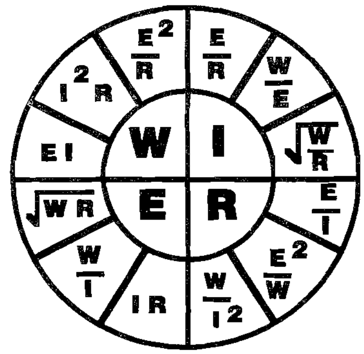
FORMULAS



POWER
746w = 1 hp output work
E x I = WATT (true power)
E x I = VOLT-AMP (apparent power)
E x I x 1.732 = 3 ø volt-amps

POWER FACTOR (PF)
PF = W/VA (watts divided by volt-amps)
Unity = 1.0

EFFICIENCY
EFF = Output/Input
INPUT = Output/Eff
OUTPUT = Input x Eff

OUTPUT is the work (hp) secondary INPUT is the primary

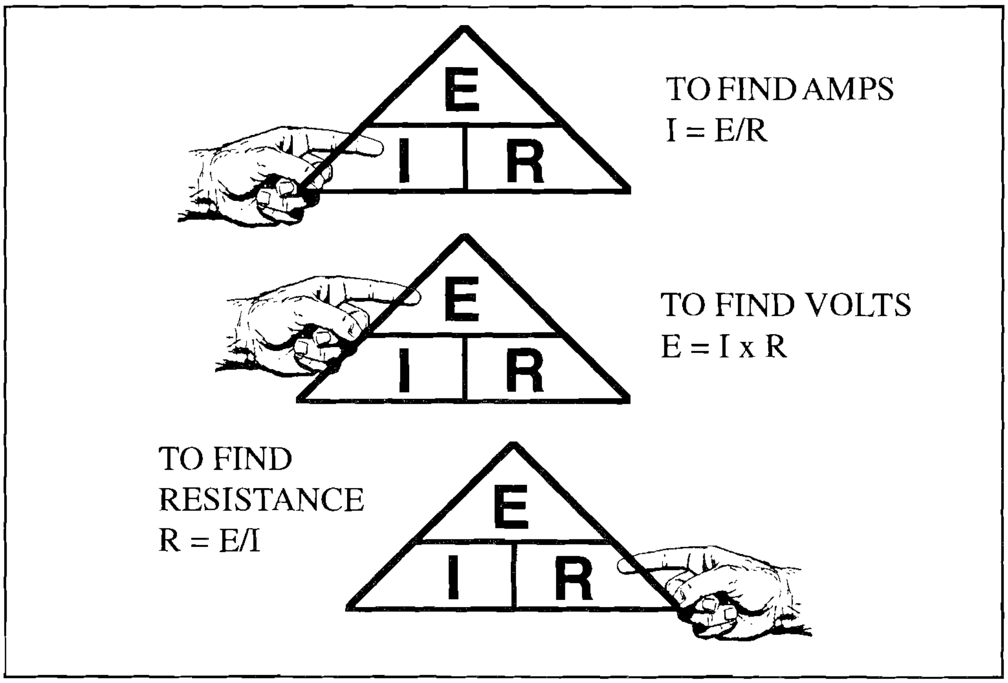
$$\$\ \text{COST}\ \$ = \frac{\text{Watts x Hours Used x Rate per Hour}}{1000}$$

