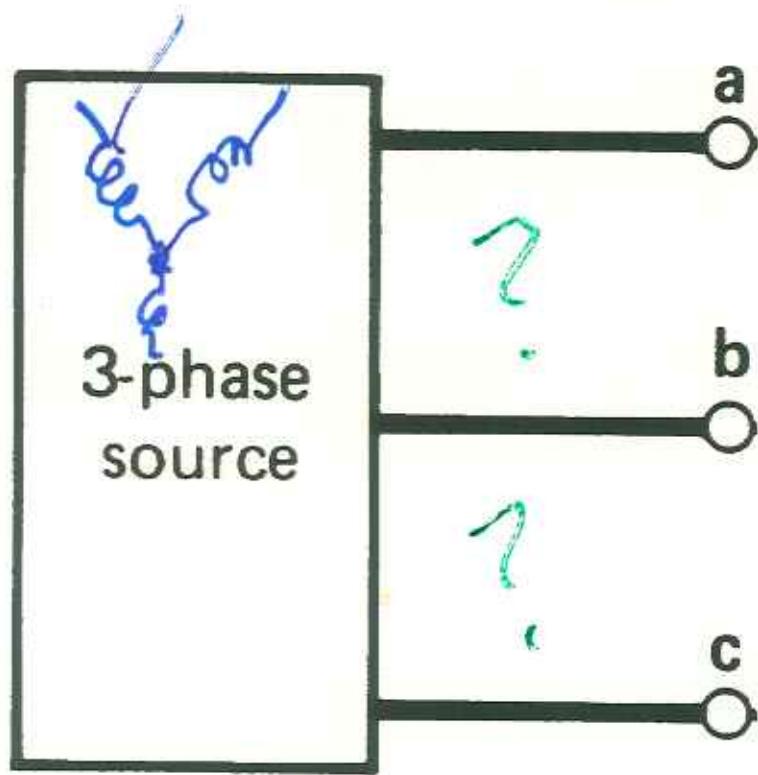
Service Transformer 208Y/120V,
3PH,4W,GN



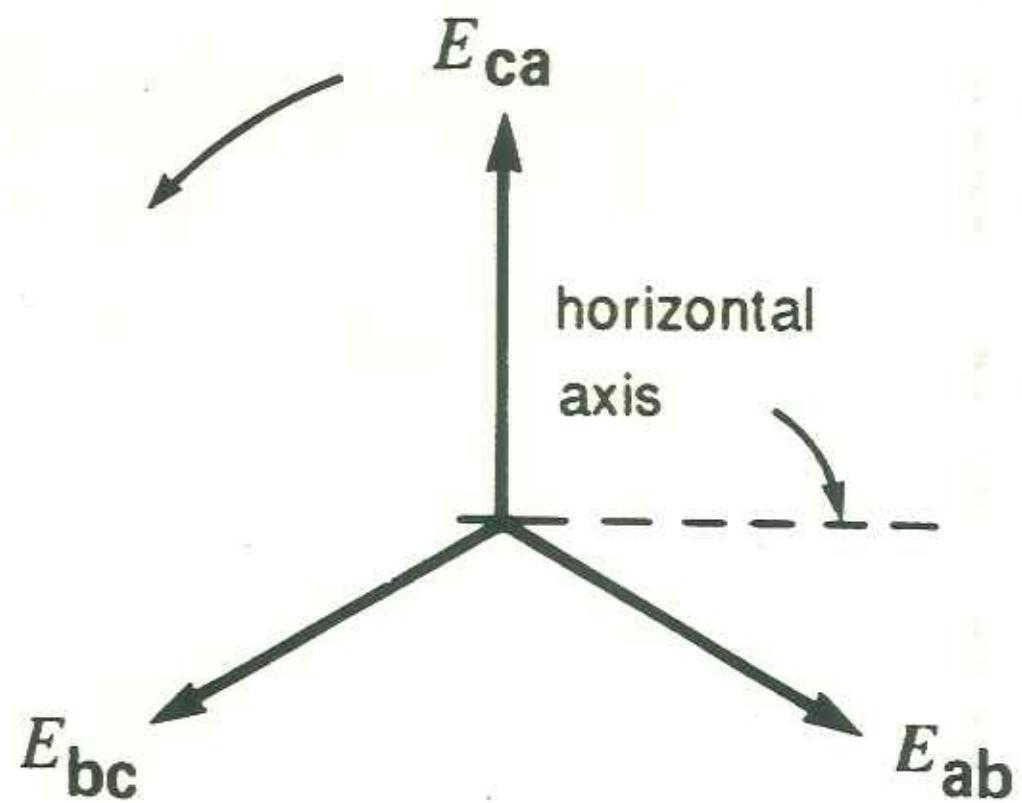
Triple Trace
Oscilloscope
See Oscilloscope
Safety

480

277



(a)



(b)

