CONTENT

This is probably the most misused table in the Code book as the ampacities listed in Table 310.16 are generally **never** correct. This is a very important table that you must learn to use correctly.

Table 310.16. Allowable Ampacities of Insulated Conductors
Rated 0-2000 Volts, 60°to 90°C (140°to 194°F)
Not More Than Three Conductors in Raceway or Cable or Earth
(Directly Buried), Based on Ambient Temperature of 30°C (86°F)*.

Size	Temperature Rating of Conductor. See Table 310.4(A).						Size
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
AWG kcmil	TYPES TW, UF	RHW, THHW, THW, THWN, XHHW, XHHWN, USE, ZW	TYPES TBS,SA, SIS, FEP, FEPB, MI, PFA RHH, RHW-2, THHN, THHW, THW-2, THWN-2 USE-2, XHH XHHW, XHHW-2 Z ZW-2	TYPES TW, UF	RHW, THHW, THW, THWN, XHHW, USE	TYPES TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHHN	**AWG kcmil**
	COPPER			**ALUMINUM OR COPPER-CLAD ALUMINUM**			
18**	....	....	14	....	....	....	....
16**	....	....	18	....	....	....	....
14**	15	20	25	....	....	....	....
12**	20	25	30	15	20	25	12**
10**	30	35	40	25	30	35	10**
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	445	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	555	665	750	470	560	630	2000

***Table 310.15(B)(1) CORRECTION FACTORS based on 30°C (86°F)**

Ambient Temp. °C	**For ambient temperatures other than 30°C (86°F), multiply the ampacities shown above by the appropritate factor shown below.**						**Ambient Temp. °F**
10 or less	1.29	1.20	1.15	1.29	1.20	1.15	50 or less
11-15	1.22	1.15	1.12	1.22	1.15	1.12	51-59
16-20	1.15	1.11	1.08	1.15	1.11	1.08	60-68
21-25	1.08	1.05	1.04	1.08	1.05	1.04	69-77
26-30	1.00	1.00	1.00	1.00	1.00	1.00	78-86
31-35	.91	.94	.96	.91	.94	.96	87-95
36-40	.82	.88	.91	.82	.88	.91	96-104
41-45	.71	.82	.87	.71	.82	.87	105-113
46-50	.58	.75	.82	.58	.75	.82	114-122
51-55	.41	.67	.76	.41	.67	.76	123-131
56-60	—	.58	.71	—	.58	.71	132-140
61-65	—	.47	.65	—	.47	.65	141-149
66-70	—	.33	.58	—	.33	.58	150-158
71-75	—	—	.50	—	—	.50	159-167
76-80	—	—	.41.	—	—	.41.	168-176
81-85	—	—	29	—	—	29	177-185

* Refer to 310.15(B)(1) for the amapacity correction factors where the ambient temperature is other than 30°C (86°F). Refer to 310.15(C)(1)(a) for more than three current carrying conductors.
** See Section 240.4(D)

The reason for the misuse of the table comes from not reading the heading which states the ampacities shown for the various conductors are correct if you don't: (1) install over three current carrying conductors in a raceway or cable (2) exceed 30°C or 86°F in ambient temperature.

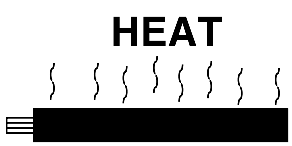
(1)

Table 310.16. Ampacities of Insulated Conductors Rated 0-2000 Volts,
60° to 90°C (140° to 194°F) **Not more Than Three Conductors in Raceway or Cable or Earth** (Directly Buried),
Based on Ambient Air Temperature of 30°C (86°F).

(2)

Common sense would remind you that normally you are installing more than three conductors in a conduit and also the surrounding temperature of these conductors would be above 86°F. The **normal** ampacities listed in the table must be corrected if either condition (1) or (2) is present.

The conductor ampacity is the current carried **continuously** without increasing the temperature of its insulation beyond the danger point. The conductor ampacity varies with the type of insulation and the method of installation.