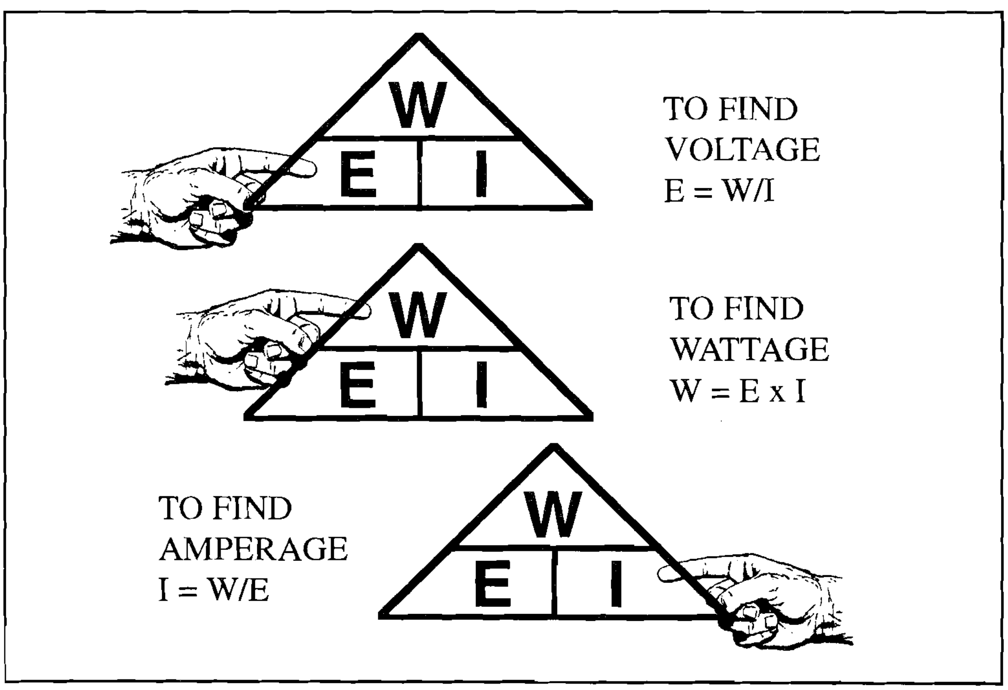
REQUIRED WIRE SIZE FOR AMBIENT TEMPERATURE
Load/Correction Factor or Load/Correction Factor x T.310-15b2a

TO FIND	DC	AC 1ø	AC 3 ø
Amperes when hp is known	$\frac{hp \times 746}{E \times Eff}$	$\frac{hp \times 746}{E \times Eff \times PF}$	$\frac{hp \times 746}{1.732 \times E \times Eff \times PF}$
Amperes when kw is known	$\frac{kw \times 1000}{E}$	$\frac{kw \times 1000}{E \times PF}$	$\frac{kw \times 1000}{1.732 \times E \times PF}$
Amperes when kva is known		$\frac{kva \times 1000}{E}$	$\frac{kva \times 1000}{E \times 1.732}$
Kilowatts	$\frac{E \times I}{1000}$	$\frac{E \times I \times PF}{1000}$	$\frac{E \times I \times PF \times 1.732}{1000}$
KVA		$\frac{E \times I}{1000}$	$\frac{E \times I \times 1.732}{1000}$
Horsepower	$\frac{E \times I \times Eff}{746}$	$\frac{E \times I \times Eff \times PF}{746}$	$\frac{E \times I \times Eff \times PF \times 1.732}{746}$

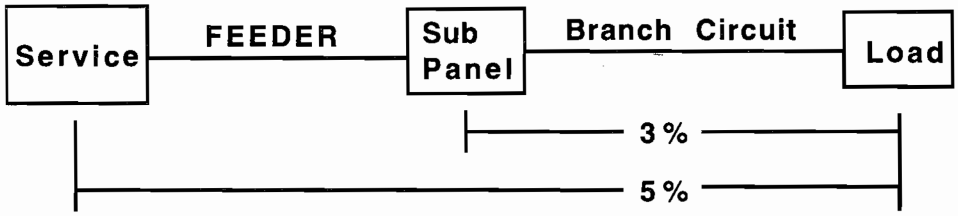
To solve an unknown you will need to know two knowns.

Put your **finger** on the one **you want to solve** and the other two knowns will show you how to solve it.





VOLTAGE DROP



POWER LOSS = VD x I

Voltage Drop.... $VD = \frac{2 \times K \times D \times I}{CM}$ (or) $VD = I \times R$