TRANSFORMER PHASE VOLTAGE

$$V_{an} = 240 - 138.564J = 277.128 \angle -30^\circ$$

$$V_{bn} = -240 - 138.564J = 277.128 \angle 210^\circ$$

$$V_{cn} = 0 + 277.128J = 277.128 \angle 90^\circ$$

$$V_{ab} = V_{an} + V_{nb}$$

$$V_{ab} = 480 + 0J = 480 \angle 0^\circ$$

$$V_{bc} = V_{bn} + V_{nc}$$

$$V_{bc} = -240 - 415.692J = 480 \angle 240^\circ$$

$$V_{ca} = V_{cn} + V_{na}$$

$$V_{ca} = -240 + 415.692J = 480 \angle 120^\circ$$

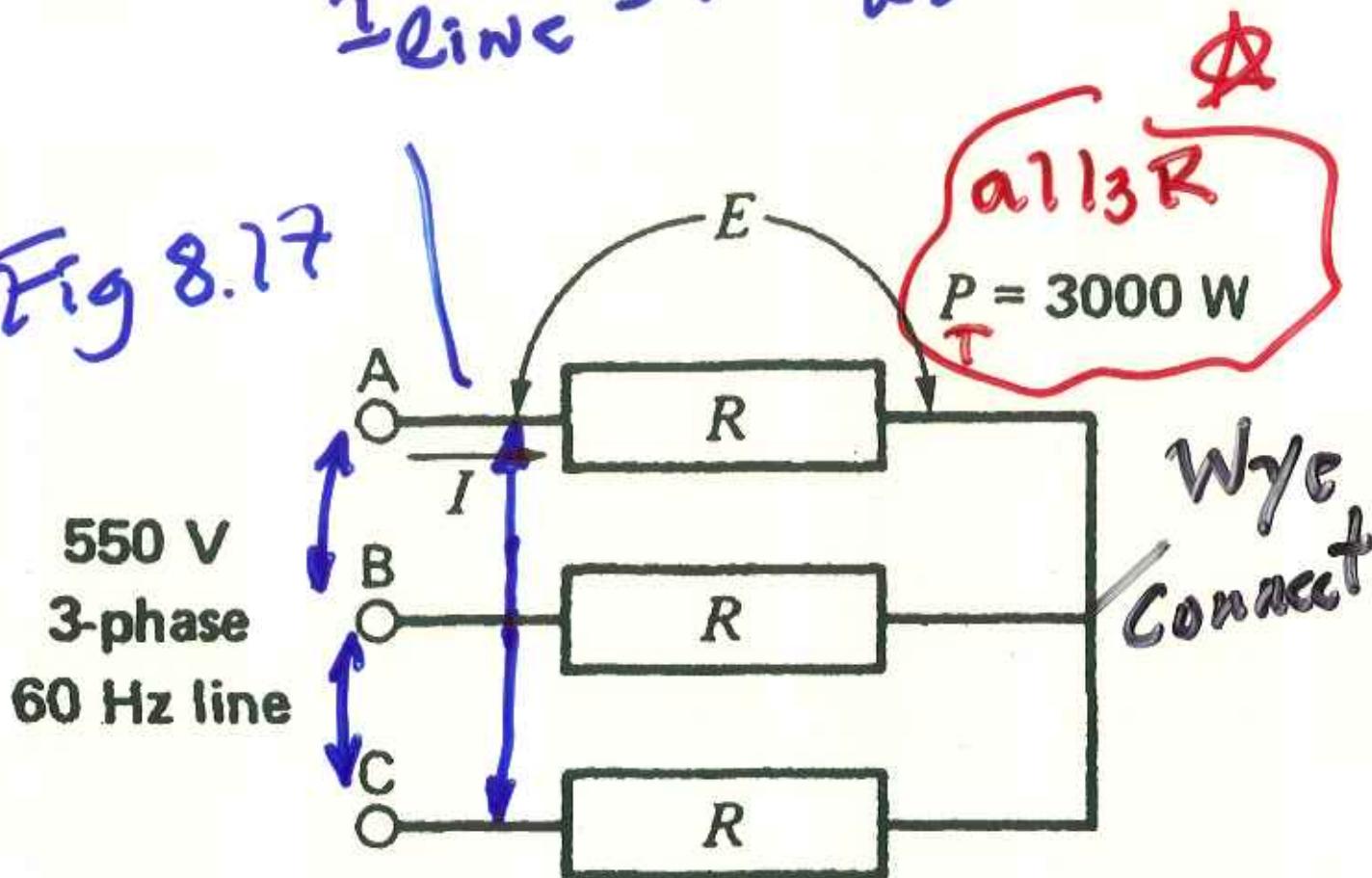
ASSUMPTION: ALL PHASE CURRENTS FLOW INTO THE TRANSFORMER AND NEUTRAL CURRENT FLOWS OUT OF THE TRANSFORMER

