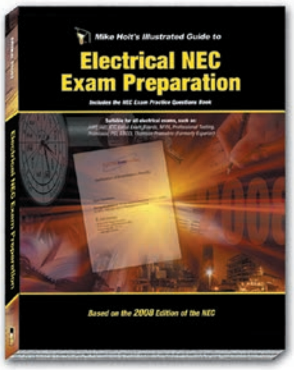
Mike Holt's Illustrated Guide to Electrical NEC Exam Preparation 2008



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Click on the corrections listed below to go to the corrected page. Click anywhere on that page to return to this page

Textbook

Page #	Reference	Correction
16	Section 1.25	In the example, the words "in a 240V circuit" were inserted for clarity.
27	Question 10	In the last sentence of the problem, the word "ohms" should be "watts." It should read: Tip: at 120V, the load consumes more than 500 watts, but the resistance of the load remains constant
124	Figure 5-8	The superscript "2" was removed from the Internal Diameter dimension of the 2 in. EMT raceway, the correct diameter is 2.067 in.
126	Table 5, Ex. 2	In the question 1/0 should be 4/0.
129	Ex. 2 on page	Wireway Allowable Conductor Fill Area: Answer and answer choices were changed. Click here to see updated example text.
129	Ex. 4 on page	Wireway Conductor Fill: Answer changed to (b) 6 in. x 6 in. The math of the solution was changed. Click here to see updated example text.
140	Ex. 2 on page	Horizontal Dimension: Answer choice (a) was changed to 20 in. Answer was changed to (a) 20 in.
152	Section 6.4	In the Author's Comment, change "has a 90C ampacity of 50A" to "has a 90C ampacity of 55A."
165	Examples 1-4	Change "ampacity of 500kcmil, which is rated 380A at 75C [Table 310.16]." to "ampacity of the 400A overcurrent device [Table 310.16]."
175	Figure 6-47	The conductor insulation was changed from THHN to THWN-2.
175	310.15	In the left column, first Author's Comment, change "THHN" to "THHN/THWN."
196	Section 7.4	Motor Branch Circuit Conductors example: In the solution, change 30A to 35A so it reads: *10 AWG rated 35A at 75ºC* .
204	Example 1	Branch Circuit Summary Example 1: Choice (c) should read **10** AWG, 70A breaker instead of **8** AWG, 70A breaker.
220	Example	In the Conductor Resistance Copper example, there is a decimal point error that needs to be fixed in answer (d). It should read 0.098 ohms not 0.98 ohms.
228	Example	Example on Size Conductor-Three Phase: The following should be noted for clarification: Section 430.22(A) requires that the motor conductors be sized not less than 125 percent of the motor FLCs as listed in Table 430.248. The motor FLC is 18A so the conductor must be sized at: 18A x 1.25 = 22.50A. This would require a 12 AWG conductor, even though a 14 AWG conductor would meet the minimum requirement for voltage drop. 12 AWG is rated for 25A at 75ºC according to 110.14(C) and Table 310.16. *[Note: there is no corresponding corrected page on the website for this update.]*

Click here for Answer Key corrections.

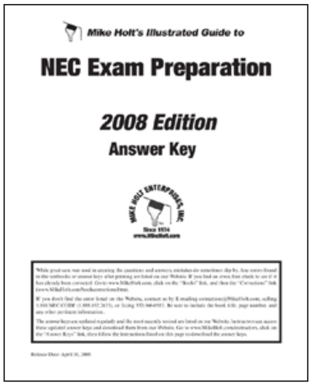
Continued on next page

Mike Holt's Illustrated Guide to Electrical NEC Exam Preparation 2008 (continued)

Click on the corrections listed below to go to the corrected page. Click anywhere on that page to return to this page

Page #	Reference	Correction
230	Example	Maximum Load—Three-Phase Note: It should be "155.80A" not "180A."
238	Question 41	The "/26A" in the term "52/26A" should be deleted and read "52A".
238	Question 42	The "115/" in the term "115/230" should be deleted, a "V" added so it reads "230V".
301		Parallel Service Conductor Sizing Example 4: heating load was incorrectly multiplied times 12 units instead of 20 units, changing the heating load to 100,000VA and the service size to 1,600A, requiring 4 parallel 600 kcmil service conductors.
318	Figure 11-18	The amount of the kW of Electric Heat was changed from 10 kW to 15 kW.
320	Example	In the Service Neutral Conductor Size Example, the answer should be (a) 1/0 AWG.
353	Example 2	In the Secondary Conductor Sizing Example 2, change the answer (c) to 350 kcmil in both places.
354	Example 2	In the Secondary Conductor Sizing Example 2 continued from page 353, in Step 3, change 300 kcmil to 350 kcmil.
354	Example 3	In the Secondary Conductor Sizing Example 3, in Step 2, change "125% of the primary current rating" to "125% of the secondary current rating."
372	Question 43	Answer choice (d) should be: (d) b and c
379	Question 16	Answer choice (d) should be: (d) cubic inches.
402	Question 61	The word "neutral" should be removed and replaced with a blank line for the answer selection.
426	Question 16	The words "nonmetallic surface" should be "nonmetallic raceways."
430	Question 67	Answer choice (d) should be: (d) high impedance.
442	Question 50	The term "a/c" should be "air-conditioning."
442	Question 51	The term "a/c" should be "air-conditioning."
442	Question 52	The term "a/c" should be "air-conditioning."
451	Question 45	The word "stings" should be "fittings."
475	Question 25	Replaced the blank space in this question with the word "plastic" as it is a True-False Question
488	Question 22	The word "stings" should be "fittings."
536	Question 21	The word "stings" should be "fittings."

Click here for Answer Key corrections.



Last Correction Update: May 4, 2012

Page #	Reference	Correction
3	Answer 16	In "42 = 4 x 4 = 16" the 2 in 42 should be superscript: $4^2 = 4 \times 4 = 16$
3	Answer 17	In "122 = 12 x 12 = 144" the 2 in 122 should be superscript: $12^2 = 12 \times 12 = 144$
7	Answer 12	In step 2, 120V should be 230V. It should read: Determine the power consumed for a 132.25 ohm load connected to a 230V source.
11	Answer 10	The superscripts should be subscripts so it reads: RT = $(1/R_1 + 1/R_2 + 1/R_3$
13	Answer 18	In the first line of the solution, R_1 should be R_T so it read: $I_T = E_S / R_T$
16	Answers 66, 67	The solutions for these were transposed. The answer for question 67 should be (c) 37.50 kVA, and additional solution information was provided.
16	Answer 67	The supporting math had an error which has been corrected. The answer remains the same.
19	Answer 30	In last line of solution, the True Power should be 1,911W not 1,911 VA.
20	Answer 42	The input and output values were transposed. Input should be 4,000 VA; output should be 3,600 VA.
24	Answer 21	In the second line of solution, it should read: I = 526W/120V.
29	Answer 2	Answer should be: (b) 6 in. x 6 in. There was a math error in Total Conductor area in the solution that resulted in the new answer.
37	Answer 26	In the last line of the italicized explanation, delete the “4” in “184A” so it reads: “18A x 2.25 = 40.50A...”
52	Answer 42	Deleted first three lines of solution.
72	Answer 14	Changed Range Load from 250 kW to 25 kW.
78	Answer 6	Answer should be: (d) 208V and the solution was modified.
80	Answer 25	Removed “85A” and added this explanatory sentence: A conductor with the full 300A ampacity must be used to terminate into the 300A overcurrent device, as this is a transformer secondary tap [240.21(C)].
83	Answer 43	Change the answer from (c) to (d) so it reads: (d) 110.20 FPN
89	Answer 25	Change the answer from (b) 334.15(B) to: (d) 334.15(B)
89	Answer 43	Change the answer from (d) 110.20 FPN to: (d) 344.10(B)(1)
91	Answer 19	Changed answer to from (c) 392.3(A) to (d) 392.3(A).
94	Answer 1	Change the answer from (d) to (c). The reference is unchanged.
96	Answer 18	Answer should be: (b) 525.23(B).
96	Answer 50	Answer should be: (b) 210.70(A)(2)(c)
103	Answer 47	Change the answer from (c) to (a) so it reads: (a) 330.104
104	Answer 19	Change the answer from 410.120 to 410.12 so it reads: (c) 410.12

Click here for Textbook corrections.

16. (c) **16**
$4^2 = 4 \times 4 = 16$

17. (c) **144**
$12^2 = 12 \times 12 = 144$

18. (c) **100 ft**

D = (Cmil x VD)/(2 x K x I)
D = (4,110 Cmil x 10V)/(2 wires x 12.90 ohms x 16A)
D = 41,100/4,128
D = 99 ft

19. (b) **50A**

I = VA/(E x √3)
I = 18,000W/(208V x 1.732)
Current = 18,000W/360
Current = 50A

20. (b) **False**

21. (b) **32**
Enter the number on your calculator, then push the square root key (√).

22. (b) **1.732**
Enter the number on your calculator, then push the square root key (√).

23. (a) **cubic inches**

24. (b) **24 cu in.**

Volume = 4 in. x 4 in. x 1.50 in.
Volume = 24 cu in.

25. (a) **0.075 kW**

kW = W/1000
kW = 75W/1000
kW = 0.075 kW

26. (b) **25**
2 + 7 + 8 + 9 = 26, the multiple choice selections are rounded to the nearest "fives."

27. (c) **110W**

The input must be greater than the output.
Input = Output/Efficiency
Input = 100W/0.90
Input = 111W

28. (d) **all of these**

29. (b) **negative, positive**

30. (b) **False**

31. (a) **True**

32. (b) **False**

33. (a) **True**

10. (c) 4.50A

The power consumed by this resistor will be 500W if connected to a 115V source. But, because the applied voltage (120V) is greater than the equipment voltage rating (115V), the actual power consumed will be greater than 500W.

Step 1: Determine the resistance rating of a 500W, 115V load.

$R = E^2/P$
$R = 115V^2/500W$
$R = 13{,}225/500$
$R = 26.45$ ohms

Step 2: Determine the current of a 26.45 ohm load connected to a 120V source.

$I = E/R$
$P = 120/26.45$ ohms
$P = 4.54A$

11. (b) less

When the resistance is not changed, the power will decrease with decreasing voltage. For example a 100 ohm resistor will consume 144W of power at 120V, but only 132W of power at 115V.

$P = E^2/R$
$P = 120V^2/100$ ohms
$P = 144W$
$P = 115V^2/100$ ohms
$P = 132W$

12. (c) 400W

The power consumed by this resistor will be 100W if connected to a 115V source. But, because the applied voltage (230V) is greater than the equipment voltage rating (115V), the actual power consumed will be greater than 100W.

Step 1: Determine the resistance rating of a 100W, 115V lamp.

$R = E^2/P$
$R = 115V^2/100W$
$R = (115V \times 115V)/100W$
$R = 13{,}225/100$
$R = 132.25$ ohms

Step 2: Determine the power consumed for a 132.25 ohm load connected to a 230V source.

$P = E^2/R$
$P = 230V^2/132.25$ ohms
$P = (230V \times 230V)/132.25$ ohms
$P = 52{,}900/132.25$ ohms
$P = 400W$

4. (d) 10V

Step 1: Determine the current of the circuit.

$I = E/R_T$
$E = 30V$
$R_T = 22.50$ ohms
$I = 30V/22.50$ ohms
$I = 1.33A$

Step 2: Determine the voltage of Resistor 2.

$E_2 = I \times R_2$
$I = 1.33A$
$R_2 = 7.50$ ohms
$E_2 = 1.33A \times 7.50$ ohms
$E_2 = 9.98V$

5. (b) 6V

This is tricky. By placing the voltage meter across the switch, the circuit conductors and the load are used as part of the voltage meter leads.

6. (c) parallel

7. (b) parallel

8. (d) b and c

9. (c) in parallel

Series Example: When connected in series, each resistor will operate at 30V (one-quarter of the voltage source).

$P = E^2/R$
$P = 30V^2/10$ ohms
$P = 90W$ for each resistor in series
$P = 90W \times 4$
$P = 360W$

Parallel Example: If the four resistors are connected in parallel, each resistor will operate at 120V.

$P = E^2/R$
$P = 120V^2/10$ ohms
$P = 1{,}440W$ for each resistor in parallel
$P = 1{,}440W \times 4$
$P = 5{,}760W$

10. (b) 1 ohm

Rule: The total resistance of a parallel circuit is always less than the smallest resistor. Formula:

$R_T = 1/(1/R_1 + 1/R_2 + 1/R_3)$
$R_T = 1/(½ + 1/3 + 1/5)$
$R_T = 1/(0.50 + 0.33 + 0.20)$
$R_T = 1/1$
$R_T = 1$ ohm

Note: Figure 2-53 applies to the next three questions.

11. (c) A3

16. (b) 3V

I_T = 0.75A (last answer)
$R_{3,4,5} = R_{3,4} + R_5$
$R_{3,4,5}$ = 2 ohms + 2 ohms
$R_{3,4,5}$ = 4 ohms
$E_4 = I_T \times R_{3,4,5}$
$E_{3,4,5}$ = 0.75A x 4 ohms
$E_{3,4,5}$ = 3V

Note: Figure 2-55 applies to the next two questions.

17. (a) 10 ohms

Calculate the parallel resistance and then add the resistance of resistor R_1.

Resistance of one resistor/number of resistors = 15 ohms/3 resistors = 5 ohms

Note: The 3 parallel resistors can be thought of as a single 5 ohm resistor in series with resistor R1.

$R_T = R_1 + (R_{2,3,4})$
R_T = 5 ohms + 5 ohms
R_T = 10 ohms

18. (c) 60V

Voltage drop across R_1 is determined by: $E_1 = I_T \times R_1$

$I_T = E_S/R_T$
I_T = 120V/10 ohms
I_T = 12A
R_1 = 5 ohms
$E_1 = I_T \times R_1$
E_1 = 12A x 5 ohms
E_1 = 60V

19. (b) 0.58A

If the neutral is opened, the multiwire branch circuit becomes one 240V series circuit.

$I_T = E_S/R_T$
E_S = 240V
$R_T = R_1 + R_2$

Use the rated voltage to determine the resistance of each resistor.

$R_1 = E^2/P$
$R_1 = 130V^2/75W$
R_1 225 ohms
$R_2 = 120V^2/75W$
R_2 = 192 ohms
R_T = 225 ohms + 192 ohms
R_T = 417 ohms

$I_T = E_S/R_T$
I_T = 240V/417 ohms
I_T = 0.575A

63. (b) False

64. (a) True

65. (c) 1,200W

Power (Watts) = Volts x Amperes x Power Factor
W = 120V x 10A x 1.00 PF
W = 1,200W

66. (b) 25 kVA

Transformer kVA = (Volts x Amperes)/1,000
Transformer kVA = (240V x 100A)/1,000
Transformer kVA = 24 kVA

67. (c) 37.50 kVA

Load kW = (Volts x Amperes)/1,000
Load kW = (240V x 100A)/1,000
Load kW = 24 kW
Transformers are sized to the VA of the load, not the kW.
VA = Watts/Power Factor
VA = 24,000 W/0.85
VA = 28,235 VA
The first choice large enough to handle this load is 37.50 kVA

68. (d) 6 circuits

VA per Circuit = Volts x Amperes
VA per Circuit = 120V x 20A
VA per Circuit = 2,400 VA
Lights per Circuit = 2,400 VA/300W
Lights per Circuit = 8
Circuits = 42 luminaires/8 per circuit
Circuits = 6

69. (c) 7 circuits

VA per Circuit = Volts x Amperes
VA per Circuit = 120V x 20A
VA per Circuit = 2,400 VA
VA per Luminaire = Watts/Power Factor
VA per Luminaire = 300W/0.85 PF
VA per Luminaire = 353 VA
Lights per Circuit = 2,400 VA/353 VA = 6.8
Lights per Circuit = 6
Circuits = 42 luminaires/6 per circuit
Circuits = 7

70. (a) True

71. (a) True

72. (b) 73%

Efficiency = Output/Input
Efficiency = 1,320W/1,800W
Efficiency = 0.7333 or 73.33%

30. (c) 1.91 kW

True Power = Apparent Power x Power Factor
Apparent Power = 2,100 VA
Power Factor = 91% or 0.91
True Power = 2,100 VA x 0.91 PF
True Power = 1,911W = 1.911 kW

31. (d) resistive loads
Power factor is unity (100%) for resistive loads.

32. (c) 65A

Current = Watts/(Volts x 1.732 x Power Factor)
Watts = 24,000W
Volts = 230V
Power Factor = 92% or 0.92
Current = 24,000W/(230V x 1.732 x 0.92)
Current = 65.49A

33. (c) 87%

PF = W/VA
PF = 68W/(0.65A x 120V)
PF = 68W/(78VA)
PF = 0.8718 or 87%

34. (a) 76 VA

VA = W/PF
VA = 68W/0.90 PF
VA = 75.55 VA

35. (b) 1,150W

Watts = VA x PF
Watts = (120V x 12A) x 0.80 PF
Watts = 1,152W

36. (a) True

37. (d) $105

Step 1: Power per hour = E^2/R
E = 120V
R = 10 ohms
$P = E^2/R$
P = (120V x 120V)/10 ohms
P = 1,440W

Step 2: Power consumed per day:
1,440W x 24 hours = 34,560 Wh or 34.56 kWh

Step 3: Power consumed in 30 days:
34.56 kWh x 30 days = 1,036.80 kWh

Step 4: Cost of power at $0.10 per kWh:
1,036.80 kWh x $0.10 = $103.68

38. (a) True

39. (c) 6 kVA

kVA = (50 Fixtures x 100W)/1,000
kVA = 5,000W/1,000
kVA = 5 kVA
Apparent Power = kW/PF
Apparent Power = 5 kW/0.90 PF
Apparent Power = 5.56 kVA

40. (a) 3 circuits

Circuits are loaded according to VA, not watts!
VA of each luminaire equals:
VA = Watts/PF
VA = 100W/0.90
VA = 111 VA
Each circuit has a capacity of: 120V x 20A = 2,400 VA
Each circuit can have: 2,400 VA/111 VA = 21 luminaires
The number of circuits required is:
50 luminaires/21 luminaires per circuit = 3 circuits

41. (c) hp x 746W/W Input
Motor efficiency is equal to motor output watts (hp x 746W) divided by motor input watts.

