

Chapter 7

Part 2

- Homework
- Q and P Flow
- Circuit Solutions

2HP Motor

230 V

1725 rpm HP

7-28 (a) $P_o = 2 \times 746 = 1492 \text{ W}$

$I_m = 11.6$

$\eta = 75.5\%$

$PF = .74$ (with C) 39

$P_i = 1492 / 0.755 = 1976 \text{ W} = \frac{P_o}{\eta}$ Given
 $S = 1976 / \cos \theta = 1976 / 0.74 = 2670 \text{ VA}$ You added

(b) $Q_{\text{motor}} = \sqrt{2670^2 - 1976^2} = 1796 \text{ var}$ without LAG

$X_c = 1 / 2\pi f C = 10^6 / 2\pi \times 60 \times 45 = 66.3 \Omega$

$Q_{\text{capacitor}} = 230^2 / 66.3 = 798 \text{ var}$

Now with C and M box in parallel
 $Q(\text{line})_{\text{net}} = 1796 - 798 = 998 \text{ var}$ New Q

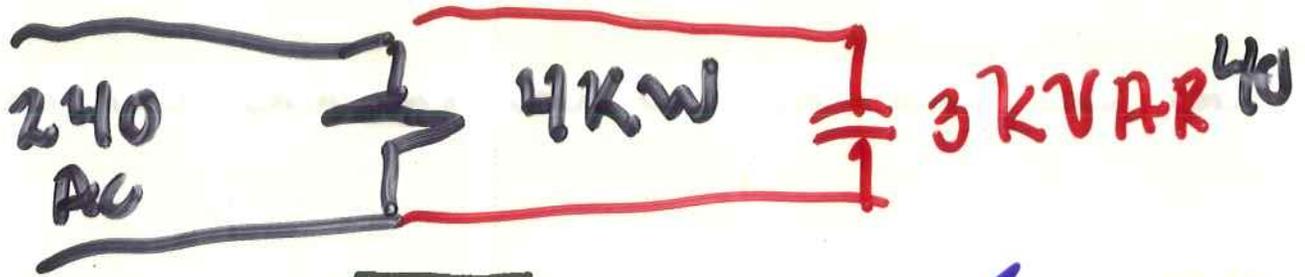
$P(\text{line}) = 1976 \text{ W}$

$S(\text{line}) = \sqrt{1976^2 + 998^2} = 2214 \text{ VA}$ from

$I(\text{line}) = 2214 / 230 = 9.63 \text{ A}$ 11.6 A

(c) No. The active power is the same.

But motor (external) cooler
why? Do for 80 μF HW!



7-29 (a) $S = \sqrt{3^2 + 4^2} = 5 \text{ kVA} \leftarrow \text{SOURCE}$

$$I = \frac{5000}{240} = 20.83 \text{ A}$$

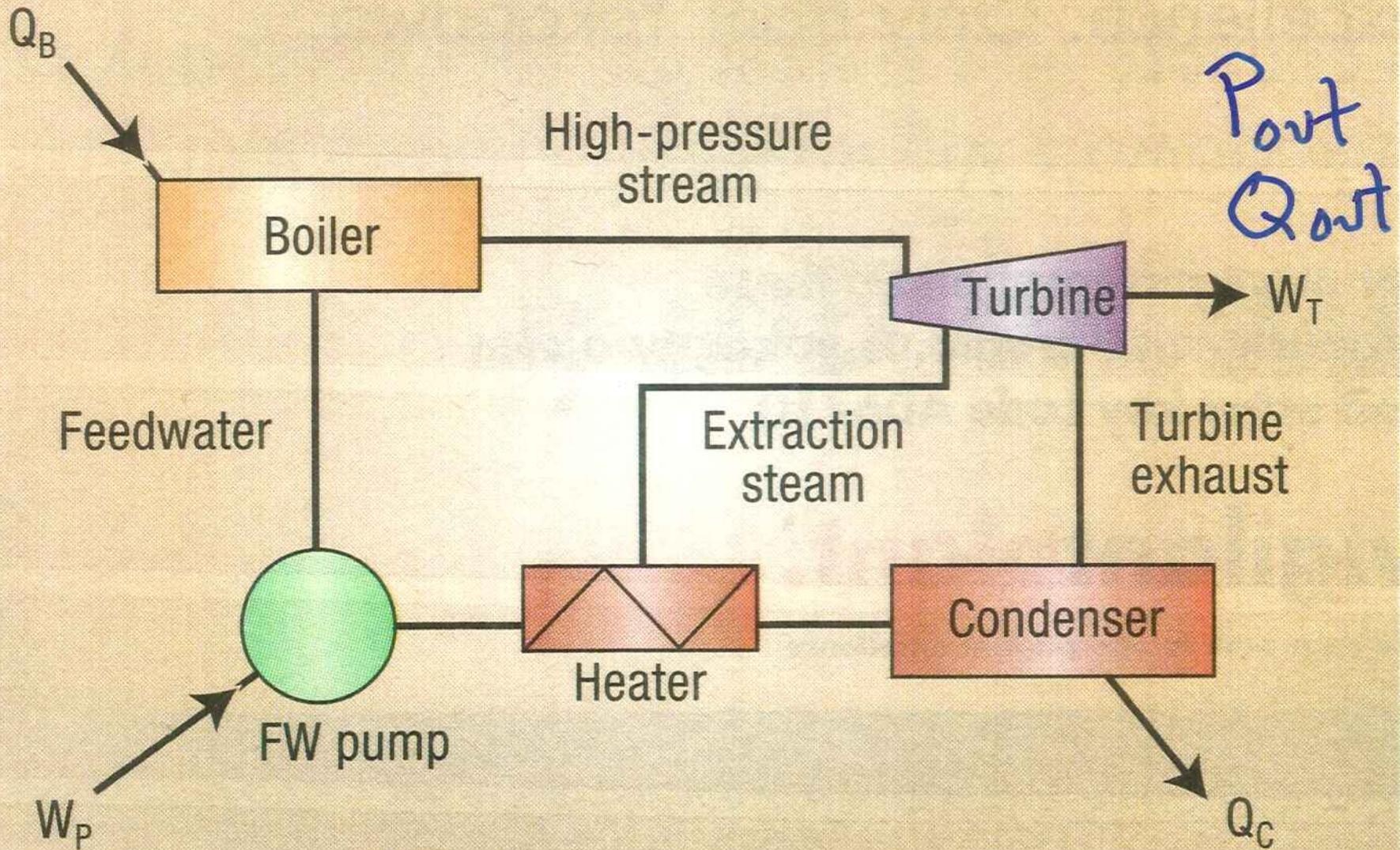
C serves ^{good} NO purpose - it harms

(b) $I = \frac{4000}{240} = 16.7 \text{ A}$ This problem

shows that adding a capacitor to a line does not always reduce the line current.

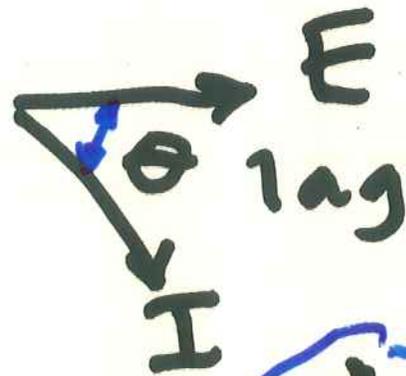
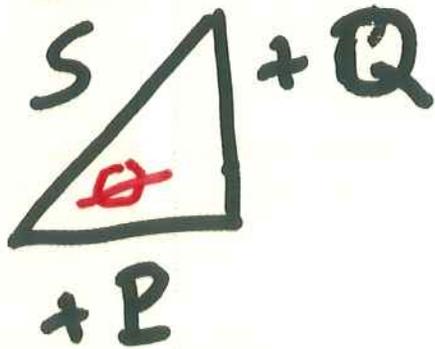
Only when X_c cancels X_L
 does $X_{\text{Total}} \downarrow$

Figure 3 STEAM GENERATOR WITH A SINGLE, TUBE-IN-SHELL FEEDWATER HEATER



S - P - Q Triangles 10

1. Inductive



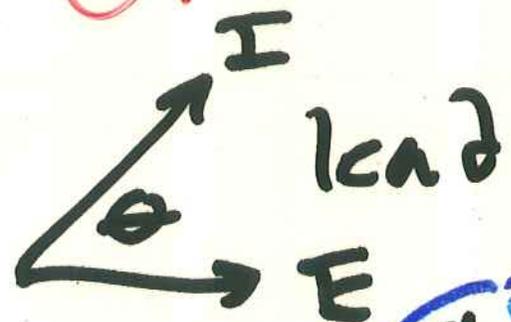
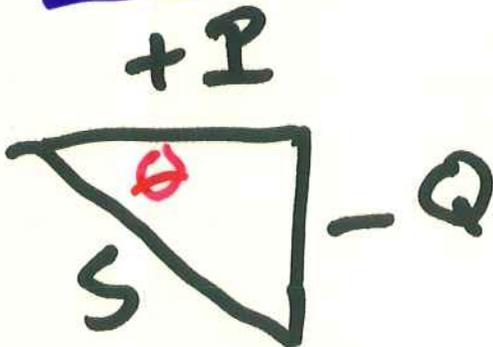
$$S = E I^*$$

I^{} draw*

$$S = EI \cos \theta + j EI \sin \theta$$

θ is \oplus or \ominus ? PF = ?

2. Capacitive



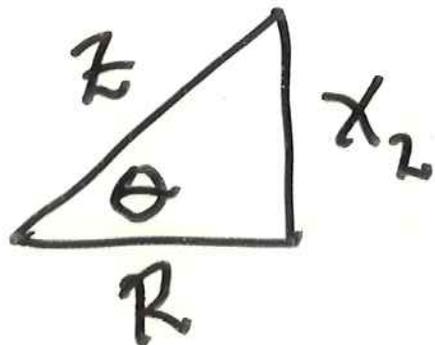
$$S = E I^*$$

$$S = EI \cos \theta - j EI \sin \theta$$

θ is \oplus or \ominus ?

which quadrant?

Inductive

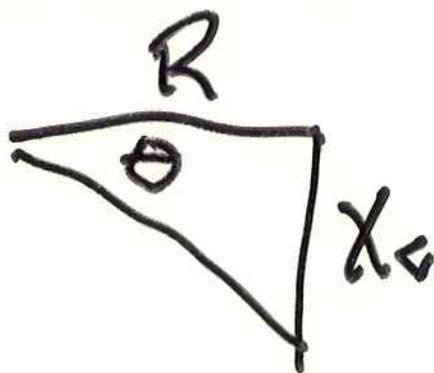


$$Z_L = R + jX_L$$

$Z_L \angle \theta$
 θ is +

$$i_L = \frac{V_L \angle 0}{Z_L} \rightarrow i_L \text{ lags } V_L$$

Capacitive: $Z_C = R - jX_C$

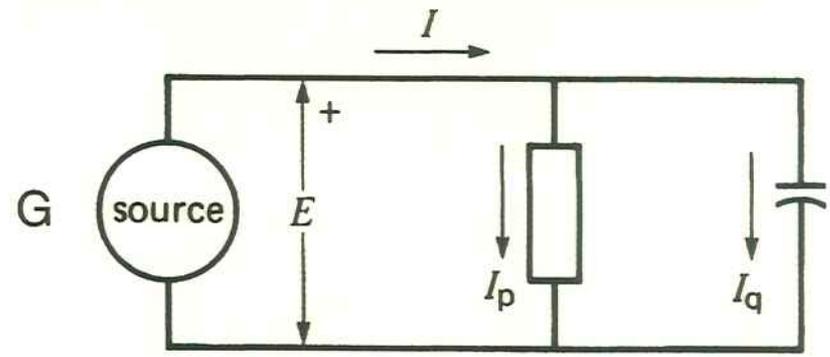


$$Z_C \angle \theta$$

θ is -

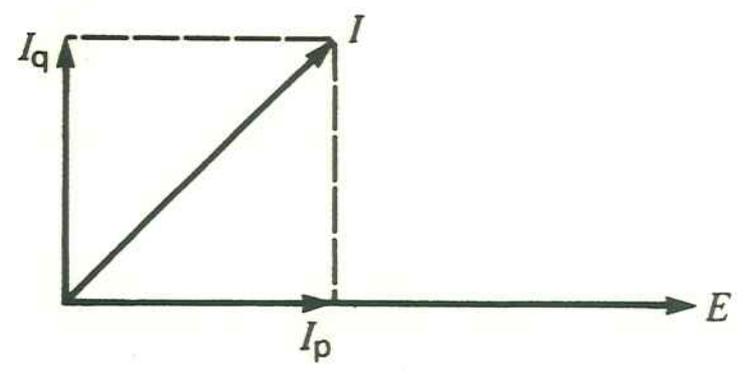
$$i_C = \frac{V_C \angle 0}{Z_C} \rightarrow i_C \text{ leads } V_C$$

(a)



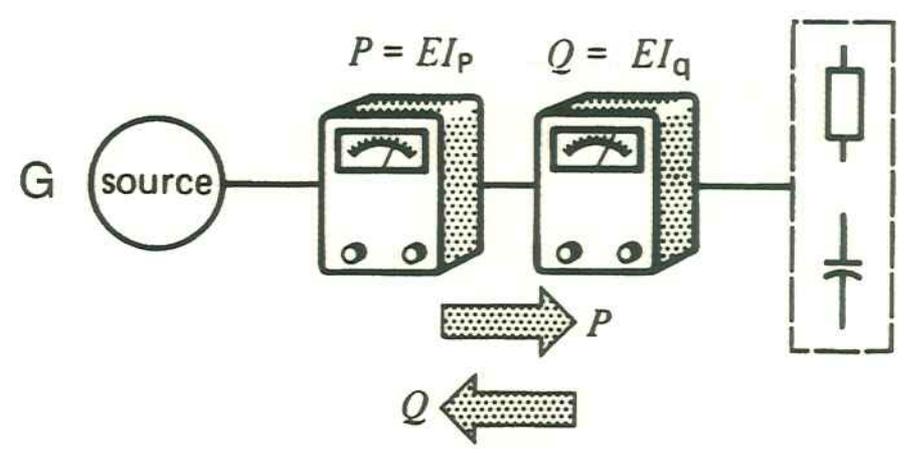
R-C load

(b)