Example 8.7

Pg 170

$I_{line} = ?$ for electrician work order

Fig 8.17



$$P(\text{each } R) = 1 \text{ kW}$$

~~$$V_R = \frac{550}{\sqrt{3}} = 318 \text{ Volt}$$~~

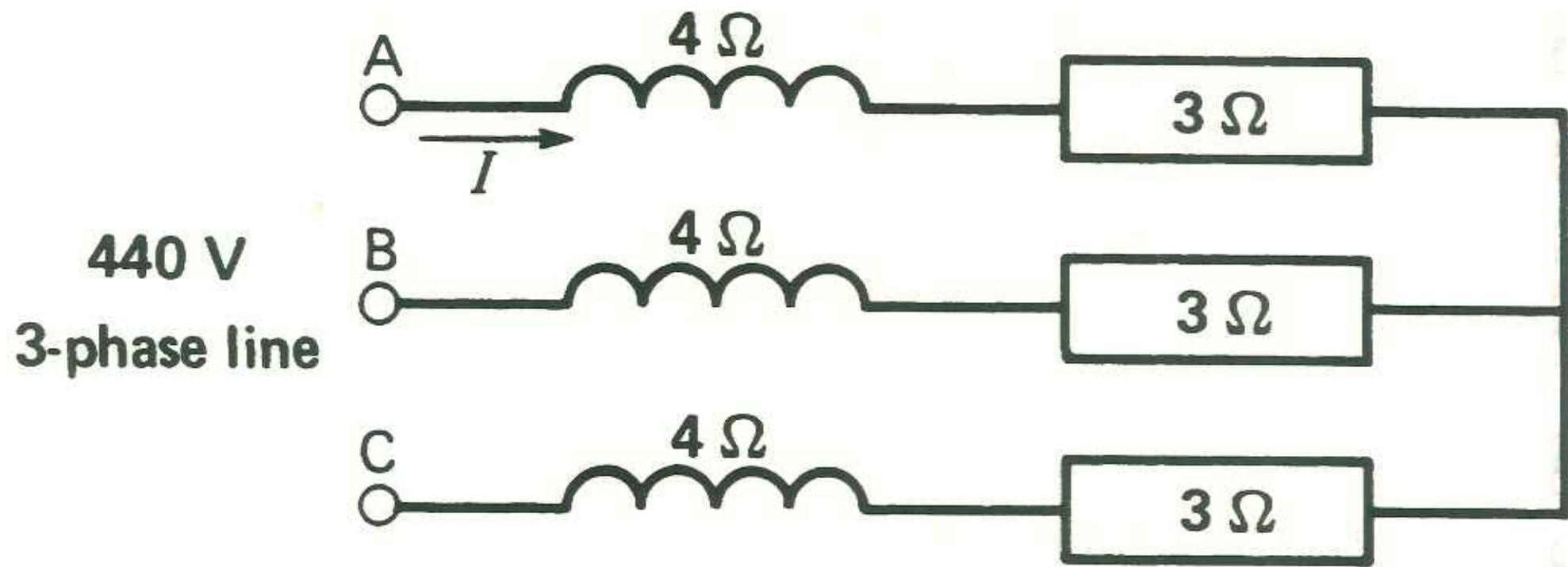
$I_{line} = \frac{1000}{318} = 3.15 \text{ Amp}$