42. (c) 90
Input = 4,000 VA
Output = 3,600 VA
Efficiency = Output/Input
Efficiency = 3,600 VA/4,000VA
Efficiency = 0.90 or 90%

Note: Efficiency is never 100% or greater.

Unit 4—Motors and Transformers

Unit 4—Practice Questions

1. (a) True

2. (b) parallel, series

3. (a) 230V, 460V

4. (c) 746W

5. (c) 40 hp

hp = Output Watts/746W
hp = 30,000W/746W
hp = 40 hp

6. (a) 11 kW

Output Watts = hp x 746W
Output Watts = 15 hp x 746W
Output kW = 11,190W/1,000
Output kW = 11.19 kW

19. (a) 6V

The turns (voltage) ratio is 200/10 or 20/1, which means that the secondary voltage will be 20 times less than the primary.

Secondary Volts = Primary Volts/Voltage Ratio
Secondary Volts = 120V/(200/10)
Secondary Volts = 120V/20
Secondary Volts = 6V

20. (c) 526W

Primary Power = Secondary Power/Efficiency
Primary Power = 500W/0.95
Primary Power = 526W

21. (c) 4.38A

I = P/E
I = 526W/120V
I = 4.38A

22. (a) 200 VA
The load (output) is given as two 100W lamps; the efficiency only affects the input, not the output.

23. (a) 120 VA

Efficiency only affects the input, not the output.
Secondary VA = Secondary Volts x Secondary Amperes
VA = 24V x 5A
VA = 120 VA

24. (c) 217 VA

Primary W = Secondary W/Efficiency
Primary W = 200W/0.92
Primary W = 217W or 217 VA (since there is no power factor)

25. (c) 31 kW

Input = Output/Efficiency
Input = 20 kW/0.65
Input = 30.80 kW

26. (b) saturated

27. (a) 0.06 kVA

Primary VA = Secondary VA
Secondary VA = Volt x Amperes
Volts = 12V
Amperes = 5A
Secondary VA = 12V x 5A
Secondary VA = 60 VA or 0.06 kVA

37. (a) 14 in.

[314.28(A)]
Bottom wall to the top wall angle pull: No calculation
Bottom wall to the top wall straight pull: No calculation
Top wall to the bottom wall angle pull: (6 x 2 in.) + 2 in. = 14 in.
Top wall to the bottom wall straight pull: No calculation

38. (a) 12 in.

[314.28(A)(2)]
2 in. x 6 = 12 in.

Unit 5—Challenge Questions

1. (a) 11

Area conductor fill for a trade size 3, Schedule 40 PVC (RNC) raceway: 2.907 sq in.
[Chapter 9, Table 4, 40% column]
Area 1 RHW without cover: 0.1901 sq in. [Chapter 9, Table 5]
Area of seven 1 RHW conductors: 0.1901 x 7 conductors = 1.3307 sq in.
Spare space: 2.907 sq in. - 1.3307 sq in. = 1.5763 sq in.
Quantity of 2 THW permitted in spare space: 1.5763 sq in./0.1333 = 11.8 conductors

Note: The answer is 11 conductors. We only round up to the next size when all of the conductors are the same size (total cross-sectional area including insulation) and the calculation results in a decimal of 0.80 or greater. See Chapter 9, Table 1, Note 7.

2. (b) 6 in. x 6 in.

Conductor area [Chapter 9, Table 5]:
400 kcmil THHN = 0.5863 sq in. x 3 = 1.7589 sq in.
250 kcmil THHN = 0.3970 sq in.
4/0 THHN = 0.3237 sq in. x 4 = 0.1295 sq in.
8 THHN = 0.0366 sq in. x 3 = 0.1098 sq in.
Total Conductor Area = 3.5607 sq in.
The wireway must not be filled over 20%, or 1⁄5 [376.22(A)]
Conductor Area x 5 = Required Wireway Minimum Area
3.5607 sq in. x 5 = 17.8035 sq in.
A 6 in. x 6 in. wireway has a cross-sectional area of 36 sq in. and would be large enough.

3. (d) 22 cu in.

2—10 AWG passing through	2—10 AWG
1—1 yoke (receptacle)	2—12 AWG
4—14 AWG spliced in the box	4—14 AWG
2—12 AWG for terminating	2—12 AWG
1—12 AWG bonding jumper	0—12 AWG

Total - two 10 AWG conductors, four 12 AWG conductors, and four 14 AWG conductors (note: insulation type does not matter for box fill calculations)

Volume of the conductors: [Table 314.16(B)]

10 AWG: 2.50 cu in. x 2 conductors	5.0 cu in.
12 AWG: 2.25 cu in. x 4 conductors	9.0 cu in.
14 AWG: 2 cu in. x 4 conductors	8.0 cu in.
Total	22.0 cu in.

22. (d) a and b
[430.62(A)]

23. (d) b and c

VA three-phase = Motor Voltage rating x Motor Ampere rating x 1.732
FLC of 5 hp, 460V, three phase motor = 7.60A
FLC of 5 hp, 230V, three phase motor = 15.20A [Table 430.250]
VA of 5 hp 460V = 460V x 7.60A x 1.732 = 6,055 VA
VA of 5 hp, 230V = 230V x 15.20A x 1.732 = 6,055 VA

24. (a) 3,890 VA

FLC of 3 hp, 208V, single-phase motor = 18.70A [Table 430.248]
VA of 3 hp, 208V, single-phase, 208V x 18.70A = 3,890 VA

25 (a) 40A

24A x 1.75 = 42A, next size down = 40A

If the 40A overcurrent device isn't capable of carrying the starting current, then the overcurrent device can be sized up to 225 percent of the equipment load current rating. 24A x 2.25 = 54A, next size down 50A [240.6(A) and 440.22(A)].

26. (a) 30A

18A x 1.75 = 31.50, next size down = 30A

If the 30A overcurrent device isn't capable of carrying the starting current, then the overcurrent device can be sized up to 225 percent of the equipment load current rating. 18A x 2.25 = 40.50A, next size down 40A [240.6(A) and 440.22(A)].

27. (c) 10AWG
[Table 310.16]

24A x 1.25 = 30A, 10 AWG, rated 30A at 75°C

28. (b) 12 AWG
18A x 1.25 = 22.50A, 12 AWG, rated 25A at 75°C

Unit 7—Challenge Questions

1. (a) 21A
[430.22(E)]

Table 430.22(E) Intermittent and 5-minute rated motor: Branch-circuit conductor ampacity must not be less than 85% of the motor nameplate amperes. 25A x 0.85 = 21.25A.

41. (c) 5,100 VA
[220.52(A), 220.52(B), Table 220.12, and Table 220.42]

General lighting			
1,500 sq ft x 3 VA	4,500 VA		
2 Small-Appliance Circuits (1,500 x 2)	3,000 VA		
Laundry	+1,500 VA		
	9,000 VA		
	-3,000 VA	at 100% =	3,000 VA
	6,000 VA	at 35% =	+ 2,100 VA
Total Calculated Load			5,100 VA

Note: 15A and 20A receptacles are considered part of the general lighting load (3 VA), Table 220.12.

42. (d) 4,140 VA
A/C VA Load = 18A x 230V
A/C VA Load = 4,140 VA
Heat (4 kW) omitted because it's smaller than air-conditioning [220.60].

43. (c) 5.50 kVA
[220.53]

Dishwasher	1,500 VA
Water Heater	+ 4,000 VA
Calculated Load at 100%	5,500 VA /1,000 = 5.50 kVA

44. (b) 5 kW
[220.54]

45. (c) 8.80 kW
[Table 220.55, Note 1]

Column C (8 kW) is increased 5% for each kW or major fraction of a kW over 12 kW [220.55 Note 1].
14 kW – 12 kW = 2 kW
2 x 5% = 10%, an increase of 10% of the Column C value results in a 110%, or 1.10 multiplier

Calculated Load = Column C Value x Multiplier
Calculated Load = 8 kW x 1.10
Calculated Load = 8.80 kW

46. (b) 2 AWG
[Table 310.15(B)(6)]
I = VA/E
I = 30,000 VA/240V
I = 125A
Service Conductor: 2 AWG copper, rated 125A [Table 310.15(B)(6)]

47. (a) 8 AWG
[250.102(C) and Table 250.66]

48. (a) 8 AWG
[250.66 and Table 250.66]

9. (b) 38.40 kW
[Table 220.55, Note 3]

The word "maximum" in a range question is asking for the larger of Columns B or C.
Table 220.55, Note 3 permits the Column B demand factors to be used.

Step 1: Determine the total connected load = 15 units x 8 kW = 120 kW

Step 2: Apply the Column B demand factor to the total connected load, 120 kW x 0.32 = 38.40 kW.
Column C for fifteen units = 30 kW minimum calculated load.

10. (c) 70
[220.61(B)(1)]

11. (a) 21 kW
[220.61(B)(1) and Table 220.55]

Column C, Fifteen units: 30 kW

Neutral Calculated Load = Range Calculated Load x 0.70 [220.61(B)(1)]
Neutral Calculated Load = 21 kW

12. (a) 17.50 kW
[220.54 and 220.61(B)(1)]

Dryer Calculated Load = Nameplate x Number of Units x Demand Factor [Table 220.54]
Dryer Calculated Load = 5 kW x 10 Units x 0.50
Dryer Calculated Load = 25 kW

Neutral Calculated Load = Dryer Calculated Load x Demand Factor [220.61(B)(1)]
Neutral Calculated Load = 25 kW x 0.70
Neutral Calculated Load = 17.50 kW

13. (a) 18.10 kW
[220.54 and 220.61(B)(1)]

Dryer Calculated Load = Nameplate x Number of Units x Demand Factor [Table 220.54]
Dryer Calculated Load = 5 kW* x 11 Units x 0.47
Dryer Calculated Load = 25.85 kW

Neutral Calculated Load = Dryer Calculated Load x Demand Factor [220.61(B)(1)]
Neutral Calculated Load = 25.85 kW x 0.70
Neutral Calculated Load = 18.10 kW
*The minimum is 5 kW for the standard calculation method.

14. (d) 17.50 kW
[220.61(B)(1) and Table 220.55]

Range Calculated Load = Column C, ten units = 25 kW [Table 220.55]

Neutral Calculated Load = Range Calculated Load x Demand Factor [220.61(B)(1)]
Neutral Calculated Load = 25 kW x 0.70
Neutral Calculated Load = 17.50 kW

7. (a) 83 kVA
[551.71 and 551.73(A)]

Note: A minimum of 70% of the sites must have a 30A or 20A facility (3,600 VA per site) and a minimum of 20% of the sites must have a 50A facility (9,600 VA per site). Check: 42 sites x 0.70 = 29 minimum 3,600 VA sites
42 sites x 0.20 = 8.40 or 9 minimum 9,600 VA sites.

Step 1: Determine the total connected load:

9 sites at 50A (9 sites x 9,600 VA)	86,400 VA
30 sites at 30A (30 sites x 3,600 VA)	108,000 VA
3 sites at 20A (3 sites x 2,400 VA)	+ 7,200 VA
Total Connected Load	201,600 VA

Step 2: Determine the demand factor for 42 sites [Table 551.73]: 41%

Step 3: Determine the calculated load:
Calculated Load = 201,600 VA x 0.41
Calculated Load = 82,656 VA
Calculated Load in kVA = 82,656 VA/1,000 = 82.66 kVA

8. (d) 64 kVA
[220.88]

Step 1: Determine the connected load:

General Lighting	30 kVA
Dishwasher	5 kW
Coffee Makers (2 kW x 2 units)	4 kW
Kitchen Appliances (2 kW x 5 units)	10 kVA
Small-Appliances Circuits (1.50 kVA x 10 units)	+ 15 kVA
Total Connected Load	64 kVA

Step 2: Apply the Table 220.88 demand factor for not all electric: 64 kVA at 100% = 64 kVA calculated load.

Unit 12—Transformer Calculations

Unit 12—Practice Questions

1. (a) series

2. (a) Delta

3. (b) line

4. (b) Line

5. (a) True

6. (d) 208V

High Leg Voltage = Voltage to Ground x 1.732
High Leg Voltage = 120V x 1.732
High Leg Voltage = 208V

7. (d) orange
[110.15]

25. (c) 350 kcmil
350 kcmil is rated 310A at 75°C [Table 310.16]. A conductor with the full 300A ampacity must be used to terminate into the 300A overcurrent device, as this is a transformer secondary tap [240.21(C)].

26. (c) at any single point
[250.30(A)(1)]

27. (a) True
[250.30(A)(3)]

28. (d) a and b
[250.30(A)(6)]

29. (a) 250.66
[250.30(A)(3)]

30. (d) 4 AWG
[250.66(B)]

31. (a) True
[110.9]

Unit 12—Challenge Questions

1. (a) 45A

$I_{Primary}$ = $VA_{Primary}$/($E_{Primary}$ x 1.732)
$I_{Primary}$ = (35.70 kVA x 1000)/(480V x 1.732)
$I_{Primary}$ = (35.70 kVA x 1000)/831V
$I_{Primary}$ = 45.10A

2. (c) 113A

There are two ways to calculate this problem.

(1) Calculate the primary line current, then use the ratio to determine the secondary line current:

Primary Line Current = Primary Phase Power/(Primary Phase Volts x 1.732)
Primary Line Current = 45,000 VA/(460V x 1.732)
Primary Line Current = 45,000 VA/797V
Primary Line Current = 56.50A

Next, use the ratio to determine the secondary voltage, and then calculate the secondary line current.
The ratio is 2:1, therefore the secondary voltage is ½ of the primary voltage and the current will be twice the primary line current.

Secondary Line Current = 56.50A x 2
Secondary Line Current =113A

(2) The voltage ratio is 2:1. If the primary voltage is 460V, the secondary is 230V
Secondary line current = 45,000 VA/(230V x 1.732)
Secondary line current = 113A

CHAPTER 4— NEC PRACTICE QUIZZES, CHALLENGE QUIZZES, AND FINAL NEC EXAMS

Practice Quizzes

UNIT 1 PRACTICE QUESTIONS IN STRAIGHT ORDER—90.1 THROUGH 225.6

1. (d) 90.1(B)
2. (d) 90.2(A)
3. (c) 90.2(B)(4)
4. (d) 90.2(B)(5) FPN
5. (a) 90.3
6. (d) 90.4, 100 Special Permission
7. (c) 90.4
8. (c) 90.7
9. (a) 100 Accessible (as applied to equipment)
10. (b) 100 Accessible (as applied to wiring methods)
11. (c) 100 Accessible, Readily
12. (d) 100 Attachment Plug (Plug Cap) (Plug)
13. (b) 100 Branch Circuit
14. (d) 100 Cabinet
15. (d) 100 Circuit Breaker
16. (b) 100 Circuit Breaker, Inverse Time
17. (d) 100 Communications Equipment
18. (c) 100 Disconnecting Means
19. (a) 100 Electric Sign
20. (d) 100 Equipment
21. (a) 100 Garage
22. (b) 100 Ground
23. (c) 100 Grounded
24. (c) 100 Ground-Fault Circuit Interrupter (FPN)
25. (c) 100 Grounding Electrode
26. (b) 100 Handhole Enclosure
27. (d) 100 In Sight from (Within Sight)
28. (a) 100 Location, Dry
29. (c) 100 Location, Wet
30. (c) 100 Outlet
31. (d) 100 Receptacle Outlet
32. (b) 100 Remote-Control Circuit
33. (c) 100 Service
34. (c) 110.5
35. (c) 110.8
36. (d) 110.12(A)
37. (c) 110.14 FPN
38. (b) 110.14(C)(1)(a)
39. (c) 110.14(C)(1)(a)(3)
40. (c) 110.14(C)(1)(b)
41. (d) 110.15
42. (d) 110.16
43. (d) 110.20 FPN
44. (b) 110.26(A)(1) and Table 110.26(A)(1), Condition 2
45. (c) 110.26(A)(1) and Table 110.26(A)(1), Condition 3
46. (c) 110.26(A)(1)
47. (b) 110.26(A)(2)
48. (b) 110.26(A)(3)
49. (b) 110.26(B)
50. (c) 110.26(C)(2)
51. (d) 110.26(E)
52. (b) 110.26(F)(1)(a)
53. (b) 110.27(B)
54. (b) 200.6(A)
55. (c) 200.6(B)
56. (b) 200.10(B)(1)
57. (c) 210.3
58. (d) 210.4(B)
59. (a) 210.7(B)
60. (b) 210.8(A)(2)
61. (b) 210.11(C)(1)
62. (b) 210.11(C)(2)
63. (b) 210.19(A)(1) FPN 4
64. (a) 210.21(B)(2) and Table 210.21(B)(2)
65. (b) 210.21(B)(3) and Table 210.21(B)(3)
66. (a) 210.23(A)(2)
67. (d) 210.25(B)
68. (a) 210.52(A)(1)
69. (a) 210.52(A)(2)(1)
70. (c) 210.52(A)(2)(2)
71. (d) 210.52(C)(1)
72. (b) 210.52(C)(3)
73. (c) 210.52(C)(5)
74. (a) 210.52(D)
75. (b) 210.52(E)(3)
76. (d) 210.52(G)(1)
77. (b) 210.62
78. (d) 210.63
79. (d) 210.70(B) Ex 1
80. (c) 210.70(C)
81. (c) 215.6
82. (b) 215.8
83. (d) 215.12(C)
84. (b) 220.5(B)
85. (a) 220.14(H)(1)
86. (b) 220.14(I)