Measure at load source

(c)



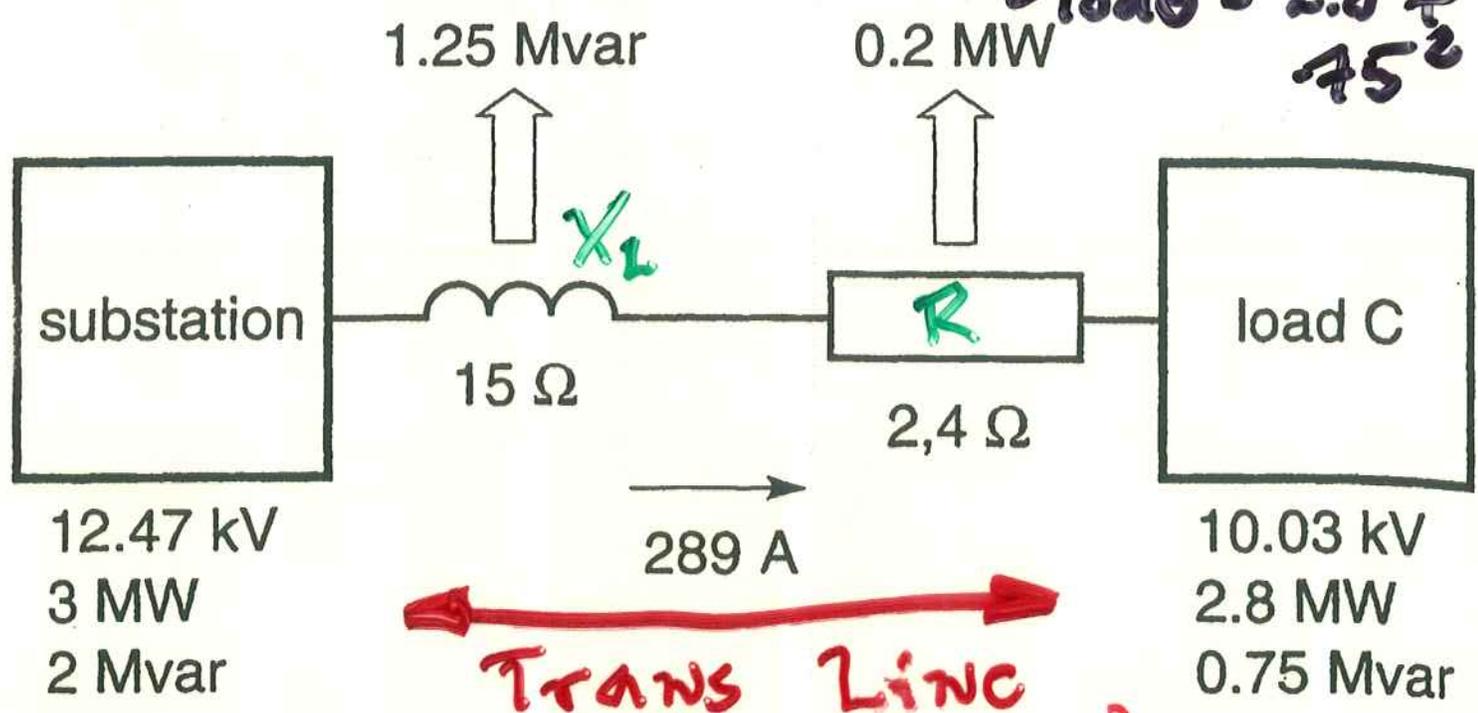
$$P_{IN} = \sum_x P_x$$

$$Q_{IN} = \sum_y Q_y$$

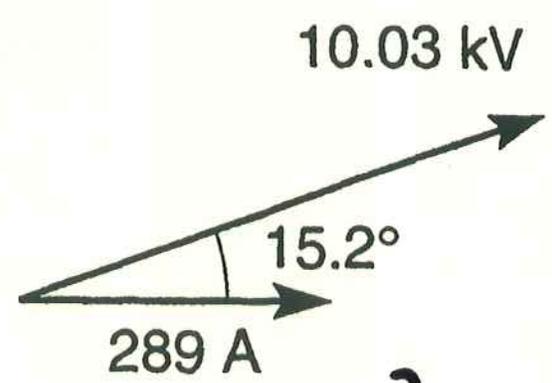
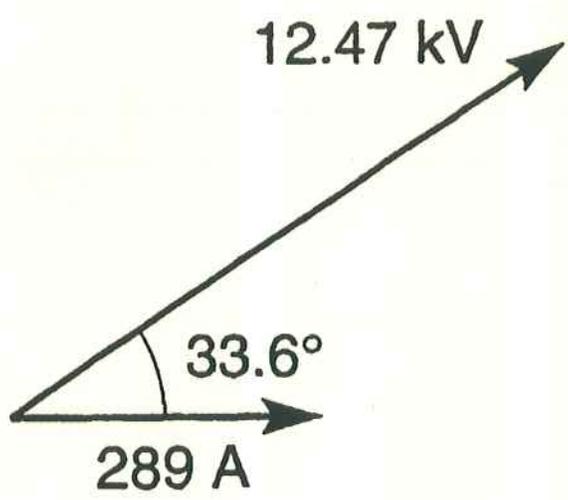
Handwritten notes on the left margin: "A", "G", "IT", "R".

Sub - Line - Load

$$S_{load}^2 = 2.8^2 + 0.75^2$$



TRANS LINE
|I| is measured
SO CAN FIND
?

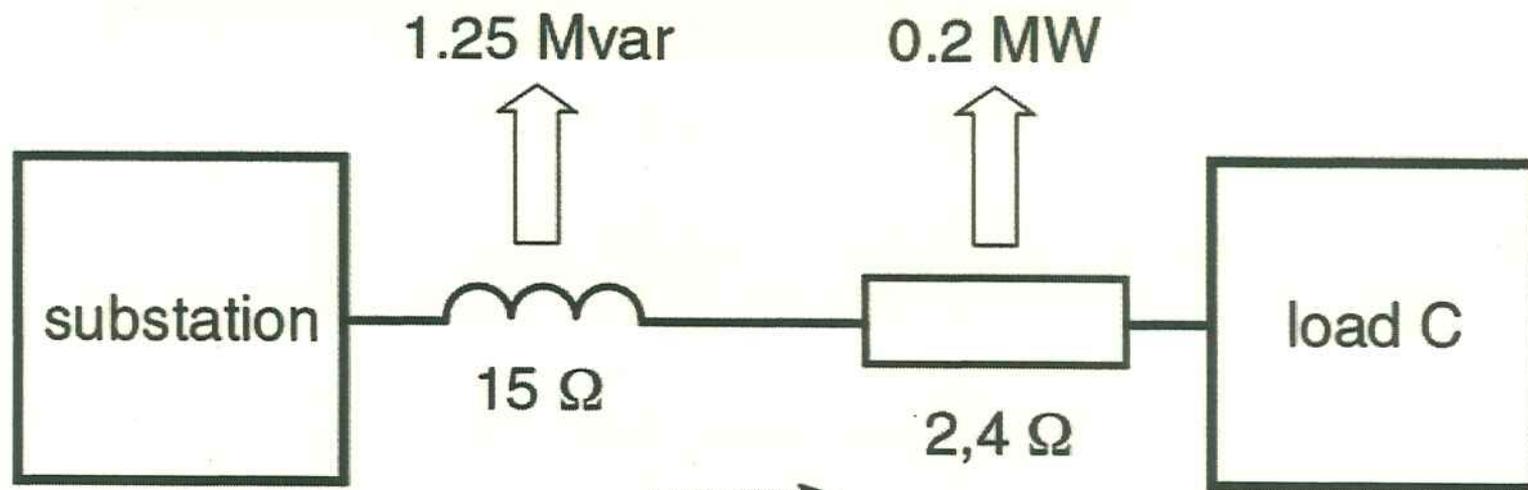


SOURCE

$$S_{source} = (3)^2 + (2)^2$$

Load

$$S_{load}^2 = (2.8)^2 + (0.75)^2$$



→
289 A

12.47 kV
3 MW
2 Mvar

10.03 kV
2.8 MW
0.75 Mvar

P'_S

$P_{IN} = \sum P_x$
 3 MW → 0.2 MW + 2.8 MW

$Q'_S = \sum Q_x$
 2 MVAR → 1.25 + 0.75

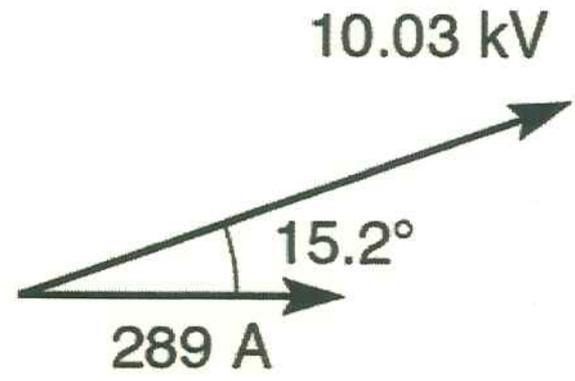
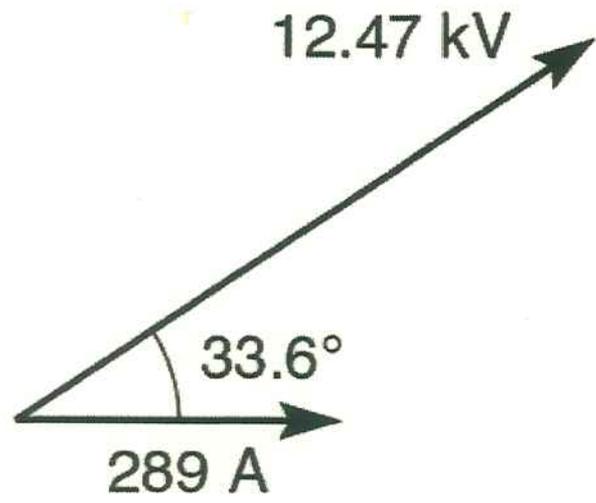
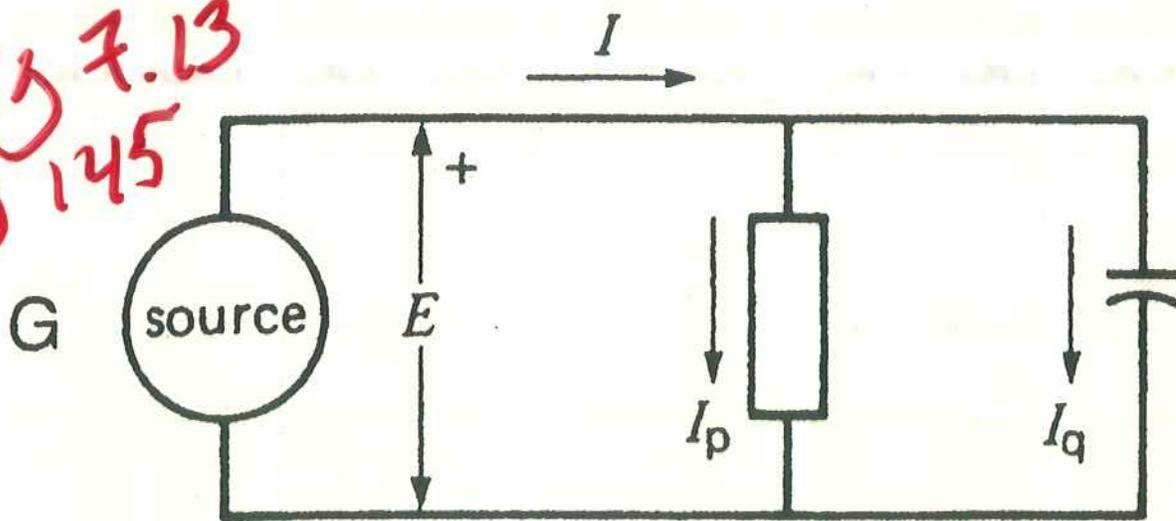
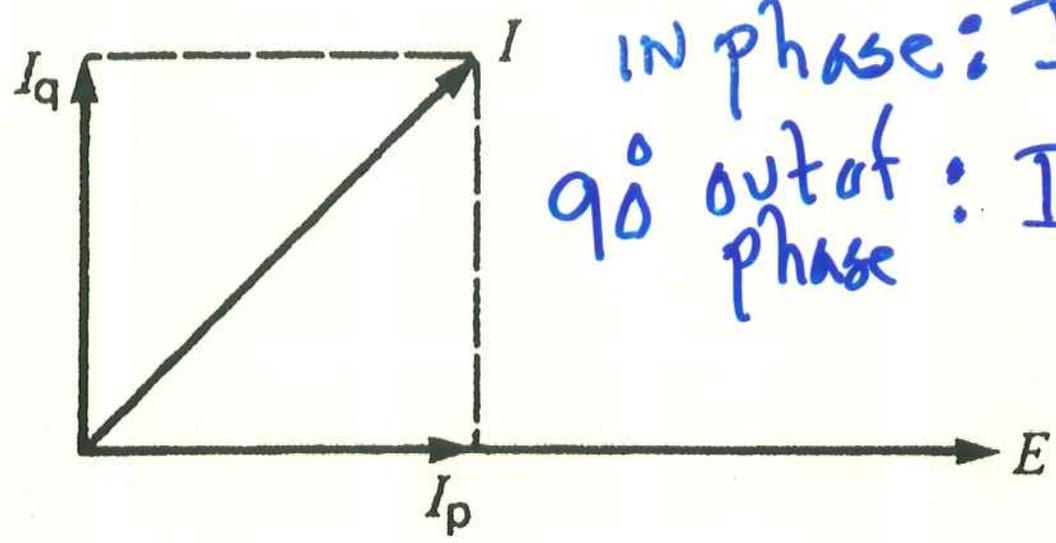