$R = ?$

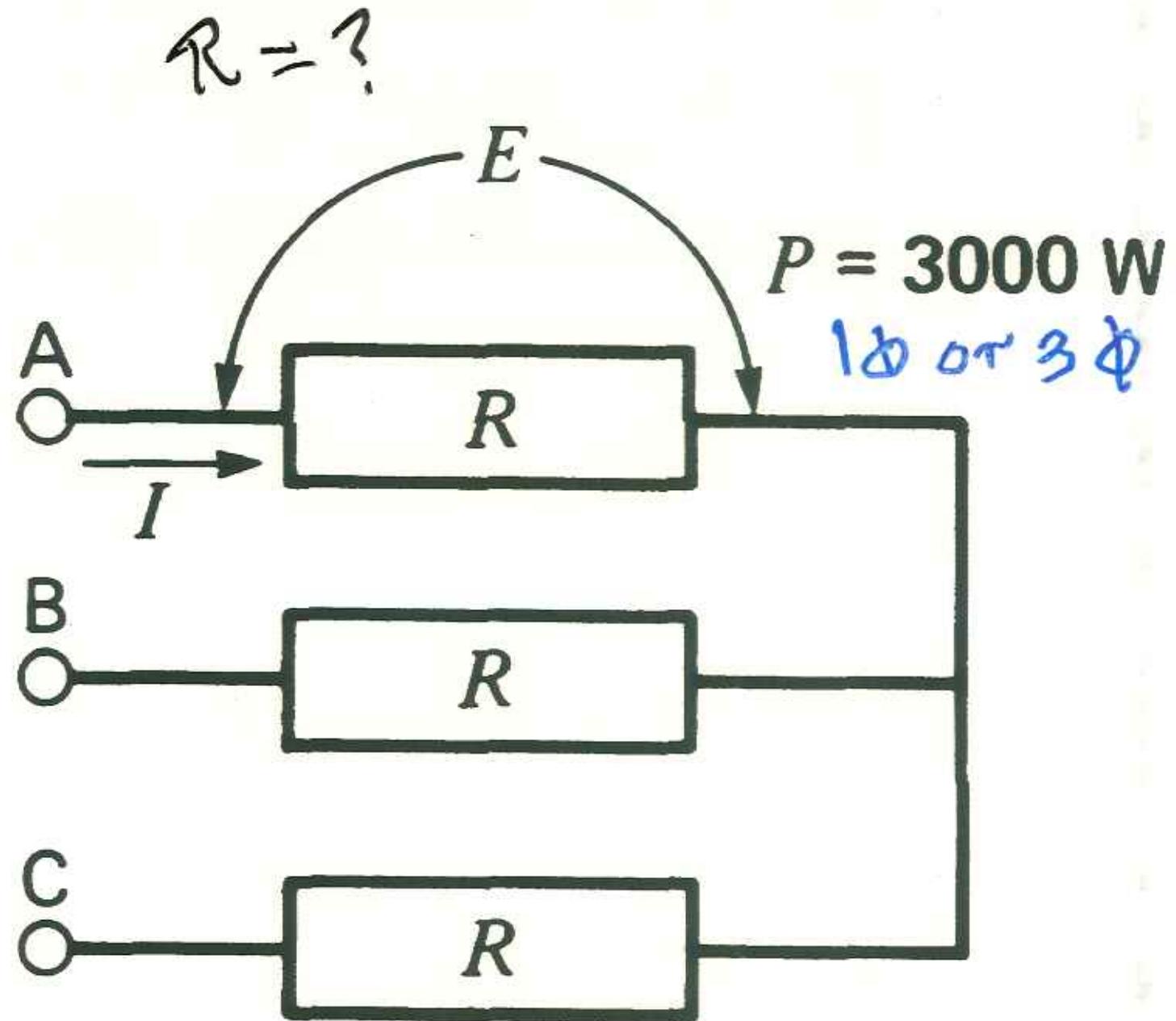
Choose wire

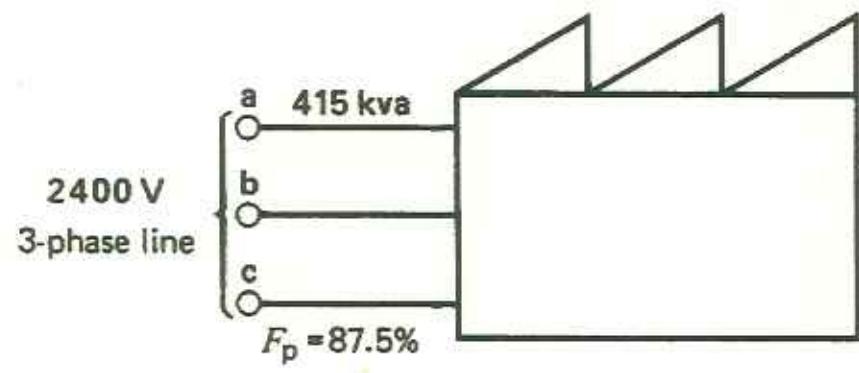
440/13 13

$$I = \frac{V}{R}$$

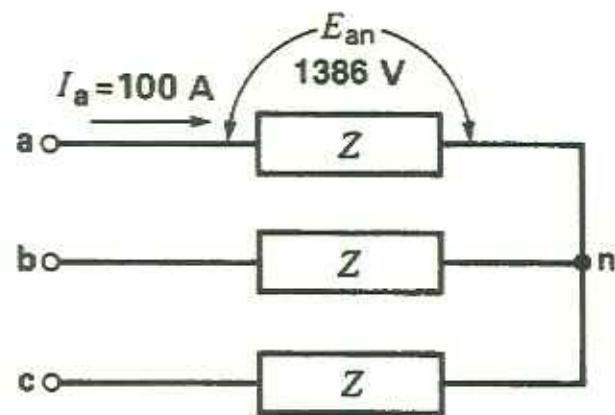


550 V
3-phase
60 Hz line

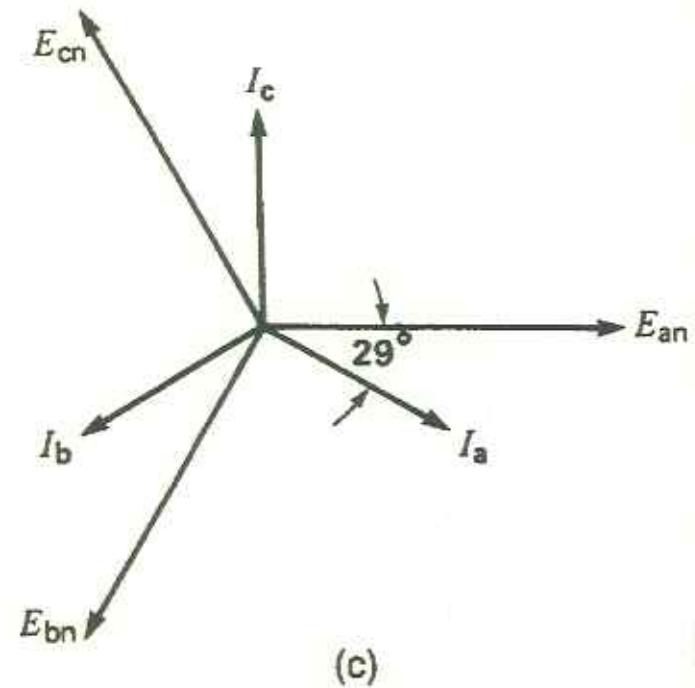




(a)