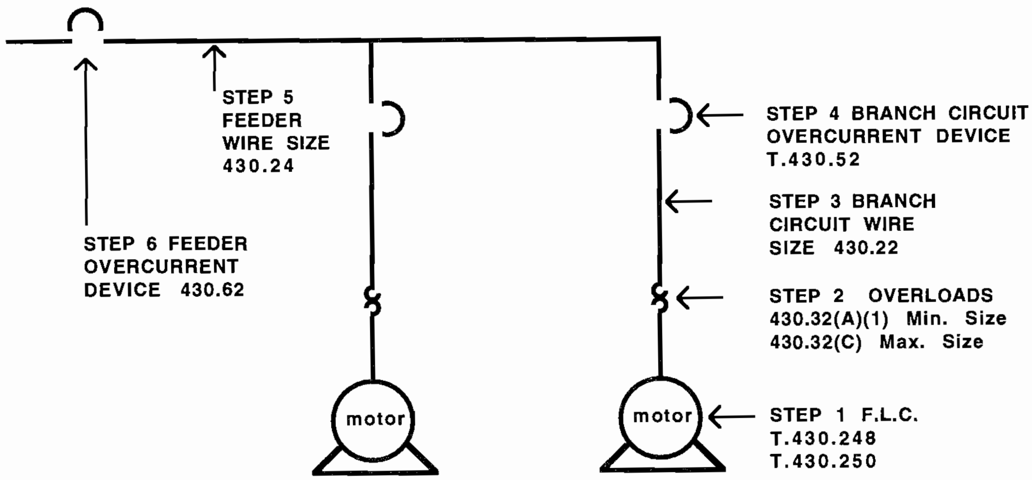
Wire Size .... $CM = \frac{2 \times Ⓚ \times D \times I}{VD\ per}$

Distance .... $D = \frac{CM \times VD\ per}{2 \times K \times I}$

Load .... $I = \frac{CM \times VD\ per}{2 \times K \times D}$

- The "2" in the formulas is for 1 ø.
- For 3 ø change the "2" to 1.732.
  "k" is the resistance of a cm foot $K = \frac{R \times CM}{1000'}$
- When using the formula to find "WIRE SIZE" use the approximate Ⓚ of 12.9 for copper and 21.2 for alum.
- "D" is the distance ONE WAY in a circuit.
- "I" is the load in amperes.
- "CM" is the wire size in circular mils, found in Table 8.
- "VD per" is the percentage of the applied voltage.
  3% VD per for a branch circuit and 5% total system.
  Example: A 120v branch circuit is permitted to drop 3% x 120v = 3.6 volts. A 240v branch circuit 3% x 240v = 7.2 volts. A 208v branch circuit 3% x 208v = 6.24 VD permitted.
  Total system: 240v x 5% = 12 volts permitted.

MOTOR FORMULA



STEP 1 F.L.C. (full load current) T.430.248 1ø - T.430.250 3 ø

STEP 2 Motor running overload protection. Thermal protector "heater"
•430.32(A)(1) MINIMUM SIZE •430.32(C) MAXIMUM SIZE
•Use motor nameplate only for heaters, if given.

STEP 3 Branch circuit wire size. 430.22 F.L.C. x 125% = Required ampacity
Table 310.16 size wire ampacity to insulation.

STEP 4 Branch circuit overcurrent protection (fuse or CB) shall be selected from Table 430.52. First select the type of motor (1ø, 3ø, AC, DC, wound rotor, code letter) next select type of protection (non-time delay, dual-element, inverse-time CB) now select the percentage from the proper column and multiply it times the F.L.C. of the motor. Use 240.6 to select the standard size the Code permits. •When the value found does not match a standard size, the Code permits the next higher standard size per 430.52 ex.1.

STEP 5 Feeder conductor size 430.24. Multiply the largest rated motor in F.L.C. by 125% and add the F.L.C. of all the other motors connected to the SAME feeder conductor for required ampacity. T.310.16.

STEP 6 Feeder overcurrent protection 430.62. Select the largest branch circuit over-current device and add all the other motor F.L.C. connected on the SAME feeder to select feeder fuse or CB. The Code does not permit going up to the next size on a feeder, must go down.

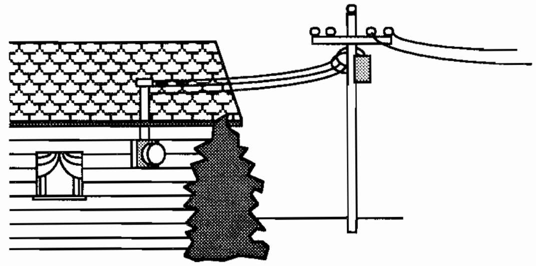
When conductors are **all the same size** (area sq. in.) you can turn to Annex C and determine the size of conduit required. There are 12 Tables so always check the heading of the Table to make sure you have selected the **correct** Table.