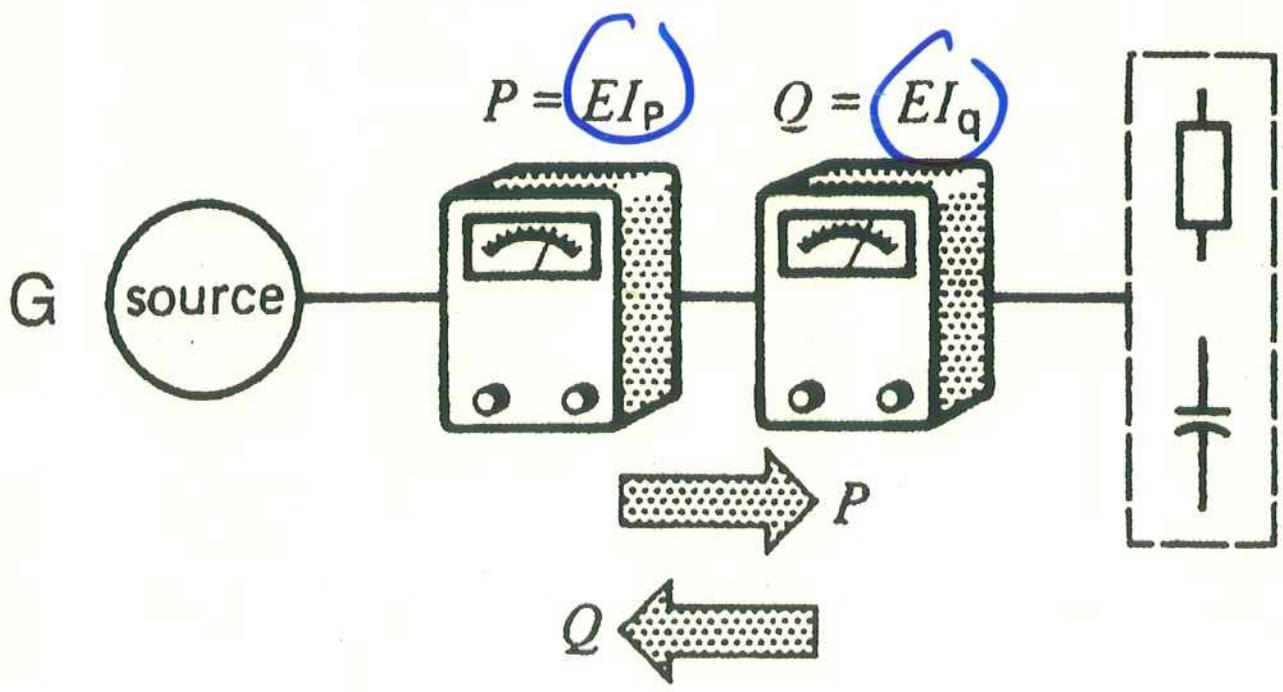
Fig 7.13
Pg 145

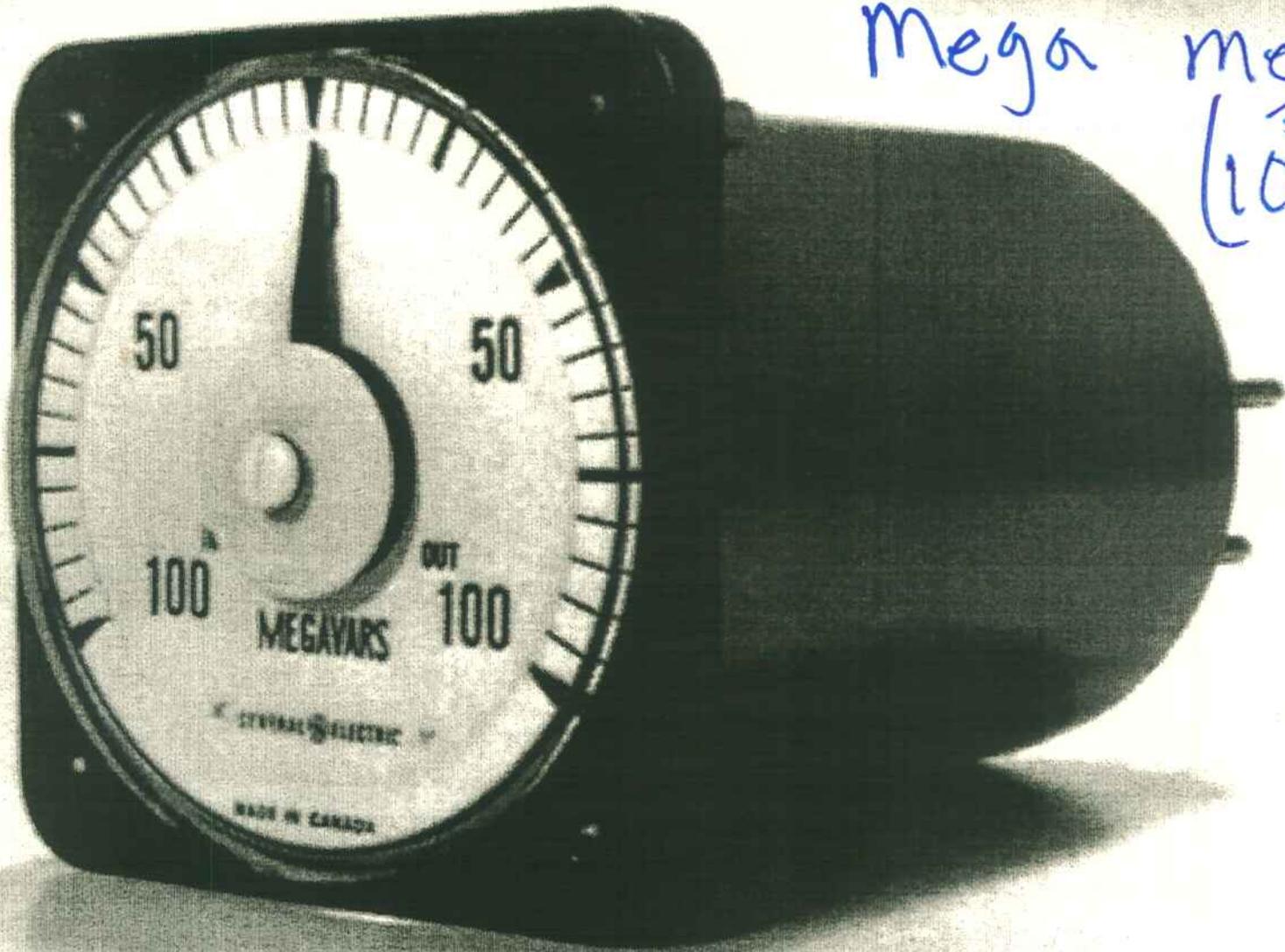


I_N has two components



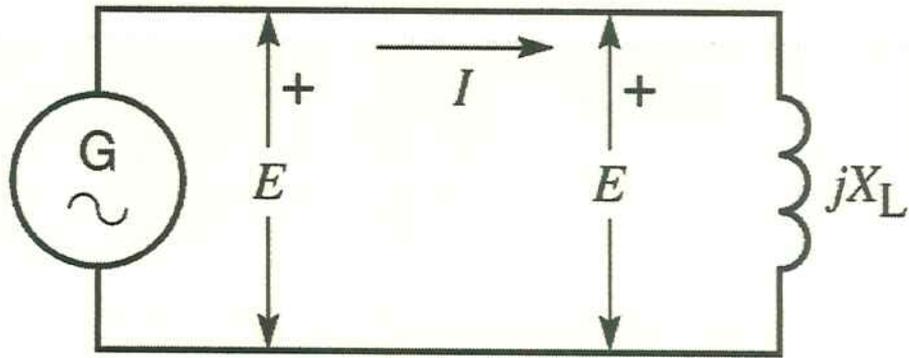
in phase: I_p
 90° out of phase: I_q





Mega meter
($10^3 A$) ($10^3 v$)

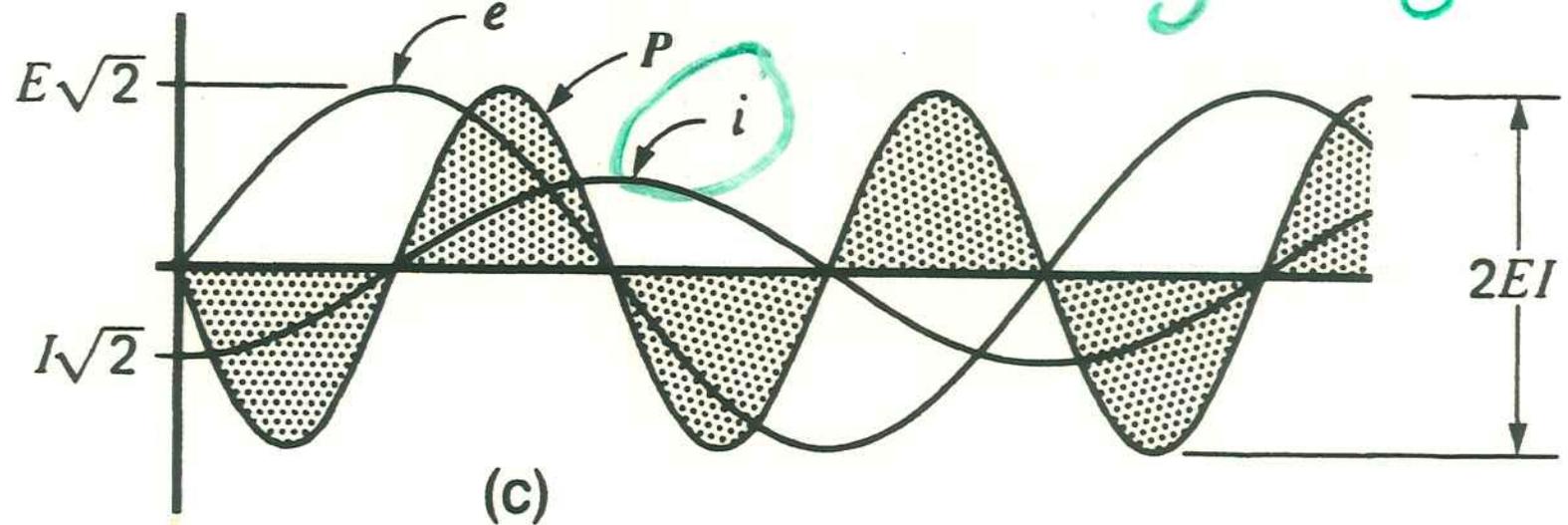
(a)



(b)



From CRT: i lags by?



(c)

