 Write-ups must provide a concise description of procedures and ckt diagrams. Your lab TA must sign and date each page of your lab notebook. To the front of the report on a separate sheet of paper, staple a one-page abstract. The abstracts, one per team, should state the lab objectives, describe methods, summarize results and general conclusions. Your grade will be based in part upon the conciseness, grammar, and spelling of your writing. **Late work will not be accepted.**

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0. Laboratory preparation
Read closely Section 8-4 of the text, paying particular attention to 8-4.2 and Example 8-6.

I. Power factor of AC circuits
Consider the AC circuit shown in Fig. 1, consisting of a series L–R plus a capacitor C connected in parallel.

![Diagram of AC circuit](image)

**Figure 1.** AC circuit consisting of inductive load and shunt capacitor C.

The series L–R represents a load such as an induction motor. Without the capacitor, PF = \( \cos \phi \) (lagging), where \( \phi = -\tan^{-1}(\omega L/R) \). In terms of rms current \( I \), the real and reactive power quantities are, respectively, \( P_R = RI^2 \) and \( Q_X = +XI^2 \).

Reactive power does not contribute to the time-average power consumed by the load, but does increase the required current-carrying capacity (ampacity) of the wiring. The higher current flow ultimately increases ohmic losses in the wiring and the leads to the need for heavier wiring, which increases capital costs of the distribution system. Power engineers, striving to minimize delivery losses, can "correct" the PF by adding shunt capacitance at the load. The capacitance is chosen so that its reactive power, \( Q_B = -BV^2 \) (where \( V \) = rms voltage and \( B = \omega C \) is capacitive susceptance) tends to cancel out the reactive power to the inductor.

To achieve \( PF = 1.0 \), the requirement is \( Q_B + Q_X \approx 0 \). Power factor correction works because the current flowing through the capacitor is 180° out of phase with respect to the reactive component of the load current. Thus, the net current to
the combined network consisting of the LR load and the parallel capacitor can be reduced, as long as the capacitance is correctly sized.

II. Experimental procedure & lab questions

A. Assemble the series R-L circuit shown in Fig. 2, using \( R_L \sim 1.8 \, k\Omega \), \( L_L \sim 30 \) to 60 mH, and \( R_m \sim 100 \, \Omega \). The resistor \( R_m \) is chosen to be small compared to the load impedance, that is, \( R_m << |R_L + j\omega L_L| \). If this inequality is maintained, then the resistor can measure the load current \( i(t) = v_R(t)/R_m \) without significantly reducing the load voltage.

\[
\begin{align*}
\text{shunt capacitor is to be added in part E} \\
\end{align*}
\]

Figure 2. Laboratory setup for Lab #2.

B. Set \( v_s(t) = 2\cos(2\pi \times 10^4) \), then measure the peak value of current \( i(t) \) and the phase angle \( \phi \) between \( v_s(t) \) and \( i(t) \). What is the power factor? Is it leading or lagging?

C. Ignoring the effect of the resistor \( R_m \) on the network, calculate theoretical predicted values for \( \phi \) and the peak value of \( i(t) \) and compare to your measurements. Explain any discrepancies observed between the calculated and measured results.

D. Plot the current phasor with respect to the voltage reference.

E. Now add shunt capacitance to the network as shown. Use values for \( C \) as follows: \( C \sim 1000 \, pF, 2200 \, pF, 4700 \, pF, 0.01 \, \mu F, 0.022 \, \mu F, \) and \( 0.047 \, \mu F \). Measure \( \phi \) and the peak magnitude of the current for each capacitance value.

F. From your experimental data, calculate the power factor PF and tabulate these results, along with all experimental data from E above. Use your data to plot PF versus \( C \). What value of \( C \) has given you the minimum current \( i(t) \)?
G. Now use \( Q_B + Q_X = 0 \) to determine the value of \( C \) at which \( PF = 1.0 \). To do this, you must correctly calculate the current through the L-R load. Compare your result to the experimental results from part F.

H. Refer to Section 8-5, then answer the following questions. What is the relationship between max. power transfer and PF correction? Why is max. power transfer not a practical possibility in high-power circuits?

III. PF correction of a simulated load

Warning: In this part of the laboratory, you will be working with potentially lethal voltages and currents. Follow procedures exactly and do not touch any circuit or re-wire anything unless the Variac supply is unplugged!!

Figure 3. Alternate setups for 60 Hz power factor determination.

The lab setups use variable autotransformers (Variac®) to provide adjustable 60 Hz AC to a load consisting of a DC choke coil (basically an inductor) connected in series with wire-wound, ceramic resistors). A bank of shunt-connected capacitors may be switched into the network to adjust PF. You are to use one or the other of the two instrumentation setups shown in Fig. 3 above. One uses three separate electromechanical instruments to measure current, voltage, and power. These instruments are bulky and old, but rugged and very accurate. With this arrangement, the power factor is determined from the readings using \( PF = \frac{P}{V_{\text{rms}}I_{\text{rms}}} \). The other set-up uses an electronic power meter (Kill-A-Watt®). This instrument is cheap and easy to use but requires a minimum operational voltage of \(~100 \text{ V-rms} \) and is far less accurate partly because it cannot handle harmonics.

A. Set voltage to 80 V-rms if you use the electromechanical instrument setup or 100 V-rms for the electronic meter setup, and then characterize the series resistor/choke load by measuring current, average power, and power factor. Is \( PF \) leading or lagging? How do you know? Calculate \( Q_{\text{load}} \).
B. Use the results from part III.A to determine the net resistance $R$ and reactance $X$ of the load. Specify units for these quantities.

** TO AVOID OVERHEATING, DO NOT EXCEED SPECIFIED VOLTAGE LIMIT **

C. Maintaining the voltage fixed, record current, power, and PF for all possible values of shunt capacitance that can be switched in.

D. Construct a table containing all data from the above measurements plus all the calculated results shown below. The measured and calculated values for current, $I_{\text{meas}}$ and $I_{\text{calc}}$, should agree within measurement error.

<table>
<thead>
<tr>
<th>C(µF)</th>
<th>$V_{\text{meas}}$</th>
<th>$I_{\text{meas}}$</th>
<th>$P_{\text{meas}}$</th>
<th>$PF_{\text{meas}}^*$</th>
<th>$PF_{\text{calc}}$</th>
<th>$Q_{\text{calc}}$</th>
<th>$I_{\text{calc}}$</th>
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</table>

*... PF is not directly obtainable using the electromechanical instrument setup.

To complete the table, you will need the following equations:

$$PF_{\text{calc}} = \frac{P_{\text{meas}}}{V_{\text{meas}}I_{\text{meas}}}$$
$$Q_{\text{calc}} = \sqrt{(V_{\text{meas}}I_{\text{meas}})^2 - P_{\text{meas}}^2}$$

$$I_{\text{calc}} = \sqrt{P_{\text{meas}}^2 + (Q_{\text{load}} + Q_{c})^2} / V_{\text{meas}}$$

where $Q_{\text{load}} = Q_{\text{calc}} @ C = 0$, and $Q_{c} = -\omega CV_{\text{meas}}^2$.

Note: $\omega = 2\pi \cdot 60 \approx 377$ rad/sec.

E. In a few well-written paragraphs, answer the following. In whose interest is it, the consumer and/or the power company, to correct power factor? Explain your answer. Read the web page cited below (or find another similar one) and then discuss the circumstances where investing in PF correction equipment makes sense.