(b)

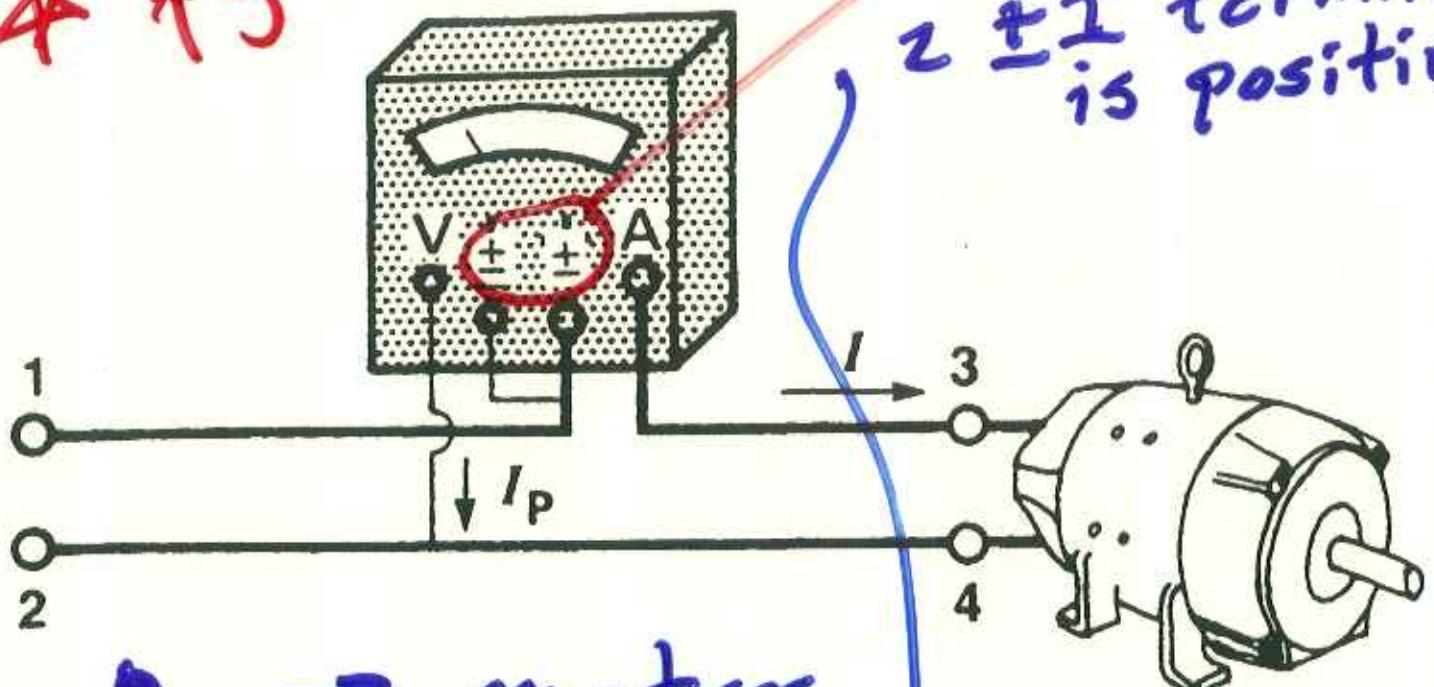


Wattmeter ± terminal
is marked

V across lines

I through line

* Fig 8.2A
* Pg 176



1. $\pm V$ terminal
is positive

2 $\pm I$ terminal
is positive

\rightarrow meter movement