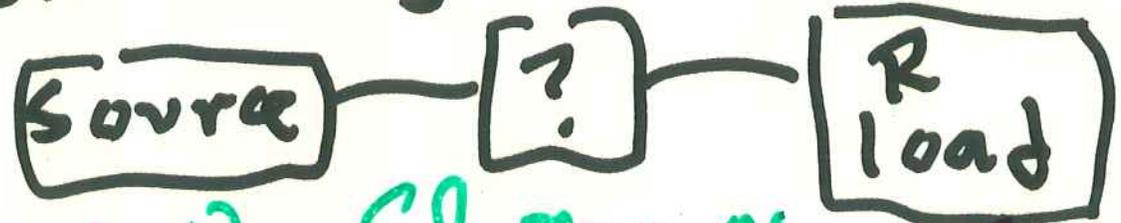
Q without L or C 21

CAN we have Q other ways? *Change P → Q*

1. "L" via \vec{B} field } energy flow 

2. "C" via \vec{E} field energy flow 

CAN we "artificially" make I either lag or lead E when using a R load

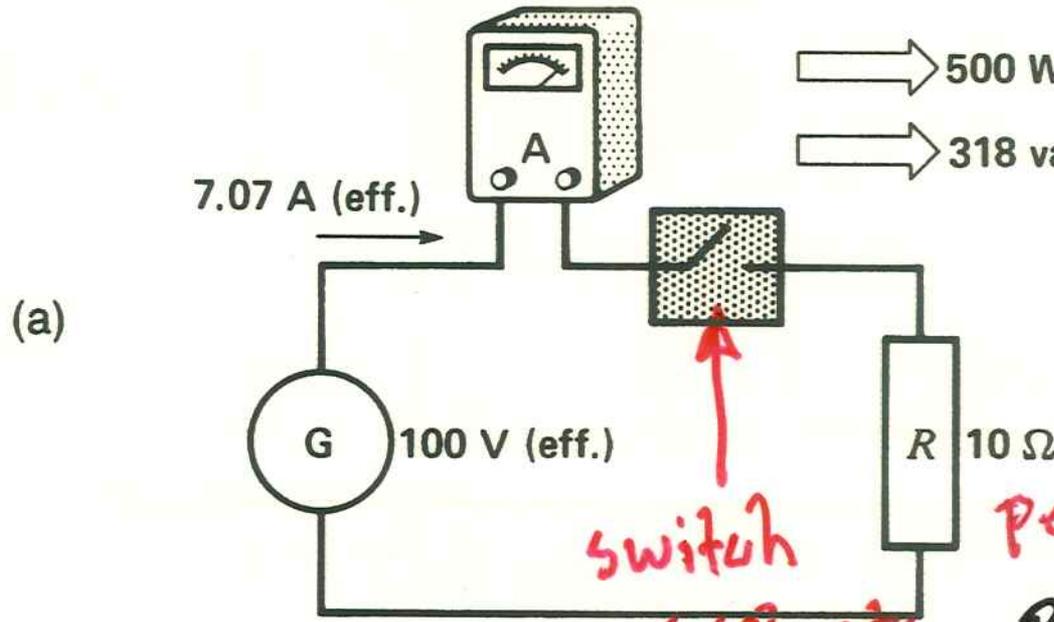


Beyond Ch 7: New Grid

Measure $P = 500 \text{ W}$

$Q = 318 \text{ W}$

$\text{PF} = 0.84$



Sw closed

$$P = \frac{V^2}{R} = \frac{10^4}{10}$$

peak $\approx 1 \text{ kW}$

$$P = \left(\frac{14.1}{\sqrt{2}} \right)^2 R = 10^3$$

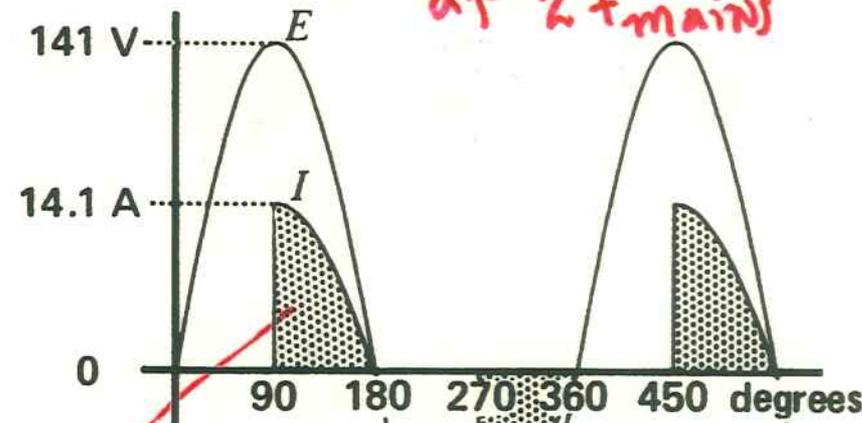
10 rms

Sw open half the time

$$P \rightarrow \frac{1}{2} \text{ kW}$$

intuitive

$$\Rightarrow I_{\text{eff}} = 7.07 \text{ A}$$



I lags E

Next Look only at

mains fundamentals

Look ahead Ch 21 / Ch 30

fund plus harmonics
Ch 30

Measured Values

7.07 A (eff.)

500 W

22

318 vars

Who needs VARs supplies

Fig 7.16

Pg 149

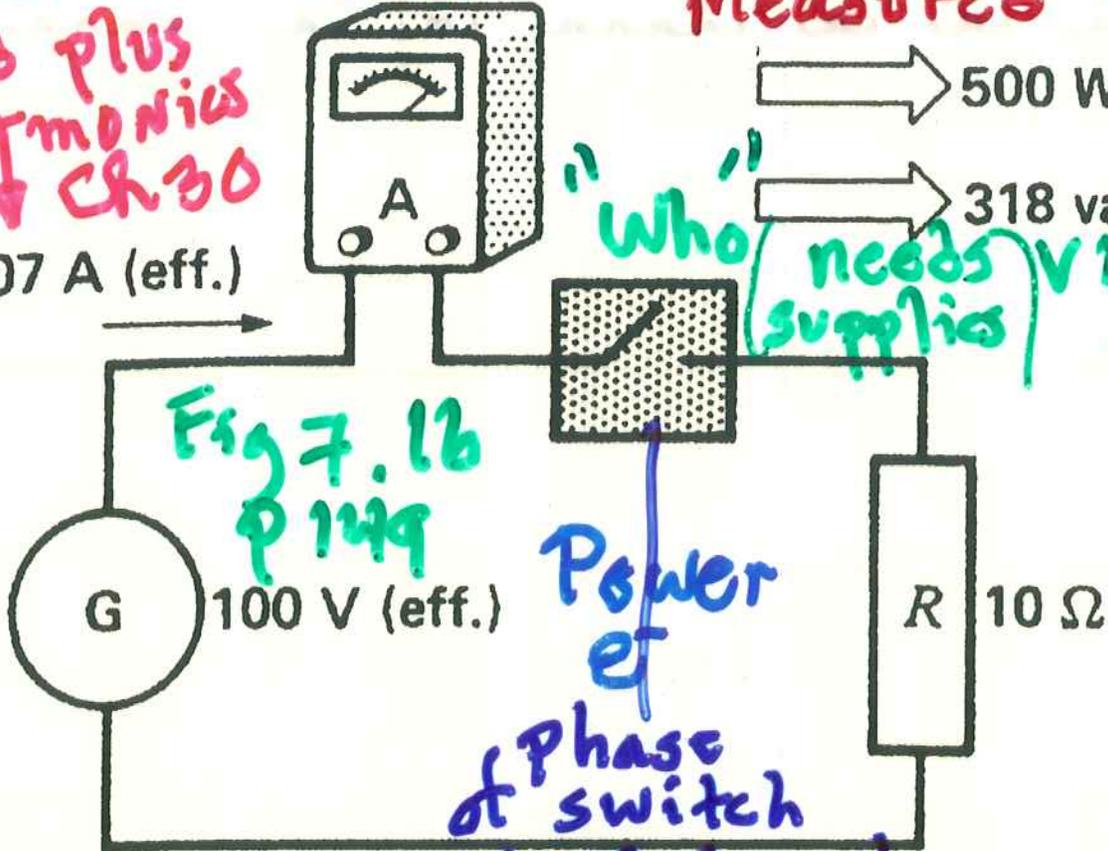
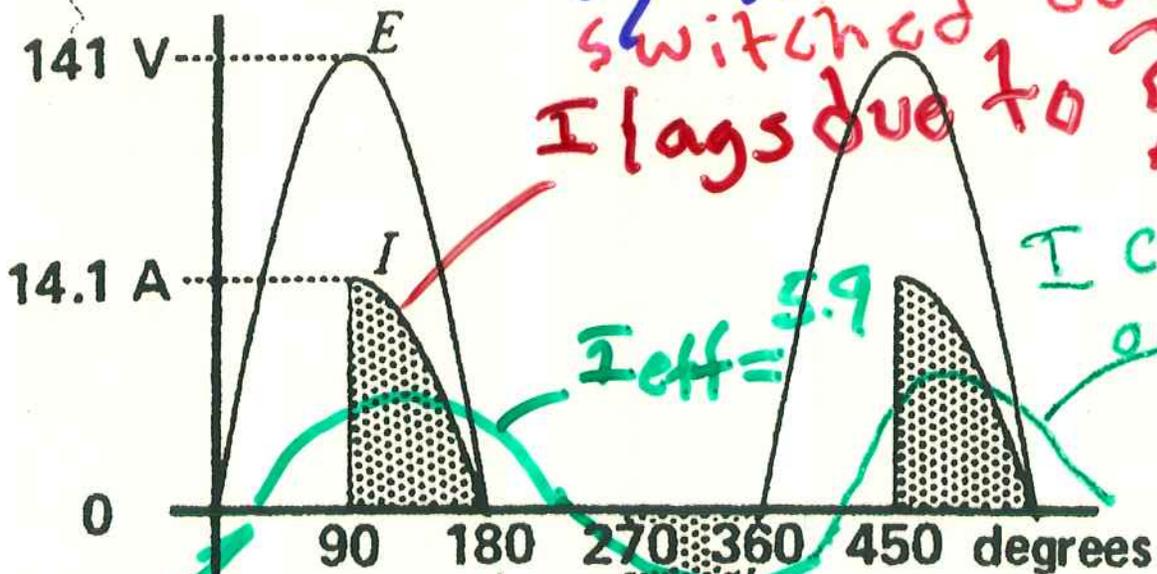


Fig 7.16
Pg 149

Power of phase of switch is delayed by 90°



I lags due to?

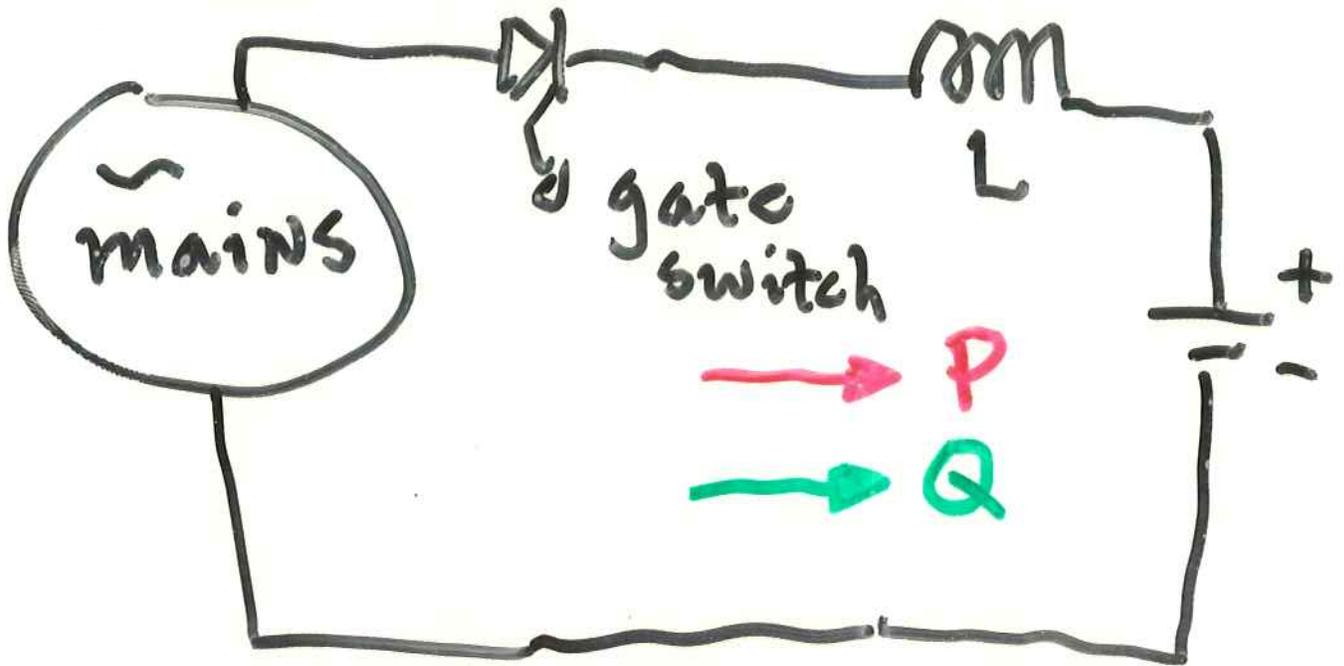
I component of mains only

$\theta_{eff} = 32.5^\circ$ of lag

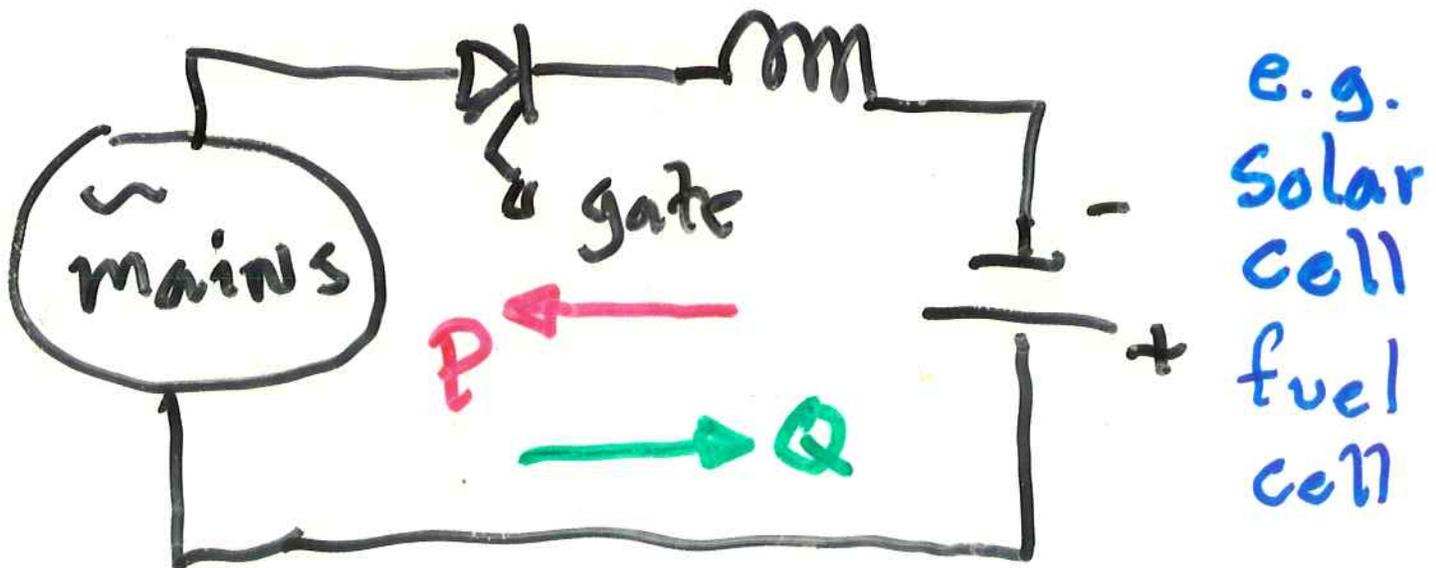
How could I lead E?