Table C1• Electrical Metallic Tubing (EMT)	Conductors and Fixture Wires
Table C1A Electrical Metallic Tubing (EMT)	**Compact Conductors**
Table C2• Electrical **Non**metallic Tubing (ENT)	Conductors and Fixture Wires
Table C2A Electrical **Non**metallic Tubing (ENT)	**Compact Conductors**
Table C3• Flexible Metallic Conduit (greenfield)	Conductors and Fixture Wires
Table C3A Flexible Metallic Conduit (greenfield)	**Compact Conductors**
Table C4• Intermediate Metallic Conduit (IMC)	Conductors and Fixture Wires
Table C4A Intermediate Metallic Conduit (IMC)	**Compact Conductors**
Table C5• Liquidtight Flexible **Non**metallic Conduit (Type FNMC-B**)	Conductors and Fixture Wires
Table C5A Liquidtight Flexible **Non**metallic Conduit (Type FNMC-B**)	**Compact Conductors**
Table C6• Liquidtight Flexible **Non**metallic Conduit (Type FNMC-**A****)	Conductors and Fixture Wires
Table C6A Liquidtight Flexible **Non**metallic Conduit (Type FNMC-**A****)	**Compact Conductors**
Table C7• Liquidtight Flexible Metallic Conduit	Conductors and Fixture Wires
Table C7A Liquidtight Flexible Metallic Conduit	**Compact Conductors**
Table 8• Rigid Metallic Conduit	Conductors and Fixture Wires
Table 8A Rigid Metallic Conduit	**Compact Conductors**
Table 9• Rigid PVC Conduit Schedule **80**	Conductors and Fixture Wires
Table 9A Rigid PVC Conduit Schedule **80**	**Compact Conductors**
Table 10• Rigid PVC Conduit Schedule **40** and **HDPE**	Conductors and Fixture Wires
Table 10A Rigid PVC Conduit Schedule **40** and **HDPE**	**CompactConductors**
Table 11• **Type A** Rigid PVC Conduit	Conductors and Fixture Wires
Table 11A **Type A** Rigid PVC Conduit	**Compact Conductors**
Table 12• **Type EB** PVC Conduit	Conductors and Fixture Wires
Table 12A **Type EB** PVC Conduit	**Compact Conductors**

•This table is for **concentric stranded** conductors only. Tables "A" are for compact conductors.

*Types RHH, RHW, and RHW-2 **without** outer covering.

Definition : **Compact stranding** is the result of a manufacturing process where the standard conductor is **compressed** to the extent that the interstices (voids between strand wires) are virtually eliminated.



SINGLE-PHASE TRANSFORMERS

Ep = primary voltage **Ip** = current in primary
Es = secondary voltage **Is** = current in secondary

To find **primary voltage** when the current & secondary voltage are known:

$$Ep = \frac{Es \times Is}{Ip}$$

To find **primary current** when the secondary currents are known:

$$Ip = \frac{Es \times Is}{Ep}$$

To find **secondary voltage** when the current & primary voltage are known:

$$Es = \frac{Ep \times Ip}{Is}$$

To find **secondary current** when the voltages & the primary current are known:

$$Is = \frac{Ep \times Ip}{Es}$$

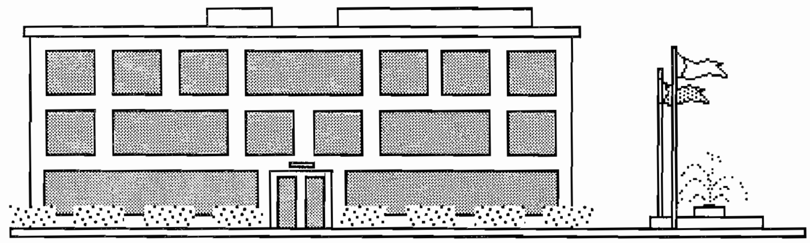
TURNS RATIO

Np = number of primary turns
Ns = number of secondary turns

$$\frac{Np}{Ns}$$

Ep = primary voltage
Es = secondary voltage

$$\frac{Ep}{Es}$$



OFFICE BUILDING

COMMERCIAL SERVICE CALCULATION

CONDUCTOR SIZING

STEP 1 - Table 220.12 °Lighting load of ____ va x total square footage.

**Feeder* conductor 125% for continuous load.

STEP 2 - T. 220.42 Demand for motel, hospital, warehouse. All others 100%.

STEP 3 - 220.60 Compare heat against A/C, omit smaller.