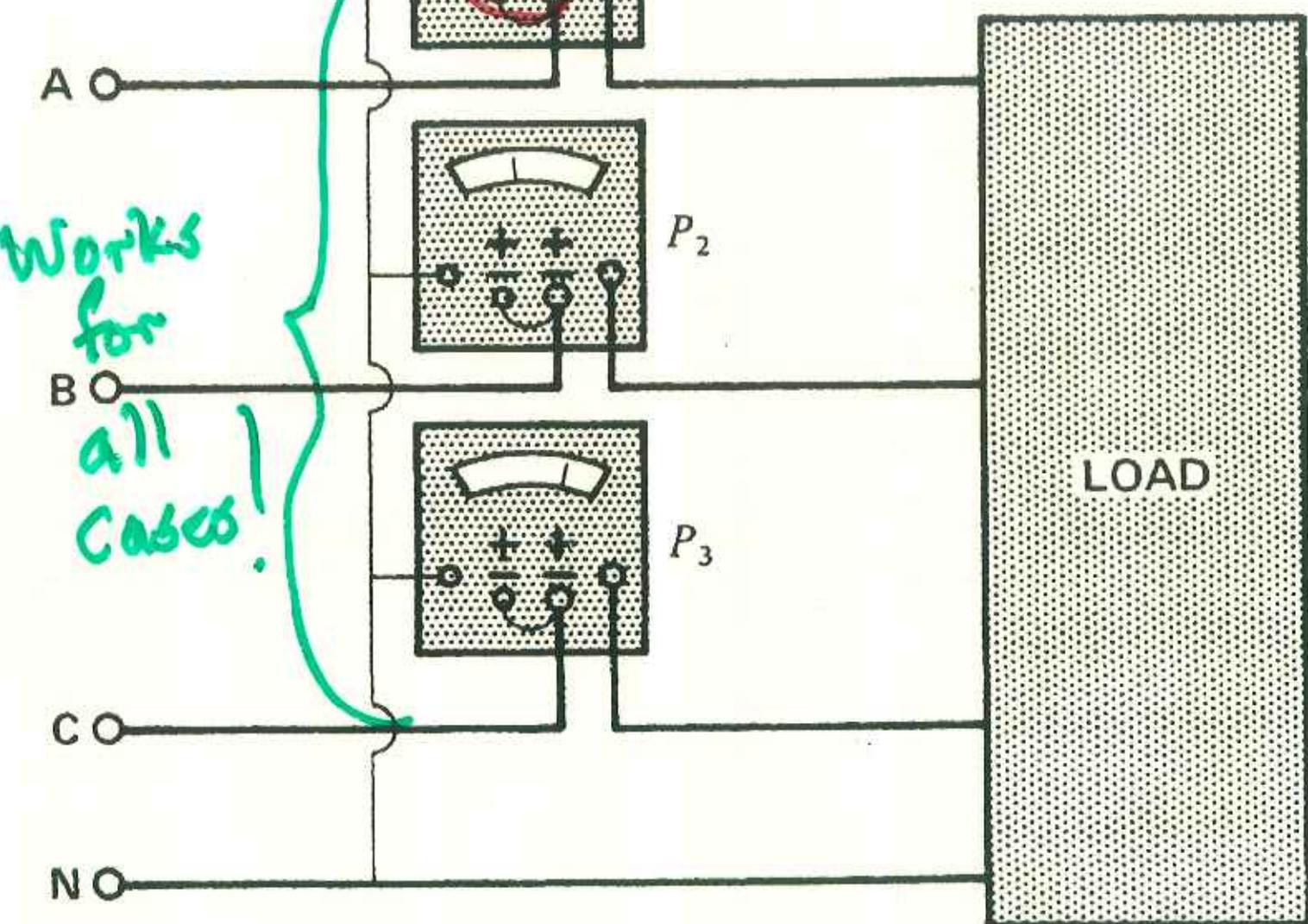
for positive
both 1 & 2 (simultaneously)
ON \pm terminals

1 P flow → 3
2 → 4

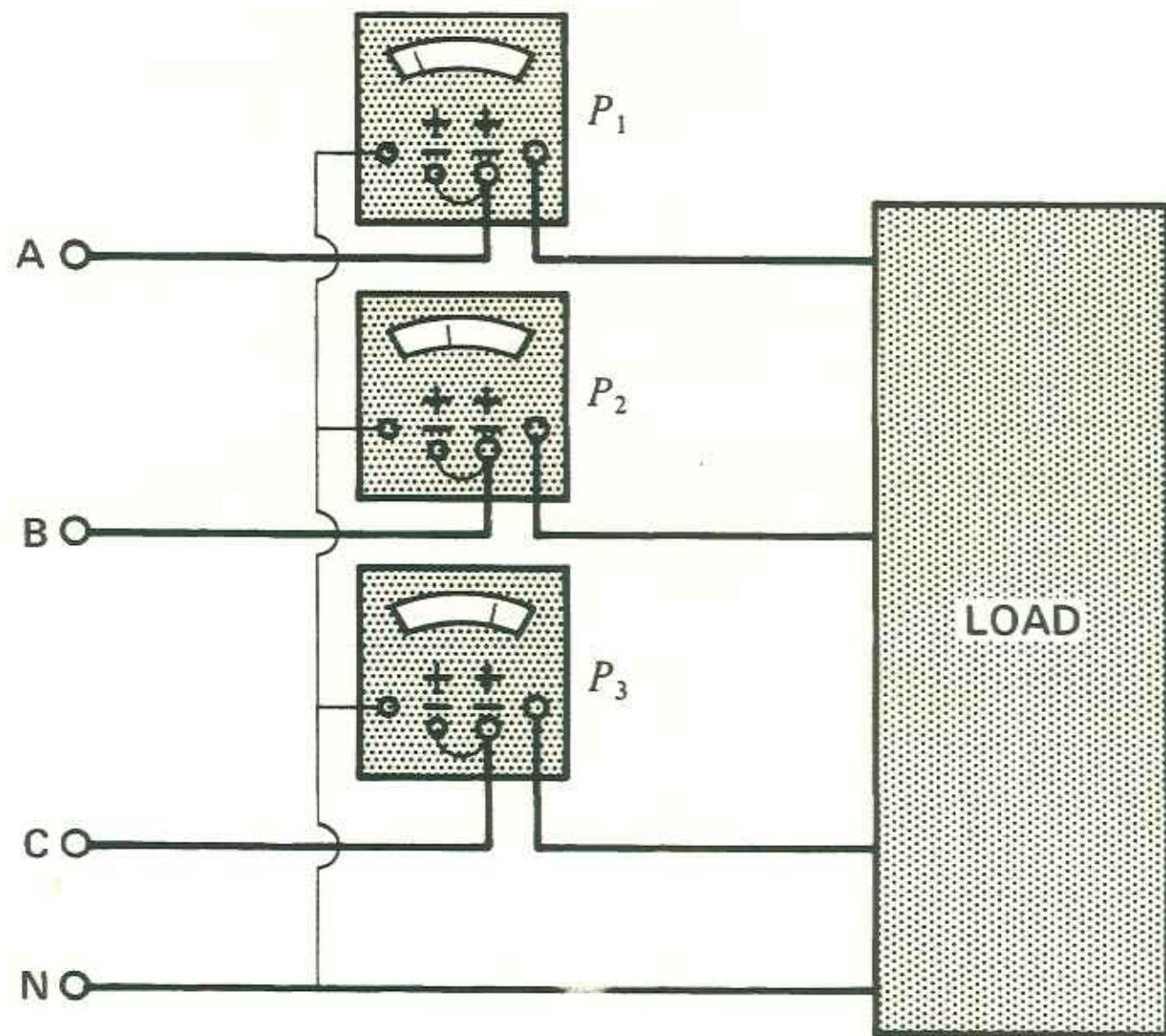
3 Wattmeters required
for P_{total} (4 wire 3 ϕ)?