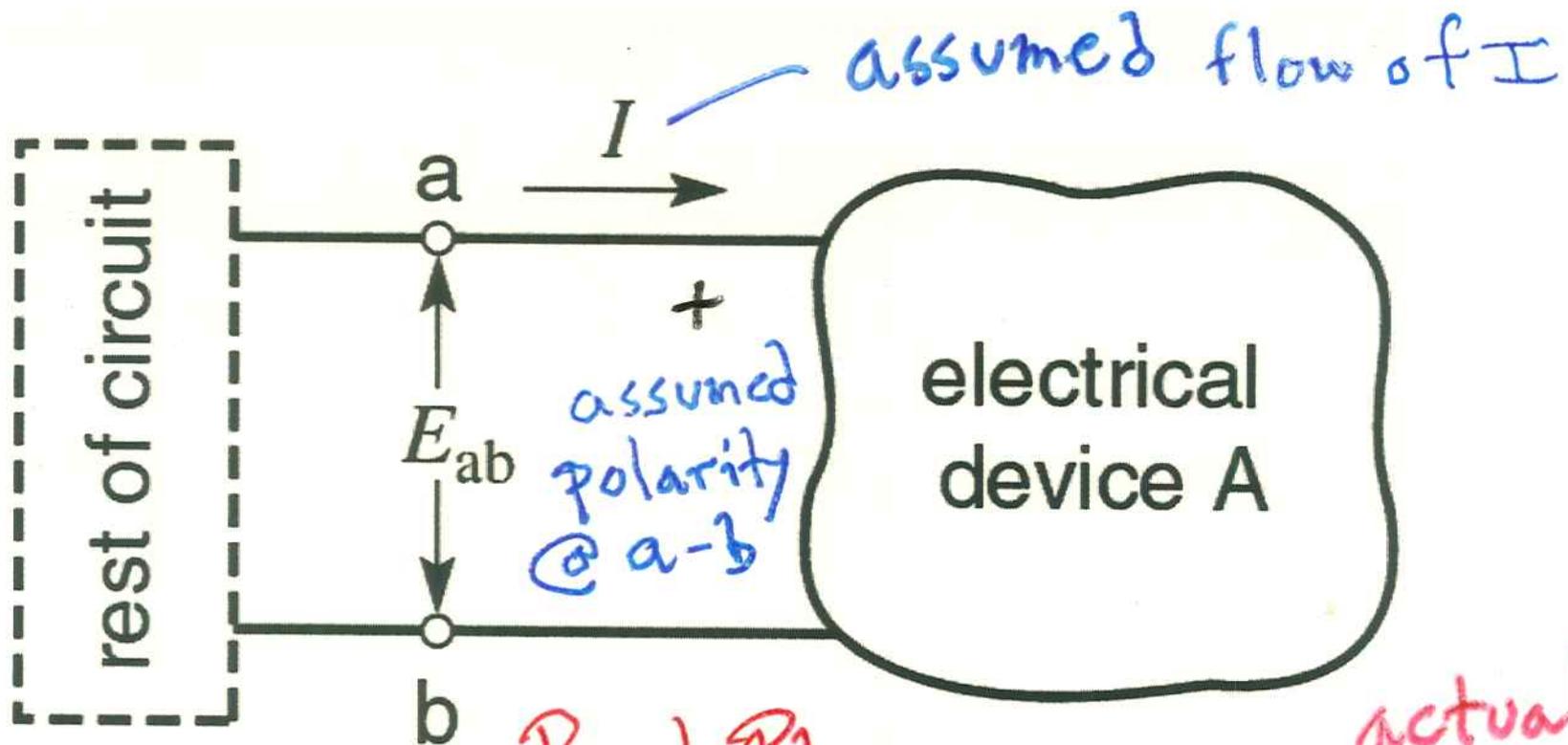
Later

I. Thyristor controlled Battery Charger

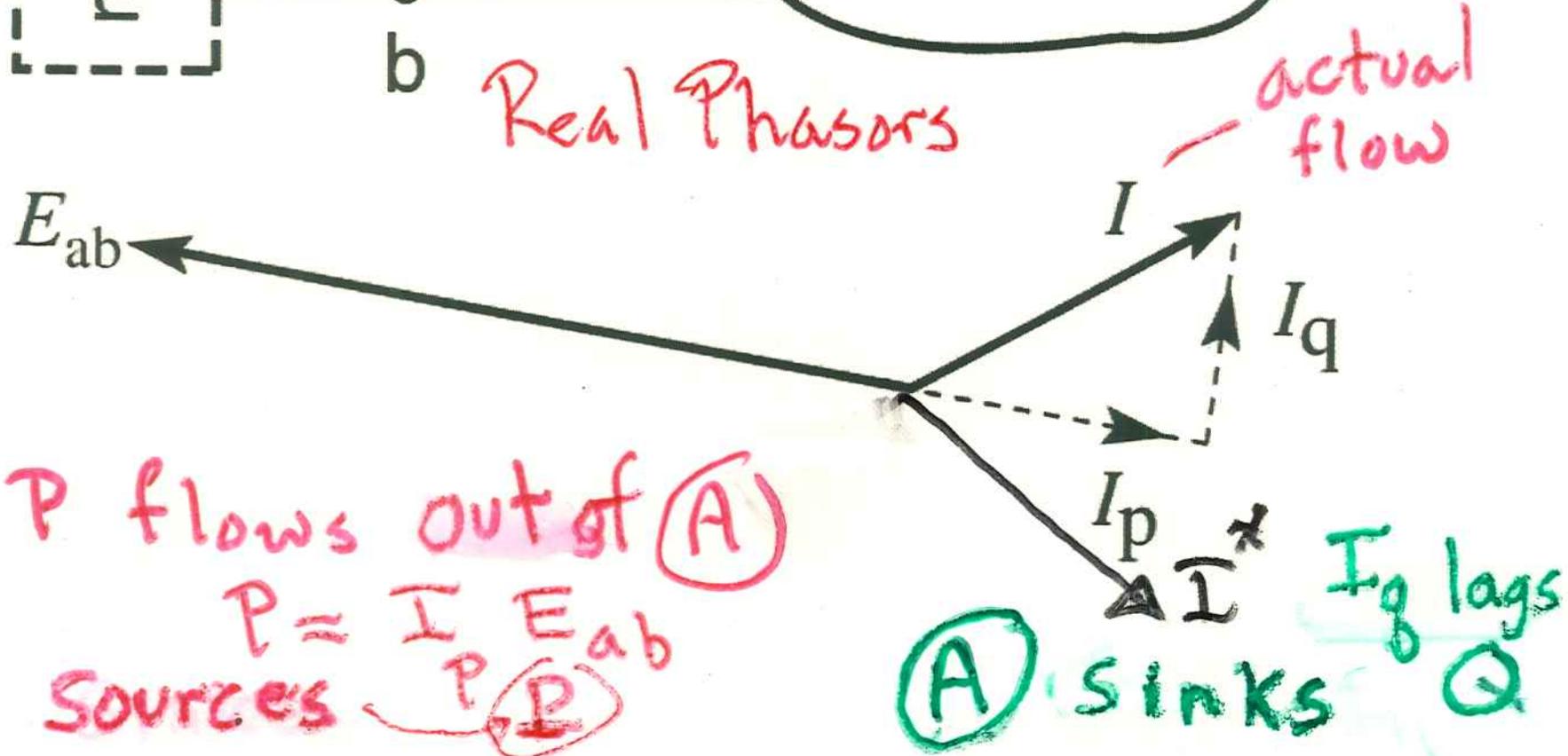


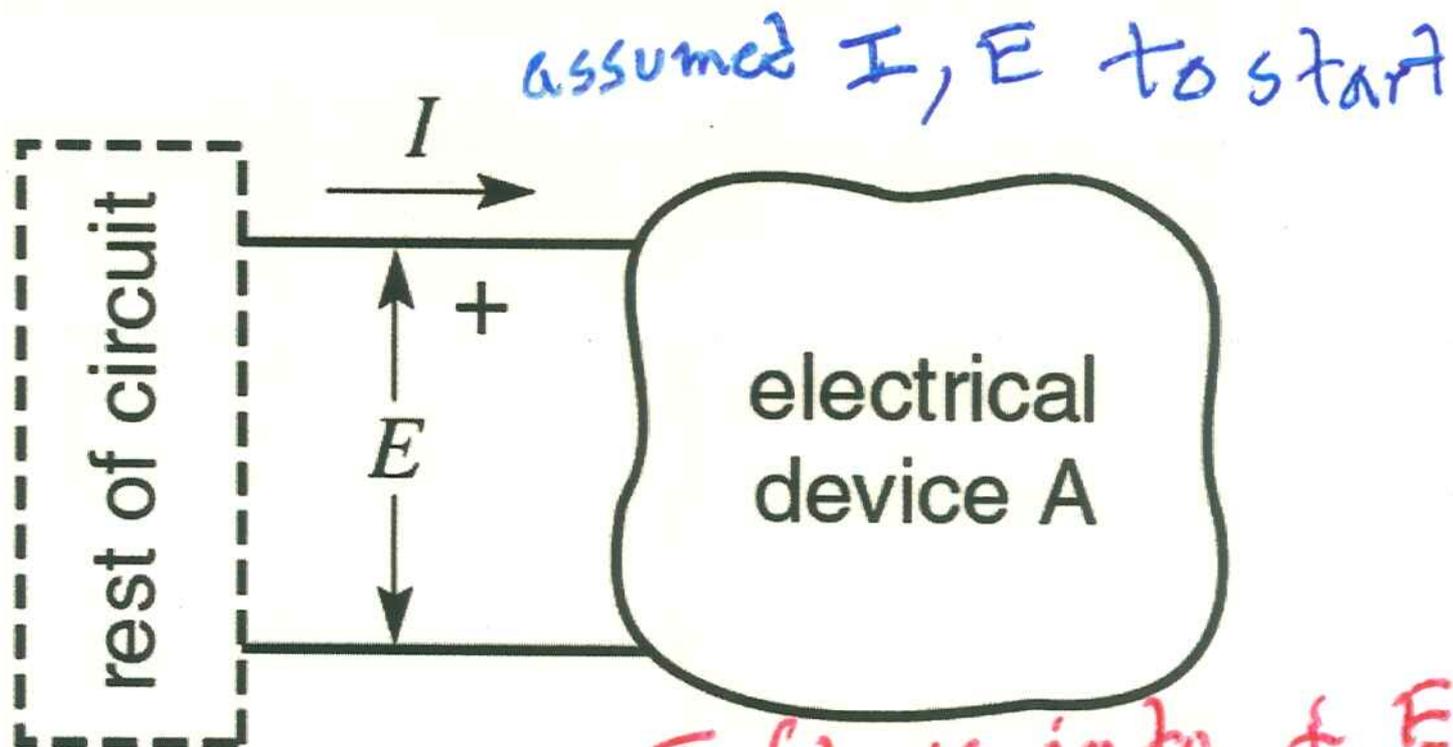
II DC to AC Inverter





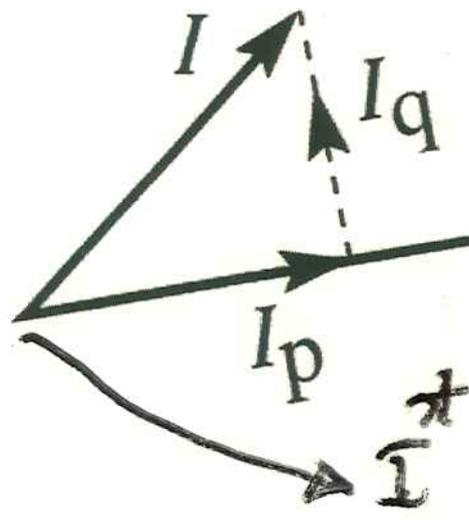
Real Phasors





actual

I flows into $+ E$ of A
 P flows into (A)



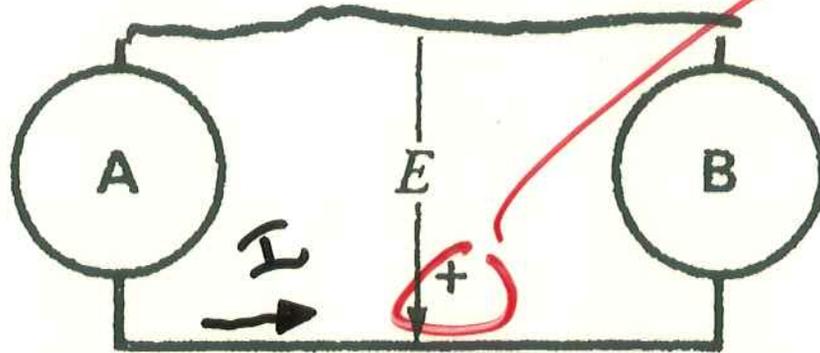
I_q leads E
 Q flows out of (A)
 (A) is capacitive

Easy

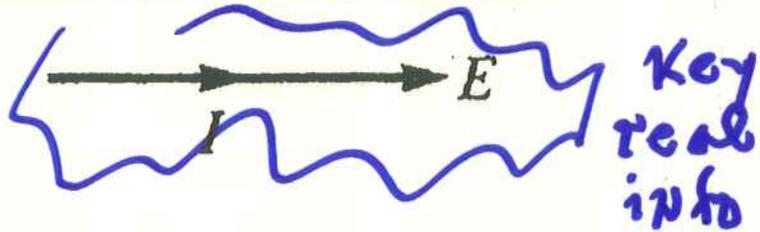
(a)

A is POWER or Q SOURCE? SINK

arbitrary first guess



(a)