UNIT 4 PRACTICE QUESTIONS IN STRAIGHT ORDER—ARTICLE 100 THROUGH 378.10

1. (c) 100 Panelboard
2. (d) 100 Special Permission
3. (a) 100 Supplementary Overcurrent Protective Device
4. (b) 110.14(C)
5. (c) 110.22(A)
6. (a) 210.4(C)
7. (d) 210.70(A)(3)
8. (d) 230.23(A)
9. (b) 240.83(D)
10. (b) 240.85
11. (a) 250.28(D)(1)
12. (d) 250.30(A)
13. (a) 250.30(A)(1)
14. (d) 250.30(A)(6)
15. (a) 250.102(C)
16. (a) 250.104(A)(1)
17. (a) 250.104(A)(3)
18. (a) 300.4(C)
19. (d) 300.18(B)
20. (a) 300.21
21. (d) 314.23(C)
22. (a) 314.30(C)
23. (d) 334.6
24. (d) 334.12(A)(9)
25. (d) 334.15(B)
26. (a) 334.15(C)
27. (d) 334.17
28. (d) 320.30
29. (b) 334.80
30. (c) 334.112
31. (d) 336.10
32. (c) 338.2
33. (c) 338.10(B)(1)
34. (b) 338.10(B)(2)
35. (b) 340.2
36. (d) 340.12(4), (5) and (6)
37. (d) 340.12(7), (8) and (9)
38. (a) 340.80
39. (b) 342.14
40. (d) 342.26
41. (b) 342.30(B)(1)
42. (a) 342.46
43. (d) 344.10(B)(1)
44. (d) 344.14
45. (b) 344.24 and Chapter 9, Table 2
46. (d) 344.26
47. (b) 344.30(C)
48. (c) 344.42(B)
49. (a) 344.46
50. (d) 348.12(1), (6) and (7)
51. (b) 348.24
52. (c) 348.26
53. (b) 348.28
54. (a) 348.30(A)
55. (d) 348.30(A) Ex 1
56. (b) 348.42
57. (d) 350.10(3)
58. (a) 350.30(A) Ex 1
59. (b) 350.42
60. (c) 350.60
61. (d) 352.10 FPN
62. (d) 352.12(A), (B) and (C)
63. (c) 352.26
64. (d) 352.30(A)
65. (d) 353.2
66. (d) 353.10(1)
67. (a) 353.12(4)
68. (d) 353.24
69. (b) 353.48
70. (d) 353.48 FPN
71. (b) 353.60
72. (c) 354.2
73. (a) 354.6
74. (d) 354.10(1), (2), and (3)
75. (d) 354.12(1), (2), and (3)
76. (a) 354.24
77. (c) 354.26
78. (c) 354.28
79. (c) 354.48
80. (d) 355.2
81. (a) 356.2
82. (a) 356.22
83. (a) 356.24
84. (c) 356.26
85. (b) 358.2
86. (c) 358.10(C)
87. (d) 358.12(1), (2) and (5)
88. (b) 362.2
89. (c) 362.10(2) Ex
90. (c) 362.10(6)
91. (b) 362.12(9)
92. (a) 362.22
93. (a) 362.28
94. (a) 362.30(A) Ex 3
95. (d) 376.10(1), (2), and (3)
96. (a) 376.10(4)
97. (a) 376.23(A)
98. (d) 376.56(B)(3) and (4)
99. (c) 378.2
100. (d) 378.10(1) and (3)

UNIT 5 PRACTICE QUESTIONS IN STRAIGHT ORDER—ARTICLE 378.10 THROUGH 410.151

1. (a) 378.10(4)
2. (a) 378.22
3. (b) 378.44
4. (b) 378.56
5. (a) 380.2(A)
6. (d) 380.2(B)(2), (4) and (5)
7. (c) 384.12(1) and (2)
8. (d) 384.30(A)
9. (b) 384.56
10. (b) 386.22
11. (a) 386.30
12. (d) 386.56
13. (c) 386.60
14. (a) 388.10(1)
15. (b) 388.22
16. (d) 388.56
17. (d) 392.3
18. (c) 392.3
19. (d) 392.3(A)
20. (d) 392.4
21. (d) 392.6(C)
22. (d) 392.6(H)
23. (d) 392.6(J)
24. (a) 392.6(J)
25. (a) 392.7(B)(1)
26. (c) 392.8(A)
27. (c) 392.8(C)
28. (b) 392.8(D)
29. (a) 400.4 Table
30. (a) 400.5(A)
31. (d) 400.8(2), (3), and (4)
32. (d) 400.10 FPN
33. (c) 400.14
34. (b) 400.14
35. (a) 400.22
36. (a) 402.5, Table
37. (c) 402.6
38. (a) 402.7
39. (b) 402.10
40. (d) 404.7
41. (b) 404.8(A) Ex 2
42. (c) 404.8(B)
43. (c) 404.8(C)
44. (c) 404.9(B) Ex
45. (b) 404.12
46. (d) 404.14(A)
47. (b) 404.14(C)
48. (a) 404.14(E)
49. (d) 404.15(A)
50. (b) 404.15(B)
51. (b) 406.2(B)
52. (c) 406.3(B)
53. (b) 406.3(D)(1)
54. (c) 406.3(D)(2)
55. (d) 406.3(D)(3)
56. (b) 406.4(A)
57. (a) 406.4(B)
58. (b) 406.4(E)
59. (c) 406.4(G)
60. (a) 406.8(A)
61. (b) 406.8(A)
62. (d) 406.8(A)
63. (d) 406.8(E)
64. (a) 406.9(E)
65. (d) 406.11
66. (b) 408.3(C)
67. (b) 408.3(D)
68. (b) 408.3(E)
69. (a) 408.5
70. (b) 408.7
71. (b) 408.36
72. (a) 408.36(B)
73. (a) 408.41
74. (a) 408.54
75. (a) 408.56, Table
76. (d) 410.1
77. (a) 410.2
78. (c) 410.2
79. (b) 410.10(A)
80. (b) 410.10(C)(1)
81. (c) 410.10(D)
82. (c) 410.10(D)
83. (d) 410.10(E)
84. (d) 410.16(A)
85. (a) 410.18
86. (d) 410.24(A)
87. (d) 410.30(A)
88. (d) 410.30(B)(1) Ex 2
89. (c) 410.30(B)(5)
90. (d) 410.36(B)
91. (d) 410.36(B)
92. (a) 410.42(A)
93. (c) 410.115(C)
94. (b) 410.116(A)(1)
95. (d) 410.116(A)(2)
96. (b) 410.116(B)
97. (a) 410.117(C)
98. (c) 410.117(C)
99. (c) 410.136(B)
100. (b) 410.151(C)(8)

UNIT 6 PRACTICE QUESTIONS IN RANDOM ORDER—ARTICLE 90.2 THROUGH 502.10

1. (c) 445.18
2. (c) 440.63
3. (d) 500.5(B)(2) FPN No. 1
4. (d) 501.15(C)(1), (3), and (4)
5. (d) 501.10(A) (1), (2), and (3)
6. (a) 502.10(A)(1)
7. (b) 430.84
8. (a) 501.10(B)(4)
9. (a) 411.3(A) and (B)
10. (a) 430.87
11. (b) 411.4(A)(1)
12. (b) 501.125(A)(1)
13. (b) 320.23(B)
14. (b) 334.10(1)
15. (a) 100 Neutral Point
16. (a) 100 Service Conductors
17. (a) 210.21(B)(1)
18. (a) 250.32(B)
19. (a) 300.3(A)
20. (b) 334.12(A)(2)
21. (a) 348.12(7) and 348.10
22. (a) 362.10(5) Ex
23. (a) 380.3
24. (a) 430.103
25. (a) 501.125(A)
26. (a) 210.8(A)(4)
27. (a) 210.70(A)(1)
28. (b) 220.56
29. (a) 250.53(B) and 250.58
30. (a) 250.64(E)
31. (a) 300.6(D) FPN
32. (a) 310.15(B)(2)(a)
33. (a) 384.2
34. (b) 410.2
35. (b) 424.9
36. (a) 90.5(C)
37. (a) 200.7(C)(2)
38. (a) 250.20(A)(1)
39. (a) 300.15
40. (a) 300.23
41. (a) 314.22
42. (a) 334.15(A)
43. (a) 352.46
44. (a) 362.12(1)
45. (a) 388.2
46. (a) 404.9(B)
47. (a) 460.8(B) Ex
48. (b) 90.2(B)(2)
49. (a) 210.52(C)(4)
50. (a) 250.20(B)(2)

UNIT 7 PRACTICE QUESTIONS IN RANDOM ORDER—ARTICLE 90.2 THROUGH 547.10

1. (a) 514.11(A)
2. (b) 525.20(A)
3. (a) 547.5(C)(1)
4. (a) 517.80
5. (a) 525.20(F)
6. (a) 514.13
7. (a) 547.5(C)(2)
8. (b) 502.130(B)(4)
9. (a) 511.3(A)
10. (a) 525.21(B)
11. (a) 525.23(A)(1)
12. (a) 300.7(B)
13. (a) 300.15(C)
14. (a) 310.2(A)
15. (b) 362.12(5)
16. (a) 406.4(C)
17. (a) 430.107
18. (b) 525.23(B)
19. (a) 547.10(A)(1) and (2)
20. (a) 90.9(D)
21. (b) 100 Overload
22. (a) 110.9
23. (a) 210.70(A)(2)(b)
24. (a) 230.50(A)
25. (a) 250.4(A)(2)
26. (a) 250.20(B)(3)
27. (a) 250.102(A)
28. (a) 300.5(E)
29. (a) 300.15(G)
30. (a) 314.15
31. (a) 410.130(G)(1)
32. (a) 430.52(C)(1) Ex 1
33. (b) 460.8(C) Ex
34. (a) 501.15(D)(2) Ex 2
35. (a) 501.130(A)(4)
36. (a) 547.10(A)(2)
37. (a) 210.8(A)(8)
38. (a) 210.52(C)(5) Ex
39. (b) 210.70(A)(2)(b)
40. (b) 230.10
41. (a) 300.15(L)
42. (a) 342.28
43. (a) 376.56(B)(1)
44. (a) 388.21
45. (a) 410.36(G)
46. (a) 460.9
47. (a) 501.15(E)(1) Ex
48. (a) 90.2(B)(5) FPN
49. (a) 100 Signaling Circuit
50. (b) 210.70(A)(2)(c)

CHALLENGE QUIZ 1—ARTICLE 90 THROUGH CHAPTER 9

1. (a) 670.3(B)
2. (c) 326.2
3. (c) 366.100(E)
4. (a) 430.12(C) and Table 430.12(C)(1)
5. (c) 332.24(1)
6. (b) 390.3(B)
7. (c) 450.21(C)
8. (a) 370.4(C)
9. (b) 374.4
10. (a) 430.81(A)
11. (c) 353.120
12. (d) 480.6(B)
13. (a) 810.16(A) Table
14. (b) 810.16(A) Table
15. (c) 830.100(D)
16. (b) 368.30
17. (a) 460.2(A)
18. (d) 430.32(C)(1)
19. (b) 430.110(B)
20. (a) 450.46
21. (a) 240.83(B)
22. (b) 520.53(G)
23. (b) 720.6
24. (d) 427.12
25. (d) 314.71(A)
26. (d) 314.71(B)(1)
27. (d) 314.71(B)(2)
28. (b) 110.14(A)
29. (c) 540.13
30. (d) 408.18(A)
31. (d) 410.140(B)
32. (b) 424.35
33. (c) 440.12(A)(1)
34. (c) 322.104
35. (d) 340.104
36. (a) 620.12(A)(1)
37. (c) 810.52 Table
38. (c) 460.6(A)
39. (d) 430.72(C)(4)
40. (a) 225.39(A)
41. (d) 225.39(B)
42. (b) 324.10(B)(2)
43. (a) 440.55(B)
44. (b) 660.9
45. (b) 408.52
46. (d) 720.4
47. (a) 330.104
48. (a) 727.6
49. (d) 550.13(D)
50. (a) 344.10(C)

CHALLENGE QUIZ 2—ARTICLE 90 THROUGH CHAPTER 9

1. (b) 394.17
2. (d) 470.3
3. (a) 250.52(A)(7)
4. (a) 620.12(A)(2)
5. (c) 392.7(B), Table Note b
6. (a) 322.56(B)
7. (c) 110.27(A)(2)
8. (b) 410.54(B), See 402.6
9. (d) 551.45(B)
10. (c) 424.22(B)
11. (d) 424.22(B)
12. (b) 430.232
13. (c) 250.112(K)
14. (c) 310.17, Table
15. (c) 650.8
16. (d) 332.30
17. (c) 344.120
18. (c) 410.5 Ex
19. (c) 410.12
20. (c) 701.11(G)
21. (c) 324.2 Definition
22. (d) 394.30(A)
23. (c) 360.20(B)
24. (a) 727.1
25. (d) 408.36(A)
26. (c) 422.11(C)
27. (c) 550.10(A) Ex 1
28. (d) 810.11 Ex
29. (d) 540.2
30. (c) 324.41
31. (b) 727.9
32. (c) 398.15(C)
33. (c) 330.24(A)(2)
34. (a) 338.24
35. (d) 830.100(A)(4)
36. (a) 830.100(A)(4) Ex and 830.100(B)(3)(2)
37. (c) 366.12(2)
38. (c) 660.6(A)
39. (a) 660.5
40. (d) 366.23(A)
41. (d) 366.23(A)
42. (a) 368.10(C)(2)(a)
43. (a) 830.44(I)(3)
44. (b) 382.30(A)
45. (a) 398.30(A)(1)
46. (c) 408.5, Table
47. (d) 424.34
48. (c) 310.13(A), Table
49. (d) 310.15(B)(3)
50. (c) 324.10(B)(1)

1.24 Using the Formula Wheel

The formula wheel is divided into four sections with three formulas in each section. Figure 1–25. When working the formula wheel, the key to calculating the correct answer is to follow these steps:

Step 1: Know what the question is asking for: I, E, R, or P.

Step 2: Determine the knowns: I, E, R, or P.

Step 3: Determine which section of the formula wheel applies: I, E, R, or P and select the formula from that section based on what you know.

Step 4: Work out the calculation.

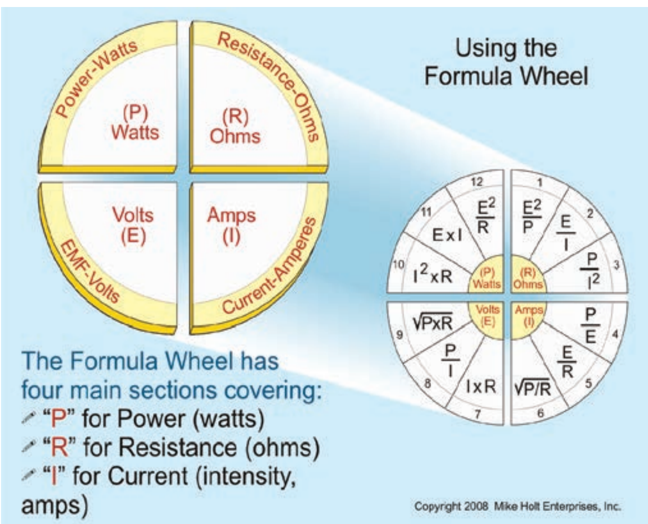


Figure 1–25

▶ Example

Question: *The total resistance of two 12 AWG conductors, 75 ft long is 0.30 ohms, and the current through the circuit is 16A. What is the power loss of the conductors?* Figure 1–26

(a) 20W (b) 75W (c) 150W (d) 300W

Answer: *(b) 75W*

Step 1: What is the question? What is the power loss of the conductors "P?"

Step 2: What do you know about the conductors?
$I = 16A$, $R = 0.30$ ohms

Step 3: What is the formula? ***$P = I^2 \times R$***

(continued in next column)

Step 4: Calculate the answer: $P = 16A^2 \times 0.30$ ohms = 76.80W
The answer is 76.80W

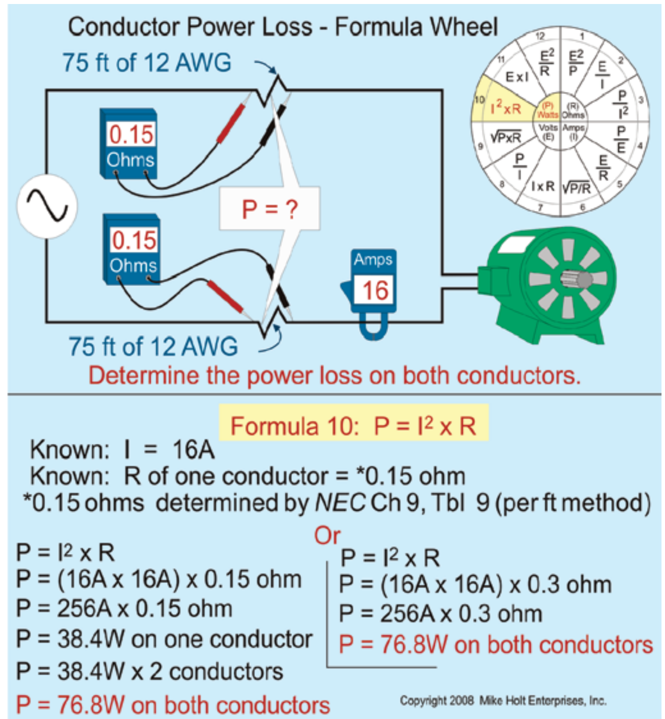


Figure 1–26

1.25 Power Losses of Conductors

Power in a circuit can be either "useful" or "wasted." Most of the power used by loads such as fluorescent lighting, motors, or stove elements is consumed in useful work. However, the heating of conductors, transformers, and motor windings is wasted work. Wasted work is still energy used; therefore it must be paid for, so we call these power losses.