Except for mechanical abuse, the greatest hazard that conductors must endure is **heat**. Conductor insulation can be damaged by excessive heat in various ways, depending on the type of insulation and the degree of overheating. Continued exposure to excessive heat causes insulation to become soft, perhaps to melt, and in extreme cases to burn.

This heat comes from two sources: From the ambient air surrounding the conductors or from the current the conductors must carry. There is a point where an increase in current causes excessive heat even though conducting materials such as copper or aluminum have a low resistivity.

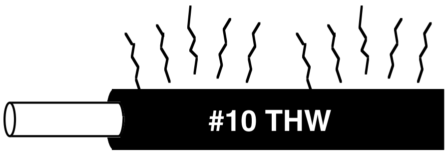
For many years natural rubber was used to insulate conductors, but age along with heat caused such rubber insulation to dry out, to crack, and to become brittle. Today we have better quality rubber and thermoplastic materials that not only permit thinner insulation on conductors but also withstand temperature better resulting in higher ampacities of conductors.

The maximum temperature permitted for conductor insulation is called the **temperature rating** of the conductor. **Table 310.4(A)** shows the **maximum** temperature that the insulation type is permitted to reach. That maximum temperature will be reached when a conductor is loaded to its full ampacity in an ambient temperature of 30 degrees C or 86 degrees F.

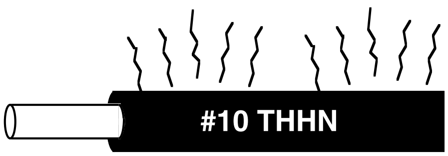
The type letter on the insulation indicates its insulation, maximum operating temperature, and application provisions.

RHW insulation, the "R" indicates rubber insulation. The "H" indicates 75°C - 167°F maximum operating temperature (insulation rating). The "W" indicates moisture resistant.

THHN insulation, the "T" indicates thermoplastic insulation. The "HH" indicates 90°C - 194°F maximum operating temperature (insulation rating). The "N" indicates nylon covering.



The #10 THW has a maximum operating temperature of 75°C which is 167°F.



The #10 THHN has a maximum operating temperature of 90°C which is 194°F. An "HH" rated insulation will allow more heat to be dissipated faster than an "H" rated insulation thus raising the ampacity (the current the conductor can carry safely without damage).

The maximum operating temperature is the insulation rating of the conductor and must not be exceeded. Proper designing is a very important factor.

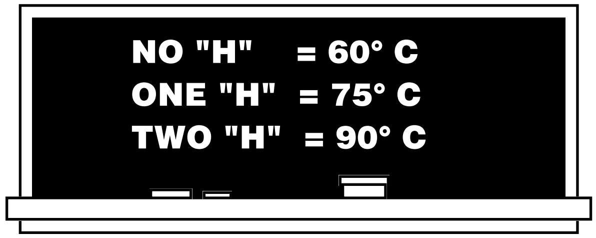
You must first understand what words mean; such as ampacity, ambient temperature, insulation rating, etc.

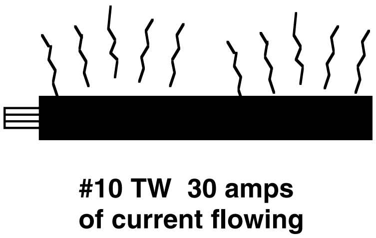
#10 TW 30 ampacity
60°C - 140°F temperature rating

A #10 TW conductor has an ampacity of 30 amperes. The insulation rating is 60°C or 140°F.
This does *not* mean that a TW insulation can be installed where the ambient temperature reaches 140°F.

What this means is: If a #10 TW conductor is loaded to the allowable ampacity, 30 amperes in an ambient that has a temperature of 30°C or 86°F, the temperature of the *insulation* will reach 60°C or 140°F.