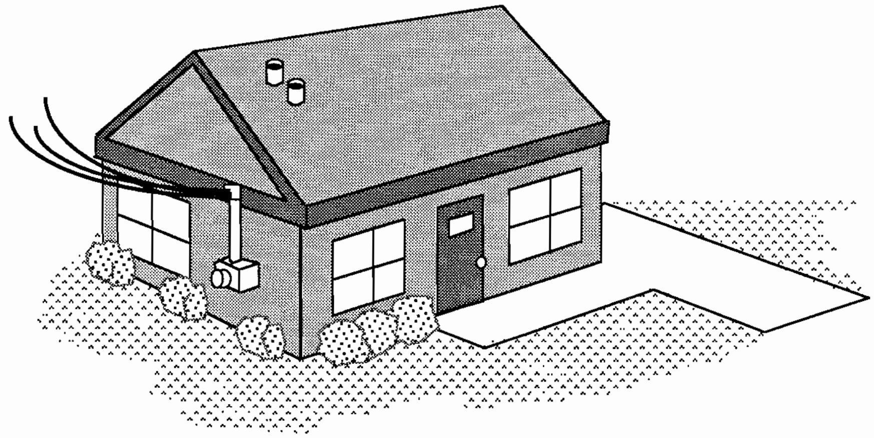
STEP 4 - 220.14(E) Heavy-duty lampholders @ 600va each.
220.14(L) Other outlets @ 180va each.
220.14(H) Multioutlet assemblies each 5' @ 180va.
220.14(G) •Show window each linear foot @ 200va.

STEP 5 - T.220.44 Demand for receptacle loads over 10kva.

STEP 6 - T. 220.56 Demand for kitchen equipment.

STEP 7 - 220.50 Largest motor is to be increased 25%.

STEP 8 - Size the service by dividing the total va by the line voltage. Table 250.66 to size grounding electrode conductor, it cannot be smaller than the neutral.



DWELLING SERVICE CALCULATION

General Method for a single dwelling unit:

STEP 1 - Table 220.12 Square footage living area x 3va.

STEP 2 - 220.52 Small appliance 2 x 1500 va.
Laundry 1500 va.

STEP 3 - T.220.42 Apply lighting demand to Steps 1 & 2.

STEP 4 - 220.60 Compare heat against A/C, omit smaller.

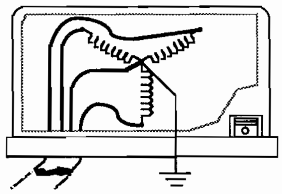
STEP 5 - 220.53 75% demand for 4 or more fixed appliances.

STEP 6 - 220.54 Dryers 5kw minimum. T.220.54 demand for 5 or more. Neutral demand 70% per 220.61.

STEP 7 - T.220.55 Demand for cooking eqipment. Neutral 70%.

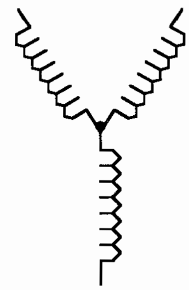
STEP 8 - 220.50 Largest motor is to be increased 25%.

STEP 9 - Size the service by dividing the total va by the line voltage and apply Table 310.15(b)(6).
Table 250.66 to size grounding electrode conductor.