▶ Example

Question: *What is the conductor power loss in watts for a 10 AWG conductor that has a voltage drop of 3 percent in a 240V circuit and carries a current flow of 24A?* Figure 1–27

(a) 17W (b) 173W (c) 350W (d) 450W

Answer: *(b) 173W*

(continued in next column)

9. •The energy consumed by a 5 ohm resistor is _____ than the energy consumed by a 10 ohm resistor, assuming the current in both cases remains the same.

   (a) more
   (b) less

10. When a load is rated 500W at 115V is connected to a 120V power supply, the current of the circuit will be _____. Tip: At 120V, the load consumes more than 500 watts, but the resistance of the load remains constant.

    (a) 2.70A
    (b) 3.80A
    (c) 4.50A
    (d) 5.50A

1.27 Power Changes with the Square of the Voltage

11. A 120V rated toaster will produce _____ heat when supplied by 115V.

    (a) more
    (b) less
    (c) the same
    (d) none of these

12. •When a 100W, 115V lamp operates at 230V, the lamp will consume approximately _____.

    (a) 150W
    (b) 300W
    (c) 400W
    (d) 450W

13. •A 1,500W resistive heater is rated 230V and is connected to a 208V supply. The power consumed for this load at 208V will be approximately _____.

    (a) 1,225W
    (b) 1,625W
    (c) 1,750W
    (d) 1,850W

14. •The total resistance of a circuit is 10.20 ohms. The load has a resistance of 10 ohms and the wire has a resistance of 0.20 ohms. If the current of the circuit is 12A, then the power consumed by the circuit conductors (0.20 ohms) is approximately _____.

    (a) 8W
    (b) 29W
    (c) 39W
    (d) 45W

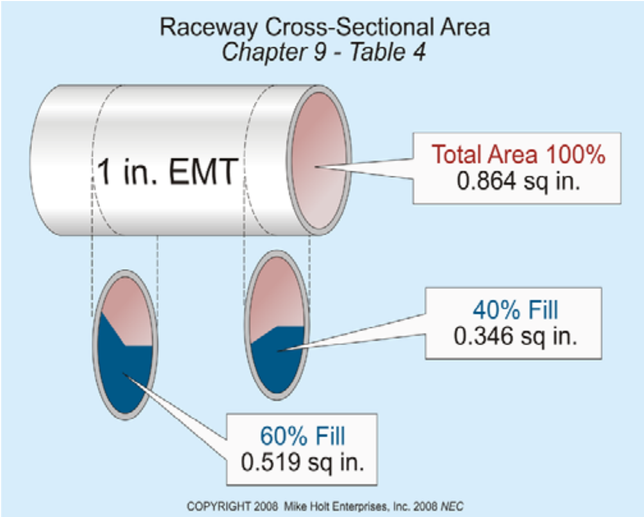


Figure 5–7

▶ Raceway Cross-Sectional Area Example 2

Question: *What is the cross-sectional area of permitted conductor fill for a trade size 2 EMT raceway that is 20 inches long?* Figure 5–8

(a) 1.342 sq in. *(b) 2.013 sq in.*
(c) 2.067 sq in. *(d) 3.356 sq in.*

Answer: *(b) 2.013 sq in.*
[Chapter 9, Table 1, Note 4 and Table 4, 60% column]

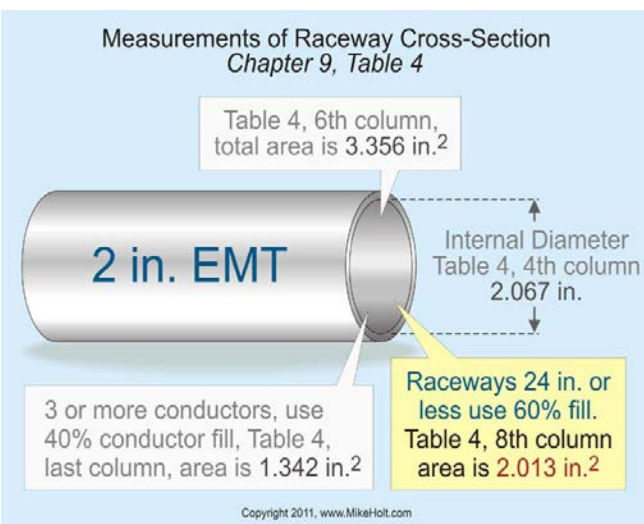


Figure 5–8

▶ Raceway Cross-Sectional Area Example 3

Question: *What is the cross-sectional area of permitted conductor fill for a trade size 2 EMT raceway 30 inches long that contains four conductors?*

(a) 1.342 sq in. *(b) 2.013 sq in.*
(c) 2.067 sq in. *(d) 3.356 sq in.*

Answer: *(a) 1.342 sq in.*
[Chapter 9, Table 1 and Table 4, 40% column]

▶ Raceway Cross-Sectional Area Example 4

Question: *What is the minimum size EMT raceway required for three conductors with a wire fill of 0.25 sq in.?*

(a) Trade size ½ *(b) Trade size 1*
(c) Trade size 1¼ *(d) Trade size 1½*

Answer: *(b) Trade size 1*

▶ Raceway Cross-Sectional Area Example 5

Question: *What is the minimum size Schedule 80 PVC raceway required for three conductors with a wire fill of 0.35 sq in.?*

(a) Trade size ½ *(b) Trade size 1*
(c) Trade size 1¼ *(d) Trade size 1½*

Answer: *(c) Trade size 1¼*

Table 5—Dimensions of Insulated Conductors and Fixture Wires

Chapter 9, Table 5 lists the cross-sectional area of insulated conductors and fixture wires (see Table 5–1).

Table 5A—Dimensions of Compact Insulated Conductors

Chapter 9, Table 5A, lists the cross-sectional areas for compact copper and aluminum building wires. These conductors use specially shaped strands so that the overall size of the conductor is more compact. The outer covering is labeled as a compact conductor.

> **▶ Table 5—THHN Compact Conductors**
>
> ***Question:*** *What is the cross-sectional area for one 1 THHN compact conductor?*
>
> *(a) 0.0117 sq in.* *(b) 0.1352 sq in.*
> *(c) 0.2733 sq in.* *(d) 0.5216 sq in.*
>
> ***Answer:*** *(b) 0.1352 sq in.*

> **▶ Table 5—Compact Conductors**
>
> ***Question:*** *What is the cross-sectional area for one 4/0 XHHW compact conductor?*
>
> *(a) 0.0117 sq in.* *(b) 0.1352 sq in.*
> *(c) 0.2733 sq in.* *(d) 0.5216 sq in.*
>
> ***Answer:*** *(c) 0.2733 sq in.*

Table 8—Conductor Properties

Chapter 9, Table 8 contains conductor properties such as cross-sectional area in circular mils, number of strands per conductor, cross-sectional area in square inches for bare conductors, and dc resistance at 75ºC for both copper and aluminum conductors.

> **▶ Bare Conductor—Cross-Sectional Area**
>
> ***Question:*** *What is the cross-sectional area for one 10 AWG bare conductor with seven strands?* Figure 5–10
>
> *(a) 0.008 sq in.* *(b) 0.011 sq in.*
> *(c) 0.038 sq in.* *(d) a or b*
>
> ***Answer:*** *(b) 0.011 sq in. [Chapter 9, Table 8]*

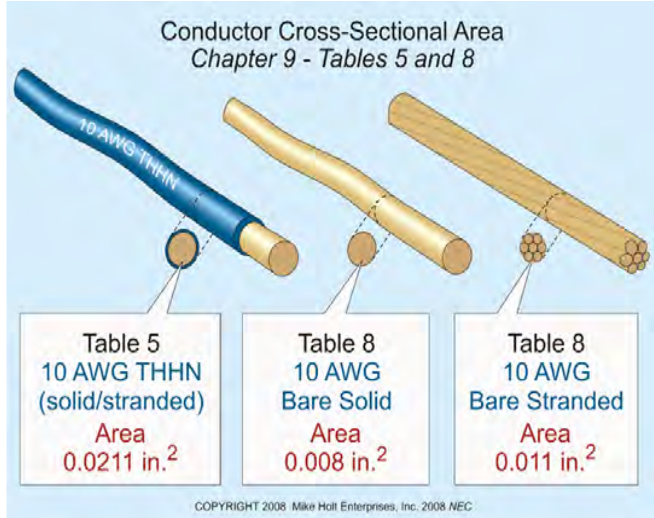


Figure 5–10

5.2 Raceway Calculations

Annex C—Tables 1 through 12 can't be used to determine raceway sizing when conductors of different sizes are installed in the same raceway. When this situation is encountered, the following steps are used to determine the raceway size and nipple size:

Step 1: Determine the cross-sectional area (in square inches) for each conductor from Chapter 9, Table 5 for insulated conductors and from Chapter 9, Table 8 for bare conductors.

Step 2: Determine the total cross-sectional area for all conductors.

Step 3: Size the raceway according to the percent fill as listed in Chapter 9, Table 1. Chapter 9, Table 4 includes the various types of raceways with columns representing the allowable percentage fills; such as 40 percent for three or more conductors, and 60 percent for raceways 24 in. or less in length (nipples). Be careful when selecting the raceway from Chapter 9, Table 4 as this table is divided up into numerous tables for each raceway type, and you must choose the correct section of the table for the type of raceway.

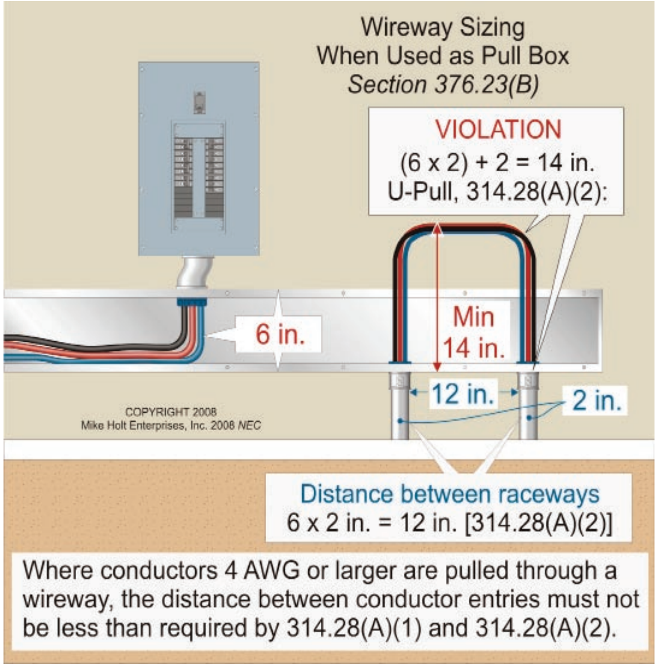


Figure 5–15

- Angle Pulls. The distance from the raceway entry to the opposite wall must not be less than six times the trade diameter of the largest raceway, plus the sum of the trade sizes of the remaining raceways in the same row on the same wall [314.28(A)(2)].
- U Pulls. When a conductor enters and leaves from the same wall, the distance from where the raceways enter to the opposite wall must not be less than six times the trade size of the largest raceway, plus the sum of the trade sizes of the remaining raceways on the same wall and row [314.28(A)(2)].
- The distance between raceways enclosing the same conductor must not be less than six times the trade size of the largest raceway [314.28(A)(2)].

▶ Wireway Cross-Sectional Area

Question: *What is the cross-sectional area of a 6 in. x 6 in. wireway?*

(a) 6 sq in. (b) 16 sq in. (c) 36 sq in. (d) 66 sq in.

Answer: *(c) 36 sq in.*

The cross-sectional area is found by multiplying height by depth: 6 in. x 6 in. = 36 sq in.

▶ Wireway Allowable Conductor Fill Area

Question: *What is the maximum allowable conductor fill in square inches for a 6 in. x 6 in. wireway?*

(a) 5 sq in. (b) 6.5 sq in. (c) 7.20 sq in. (d) 8.9 sq in.

Answer: *(c) 7.20 sq in.*

36 sq in. x 0.20 = 7.20 sq in. [376.22(A)]

▶ Wireway Conductor Fill

Question: *What is the maximum number of 500 kcmil THHN conductors that can be installed in a 6 in. x 6 in. wireway?*

(a) 4 (b) 6 (c) 10 (d) 20

Answer: *(c) 10*

36 sq in. x 0.20 = 7.20 sq in. [376.22(A)]

500 kcmil THHN = 0.7073 sq in. [Chapter 9, Table 5]

Maximum Allowable Area/Area per Conductor = Number of Conductors

7.20 sq in./0.7073 sq in. = 10.17 conductors

10 conductors can be installed.

Note: Conductor ampacity adjustment for bundling isn't required because there are fewer than 30 conductors [376.22(B)].

▶ Wireway Conductor Fill

Question: *What size wireway is required for three 500 kcmil THHN, one 250 kcmil THHN, and four 4/0 THHN conductors?*

(a) 4 in. x 4 in. (b) 6 in. x 6 in.
(c) 8 in. x 8 in. (d) 10 in. x 10 in.

Answer: *(b) 6 in. x 6 in.*

Find the conductor area [Chapter 9, Table 5]

500 kcmil THHN = 0.7073 sq in. x 3 = 2.1219 sq in.
250 kcmil THHN = 0.3970 sq in.
4/0 THHN = 0.3237 x 4 = 0.12948 sq in.
Total Conductor Area = 3.8137 sq in.

The wireway must not be filled to over 20 percent of its cross-sectional area [376.22(A)]. Twenty percent is equal to one-fifth, so we can multiply the required conductor area by five to find the minimum square inch area required.

Conductor Area x 5 = Required Wireway Minimum Area
3.8137 x 5 = 19.07 sq in.

A 6 in. x 6 in. wireway has a cross-sectional area of 36 sq in. and will be large enough.

▶ Distance Between Raceways

Question: *What is the minimum distance between the two trade size 3 raceways that contain the same conductors?*

(a) 18 in. *(b) 21 in.* *(c) 24 in.* *(d) 30 in.*

Answer: *(a) 18 in. [314.28]* Figure 5–41

6 x 3 in. = 18 in.

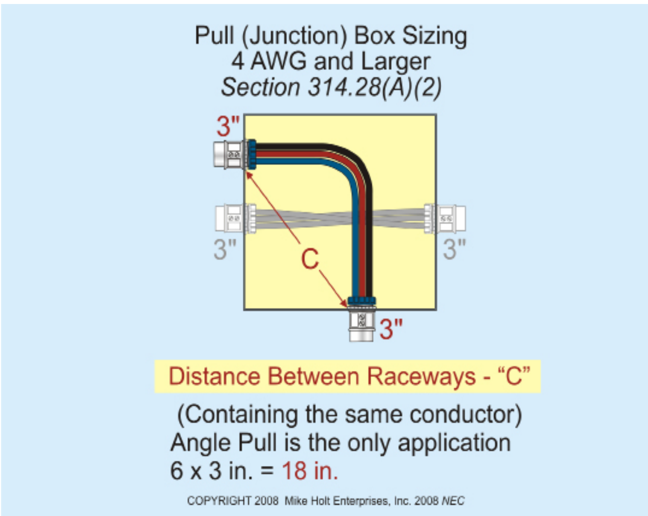


Figure 5–41

Pull Box Sizing

A pull box contains a trade size 2 and trade size 3 raceway on the left side, a trade size 3 raceway on the top, and a trade size 2 raceway on the right side. The trade size 2 raceways are a straight pull and the trade size 3 raceways are an angle pull.

▶ Horizontal Dimension

Question: *What is the horizontal dimension of the box?* Figure 5–42

(a) 20 in. *(b) 24 in.* *(c) 28 in.* *(d) 30 in.*

Answer: *(a) 20 in. [314.28(A)(2)]*

Left to right straight pull	*8 x 2 in. = 16 in.*
Right to left straight pull	*8 x 2 in. = 16 in.*
Left to right angle pull	*(6 x 3 in.) + 2 in. = 20 in.*
Right to left angle pull	*No calculation*

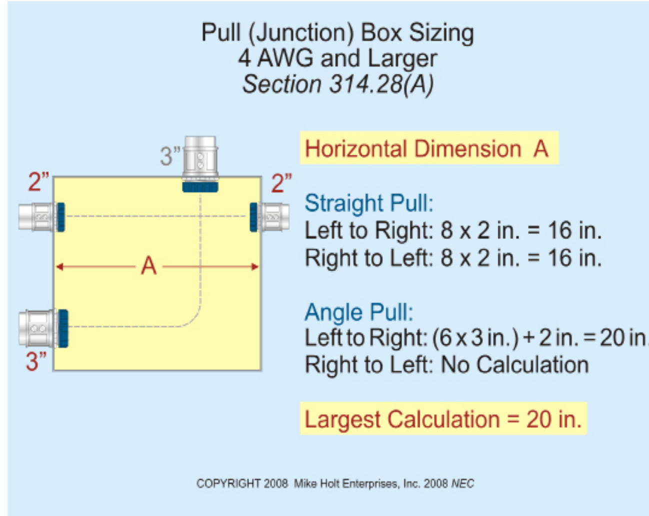


Figure 5–42

▶ Vertical Dimension

Question: *What is the vertical dimension of the box?* Figure 5–43

(a) 14 in. *(b) 18 in.* *(c) 21 in.* *(d) 26 in.*

Answer: *(b) 18 in. [314.28(A)(2)]*

Top to bottom straight	*No calculation*
Bottom to top straight	*No calculation*
Top to bottom angle	*6 x 3 in. = 18 in.*
Bottom to top angle	*No calculation*

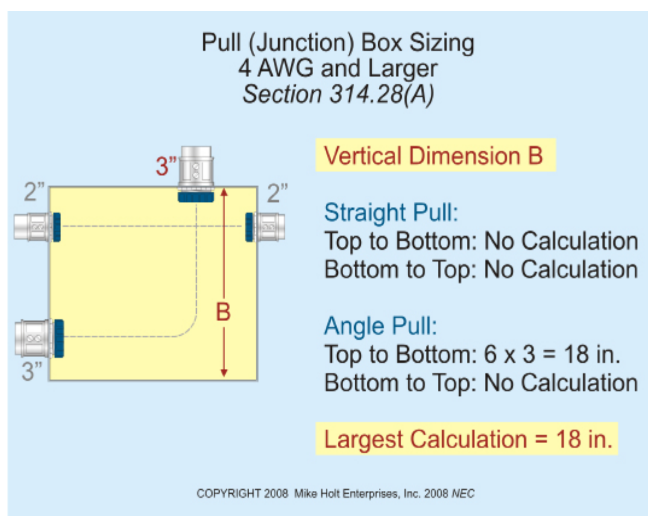


Figure 5–43

▶ Table 402.3

Question: Which of the following describe type TFFN insulation?