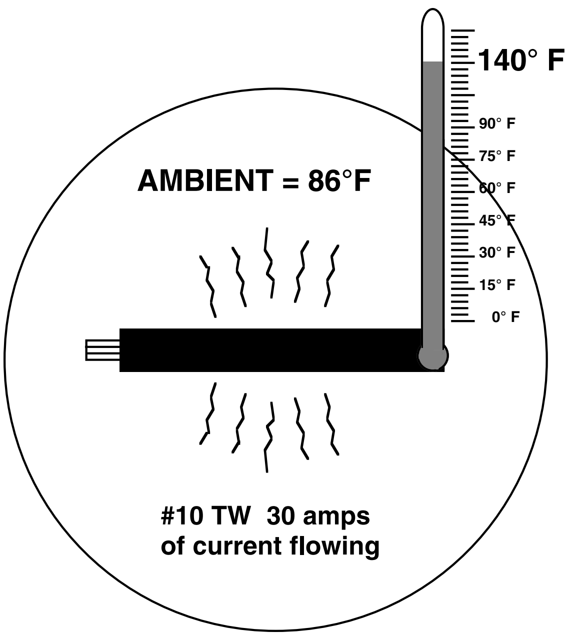
Table 310.16 the table of ampacity is aimed at designating a level of current that will permit the conductor to reach its thermal limit, but not exceed it.





The 30 amps of current flowing produces heat in the conductor which must dissipate through the insulation to the ambient.

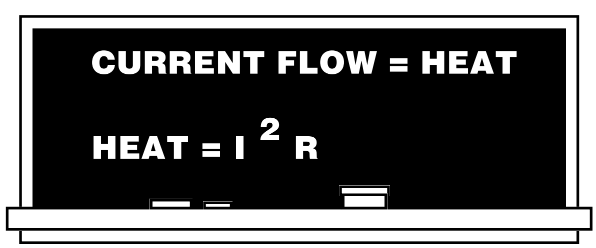
With the ambient temperature at 86°F and with 30 amperes of current flowing through the conductor, a thermometer placed on the *insulation* would read 140°F which is maximum operating temperature for this type insulation (TW).



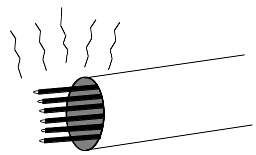
For a #10 TW conductor, any current above 30 amps or any ambient temperature above 86°F will cause insulation damage, as you will exceed the maximum operating temperature of the conductor; 140°F.

Maximum operating temperature = Full ampacity at 86°F.

140°F - 86°F = 54°F for the 30 amperes of current flow in the #10 TW conductor.



ADJUSTMENT FACTORS



When there are more than three current-carrying conductors in a raceway or cable, the ampacity of each conductor must be reduced as indicated in Table 310.15(C)(1) to compensate for heating effects and reduced heat dissipation due to reduced ventilation of individual conductors.

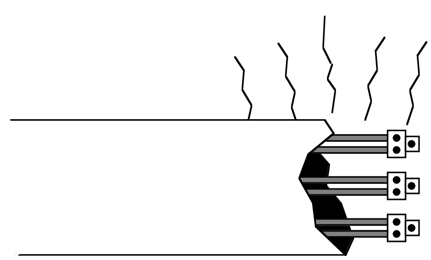
Table 310.15(B)(3)(a). Adjustment Factors.

(a) More than Three Current Carrying Conductors in a Raceway or Cable. Where the number of conductors in a raceway or cable exceeds three, the ampacities shall be reduced as shown in the following table:

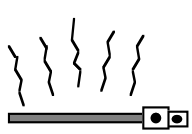
Number of Conductors	Percent of Values in Tables 310.16 through Table 310.19 as Adjusted for Ambient Temperature if Necessary
4 through 6	80
7 through 9	70
10 through 20	50
21 through 30	45
31 through 40	40
41 and above	35

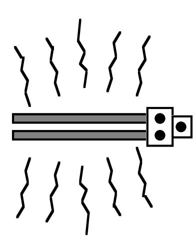
Example: A conduit contains six #8 TW current carrying conductors. The normal ampacity is 40 amps x 80% from Table 310.15(B)(3)(a) = 32. The maximum current that can be passed through the #8 TW conductor without subjecting it to insulation damage is 32 amps.

Adjustment factors also apply when paralleling conductors per Section 310.10(H)(4).