3ø

WYE CONNECTED



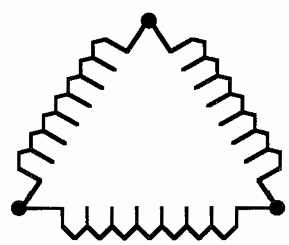
PHASE AMPS = LINE AMPS

PHASE VOLTS x 1.732 = LINE VOLTS

OR

$$\frac{\text{LINE VOLTS}}{1.732} = \text{PHASE VOLTS}$$

DELTA CONNECTED

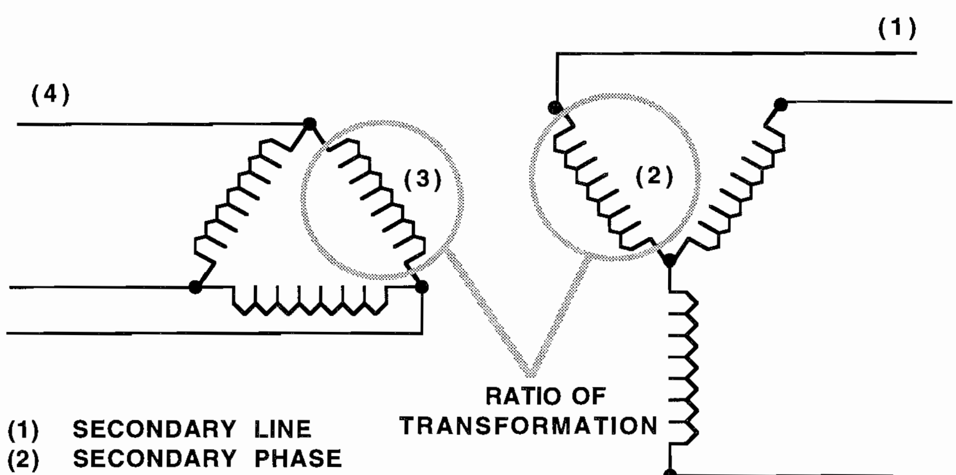


PHASE AMPS x 1.732 = LINE AMPS

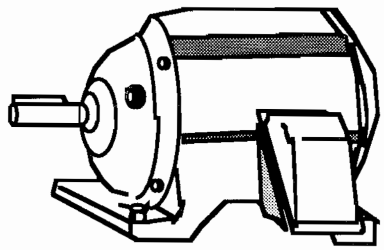
OR

$$\frac{\text{LINE AMPS}}{1.732} = \text{PHASE AMPS}$$

PHASE VOLTS = LINE VOLTS



(1) SECONDARY LINE
(2) SECONDARY PHASE
(3) PRIMARY PHASE
(4) PRIMARY LINE

3ø  F.L.C.

THREE-PHASE AC MOTOR TABLE

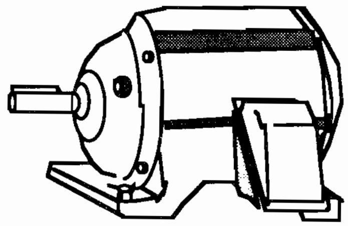
HP	115v F.L.C.	230v F.L.C.	208v F.L.C.	460v F.L.C.	115-230-460v volt-amps	208v volt-amps
1/2	4.4	2.2	2.4	1.1	876	865
3/4	6.4	3.2	3.5	1.6	1275	1261
1	8.4	4.2	4.6	2.1	1673	1657
1-1/2	12	6	6.6	3	2390	2378
2	13.6	6.8	7.5	3.4	2709	2702
3		9.6	10.6	4.8	3824	3819
5		15.2	16.7	7.6	6055	6016
7-1/2		22	24.2	11	8764	8718
10		28	30.8	14	11154	11096
15		42	46.2	21	16731	16644
20		54	59.4	27	21511	21399
25		68	74.8	34	27088	26947
30		80	88	40	31869	31703
40		104	114.4	52	41429	41213
50		130	143	65	51787	51517

Three-phase volt-amps = E x I x 1.732

Example: What is the va input for a three-phase 10 HP 208v motor?

208v x 30.8 amps x 1.732 = **11,096va**

3ø va = E x I x 1.732

1ø  F.L.C.

SINGLE-PHASE AC MOTOR TABLE

HP	115v F.L.C.	230v F.L.C.	208v F.L.C.	115-230v F.L.C.	208v volt-amps
1/6	4.4	2.2	2.4	506	499
1/4	5.8	2.9	3.2	667	666
1/3	7.2	3.6	4.0	828	832
1/2	9.8	4.9	5.4	1127	1123
3/4	13.8	6.9	7.6	1587	1581
1	16	8	8.8	1840	1830
1-1/2	20	10	11	2300	2288
2	24	12	13.2	2760	2746
3	34	17	18.7	3910	3890
5	56	28	30.8	6440	6406
7-1/2	80	40	44	9200	9152
10	100	50	55	11500	11440