Key real info

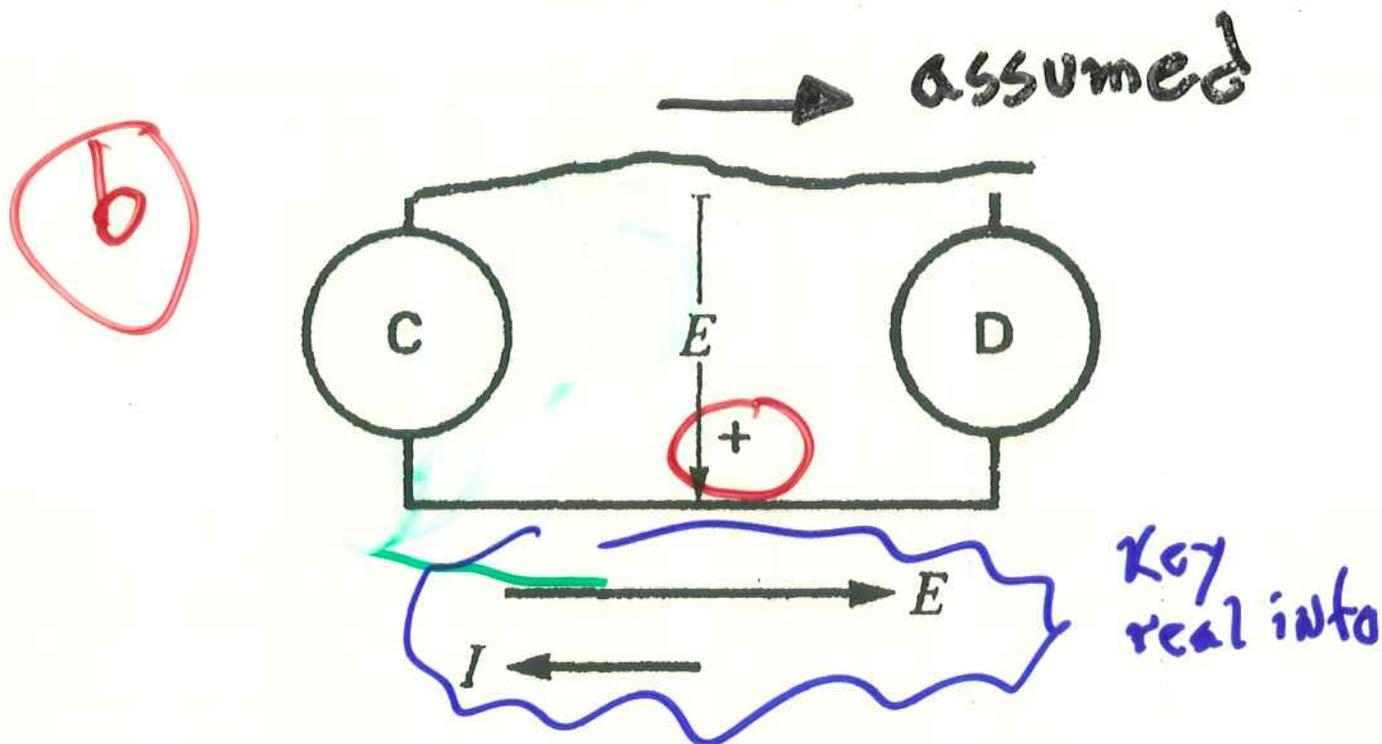
A looks like a power source because current flows out of the positive terminal. This is confirmed by the fact that the phasor diagram shows E and I in phase. A is therefore an active power source

$$Q = ?$$

1st level tricky

What is D?

power source
sink



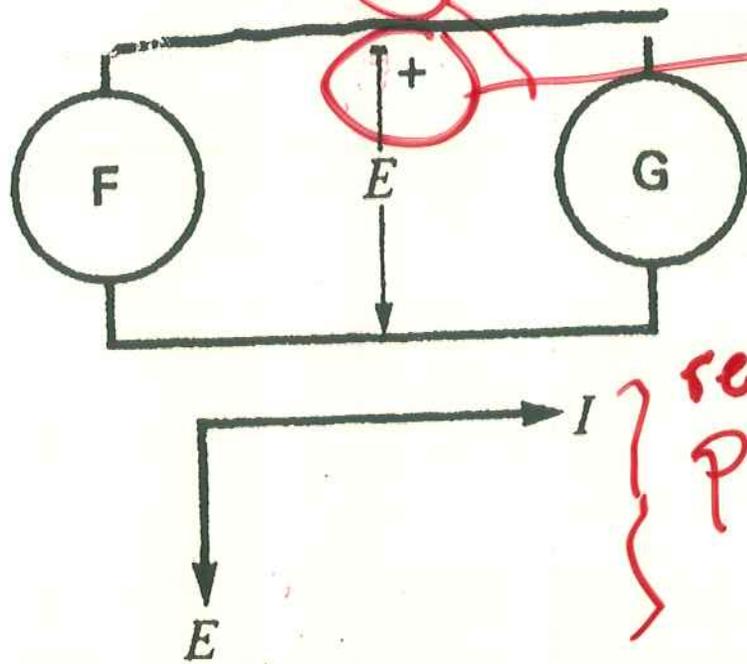
D looks like a power source (I flows out of (+) terminal). However I is 180° out of phase with E. \therefore C is the active power source.

Ready next for
power source / sink

(vs)

reactive power source / sink

(C)



Assume

What is G

What is F

Assume

real into Phases \rightarrow ?

G looks like a power source (I flows out of (+) terminal). It is ^{not} a reactive power source because I leads E. OK? $-Q$

$i \cdot Q$
★ load

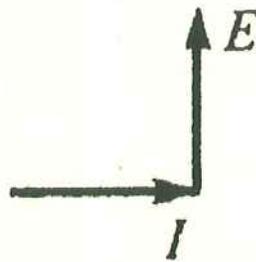
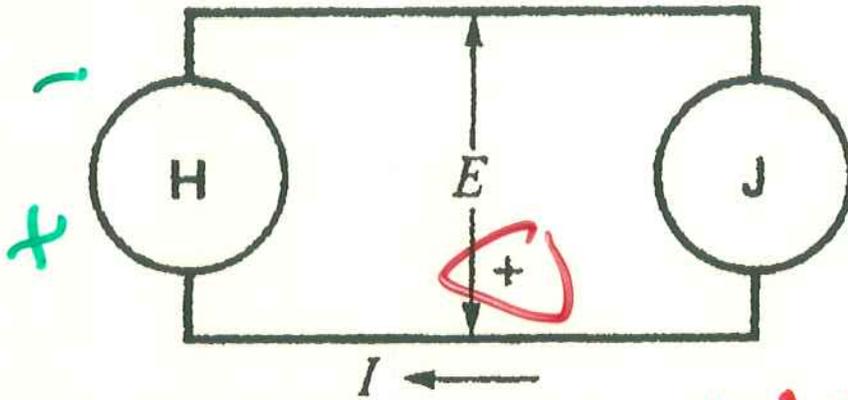
It is sometimes easier to look at the element which looks as if it is the load - in this case device F. It is not an inductive load, because the current leads the voltage. Hence F must be an inductive source. We shall use this reasoning in the next three examples.

OK with reactive source? sink

Who is the reactive power source?
 Load is L or C?
 Type?

①

Assume



Actual facts

+Q

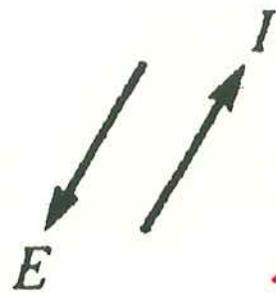
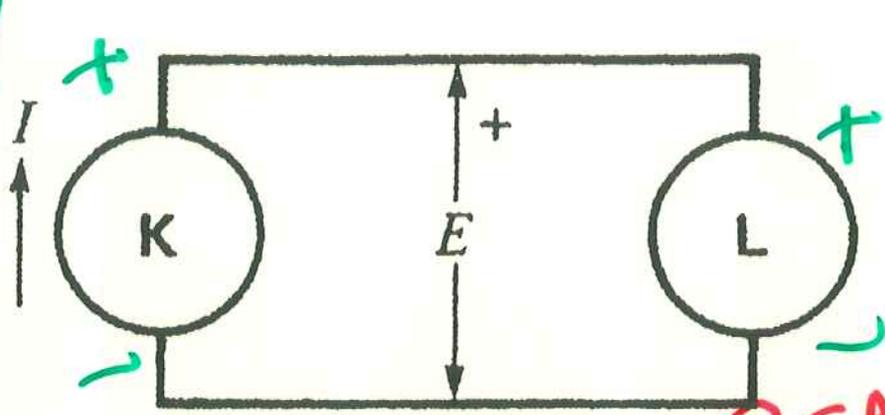
H appears to be the load. It would be inductive because E and I are 90° out of phase. It is the load because I lags behind E . Consequently, J is the reactive source.

$e \perp i$

Who is the power load?
source?

e)

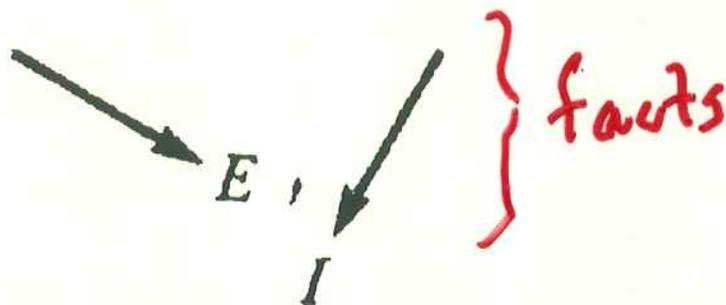
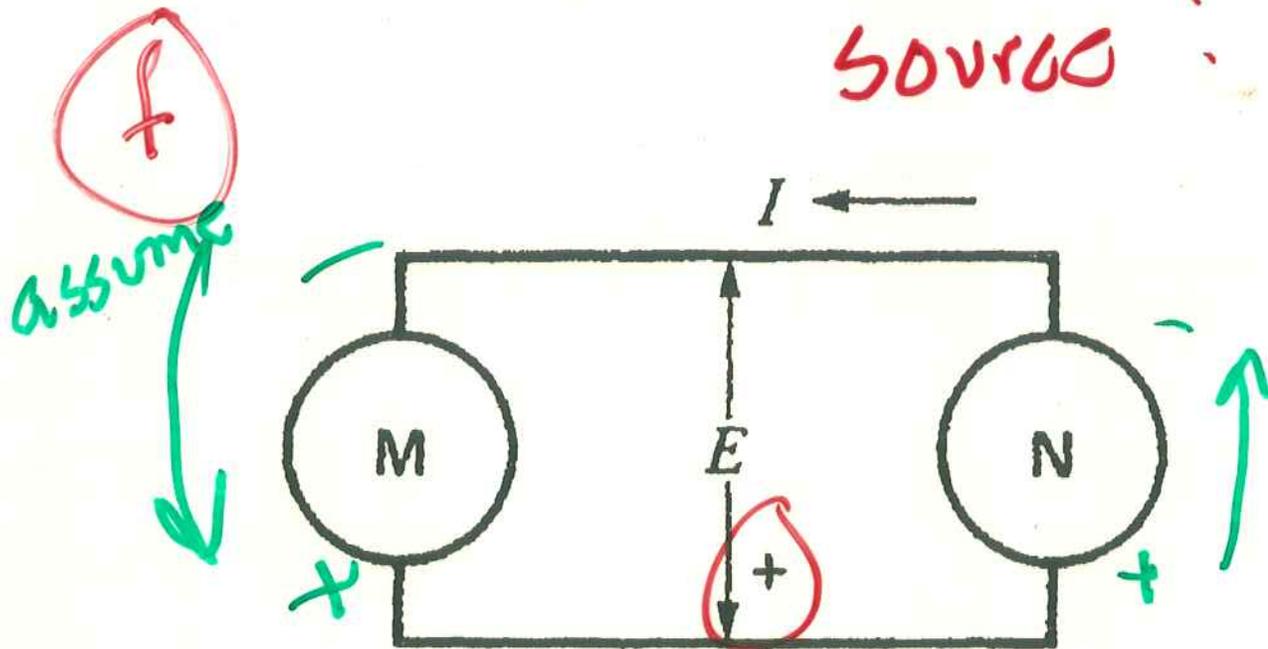
assume



REAL facts E and I in (phase) relation

L appears to be the load. It is not the load because E and I are 180° out of phase.
 \therefore L is the active source.

Who is load ?
SOURCE ?

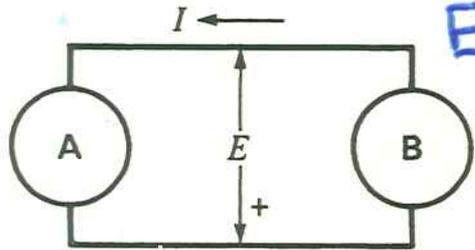


N appears to be the load. It is the load because I lags 90° behind E . \therefore M is a reactive source.



onelivewire

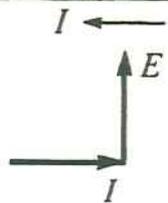
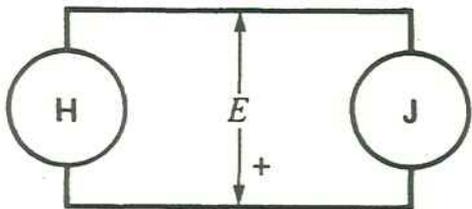
I out + (A)
 $\theta = 0$ w.r.t E^+



(A) power source

(a)

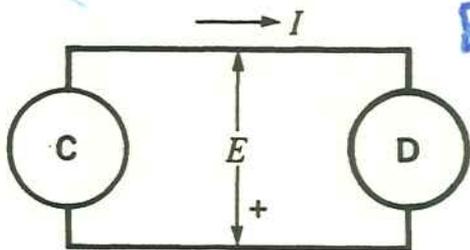
I lags E 90°



(d)

(H) is a sink

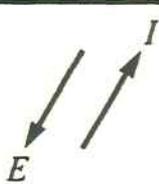
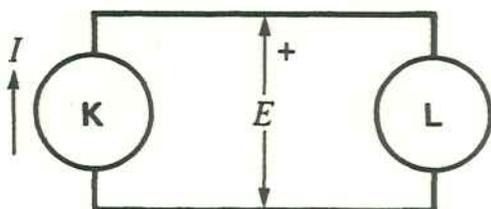
I in + (C)
 $\theta = 180$ w.r.t E^+



(D) power sink

(b)

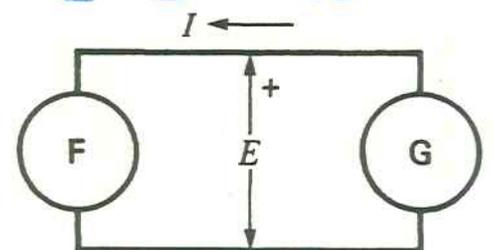
I 180° E



(e)

(K) is a power sink

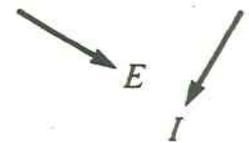
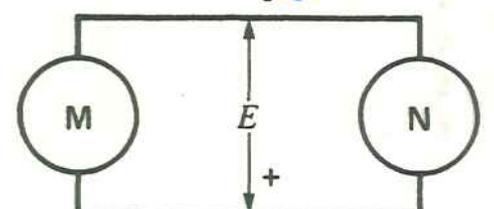
I leads E
 $\theta = 90^\circ$