(a) stranded fixture wire
(b) thermoplastic insulation with a nylon outer cover
(c) suitable for dry and wet locations
(d) both a and b

Answer: *(d) both a and b*

6.2 Conductor Sizing [110.6]

Conductors are sized according to the American Wire Gage (AWG) from 40 AWG through 4/0 AWG. The smaller conductors are represented by the larger numbers, with the AWG size numbers decreasing as the conductor size increases. Above 1 AWG are sizes 0, 2/0, 3/0, and 4/0. Conductors larger than 4/0 AWG are identified according to their cross-sectional area in circular mils, such as 250,000 cmil, 300,000 cmil, 500,000 cmil, etc. The circular mil size is usually expressed in kcmil (1,000 circular mils), such as 250 kcmil, 300 kcmil, and 500 kcmil. Figure 6–3

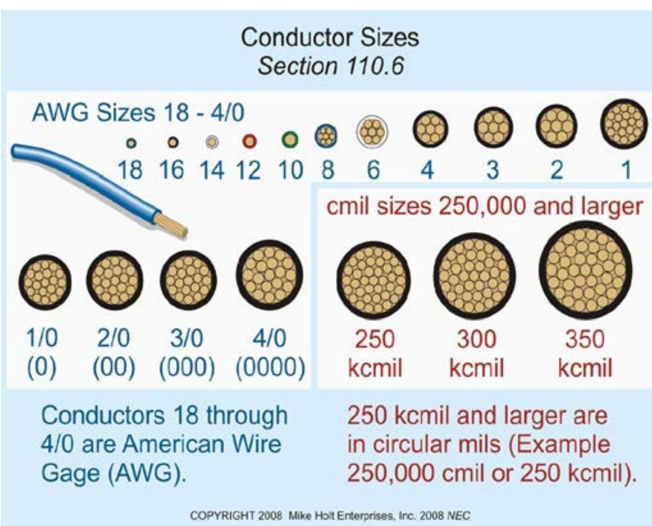


Figure 6–3

6.3 Smallest Conductor Size [310.5]

The smallest size conductors permitted by the *NEC* for branch circuits, feeders, or services are 14 AWG copper [Table 310.5]. However, some local codes require a minimum 12 AWG for commercial and industrial installations. Conductors smaller than 14 AWG are permitted for:

Class 1 remote-control circuits [725.43]
Fixture wire [402.6]
Motor control circuits [Table 430.72(B)]

6.4 Conductor Size—Terminal Temperature Rating [110.14(C)]

Conductors are to be sized to the lowest temperature rating of any terminal, device, or conductor of the circuit in accordance with the equipment terminal temperature rating as follows:

Circuits Rated 100A and Less [110.14(C)(1)(a)]

Equipment terminals rated 100A or less and pressure connector terminals for 14 AWG through 1 AWG conductors, must have the conductor sized to the 60°C temperature rating listed in Table 310.16, unless the terminals are marked for 75°C conductors.

Author's Comment: Conductors are sized to prevent the overheating of terminals, in accordance with listing standards. For example, a 50A circuit with 60°C terminals requires the circuit conductors to be sized not smaller than 6 AWG, in accordance with the 60°C ampacity listed in Table 310.16. An 8 THHN insulated conductor has a 90°C ampacity of 55A in a dry location, but 8 AWG can't be used for this circuit because the conductor's operating temperature at full-load ampacity (50A) will be near 90°C, which is well in excess of the 60°C terminal rating.

▶ Terminal Rated 60°C [110.14(C)(1)(a)(2)]

Question: *What size THHN conductor is required for a 50A circuit where the terminals are not marked with a temperature rating?* Figure 6–4

(a) 10 AWG *(b) 8 AWG* *(c) 6 AWG* *(d) 4 AWG*

Answer: *(c) 6 AWG*

► **10-Foot Feeder Tap Example 1**

Question: *Using the 10-ft tap rule, what are the minimum size conductors required to feed the 200A tap?*

(a) 3 AWG (b) 1/0 AWG (c) 3/0 AWG (d) 250 kcmil

Answer: *(c) 3/0 AWG*

3/0 AWG is rated 200A at 75°C, and is greater than 10 percent of the ampacity of the 400A overcurrent device [Table 310.16].

► **10-Foot Feeder Tap Example 2**

Question: *Using the 10-ft tap rule, what are the minimum size conductors required to feed the 150A tap?*

(a) 3 AWG (b) 1/0 AWG (c) 3/0 AWG (d) 250 kcmil

Answer: *(b) 1/0 AWG*

1/0 AWG is rated 150A at 75°C, and is greater than 10 percent of the ampacity of the 400A overcurrent device [Table 310.16].

► **10-Foot Feeder Tap Example 3**

Question: *Using the 10-ft tap rule, what are the minimum size conductors required to feed the 100A tap?*

(a) 3 AWG (b) 1/0 AWG (c) 3/0 AWG (d) 250 kcmil

Answer: *(a) 3 AWG*

3 AWG is rated 100A at 75°C, and is greater than 10 percent of the ampacity of the 400A overcurrent device [Table 310.16].

A 400A breaker protects a set of 500 kcmil feeder conductors. There are three taps fed from the 500 kcmil feeders that supply disconnects with 200A, 150A, and 30A overcurrent devices.

► **10-Foot Feeder Tap Example 4**

Question: *Using the 10-ft tap rule, what are the minimum size conductors required to feed the 30A tap?*

(a) 12 AWG (b) 8 AWG (c) 1/0 AWG (d) 3/0 AWG

Answer: *(b) 8 AWG*

(continued in next column)

8 AWG is rated 50A at 75°C, and is greater than 10 percent of the ampacity of the 400A overcurrent device [Table 310.16]. Anything smaller than 8 AWG can't be used, as it will have an ampacity of less than 10 percent of 380A (38A) in the 75°C column.

(2) 25-Foot Feeder Tap. Feeder tap conductors up to 25 ft long are permitted without overcurrent protection at the tap locaton if installed as follows: Figure 6–30

(1) The ampacity of the tap conductors must not be less than one-third the ampacity of the overcurrent device that protects the feeder.

(2) The tap conductors terminate in a single circuit breaker, or set of fuses rated no more than the tap conductor ampacity in accordance with 310.15 [Table 310.16].

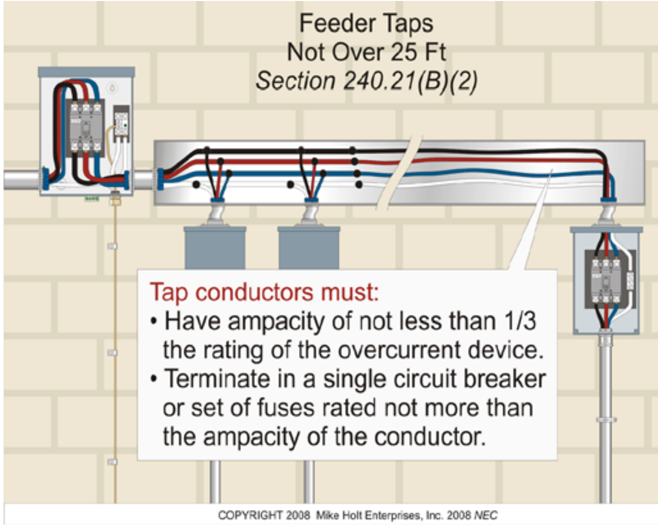


Figure 6–30

(3) The tap conductors must be protected from physical damage by being enclosed in a manner approved by the authority having jurisdiction, such as within a raceway.

25-Foot Feeder Tap

A 400A breaker protects a set of 500 kcmil feeder conductors. There are three taps fed from the 500 kcmil feeders that supply disconnects with 200A, 150A, and 100A overcurrent devices.

The temperature correction factors used to determine the new conductor ampacity are listed at the bottom of Table 310.16.

Table 310.16 Ambient Temperature Correction			
Ambient Temperature °F	Ambient Temperature °C	Correction Factor 75ºC Conductors	Correction Factor 90°C Conductors
70–77°F	21–25°C	1.05	1.04
78–86°F	26–30°C	1.00	1.00
87–95°F	31–35°C	0.94	0.96
96–104°F	36–40°C	0.88	0.91
105–113°F	41–45°C	0.82	0.87
114–122°F	46–-50°C	0.75	0.82
123–131°F	51–-55°C	0.67	0.76
132–140°F	56–60°C	0.58	0.71
141–158°F	61–70°C	0.33	0.58
159–176°F	71–80°C		0.41

Author's Comment: When correcting conductor ampacity for elevated ambient temperature, the correction factor used for THHN/THWN conductors is based on the 90°C rating of the conductor in a dry location and the 75°C rating of the conductor in a wet location, based on the conductor ampacity listed in Table 310.16 [110.14(C)].

The following formula can be used to determine the conductor's new ampacity when the ambient temperature is not 86ºF (30ºC). Figure 6–47

◆ **Corrected Conductor Ampacity—Ambient Temperature Correction Formula**

Corrected Ampacity = Table 310.16 Ampacity x Ambient Temperature Correction Factor

Author's Comment: When different ampacities apply to a conductor length, the higher ampacity can be used for the entire circuit if the reduced ampacity length isn't in excess of 10 ft and its length doesn't exceed 10 percent of the length of the part of the circuit with the higher ampacity [310.15(A)(2) Ex].

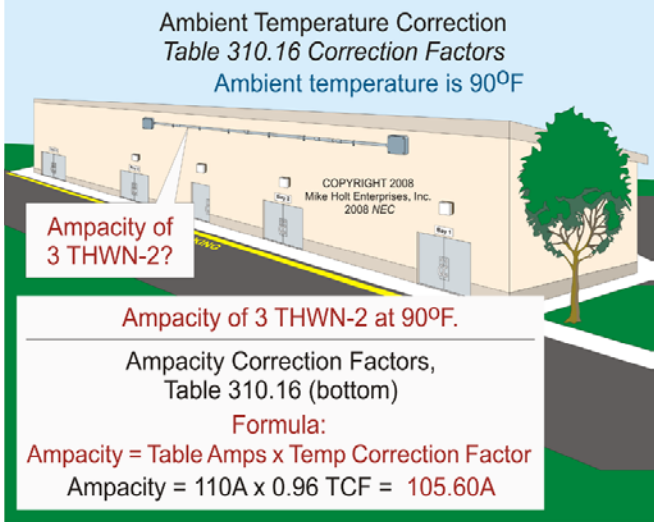


Figure 6–47

▶ **Ambient Temperature Below 86ºF**

Question: *What is the ampacity of 12 THHN when installed in a location that has an ambient temperature of 70ºF?* Figure 6–48

(a) 20A *(b) 25A* *(c) 31A* *(d) 35A*

• ***Answer:*** *(c) 31A*

Corrected Ampacity = Table 310.16 Ampacity x Ambient Temperature Correction Factor

Table 310.16 ampacity for 12 THHN installed in a dry location is 30A at 90ºC.

Temperature Correction Factor for a 90ºC conductor installed in an ambient temperature of 70ºF is 1.04.

Corrected Ampacity = 30A x 1.04 = 31.20A

Note: Ampacity increases when the ambient temperature is less than 86ºF (30ºC).

Author's Comment: 110.14(C)(1)(a) tells us that terminals are rated 60ºC for equipment rated 100A or less unless marked 75ºC. In real life, most terminals are now rated 75ºC, so in this unit, we'll assume all motors are rated 75ºC unless specified 60ºC. For exam purposes, read the problem carefully to be certain you know what terminal temperature rating the exam question specifies. If unspecified, use the rules of 110.14(C).

▶ Motor Branch-Circuit Conductors

Question: *What size branch-circuit conductors are required for a 7½ hp, three-phase, 230V motor?* Figure 7–6

(a) 14 AWG (b) 12 AWG (c) 10 AWG (d) 8 AWG

Answer: *(c) 10 AWG*

Motor FLC – Table 430.248:
7 ½ hp, 230V, three-phase FLC = 22A

The conductor is sized no less than 125 percent of motor FLC:
22A x 1.25 = 27.50A, Table 310.16, 10 AWG rated 35A at 75ºC

Note: The minimum size conductor permitted for building wiring is 14 AWG [310.5]; however, some local codes and many industrial facilities have requirements that 12 AWG be used as the smallest branch-circuit conductor.

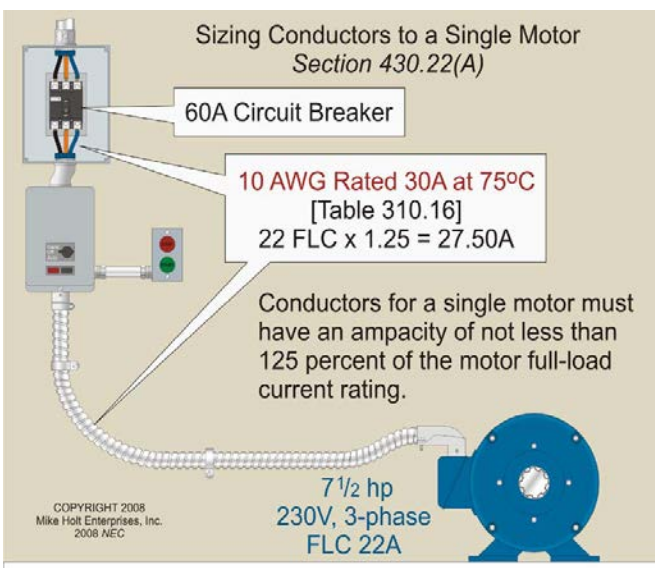


Figure 7–6

Author's Comment: The motor full-load current (FLC) is from the *Code* Tables [430.6(A)(1)] which isn't the same thing as the motor full-load amperes (FLA), which is the motor's nameplate rating [430.6(A)(2)].

7.5 Feeder Conductor Size [430.24]

Conductors that supply several motors must have an ampacity of not less than:

(1) 125 percent of the highest rated motor FLC [430.17], plus

(2) The sum of the FLCs of the other motors (on the same line). The FLC is found using the *NEC* Tables [430.6(A)(1)].

Author's Comment: The highest rated motor is based on the motor with the highest full-load current [430.17]. The "other motors in the group" value (on the same line) is determined by balancing the motors' FLCs on the feeder being sized, then selecting the line that has the highest rated motor on it (refer to Section 7.3 and Figure 7–4).

▶ Feeder Conductor Size

Question: *What size feeder conductor is required for two 7½ hp, three-phase, 230V motors? The terminals are rated for 75ºC.* Figure7– 7

(a) 40A (b) 50A (c) 60A (d) 76A

Answer: *(b) 50A*

(22A x 1.25) + 22A = 49.50A

Note: An 8 AWG conductor is rated 50A at 75ºC [Table 310.16].

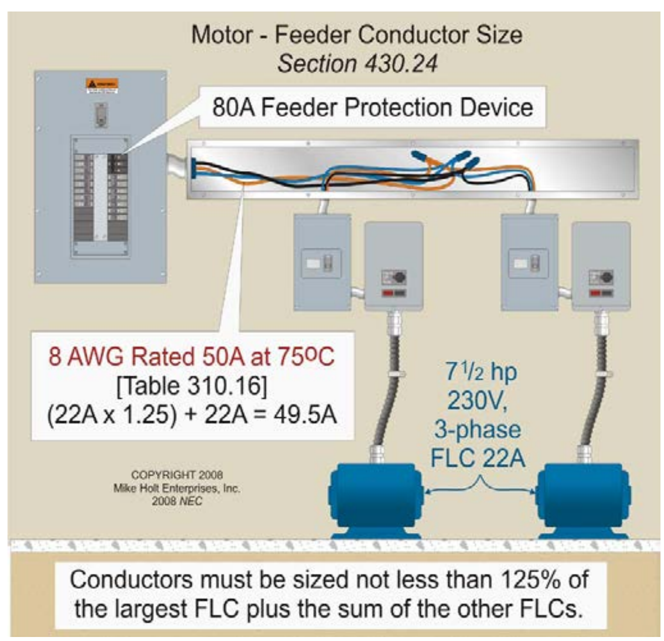


Figure 7–7

with the standard rating of overcurrent devices as listed in 240.6(A), the next higher overcurrent device can be installed [430.52(C)(1) Ex 1].

Overload Protection [430.32(A)]

Overload protection is sized based on the motor nameplate rating.

▶ Branch Circuit Summary Example 1

Question: *If an inverse time circuit breaker is used for short-circuit and ground-fault protection, what size circuit breaker and conductor is required for a 5 hp, 230V, single-phase motor having a nameplate current rating of 26A?* **Figure 7–22**

(a) 10 AWG, 50A breaker *(b) 10 AWG, 60A breaker*
(c) 10 AWG, 70A breaker *(d) 8 AWG, 80A breaker*

Answer: *(c) 10 AWG, 70A breaker*

Motor FLC = 28A [Table 430.248].