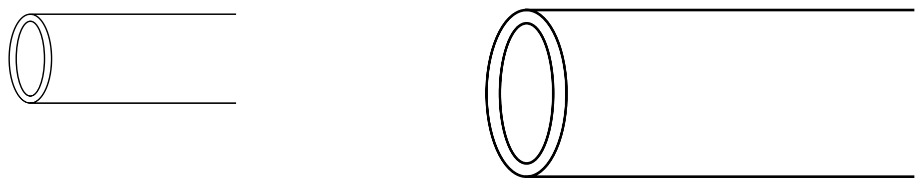


It is wrong to think since you connected two conductors in parallel on one lug that you now only have one conductor. Heat is measured by $W = I^2R$. In parallel you have **two** conductors carrying current producing heat.

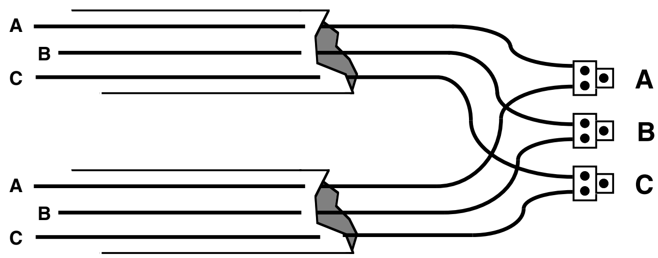




It is wrong to think that by using a larger size conduit than required would satisfy the adjustment factor required for the reduction of ampacity. The larger conduit would have more volume area, but it's like heating a rock, it may take a little longer but it will still reach the same temperature.



To avoid applying the adjustment factors of 310.15(C)(1) you can install two separate conduits as shown below. Now you only have 3 current carrying conductors in each conduit.



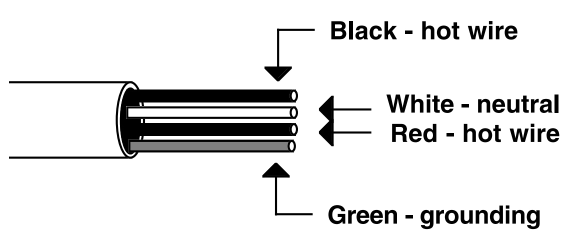
*Some conductors are **not** counted when applying 310.15(C)(1):*

310.15(C)(1)	Conductors of different systems
310.15(C)(2)	Cable trays
310.15(C)(1)(b)	Nipples
310.15(C)(1)(c)	Outdoor trench
310.15(E)(1)	The neutral conductor in a normally balanced circuit is **not** counted

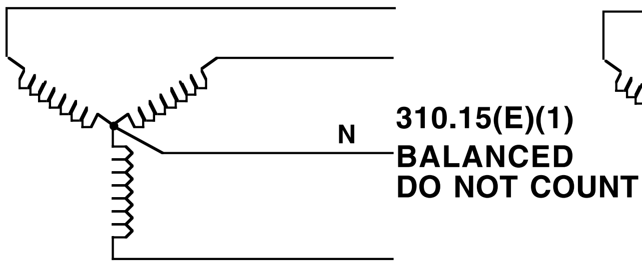
But, 310.15(E)(2) states: The neutral conductor is **counted** in a 3-wire circuit consisting of 2-phase wires of a 3-phase wye system.

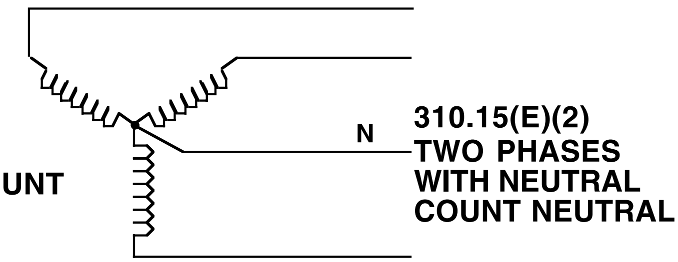
310.15(E)(3) states: The neutral is considered a **current carrying** conductor in nonlinear loads. Circuits such as discharge lighting (fluorescent, mercury, sodium) data processing, or similar equipment. The Harmonic currents in the nonlinear loads can cause the neutral currents to rise a little higher than the line current.