(F) is a source

(c)

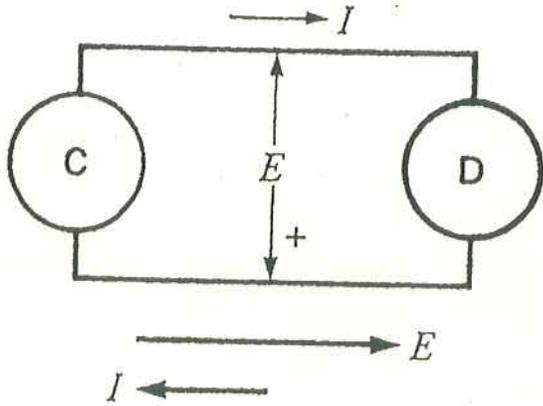
I lags E



(f)

(N) is a sink

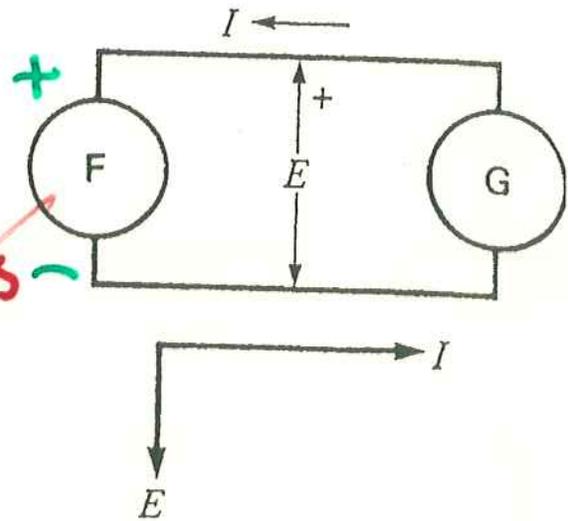
Review



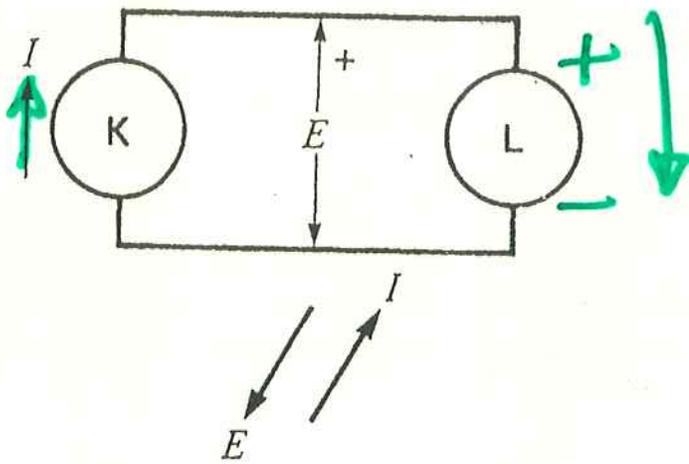
(b)

Tricky

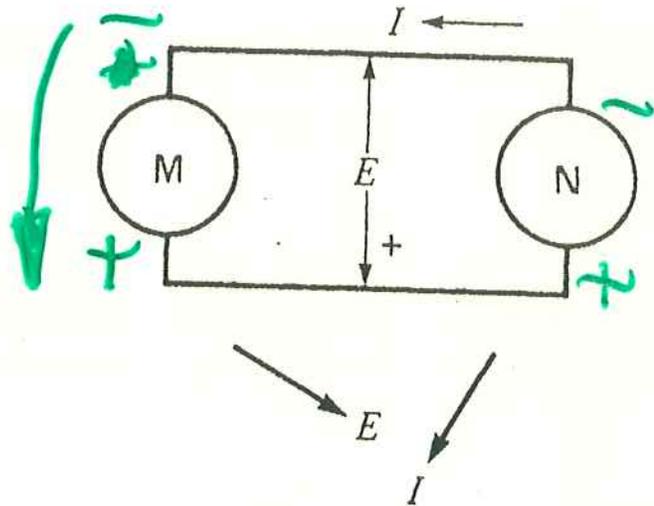
try as
load



(c)



(e)



(f)

Need Fig 7.24 99 156⁹

7-11

a. A looks like a power source because current flows out of the positive terminal. This is confirmed by the fact that the phasor diagram shows E and I in phase. A is therefore an active power source

b. D looks like a power source (I flows out of (+) terminal). However I is 180° out of phase with E . \therefore C is the active power source.

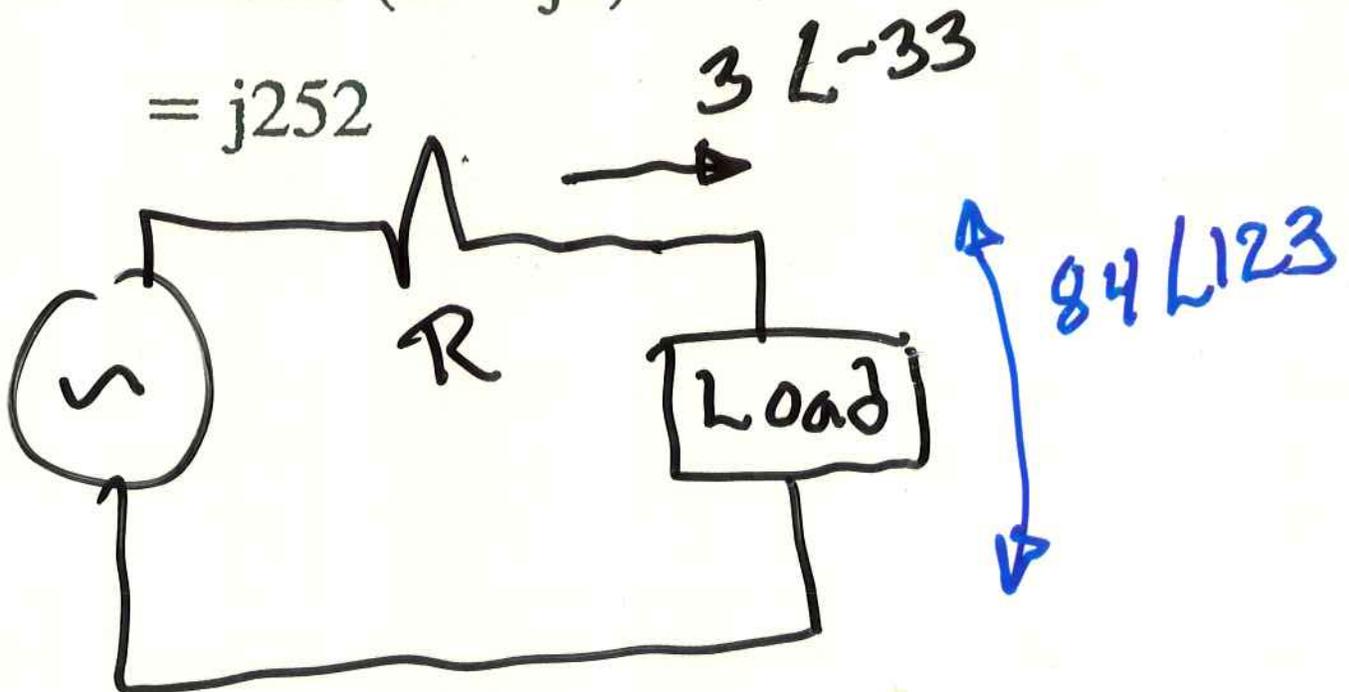
c. G looks like a power source (I flows out of (+) terminal). It is ^{not} a reactive power source because I leads E .

It is sometimes easier to look at the element which looks as if it is the load - in this case device F. It is not an inductive load, because the current leads the voltage. Hence F must be an inductive source. We shall use this reasoning in the next three examples.

d. H appears to be the load. It would be inductive because E and I are 90° out of phase. It is the load because I lags behind E . Consequently, J is the reactive source.

Load condition

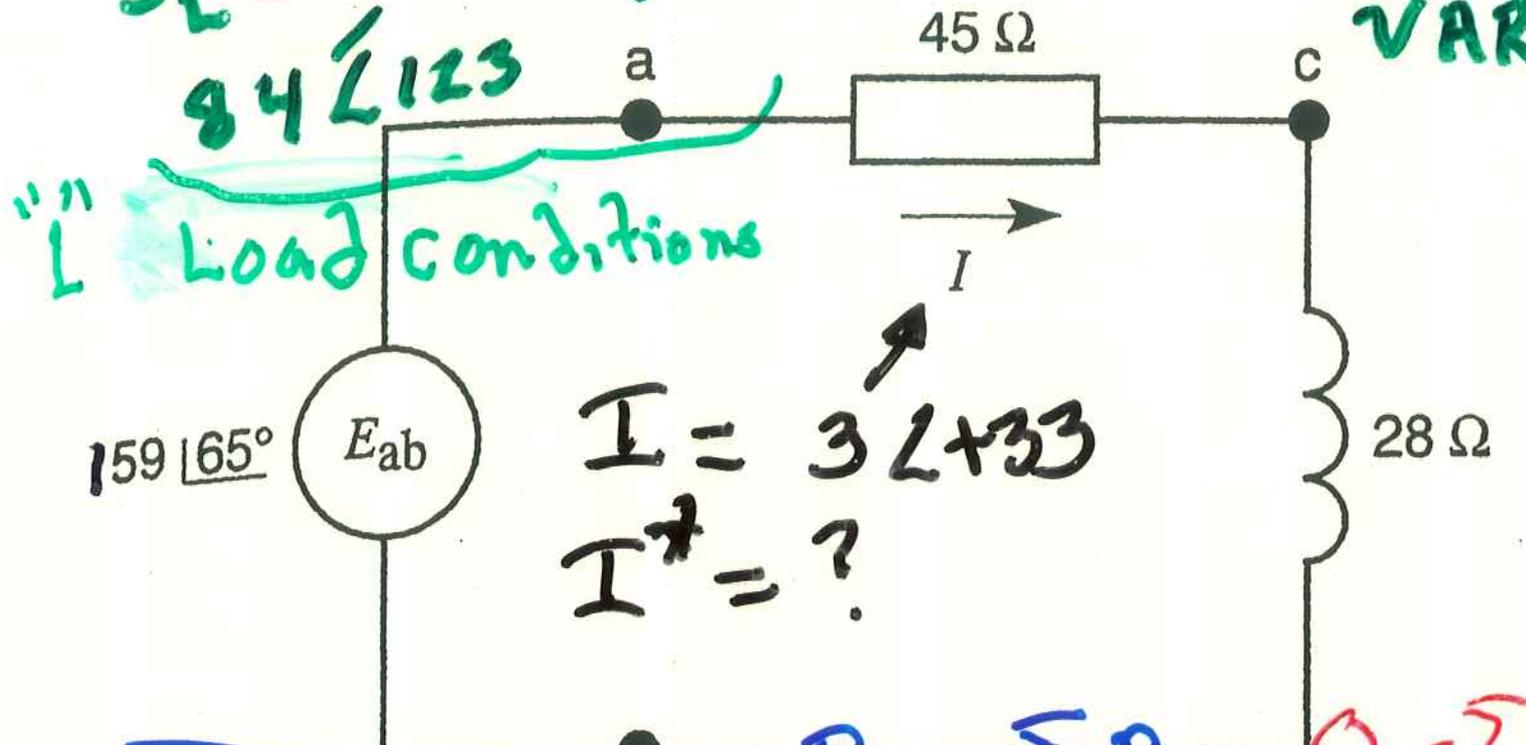
$$\begin{aligned}
 S_x &= E_{cb} I^* \\
 &= (84 \angle 123.11^\circ) (3 \angle -33.11^\circ) \\
 &= 252 \angle 90^\circ \\
 &= 252 (\cos 90^\circ + j \sin 90^\circ) \\
 &= 252 (0 + j1) \\
 &= j252
 \end{aligned}$$



$$S(\text{source}) = ?$$

35 R_{load}
 $S_R = E_{ac} I^* = [135L+33][3L-33]$
Resistor $= 405 \text{ Watts} + j0$

$S_L = E_{cb} I^* \leftarrow 3L-33 = 0 + j252$
 VAR



Source $P_s = \sum P_x$ $Q_s = \sum Q_x$

$S(\text{source } E_{ab}) = E_{ba} I^*$
 $+159 \angle 65$ $3L-33$

$= 477 \angle 32$

$= -405 \text{ W} - j252 \text{ VARs}$

- sign \Rightarrow Source delivers P Q

Multiple Loads: Wattmeter Approach 16

System Approach with

$$\Sigma P = 0$$

$$\Sigma Q = 0$$

Mind your
P's & Q's

versus

Full circuit analysis

This is quicker if all we seek is:

i drawn by source
 $\left. \begin{matrix} P \\ Q \end{matrix} \right\}$ Requirements of the source