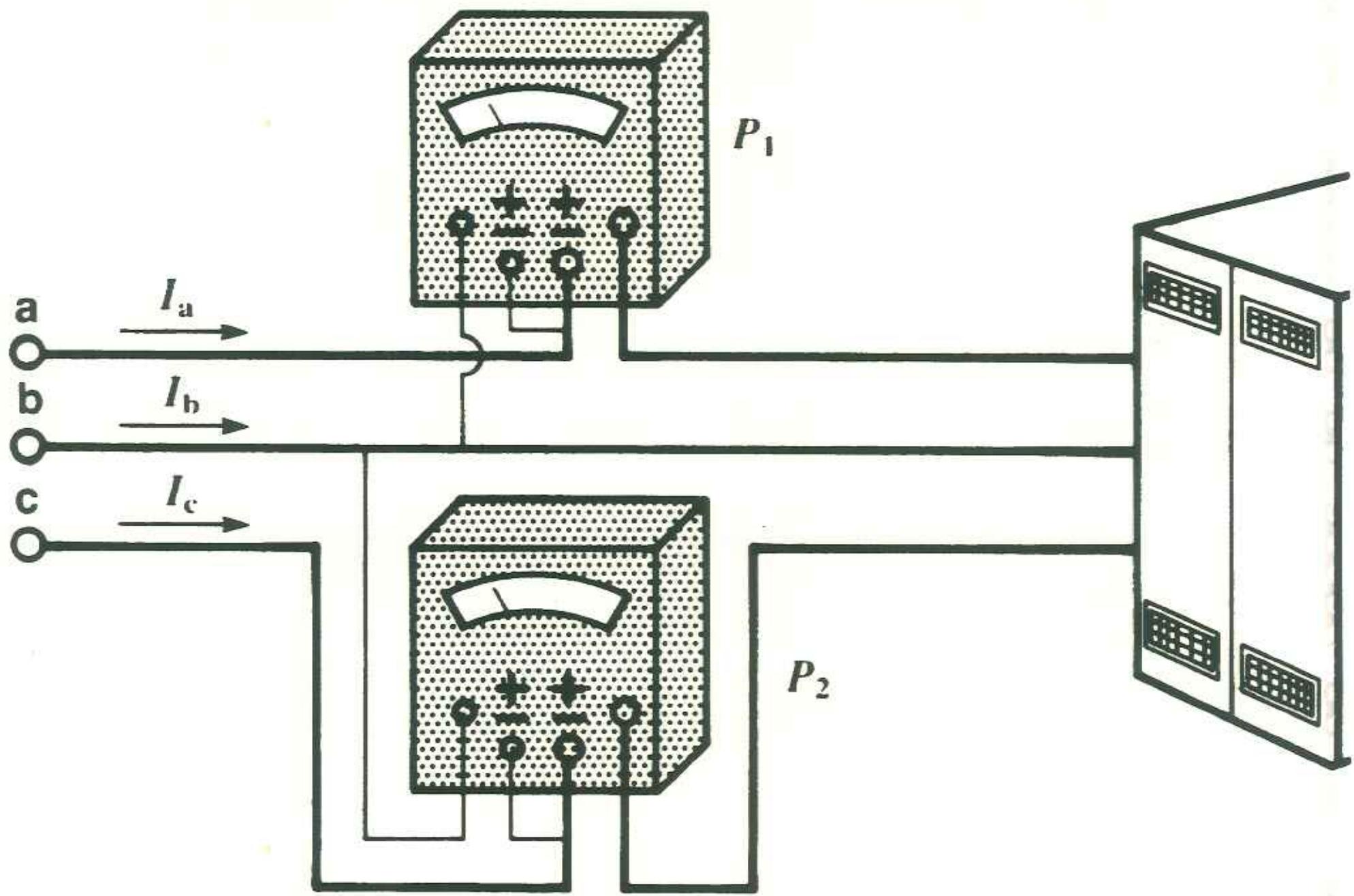
Fig 8.3)