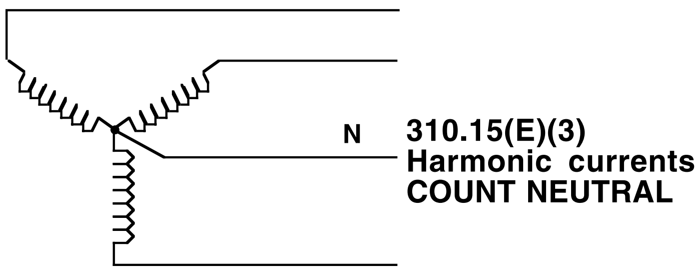
310.15(F) states: A grounding or bonding conductor shall **not** be counted when applying the provisions of Table 310.15(C)(1) The grounding conductor (green or bare wire) only carries fault current to trip the overcurrent device. This is **not** a heat factor.



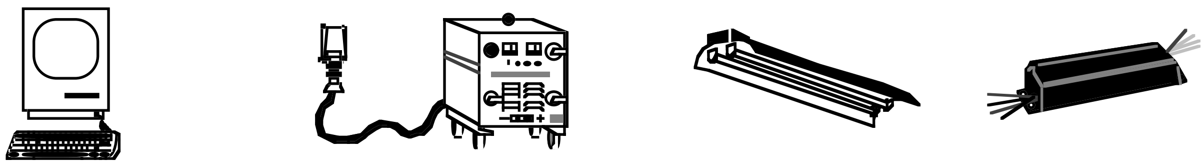
Summary of 310.15(C)(1) on when to count the neutral as current carrying:







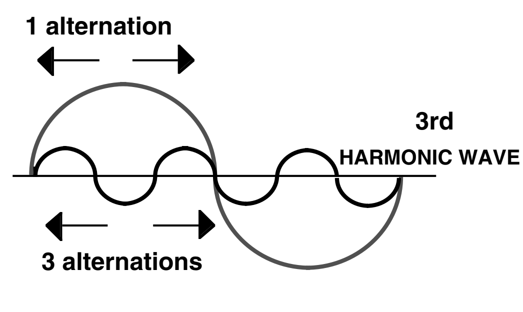
Non-linear loads which contain harmonic currents



When a linear load is turned on, the voltage and current start and turn off together. When a non-linear load is turned on, the voltage starts but the current is purposely delayed.

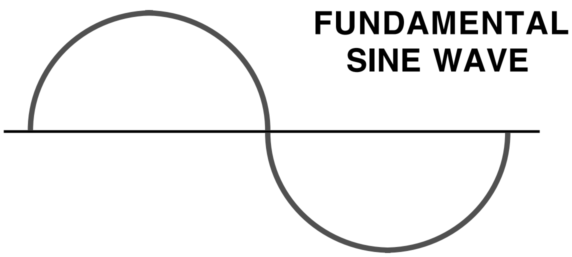
Harmonic simply indicates that the current waveform is distorted. The closer the waveform is to a fundamental sine wave, the lower the harmonic content. With a fundamental sine wave, there are no high order harmonics.

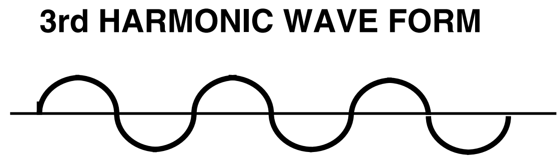
A 3rd harmonic makes 3 alternations in one alternation of the fundamental wave form. A 5th harmonic makes 5 alternations in one alternation of the fundamental wave. The 7th harmonic makes 7 alternations, and so on.



The highest peak of the wave is determined by **adding** all of the odd harmonics together. The frequency is determined by the number of complete cycles per second, measured in Hertz. 60 cycles per second equals 60 Hertz, or 60 Hz.