Next 380 ac connected
to R-L-C
 $i(380)$ Solved by ΣP
 ΣQ

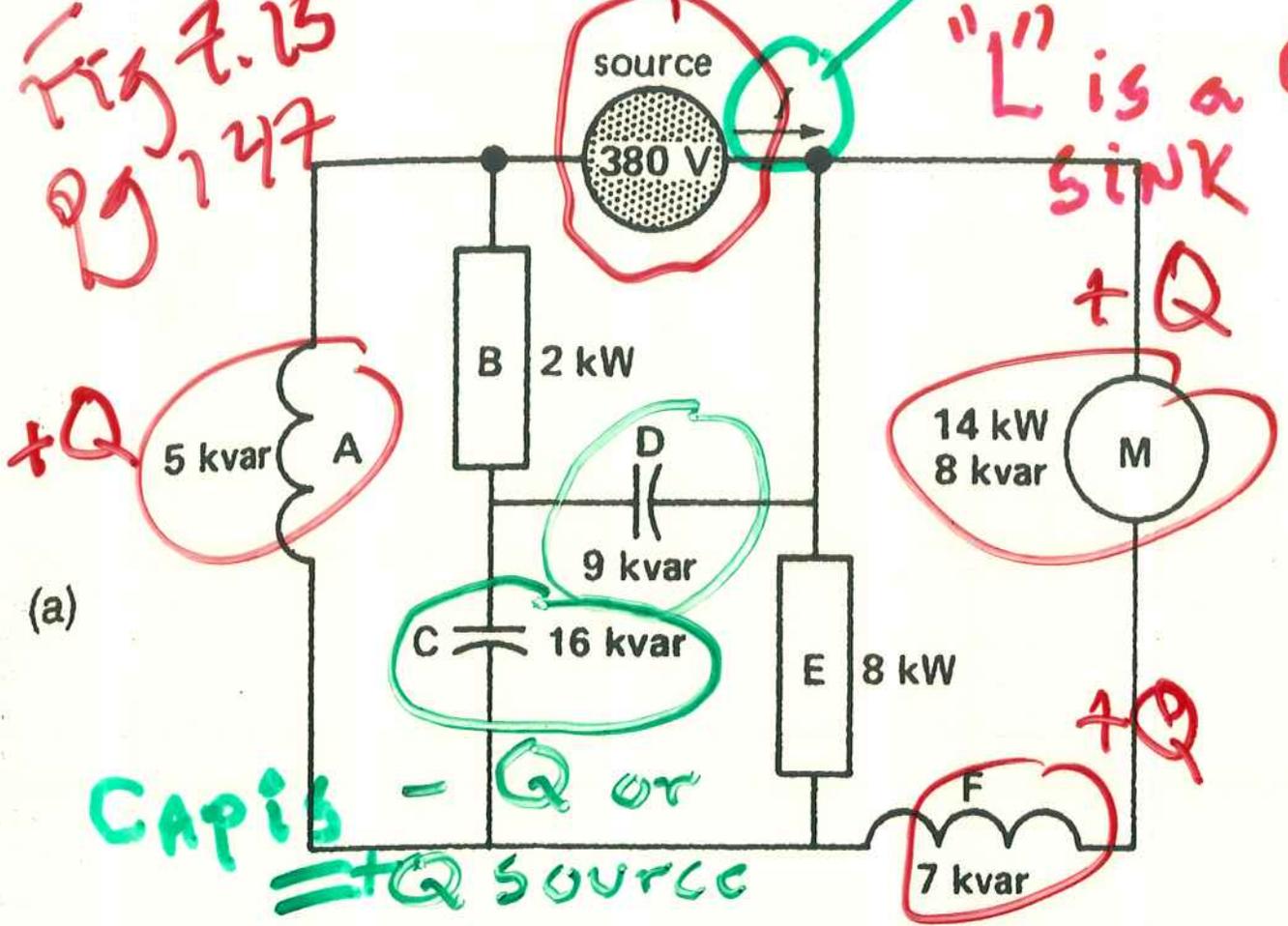
16
Q

+Q is absorbed by load

Usually a Transformer Secondary?

Fig 7.15
Pg 147

"L" is a Q sink

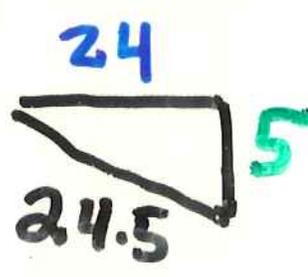


CAPIS - Q or +Q source

$$\Sigma P = 2 + 8 + 14 = 24$$

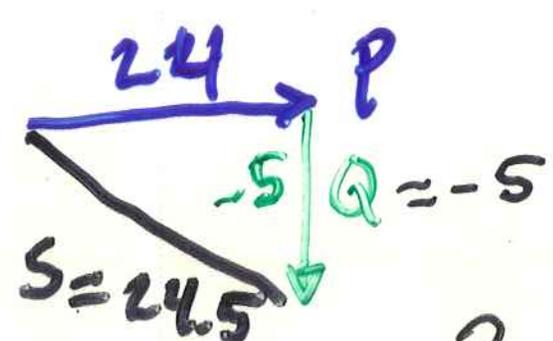
$$\Sigma Q = -9 - 16 + 5 + 7 + 8$$

$$S = \sqrt{P^2 + Q^2} = 24.5$$



16
b

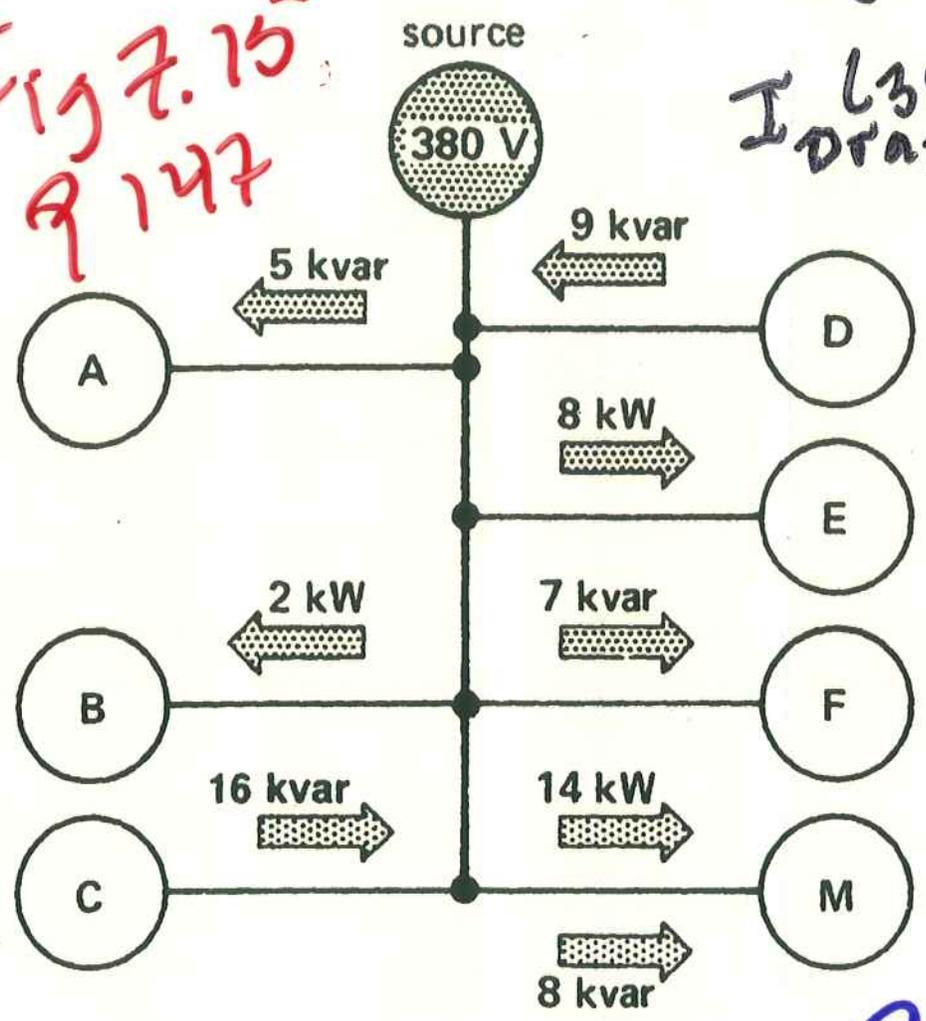
Summary:



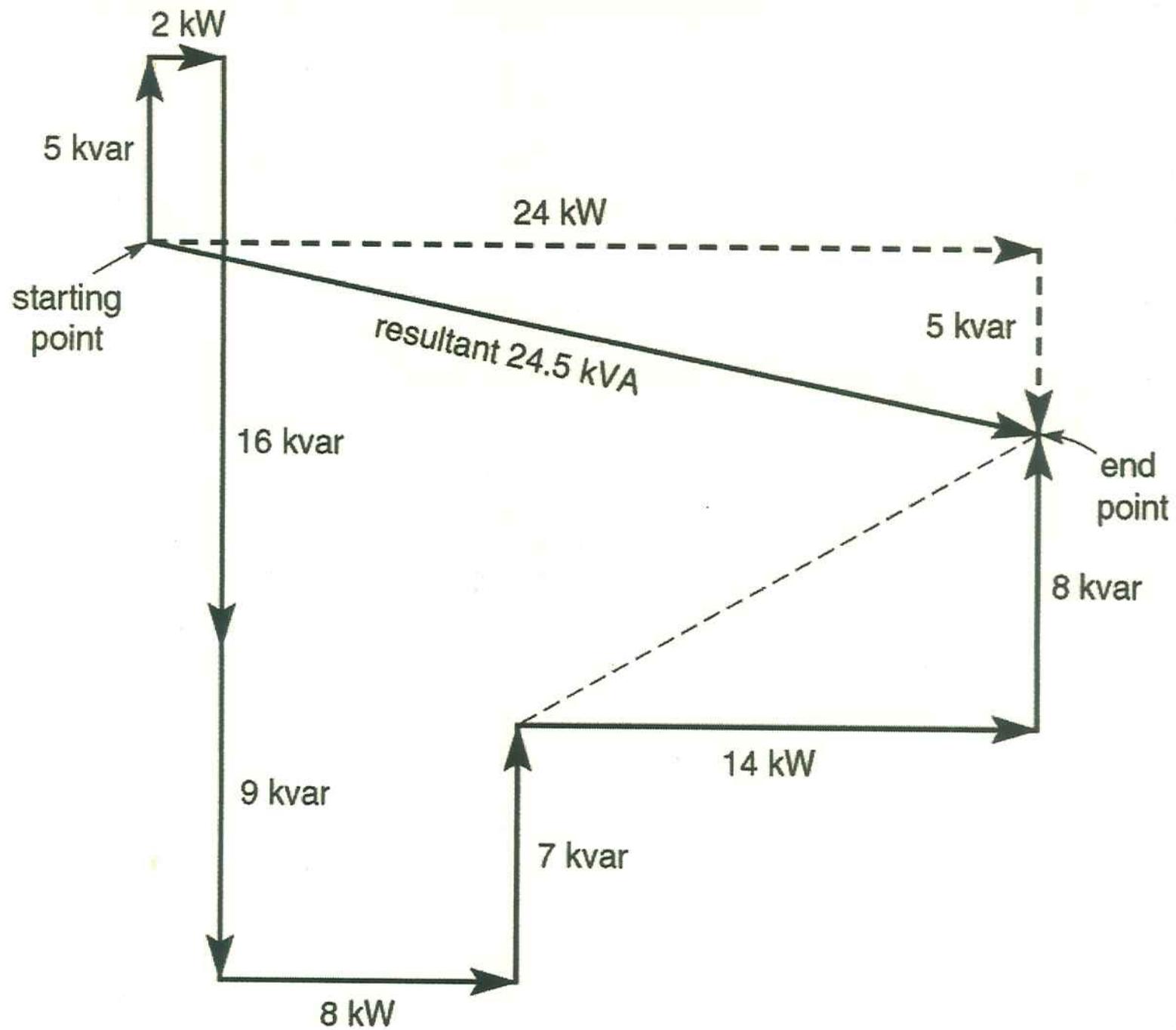
$I_{\text{Draw}}(380) = ?$

Fig 7.15
Q 147

(b)

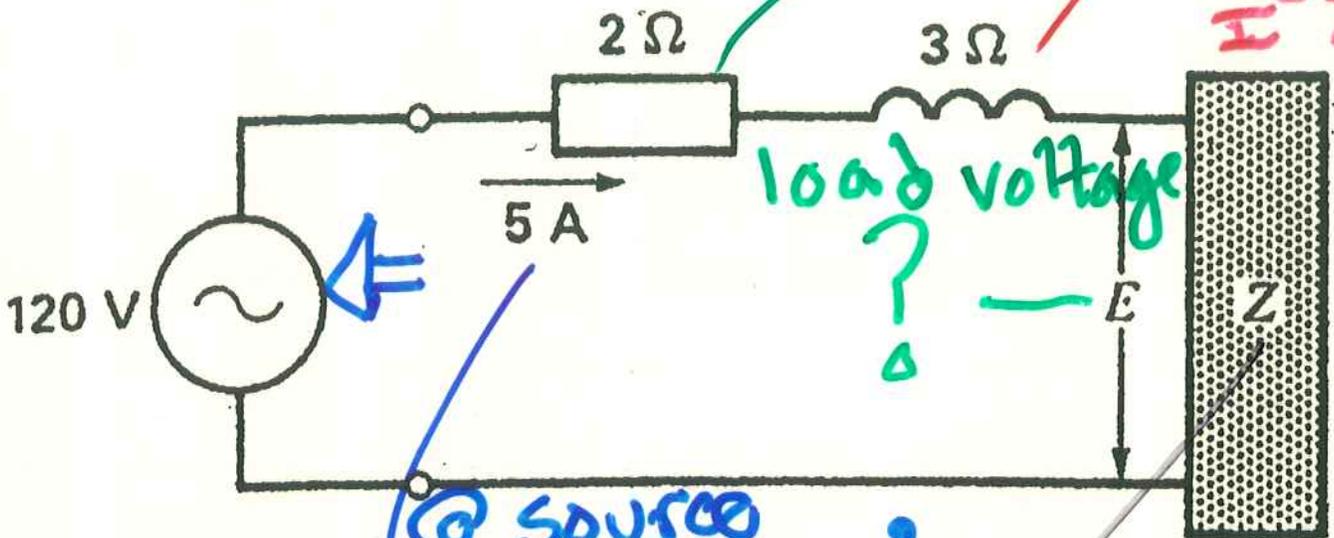


Can you ever get Q (VARS) without L or C ?
How?



Prob 7-22

Solve by $\sum_x P_x$
 $\sum_x Q_x$ $P_r = ?$ $I^2 R$



@ source
 Given/measure i
 $PF = 0.6$
 lagging

UNKNOWN?
 How to determine?

SOURCE

$S = ? \cdot \frac{120}{5}$
 $P = ? \cdot S \cdot 0.6$

$Q = ?$

$+0 \text{ or } -$
 How to determine