Conductors: 28A x 1.25 = 35A. 10AWG is rated 35A at 75°C [Table 310.16]

Circuit breaker: 28A x 2.50 = 70A [Table 430.52]

Overload Protection: 26A x 1.15 = 29.90 [430.32]

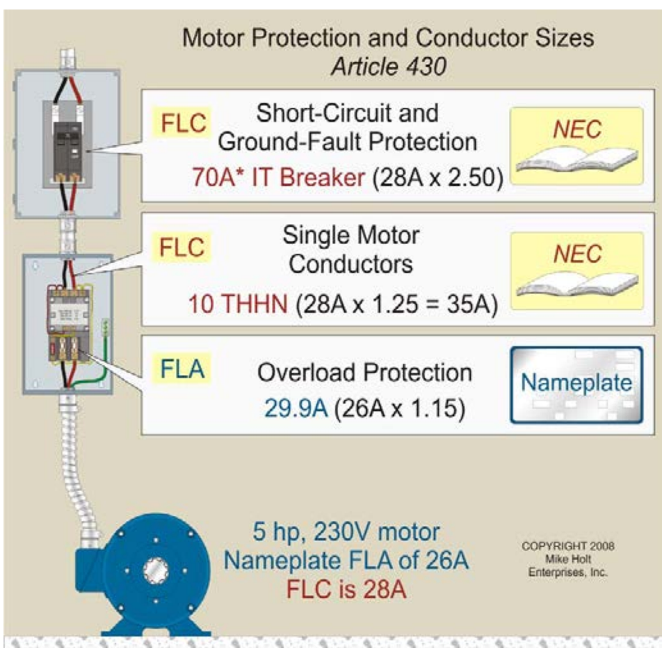


Figure 7–22

Single Overcurrent Device [430.55]

A motor can be protected against overload, short circuit, and ground faults by a single overcurrent device sized to the overload requirements contained in 430.32.

▶ Branch Circuit Summary Example 2

Question: *What size dual-element fuse is permitted to protect a 5 hp, 230V, single-phase motor with a service factor of 1.15 and a nameplate current rating of 28A from overloads as well as short-circuits and ground-faults?* **Figure 7–23**

(a) 20A *(b) 25A* *(c) 30A* *(d) 35A*

Answer: *(d) 35A*

Overload Protection [430.32(A)(1) and 430.55]
28A x 1.25 = 35A

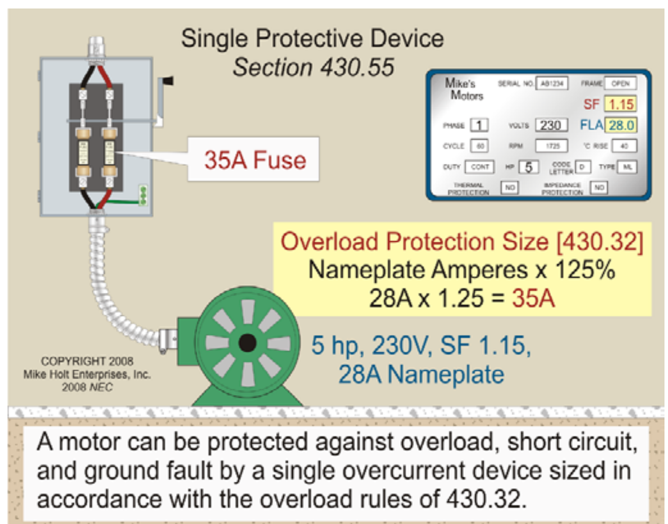


Figure 7–23

▶ Conductor Resistance Copper

Question: *What is the dc resistance of 200 ft of 6 AWG copper?* Figure 8–5

(a) 0.21 ohms	*(b) 0.29 ohms*
(c) 0.49 ohms	*(d) 0.098 ohms*

Answer: *(d) 0.098 ohms*

The dc resistance of 6 AWG copper 1,000 ft long is 0.491 ohms [Chapter 9, Table 8].

The dc resistance of 420 ft is:
(0.491 ohms/1,000 ft) x 200 ft = 0.0982 ohms

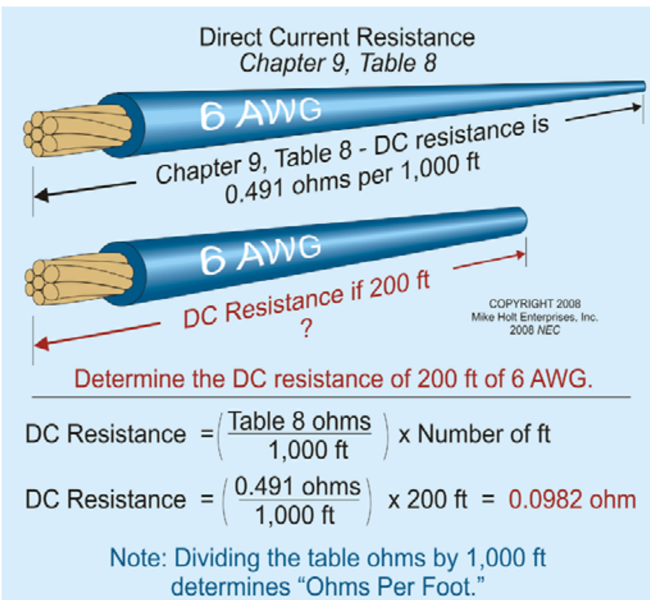


Figure 8–5

▶ Conductor Resistance Aluminum

Question: *What is the resistance of 200 ft of 1/0 AWG aluminum?* Figure 8–6

(a) 0.04 ohms	*(b) 0.29 ohms*
(c) 0.60 ohms	*(d) 0.72 ohms*

Answer: *(a) 0.04 ohms*

The resistance of 1/0 AWG aluminum 1,000 ft long is 0.201 ohms [Chapter 9, Table 8].

The resistance of 200 ft is:
(0.201 ohms/1,000 ft) x 200 ft = 0.04 ohms

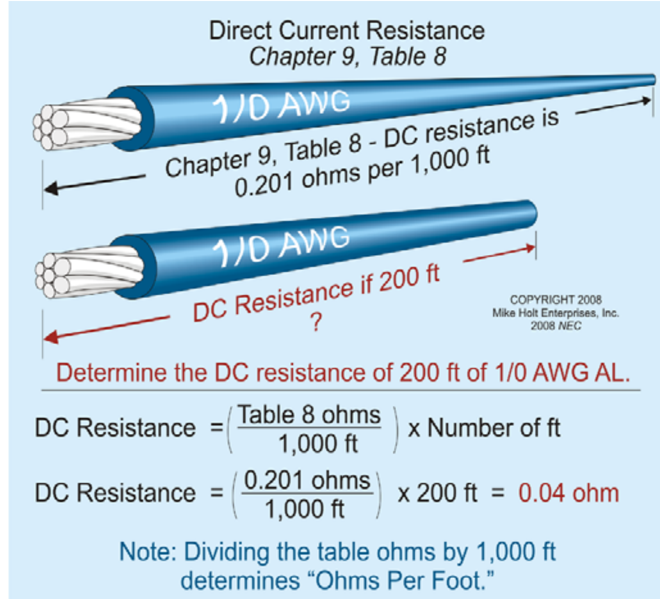


Figure 8–6

8.3 Conductor Resistance—Alternating-Current Circuits

In dc circuits, the only property that opposes the flow of electrons is resistance. In ac circuits, the expanding and collapsing magnetic field within the conductor induces an electromotive force that opposes the flow of the alternating current. This opposition to the flow of ac is called inductive reactance.

In addition, ac flowing through a conductor generates small, erratic, independent currents called eddy currents. Figure 8–7 Eddy currents are strongest in the center of the conductors and repel the flowing electrons toward the conductor surface. This is known as skin effect. Figure 8–8

Because of skin effect, the effective cross-sectional area of an ac conductor is reduced, which results in an increased opposition to current flow. The total opposition to the movement of electrons in an ac circuit (resistance plus inductive reactance plus skin effect) is called impedance.

8.4 Alternating-Current Resistance

An alternating-current conductor's opposition to current flow (resistance and reactance) is listed in Chapter 9, Table 9 of the *NEC*. The total opposition to current flow in an ac circuit is called impedance and depends on the conductor mate-

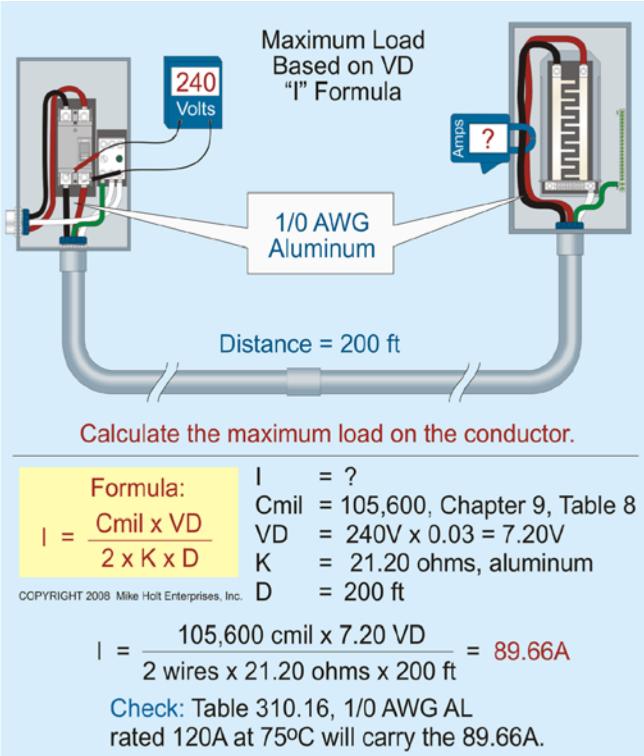


Figure 8–25

▶ Maximum Load—Three-Phase

Question: *What is the maximum recommended load that should be placed on 1 AWG copper conductors in an aluminum raceway to a panelboard located 150 ft from a 208V, three-phase power source so the NEC recommendation for voltage drop isn't exceeded?* Figure 8–26

(a) 155A *(b) 190A* *(c) 210A* *(d) 240A*

Answer: *(a) 155A*

$I = (Cmil \times E_{vd})/(1.732 \times K \times D)$

Cmil = 83,690 (1 AWG) [Chapter 9, Table 8]

E_{vd} *= 208V x 0.03*

E_{vd} *= 6.24V*

K = 12.90 ohms, copper

D = 150 ft

I = (83,690 cmils x 6.24V)/(1.732 x 12.90 x 150 ft)

I = 155.80A

Note: The maximum load of 155.80A limits the voltage drop to no more than 3 percent. When working this type of problem, don't lose sight of other Code requirements. Table 310.16 must also be consulted for the maximum ampacity permitted on 1 AWG at 75ºC, which is 130A, so 130A is the working limit for this circuit [110.14(C) and Table 310.16].

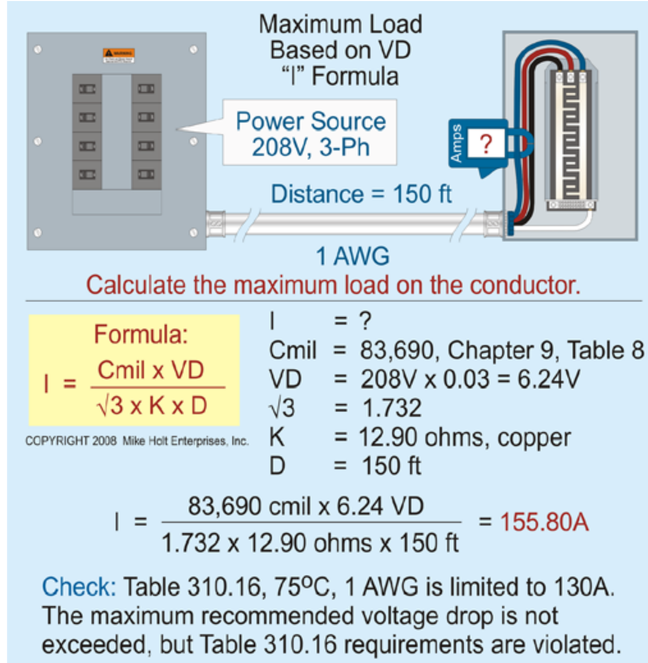


Figure 8–26

8.12 Fire Pump Motor Circuits

Power Wiring [695.6]

(C) Conductor Size.

(1) Fire Pump Motors and Other Equipment. Conductors supplying fire pump motors and accessory equipment must be sized no less than 125 percent of the sum of the motor full-load current as listed in Tables 430.248 or 430.250, plus 100 percent of the ampere rating of the fire pump's accessory equipment.

(2) Fire Pump Motors Only. Conductors supplying a single fire pump motor must be sized to the requirements of 430.22.

Author's Comment: This means that the branch-circuit conductors to a single fire pump motor must have an ampere rating of at least 125 percent of the fire pump motor full-load current (FLC), as listed in Table 430.248 or 430.250.

33. •_____ equipment such as computers, laser printers, copy machines, etc., can suddenly power down because of reduced voltage, resulting in data losses.

(a) Inductive
(b) Electronic
(c) Resistive
(d) all of these

34. When a conductor resistance causes the voltage to be dropped below an acceptable point, the conductor size should be increased.

(a) True
(b) False

35. How can conductor voltage drop be reduced?

(a) Reduce the conductor resistance.
(b) Increase the conductor size.
(c) Decrease the conductor length.
(d) all of these

36. If the branch-circuit supply voltage is 208V, the maximum recommended voltage drop of the circuit should not be more than _____.

(a) 3.60V
(b) 6.24V
(c) 6.90V
(d) 7.20V

37. If the feeder supply voltage is 240V, the maximum recommended voltage drop of the feeder should not be more than _____.

(a) 3.60V
(b) 6.24V
(c) 6.90V
(d) 7.20V

8.7 Determining Circuit Conductors' Voltage Drop—Ohm's Law Method

38. What is the voltage drop of two 12 AWG conductors supplying a 12A continuous load?

Note: The continuous load is located 100 ft from the power supply.

(a) 3.20V
(b) 4V
(c) 4.76V
(d) 12.80V

8.8 Determining Circuit Conductors' Voltage Drop—Formula Method

39. A 240V, 24A, single-phase load is located 160 ft from the panelboard. The load is wired with 10 AWG. What is the approximate voltage drop of the branch-circuit conductors?

(a) 3.20V
(b) 4.25V
(c) 5.90V
(d) 9.50V

40. A 100A, three-phase load is located 100 ft from the panelboard and is wired with 1 AWG aluminum. What is the approximate voltage drop of the circuit conductors?

(a) 3V
(b) 3.50V
(c) 4.40V
(d) 5V

8.9 Sizing Conductors to Prevent Excessive Voltage Drop

41. A single-phase, 5 hp motor is located 110 ft from a panelboard in a dry location. The nameplate indicates that the voltage is 115V and the FLA is 52A. What size conductor is required?

Note: Apply the NEC recommended voltage-drop limit for this branch circuit.

(a) 10 AWG
(b) 8 AWG
(c) 6 AWG
(d) 3 AWG

42. •A single-phase, 5 hp motor is located 110 ft from a panelboard. The nameplate indicates that the voltage is 230V and the FLA is 26A. What size conductor is required?

Note: Apply the NEC recommended voltage-drop limits.

(a) 10 AWG
(b) 8 AWG
(c) 6 AWG
(d) 4 AWG

Total Appliance Connected Load = Load Per Unit x Number of Units
Total Appliance Connected Load = 24,400 VA x 20 units
Total Appliance Connected Load = 488,000 VA

Step c: Compare the Air-Conditioning versus Heat Load:

A/C VA = 240V x 17A
A/C VA Load = 4,080, (omit) [220.60]

Heat Load = VA x Number of Units
Heat = 5,000 VA x 20 Units
Heat = 100,000 VA

Step 2: Total Connected Loads

General Lighting, Receptacle	*180,000 VA*
Appliances Connected Load	*488,000 VA*
Heat	*+100,000 VA*
Total Connected Load	*768,000 VA*

Total Calculated Load = Total Connected Load x Demand Factor [Table 220.84]
Total Calculated Load = 768,000 VA x 0.38 [Table 220.84]
Total Calculated Load = 291,840 VA

Step 3: Service Conductor Size

I = VA/E
I = 291,840 VA/240V
I = 1,216A

Note: The calculated load is above 1,200A, so will require a 1,600A service size [240.6(A)]. For conductors sized above 800A, we are not allowed to round up to the next size overcurrent device [240.4(C)] so the conductors must be have an ampacity of at least 1,600A.

1,600A/4 = 400A minimum conductor ampacity if paralleled in four raceways. Feeder/Service Conductors: Parallel 600 kcmil each for four parallel conductors, rated 420A in the 75°C Column of Table 310.16

When do you use the standard method versus the optional method? For the purpose of exam preparation, always use the standard load calculation unless the question specifies the optional method. In the field, you'll probably want to use the optional method because it's faster and easier to calculate.

feeder/service conductor must be sized at 125 percent of the continuous load [215.2(A)(1) and 230.42].