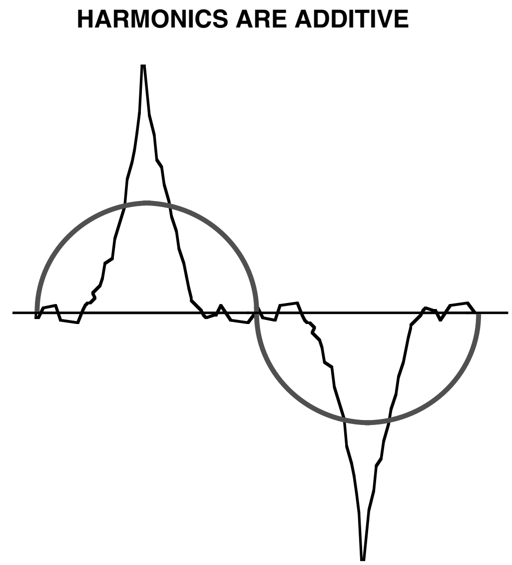
On a 60 Hz AC system, the 3rd harmonic is 180 Hz, the 5th harmonic is 300 Hz, the 7th harmonic is 420 Hz, etc.





A **harmonic wave** is a **distorted wave** pattern consisting of the fundamental wave and other **higher frequency waves** that are superimposed on the fundamental wave.

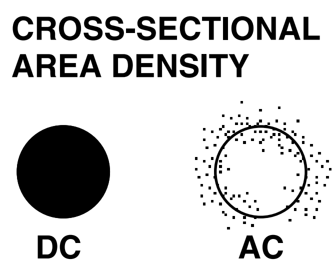
The harmonic currents are delayed then **added** together and then burst into action causing a high peak wave form and a higher frequency.



Heat is increased by an increase in current frequency. The heating effect on transformers, circuit breakers and conductors supplying **non-linear** loads is a function of **I^2R**.

The higher I^2R heating where harmonic currents are supplied is caused by what is known as **skin effect**. Skin effect is an increase in resistance due to the fact that **higher-frequency** currents flow on the **skin** of the conductor, rather than throughout the entire conductor.

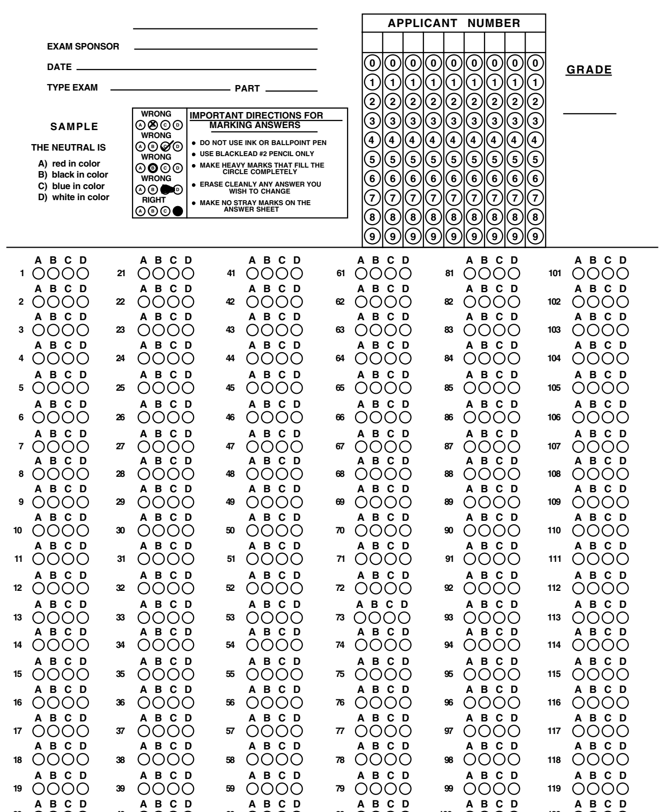
AC tends to flow along the surface of a conductor. DC acts through the entire cross-sectional area of the conductor in a uniform manner. The name skin effect is given to the action whereby AC is forced toward the surface of the conductor. Because of skin effect, there is less useful copper conductive area with AC. As a result, there is an increase in resistance.