$\pm V$ and $\pm I$
are same



Simpler way?
for balanced loads only





Surprisingly $P(3\phi)$ CAN

be measured with $\frac{\text{Total}}{\text{Two Wattmeters only}}$

Measurements shown below

All 10A

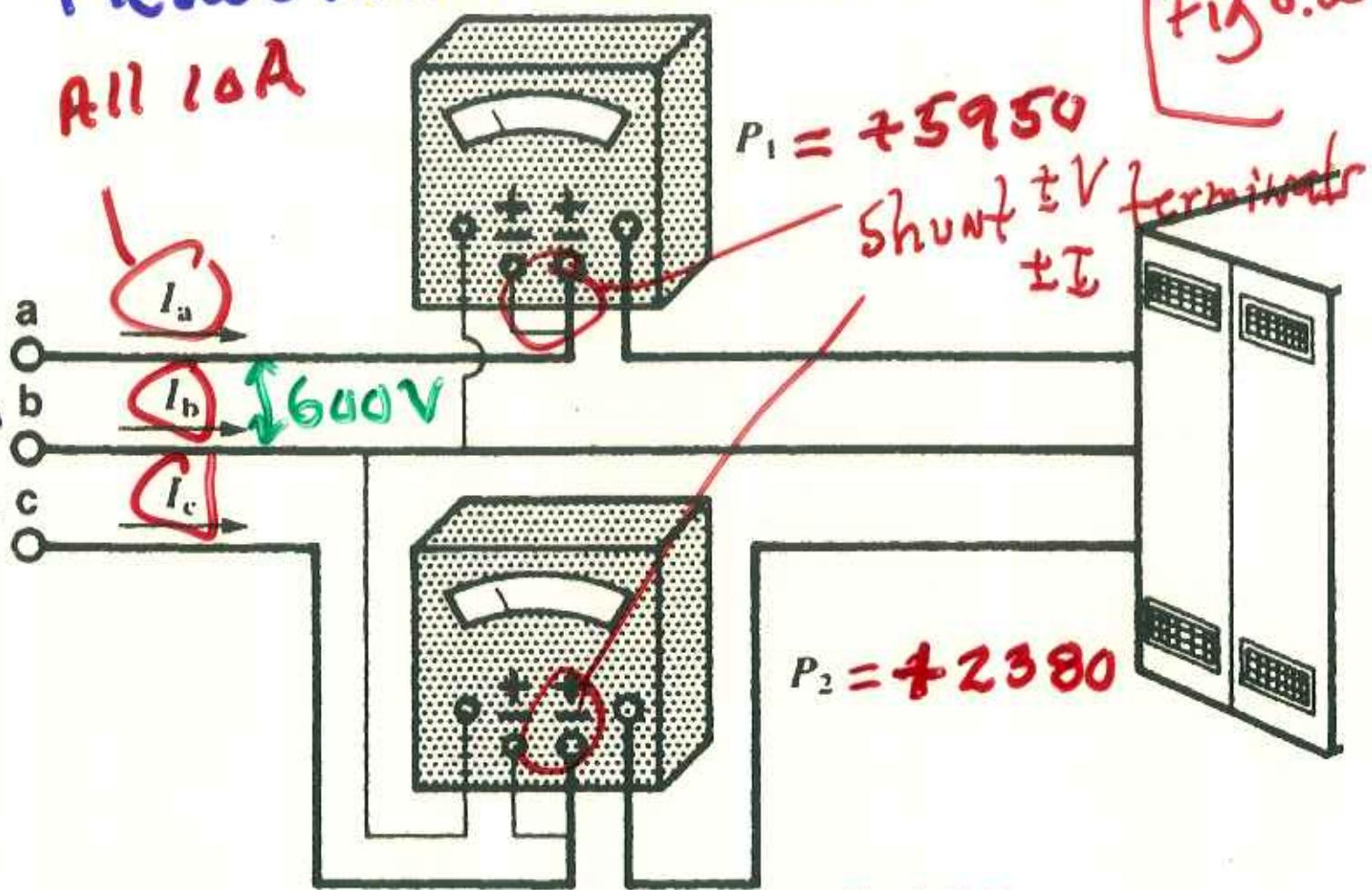


Fig 8.30

$$S = \sqrt{3} E I = 10.4 \text{ kVA}$$

$$P_{\text{Total}} = P_1 + P_2 = 8330$$

$$\cos \theta = \varphi F = \frac{P}{S} = \frac{8330}{10390} = .8$$