► **Sign Calculated Load Example**

Question: *What is the feeder/service conductor calculated load for one electric sign?* Figure 11–17

(a) 1,200 VA (b) 1,500 VA (c) 1,920 VA (d) 2,400 VA

Answer: *(b) 1,500 VA*

Feeder/Service Calculated Load = 1,200 VA x 1.25
Feeder/Service Calculated Load = 1,500 VA

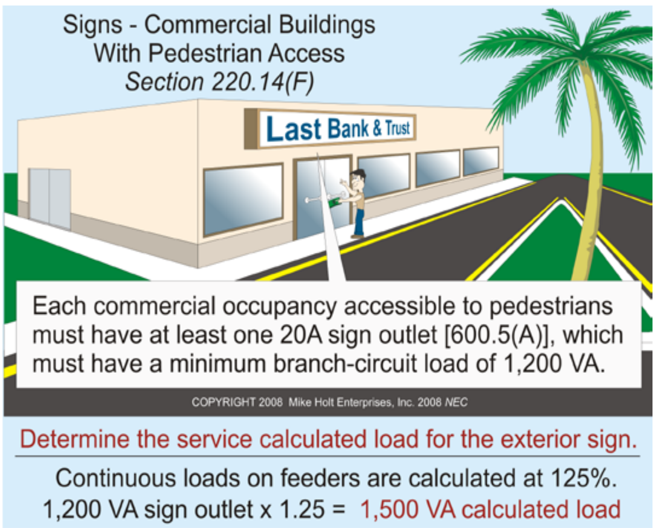


Figure 11–17

PART B—EXAMPLES

11.13 Bank/Office Building Example

Determine the feeder/service calculated load for an office building/bank with the loads listed in Figure 11–18.

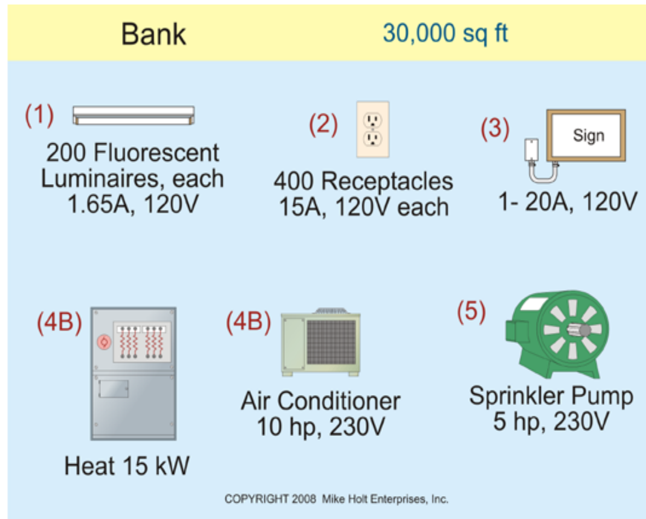


Figure 11–18

Determine the feeder/service calculated load:

Bold indicates neutral load. [215.2(A)(1) Ex 2].

Step 1a: Lighting [Table 220.12]
General Lighting = 30,000 sq ft x 3.50 VA
General Lighting = **105,000 VA**
General Lighting Calculated Load = 105,000 VA x 1.25 **131,250 VA**

Step 1b: Actual Lighting
Actual Lighting Connected Load = 200 units x 120V x 1.65A
Actual Lighting Connected Load = 39,600 VA
Actual Lighting Calculated Load = 39,600 VA x 1.25 49,500 VA (omit)

Neutral Amperes: The neutral conductor is permitted to be reduced according to the requirements of 220.61(B)(2) for that portion of the unbalanced load that exceeds 200A. Since this system is a 120/240V, single-phase system, we're permitted to reduce the neutral by multiplying the portion that exceeds 200A by 70 percent.

Neutral Conductor:

I = VA/E
I = 147,200 VA/240V
I = 613A

220.61(B)(2) allows reduction of the neutral load over 200A to 70%

First 200A at 100%	200A	x 1.00	200A
Remainder at 70%	413A	x 0.70	+ 289A
			489A

The service conductors and overcurrent device must be sized no less than 820A, and the neutral conductor must be sized to carry not less than 489A.

Summary Questions

▶ Overcurrent Protection Example

Question: *What size service overcurrent device is required to supply an 820A calculated load?*

(a) 800A (b) 1,000A (c) 1,200A (d) 1,600A

Answer: *(b) 1,000A [240.6(A)]*

▶ Service Ungrounded Conductor Size Example

Question: *What size service conductors are required in each raceway if the conductors are paralleled in four raceways to supply an 820A calculated load?*

(a) 250 kcmil (b) 300 kcmil (c) 350 kcmil (d) 400 kcmil

Answer: *(a) 250 kcmil*

When the overcurrent device is over 800A, the ampacity of the conductors must be equal to, or greater than, the rating of the overcurrent device. In this example, the overcurrent device is 1,000A, so the ampacity of the conductors must be 1,000A or more [240.4(C)].

1,000A/4 raceways = 250A per raceway, sized based on the 75ºC terminal rating [110.14(C)(1)(b)]

250 kcmil rated 255A x 4 = 1,020A [Table 310.16]

▶ Parallel Service Conductors Sizing Example

Question: *What size service conductors are required in each raceway if the conductors are paralleled in three raceways to supply an 820A calculated load?*

(a) 250 kcmil (b) 300 kcmil (c) 350 kcmil (d) 400 kcmil

Answer: *(d) 400 kcmil*

1,000A/3 raceways = 333A for each conductor, if fed by 3 parallel conductors

400 kcmil is rated 335A at 75ºC [Table 310.16].

The neutral service conductor must have an ampacity of not less than 489A and it must not be smaller than 1/0 for paralleling [310.4], and meet the requirements of 250.24(C)(1).

If using three neutral conductors in parallel per phase:

- 489A/3 raceways = 163A
- 2/0AWG is rated 175A at 75ºC [Table 310.16]

▶ Service Neutral Conductor Size Example

Question: *What size neutral service conductor is required in each of the four raceways to supply a 489A calculated neutral load if using four conductors in parallel per phase?*

(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG

Answer: *(a) 1/0 AWG*

The neutral service conductor must have the capacity to carry 489A and be sized no smaller than 1/0 AWG to meet the paralleling requirements of 310.4. [220.61(B)(2)].

489A/4 raceways = 123A; 1 AWG rated 130A at 75ºC [110.14(C)(1)(b), and Table 310.16], but the smallest size conductor permitted for paralleling is 1/0 AWG. The neutral must also be not smaller than called for by Table 250.66, based on the ungrounded conductors in the same raceway [250.24(C)(2)].

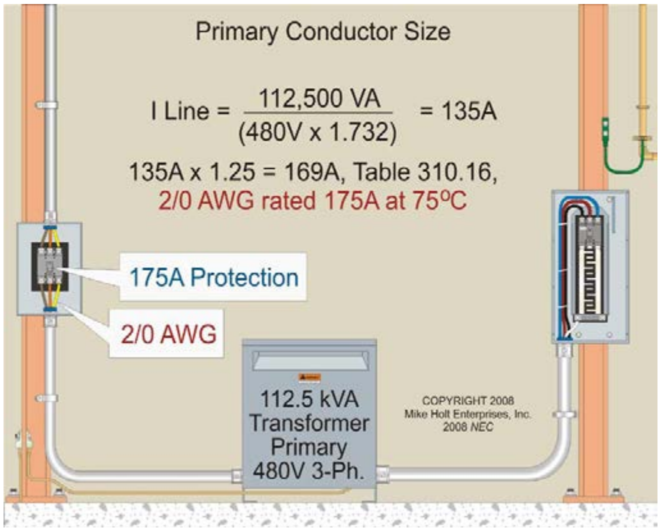


Figure 12–48

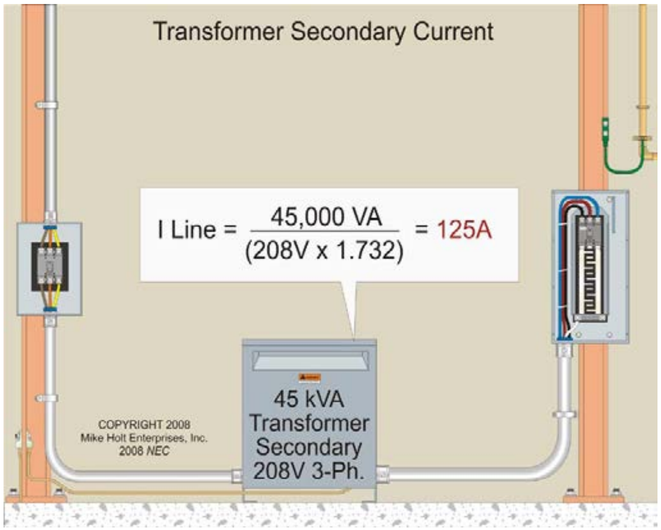


Figure 12–49

Step 1: Determine the rating of the device supplied by the secondary conductors at 125 percent of the secondary rating.

Step 2: Size the secondary conductors so that they have an ampere rating of "not less" than the device rating supplied by the secondary conductors.

▶ Secondary Conductor Sizing Example 1

Question: *What size secondary conductor is required for a 45 kVA, three-phase, 480-120/208V transformer?*

(a) 2 AWG (b) 1 AWG (c) 1/0 AWG (d) 2/0 AWG

Answer: *(d) 2/0 AWG*

Step 1: Determine the secondary current rating. **Figure 12–49**

I = VA/(E x 1.732)
I = 45,000 VA/(208V x 1.732)
I = 125A

Step 2: Size the secondary device rating at 125% of the secondary current rating. **Figure 12–50**

125A x 1.25 = 156A, 175A overcurrent device

Step 3: Size the secondary conductor where it has an ampere rating of "not less" than the rating of the secondary device [240.21(C)(2)].

2/0 AWG rated 175A at 75°C 110.14(C)(1) and Table 310.16].

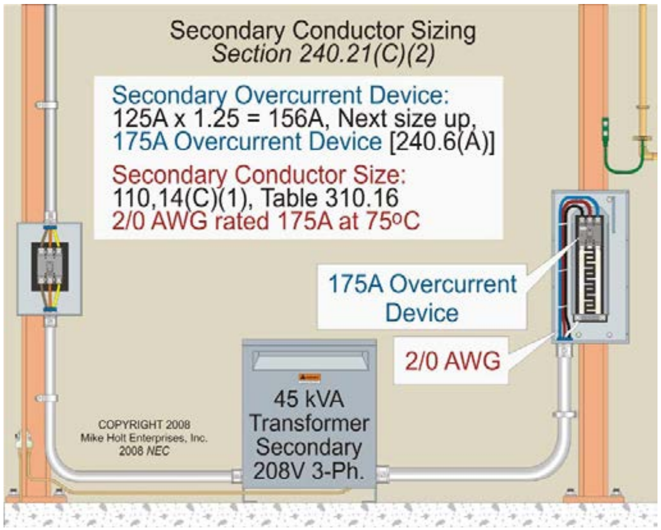


Figure 12–50

▶ Secondary Conductor Sizing Example 2

Question: *What size secondary conductor is required for a 75 kVA, three-phase, 480-120/208V transformer?*

(a) 3/0 AWG (b) 4/0 AWG (c) 350 kcmil (d) 500 kcmil

Answer: *(c) 350 kcmil*

Step 1: Determine the secondary current rating. **Figure 12–51**

I = VA/(E x 1.732)
I = 75,000 VA/(208V x 1.732)
I = 208A

(continued in next column)

Step 2: Size the secondary device rating at 125% of the secondary current rating. Figure 12–52

208A x 1.25 = 260A, round up to a 300A overcurrent device

Step 3: Size the secondary conductor where it has an ampere rating of "not less" than the rating of the secondary device [240.21(C)(2)].

350 kcmil rated 310A at 75°C [110.14(C)(1) and Table 310.16].

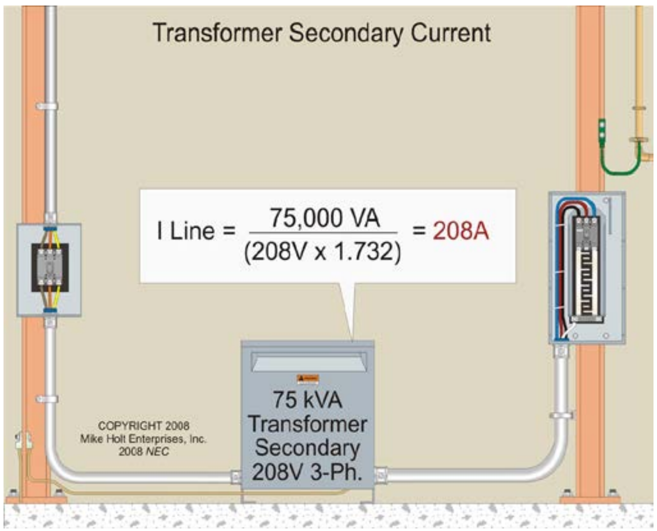


Figure 12–51

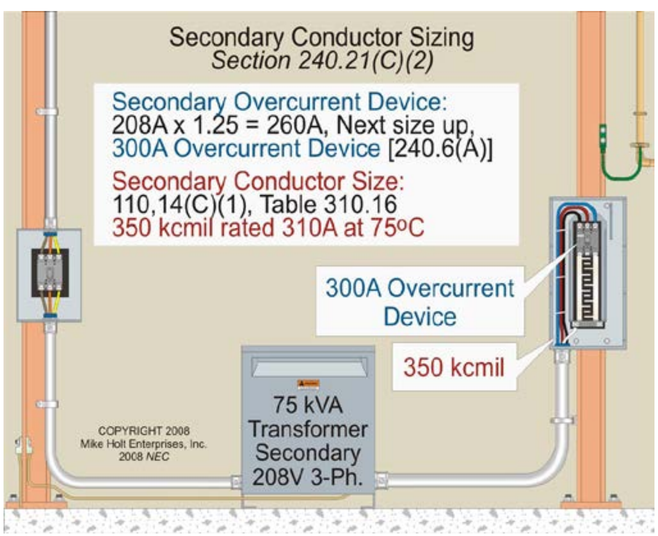


Figure 12–52

Author's Comment: We're allowed to round up to the next size overcurrent device as seen in this example. However, if you don't choose to do so, the secondary can be protected with a 250A overcurrent device and the secondary conductors can be sized at 250 kcmil, which is rated 255A at 75ºC. Figure 12–53

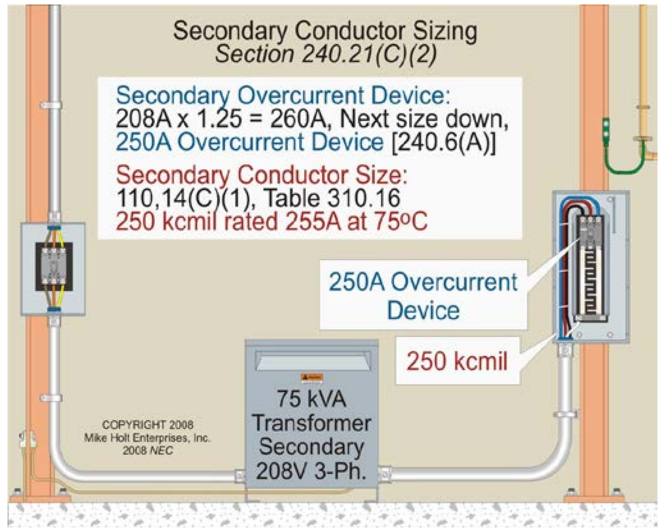


Figure 12–53

► Secondary Conductor Sizing Example 3

Question: *What size secondary conductor is required for a 112.50 kVA, three-phase, 480-120/208V transformer?*

(a) Two parallel 1/0 AWG *(b) Two parallel 2/0 AWG*
(c) Two parallel 3/0 AWG *(d) Two parallel 4/0 AWG*

Answer: *(c) Two parallel 3/0 AWG*

Step 1: Determine the secondary current rating. Figure 12–54

I = VA/(E x 1.732)
I = 112.500 VA/(208V x 1.732)
I = 313A

Step 2: Size the secondary device rating at 125% of the secondary current rating. Figure 12–55

313A x 1.25 = 391A, 400A overcurrent device

Step 3: Size the secondary conductors where they have an ampere rating of "not less" than the rating of the secondary device [240.21(C)(2)].

Two sets of parallel 3/0 AWG conductors, each rated 200A at 75°C [110.14(C)(1) and Table 310.16]

36. Unused openings other than those intended for the operation of equipment, intended for mounting purposes, or permitted as part of the design for listed equipment shall be _____.

(a) filled with cable clamps or connectors only
(b) taped over with electrical tape
(c) repaired only by welding or brazing in a metal slug
(d) effectively closed to afford protection substantially equivalent to the wall of the equipment

37. Many terminations and equipment are marked with _____.

(a) an etching tool
(b) a removable label
(c) a tightening torque
(d) the manufacturer's initials

38. Conductor ampacity shall be determined using the _____ column of Table 310.16 for circuits rated 100A or less or marked for 14 AWG through 1 AWG conductors, unless the equipment terminals are listed for use with conductors that have higher temperature ratings.

(a) 30°C
(b) 60°C
(c) 75°C
(d) 90°C

39. For circuits rated 100A or less, when the equipment terminals are listed for use with 75°C conductors, the _____ column of Table 310.16 shall be used to determine the ampacity of THHN conductors installed.

(a) 30°C
(b) 60°C
(c) 75°C
(d) 90°C

40. Conductors shall have their ampacity determined using the _____ column of Table 310.16 for circuits rated over 100A, or marked for conductors larger than 1 AWG, unless the equipment terminals are listed for use with higher temperature rated conductors.

(a) 30°C
(b) 60°C
(c) 75°C
(d) 90°C

41. On a 4-wire, delta-connected system where the midpoint of one phase winding is grounded, the conductor having the higher phase voltage to ground shall be durably and permanently marked by an outer finish that is _____ in color.

(a) black
(b) red
(c) blue
(d) orange

42. Electrical equipment such as switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers in commercial and industrial occupancies that are likely to require _____ while energized shall be field-marked to warn qualified persons of the danger associated with an arc flash.