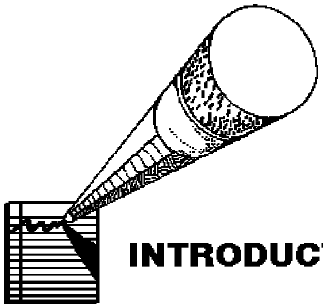
For the 3rd harmonic, instead of 60 Hz, it's now 180 Hz, there is a 42% change in the skin effect concentration point. For the 5th harmonic, there is a 55% difference and a 62% difference for the 7th harmonic. The result is a proportionate increase of resistance.

CHAPTER 8

EXAMS


EXAM SPONSOR
DATE
TYPE EXAM PART
APPLICANT NUMBER
GRADE
SAMPLE
THE NEUTRAL IS
A) red in color
B) black in color
C) blue in color
D) white in color
WRONG
WRONG
WRONG
WRONG
RIGHT
IMPORTANT DIRECTIONS FOR MARKING ANSWERS
• DO NOT USE INK OR BALLPOINT PEN
• USE BLACKLEAD #2 PENCIL ONLY
• MAKE HEAVY MARKS THAT FILL THE CIRCLE COMPLETELY
• ERASE CLEANLY ANY ANSWER YOU WISH TO CHANGE
• MAKE NO STRAY MARKS ON THE ANSWER SHEET

1 A B C D	21 A B C D	41 A B C D	61 A B C D	81 A B C D	101 A B C D
2 A B C D	22 A B C D	42 A B C D	62 A B C D	82 A B C D	102 A B C D
3 A B C D	23 A B C D	43 A B C D	63 A B C D	83 A B C D	103 A B C D
4 A B C D	24 A B C D	44 A B C D	64 A B C D	84 A B C D	104 A B C D
5 A B C D	25 A B C D	45 A B C D	65 A B C D	85 A B C D	105 A B C D
6 A B C D	26 A B C D	46 A B C D	66 A B C D	86 A B C D	106 A B C D
7 A B C D	27 A B C D	47 A B C D	67 A B C D	87 A B C D	107 A B C D
8 A B C D	28 A B C D	48 A B C D	68 A B C D	88 A B C D	108 A B C D
9 A B C D	29 A B C D	49 A B C D	69 A B C D	89 A B C D	109 A B C D
10 A B C D	30 A B C D	50 A B C D	70 A B C D	90 A B C D	110 A B C D
11 A B C D	31 A B C D	51 A B C D	71 A B C D	91 A B C D	111 A B C D
12 A B C D	32 A B C D	52 A B C D	72 A B C D	92 A B C D	112 A B C D
13 A B C D	33 A B C D	53 A B C D	73 A B C D	93 A B C D	113 A B C D
14 A B C D	34 A B C D	54 A B C D	74 A B C D	94 A B C D	114 A B C D
15 A B C D	35 A B C D	55 A B C D	75 A B C D	95 A B C D	115 A B C D
16 A B C D	36 A B C D	56 A B C D	76 A B C D	96 A B C D	116 A B C D
17 A B C D	37 A B C D	57 A B C D	77 A B C D	97 A B C D	117 A B C D
18 A B C D	38 A B C D	58 A B C D	78 A B C D	98 A B C D	118 A B C D
19 A B C D	39 A B C D	59 A B C D	79 A B C D	99 A B C D	119 A B C D
20 A B C D	40 A B C D	60 A B C D	80 A B C D	100 A B C D	120 A B C D



INTRODUCTION

Chapter 8 is a series of full calculation exams. The first exams are for the Journeyman Electrician level, the remaining exams are for the Master Electrician level.

Each exam contains 30 open book calculation questions with a time limit of three hours.

After completing each exam, turn to the answer sheets in the back of this book and grade yourself. 75% is passing.

To calculate your grade, simply **divide** the number of **correct** answers by the total number of questions (30). Example: 23 correct answers divided by 30 questions would equal 76.66%.

Don't forget Tom Henry has 12 *VIDEOS* that cover all the chapters in this book and more!