Single-phase volt-amps = E x I

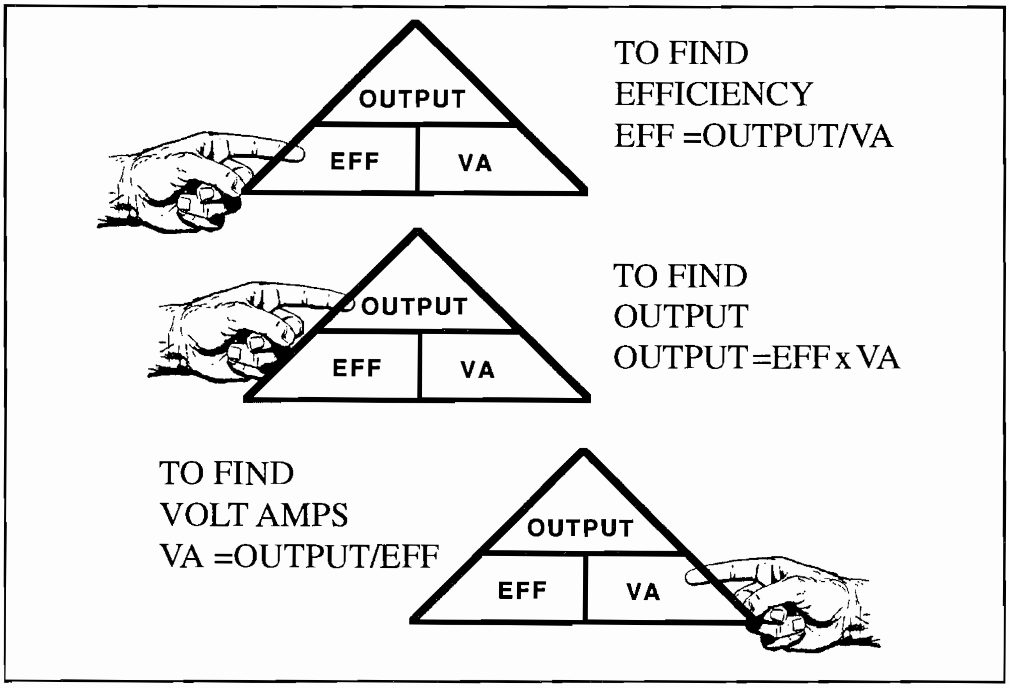
Example: What is the va input for a single-phase 5 HP 208v motor?

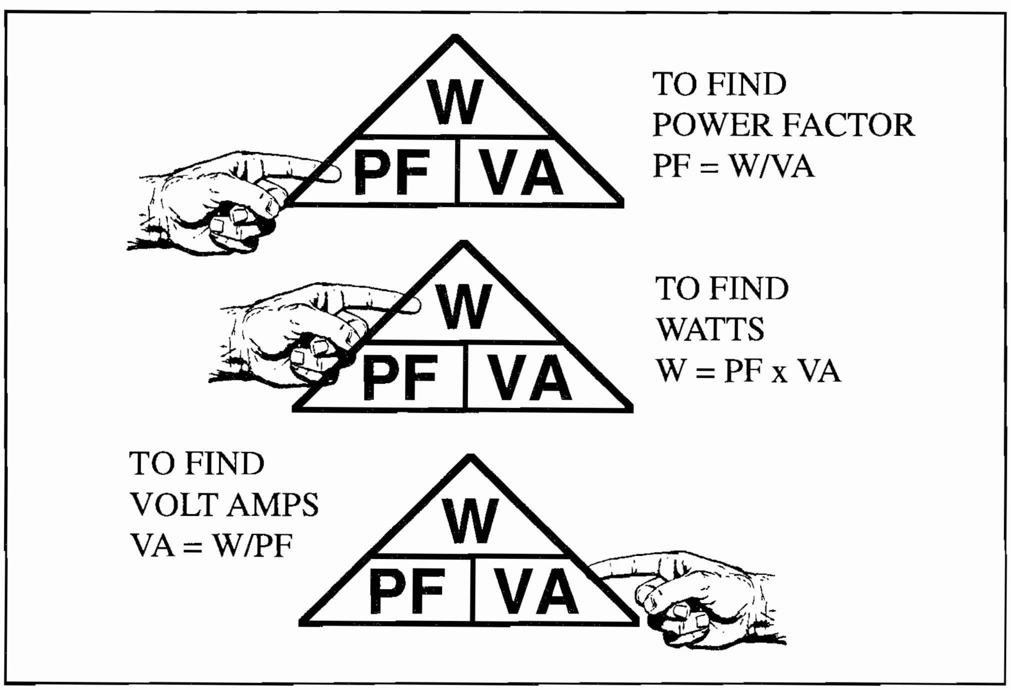
208v x 30.8 amps = **6406va**

EXACT K @ 75°C

DESIGNED BY TOM HENRY
CODE ELECTRICAL CLASSES

AWG	Area Circular Mils	Copper Un-coated Resistance	Copper Un-coated EXACT K	Copper Coated Resistance	Copper Coated EXACT K	Aluminum Resistance	Aluminum EXACT K
#14 SOLID	4110	3.07	12.6177	3.19	13.1109	5.06	20.7966
#14 STRANDED	4110	3.14	12.9054	3.26	13.3986	5.17	21.2487
#12 SOLID	6530	1.93	12.6029	2.01	13.1253	3.18	20.7654
#12 STRANDED	6530	1.98	12.9294	2.05	13.3865	3.25	21.2225
#10 SOLID	10 380	1.21	12.5598	1.26	13.078	2.00	20.76
#10 STRANDED	10 380	1.24	12.8712	1.29	13.3902	2.04	21.1752
#8 SOLID	16 510	0.764	12.61364	0.786	12.97686	1.26	20.8026
#8 STRANDED	16 510	0.778	12.84478	0.809	13.35659	1.28	21.1328
#6	26 240	0.491	12.88384	0.510	13.3824	0.808	21.20192
#4	41 740	0.308	12.85592	0.321	13.39854	0.508	21.20392
#3	52 620	0.245	12.8919	0.254	13.36548	0.403	21.20586
#2	66 360	0.194	12.87384	0.201	13.33836	0.319	21.16884
#1	83 690	0.154	12.88826	0.160	13.3904	0.253	21.17357
#1/0	105 600	0.122	12.8832	0.127	13.4112	0.201	21.2256
#2/0	133 100	0.0967	12.87077	0.101	13.443	0.159	21.1629
#3/0	167 800	0.0766	12.85348	0.0797	13.37366	0.126	21.1428
#4/0	211 600	0.0608	12.86528	0.0626	13.24616	0.100	21.16
250 kcmil	250 000	0.0515	12.875	0.0535	13.375	0.0847	21.175
500 kcmil	500 000	0.0258	12.9	0.0265	13.25	0.0424	21.2
1000 kcmil	1 000 000	0.0129	12.9	0.0132	13.2	0.0212	21.2


OUTPUT
EFF
VA
TO FIND
EFFICIENCY
EFF =OUTPUT/VA
OUTPUT
EFF
VA
TO FIND
OUTPUT
OUTPUT =EFF x VA
TO FIND
VOLT AMPS
VA =OUTPUT/EFF
OUTPUT
EFF
VA


W
PF
VA
TO FIND
POWER FACTOR
PF = W/VA
W
PF
VA
TO FIND
WATTS
W = PF x VA
TO FIND
VOLT AMPS
VA = W/PF
W
PF
VA

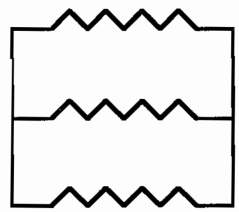
RESISTANCE

NEC Table 8 and 9 Ohms per 1000 feet

SERIES (add together)
R1 + R2 + R3 ....etc. 

PARALLEL (equal)

$$\frac{\text{Resistance of One}}{\text{Number of Resistances}}$$



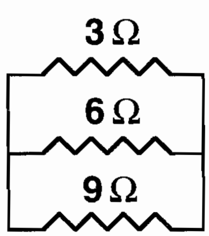
PARALLEL (unequal)

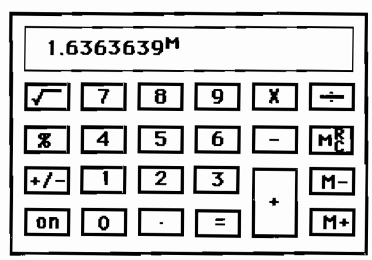
$$\frac{R1 \times R2}{R1 + R2}$$ (OR)

1/RT = 1/R1 + 1/R2 + ...etc. (OR)

CALCULATOR FORMAT
•SHOWN BELOW

UNEQUAL PARALLEL





Press [1] Press [÷] Press [3] Press [M+]

Press [1] Press [÷] Press [6] Press [M+]

Press [1] Press [÷] Press [9] Press [M+]

Press [1] Press [÷] Press [MRC] Press [=]

The total resistance is 1.63Ω