(a) examination
(b) adjustment
(c) servicing or maintenance
(d) any of these

43. The term rainproof is typically used in conjunction with Enclosure-Type Number _____.

(a) 3
(b) 3R
(c) 3RX
(d) b and c

44. The required working space for access to live parts operating at 300 volts-to-ground, where there are exposed live parts on one side and grounded parts on the other side, is _____.

(a) 3 ft
(b) 3½ ft
(c) 4 ft
(d) 4½ ft

45. The dimension of working space for access to live parts operating at 300V, nominal-to-ground, where there are exposed live parts on both sides of the workspace is _____ according to Table 110.26(A)(1).

(a) 3 ft
(b) 3½ ft
(c) 4 ft
(d) 4½ ft

9. A _____ is an accommodation with two or more contiguous rooms comprising a compartment that provides living, sleeping, sanitary, and storage facilities.

(a) guest room
(b) guest suite
(c) dwelling unit
(d) single-family dwelling

10. All 15A and 20A, 125V receptacles installed in bathrooms of _____ shall have ground-fault circuit-interrupter (GFCI) protection for personnel.

(a) guest rooms in hotels/motels
(b) dwelling units
(c) office buildings
(d) all of these

11. A clothes closet is defined as a _____ room or space intended primarily for storage of garments and apparel.

(a) habitable
(b) nonhabitable
(c) conditioned
(d) finished

12. GFCI protection shall be provided for all 15A and 20A, 125V receptacles in dwelling unit accessory buildings that have a floor located at or below grade level not intended as _____ and limited to storage areas, work areas, or similar use.

(a) habitable rooms
(b) finished space
(c) a or b
(d) none of these

13. Article 200 contains the requirements for _____.

(a) identification of terminals
(b) grounded conductors in premises wiring systems
(c) identification of grounded conductors
(d) all of these

14. Acceptable to the authority having jurisdiction means _____.

(a) identified
(b) listed
(c) approved
(d) labeled

15. All 15A and 20A, 125V receptacles _____ of commercial occupancies shall have GFCI protection.

(a) in bathrooms
(b) on rooftops
(c) in kitchens
(d) all of these

16. Conductor sizes are expressed in American Wire Gage (AWG) or _____.

(a) inches
(b) circular mils
(c) square inches
(d) cubic inches

17. Cables are considered _____ if rendered inaccessible by the structure or finish of the building.

(a) inaccessible
(b) concealed
(c) hidden
(d) enclosed

18. Outline lighting may include an arrangement of _____ to outline or call attention to the shape of a building.

(a) incandescent lamps
(b) electric-discharge lighting
(c) electrically powered light sources
(d) any of these

19. Concrete, brick, or tile walls are considered _____, as it applies to working space requirements.

(a) inconsequential
(b) in the way
(c) grounded
(d) none of these

20. A branch circuit that supplies only one utilization equipment is a(n) _____ branch circuit.

(a) individual
(b) general-purpose
(c) isolated
(d) special-purpose

57. Where six current-carrying conductors are run in the same conduit or cable, the ampacity of each conductor shall be adjusted by a factor of _____ percent.

(a) 40
(b) 60
(c) 80
(d) 90

58. Conductor derating factors shall not apply to conductors in nipples having a length not exceeding _____

(a) 12 in.
(b) 24 in.
(c) 36 in.
(d) 48 in.

59. The ampacity adjustment factors of Table 310.15(B)(2)(a) does not apply to Type AC or Type MC cable without an overall outer jacket, if which of the following conditions are met?

(a) Each cable has not more than three current-carrying conductors.
(b) The conductors are 12 AWG copper.
(c) No more than 20 current-carrying conductors are bundled or stacked.
(d) all of these

60. Where conductors or cables are installed in conduits exposed to direct sunlight on or above rooftops, the ambient temperature shall be increased by _____ where the conduits are less than ½ in. from the rooftop.

(a) 30°F
(b) 40°F
(c) 50°F
(d) 60°F

61. A _____ conductor that carries only the unbalanced current from other conductors of the same circuit shall not be required to be counted when applying the provisions of 310.15(B)(2)(a).

(a) neutral
(b) grounded
(c) grounding
(d) none of these

62. Surface-type cabinets, cutout boxes, and meter socket enclosures in damp or wet locations shall be mounted so there is at least _____ airspace between the enclosure and the wall or supporting surface.

(a) 1⁄16 in.
(b) ¼ in.
(c) 1¼ in.
(d) 6 in.

63. In walls constructed of wood or other _____ material, electrical cabinets shall be flush with the finished surface or project therefrom.

(a) nonconductive
(b) porous
(c) fibrous
(d) combustible

64. Noncombustible surfaces that are broken or incomplete shall be repaired so there will be no gaps or open spaces greater than _____ at the edge of a cabinet or cutout box employing a flush-type cover.

(a) 1⁄32 in.
(b) 1⁄16 in.
(c) 1⁄8 in.
(d) ¼ in.

65. Openings in cabinets, cutout boxes, and meter socket enclosures through which conductors enter shall be _____.

(a) adequately closed
(b) made using concentric knockouts only
(c) centered in the cabinet wall
(d) identified

66. Nonmetallic cables can enter the top of surface-mounted cabinets, cutout boxes, and meter socket enclosures through nonflexible raceways not less than 18 in. or more than _____ ft in length if all of the required conditions are met.

(a) 3
(b) 10
(c) 25
(d) 100

10. The maximum number of conductors permitted in any surface raceway shall be _____.

(a) no more than 30 percent of the inside diameter
(b) no greater than the number for which it was designed
(c) no more than 75 percent of the cross-sectional area
(d) that which is permitted in Table 312.6(A)

11. Surface metal raceways shall be secured and supported at intervals _____.

(a) in accordance with the manufacturer's installation instructions
(b) appropriate for the building design
(c) not exceeding 4 ft
(d) not exceeding 8 ft

12. The conductors, including splices and taps, in a metal surface raceway having a removable cover shall not fill the raceway to more than _____ percent of its cross-sectional area at that point.

(a) 38
(b) 40
(c) 53
(d) 75

13. Surface metal raceway enclosures providing a transition from other wiring methods shall have a means for connecting a(n) _____.

(a) grounded conductor
(b) ungrounded conductor
(c) equipment grounding conductor
(d) all of these

14. Surface nonmetallic raceways shall be permitted _____.

(a) in dry locations
(b) where concealed
(c) in hoistways
(d) all of these

15. The maximum number of conductors permitted in any surface nonmetallic raceway shall be _____.

(a) no more than 30 percent of the inside diameter
(b) no greater than the number for which it was designed
(c) no more than 75 percent of the cross-sectional area
(d) that which is permitted in Table 312.6(A)

16. The conductors, including splices and taps, in a surface nonmetallic raceways having a cover capable of being opened in place, shall not fill the raceway to more than _____ percent of its cross-sectional area at that point.

(a) 38
(b) 40
(c) 53
(d) 75

17. Cable trays can be used as a support system for _____.

(a) service conductors, feeders, and branch circuits
(b) communications circuits
(c) control and signaling circuits
(d) all of these

18. Cable trays and their associated fittings shall be _____ for the intended use.

(a) listed
(b) approved
(c) identified
(d) none of these

19. Any of the following wiring methods can be installed in a cable tray:

(a) metal raceways
(b) nonmetallic raceways
(c) cables
(d) all of these

20. Cable tray systems shall not be used _____.

(a) in hoistways
(b) where subject to severe physical damage
(c) in hazardous (classified) locations
(d) a and b

21. Supports for cable trays shall be provided in accordance with _____.

(a) installation instructions
(b) the *NEC*
(c) listing requirements
(d) all of these

22. Cable trays shall be _____ except as permitted by 392.6(G).

(a) exposed
(b) accessible
(c) concealed
(d) a and b

57. Receptacles mounted in boxes flush with the finished surface or projecting beyond it shall be installed so that the mounting yoke or strap of the receptacle is _____.

(a) held rigidly against the box or box cover
(b) mounted behind the wall surface
(c) held rigidly at the finished surface
(d) none of these

58. Receptacles in countertops and similar work surfaces in dwelling units shall not be installed _____.

(a) in the sides of cabinets
(b) in a face-up position
(c) on GFCI circuits
(d) on the kitchen small-appliance circuit

59. Receptacles shall not be grouped or ganged in enclosures unless the voltage between adjacent devices does not exceed _____.

(a) 100V
(b) 200V
(c) 300V
(d) 400V

60. An outdoor receptacle in a location protected from the weather, or in another damp location, shall be installed in an enclosure that is weatherproof when the receptacle is _____.

(a) covered
(b) enclosed
(c) protected
(d) none of these

61. Receptacles installed outdoors, in a location protected from the weather or other damp locations, shall be in an enclosure that is _____ when the receptacle is covered.

(a) raintight
(b) weatherproof
(c) rainproof
(d) weathertight

62. Nonlocking 15A and 20A, 125V and 250V receptacles installed in damp locations shall be listed as _____.

(a) raintight
(b) watertight
(c) weatherproof
(d) weather resistant

63. A receptacle installed in an outlet box flush-mounted in a finished surface in a damp or wet location shall be made weatherproof by means of a weatherproof faceplate assembly that provides a _____ connection between the plate and the finished surface.

(a) sealed
(b) weathertight
(c) sealed and protected
(d) watertight

64. Grounding-type attachment plugs shall be used only with a cord having a(n) _____ conductor.

(a) equipment grounding
(b) isolated
(c) computer circuit
(d) insulated

65. In dwelling units, 125V, 15A and 20A receptacles installed _____ shall be listed as tamper resistant.

(a) in bedrooms
(b) outdoors, above 6 ft 6 in
(c) above counter tops
(d) all areas

66. Each switchboard or panelboard used as service equipment shall be provided with a main bonding jumper within the panelboard, or within one of the sections of the switchboard, for connecting the grounded service conductor on its _____ side to the switchboard or panelboard frame.

(a) load
(b) supply
(c) phase
(d) high-leg

67. In switchboards and panelboards, load terminals for field wiring shall be so located that it is not necessary to reach across or beyond a(n) _____ ungrounded line bus in order to make connections.

(a) insulated
(b) uninsulated
(c) grounded
(d) high impedance

43. The motor disconnecting means for a motor shall _____ whether it is in the open (off) or closed (on) position.

(a) plainly indicate
(b) provide current
(c) be in the upper position
(d) none of these

44. A motor disconnecting means can be a _____.

(a) listed molded case circuit breaker
(b) listed motor-circuit switch rated in horsepower
(c) listed molded case switch
(d) any of these

45. If a motor disconnecting means is a motor-circuit switch, it shall be rated in _____.

(a) horsepower
(b) watts
(c) amperes
(d) locked-rotor current

46. A switch or circuit breaker can be used as both the controller and disconnecting means if it _____.

(a) opens all ungrounded conductors
(b) is protected by an overcurrent device in each ungrounded conductor
(c) is manually operable, or both power and manually operable
(d) all of these

47. The _____ current for a hermetic refrigerant motor-compressor is the current resulting when the motor-compressor is operated at the rated load, rated voltage, and rated frequency of the equipment it serves.

(a) full-load current
(b) nameplate rating
(c) selection current
(d) rated-load current

48. The rules of _____ shall apply to air-conditioning and refrigerating equipment that does not incorporate a hermetic refrigerant motor-compressor.

(a) Article 422
(b) Article 424
(c) Article 430
(d) all of these

49. Equipment such as _____ shall be considered appliances, and the provisions of Article 422 apply in addition to Article 440.

(a) room air conditioners
(b) household refrigerators and freezers
(c) drinking water coolers and beverage dispensers
(d) all of these

50. Short-circuit and ground-fault protection for an individual air-conditioning motor-compressor shall not exceed _____ percent of the motor-compressor rated-load current or branch-circuit protection current, whichever is greater.

(a) 80
(b) 125
(c) 175
(d) 250

51. Branch-circuit conductors supplying a single air-conditioning motor-compressor shall have an ampacity not less than _____ percent of either the motor-compressor rated-load current or the branch-circuit selection current, whichever is greater.

(a) 100
(b) 125
(c) 150
(d) 200

52. Conductors supplying more than one air-conditioning motor-compressor shall have an ampacity not less than the sum of the rated load or branch-circuit current ratings, whichever is larger, of all the air-conditioning motor-compressors plus the full-load currents of any other motors, plus _____ percent of the highest motor or motor compressor rating in the group.

(a) 25
(b) 50
(c) 80
(d) 100

53. The total rating of a cord-and-plug-connected room air conditioner, connected to the same branch circuit which supplies lighting units, other appliances, or general-use receptacles, shall not exceed _____ percent of the branch-circuit rating.

(a) 40
(b) 50
(c) 70
(d) 80

42. Type NM cable shall closely follow the surface of the building finish or running boards when run exposed.

    (a) True
    (b) False

43. Where PVC conduit enters a box, fitting, or other enclosure, a bushing or adapter shall be provided to protect the conductor from abrasion unless the design of the box, fitting, or enclosure affords equivalent protection.

    (a) True
    (b) False

44. ENT is not permitted in hazardous (classified) locations, unless permitted in other articles of the *Code*.

    (a) True
    (b) False

45. Nonmetallic surface metal raceway is a nonmetallic raceway that is intended to be mounted to the surface of a structure, with associated couplings, connectors, boxes, and fittings for the installation of electrical conductors.

    (a) True
    (b) False

46. Snap switches, including dimmer and similar control switches, shall be connected to an equipment grounding conductor and shall provide a means to connect metal faceplates to the equipment grounding conductor, whether or not a metal faceplate is installed.

    (a) True
    (b) False

47. A separate overcurrent device shall not be required for a capacitor connected on the load side of a motor overload protective device.

    (a) True
    (b) False

48. The *Code* covers underground mine installations and self-propelled mobile surface mining machinery and its attendant electrical trailing cable.

    (a) True
    (b) False

49. When breaks occur in dwelling unit kitchen countertop spaces for rangetops, refrigerators or sinks, each countertop surface shall be considered a separate counter space for determining receptacle placement.

    (a) True
    (b) False

50. AC systems of 50V to 1,000V that supply premises wiring systems shall be grounded where the system is three-phase, 4-wire, wye connected with the neutral conductor used as a circuit conductor.

    (a) True
    (b) False

13. Metal equipment racks and enclosures for permanent audio system installations shall be grounded.

    (a) True
    (b) False

14. The 3 VA per-square-foot general lighting load for dwelling units includes general-use receptacles and lighting outlets.

    (a) True
    (b) False

15. Supplementary overcurrent devices used in luminaires or appliances are not required to be readily accessible.

    (a) True
    (b) False

16. Mechanical elements used to terminate a grounding electrode conductor to a grounding electrode shall be accessible.

    (a) True
    (b) False

17. Where circuit conductors are spliced or terminated on equipment within a box, any equipment grounding conductors associated with those circuit conductors shall be connected to the box with devices suitable for the use.

    (a) True
    (b) False

18. Metal faceplates for receptacles shall be grounded.

    (a) True
    (b) False

19. Circuit directories can include labels that depend on transient conditions of occupancy.

    (a) True
    (b) False

20. Lighting track fittings can be equipped with general-purpose receptacles.

    (a) True
    (b) False

21. In Class I locations, the locknut-bushing and double-locknut types of contacts shall not be depended on for bonding purposes.

    (a) True
    (b) False

22. In Class II, Division 1 locations, multiwire branch circuits are not permitted unless a disconnect opens all of the ungrounded circuit conductors simultaneously.

    (a) True
    (b) False

23. The number of conductors in a raceway for permanent audio system installations shall not be limited by the percentage fill specified in Chapter 9, Table 1.

    (a) True
    (b) False

24. Utilities may include entities that are designated or recognized by governmental law or regulation by public service/utility commissions.

    (a) True
    (b) False

25. Some cleaning and lubricating compounds can cause severe deterioration of many plastic materials used for insulating and structural applications in equipment.

    (a) True
    (b) False

26. In other than dwelling units, GFCI protection shall be provided for all outdoor 15A and 20A, 125V receptacles.

    (a) True
    (b) False

27. The grounding electrode conductor for a single separately derived system is used to connect the grounded conductor of the derived system to the grounding electrode.

    (a) True
    (b) False

28. Grounding electrode conductor connections to a concrete-encased or buried grounding electrode shall be accessible.

    (a) True
    (b) False

29. The equipment grounding conductor shall not be required to be larger than the circuit conductors.

    (a) True
    (b) False

13. Optional standby system wiring can occupy the same raceways, cables, boxes, and cabinets with other general wiring.

    (a) True
    (b) False

14. Raceways shall not be used as a means of support for Class 2 or Class 3 cables.

    (a) True
    (b) False

15. Class 2 and Class 3 cable not terminated at equipment and not identified for future use with a tag is considered abandoned.

    (a) True
    (b) False

16. Ground-fault circuit-interrupter protection shall be provided for outlets not exceeding 240V that supply boat hoists installed in dwelling unit locations.

    (a) True
    (b) False

17. A meter disconnect switch located ahead of service equipment must have a short-circuit current rating equal to or greater than the available short-circuit current and be capable of interrupting the load served.

    (a) True
    (b) False

18. Grounding electrode conductor taps from a separately derived system to a common grounding electrode conductor are permitted when a building or structure has multiple separately derived systems, provided that the taps terminate at the same point as the system bonding jumper.

    (a) True
    (b) False

19. Exothermic or irreversible compression connections, together with the mechanical means used to attach to fire-proofed structural metal, shall not be required to be accessible.

    (a) True
    (b) False

20. When determining the number of current-carrying conductors, a grounding or bonding conductor shall not be counted when applying the provisions of 310.15(B)(2)(a) _____.

    (a) True
    (b) False

21. PVC conduit shall be permitted for exposed work where subject to physical damage if identified for such use.

    (a) True
    (b) False

22. Surface metal raceway is a metallic raceway that is intended to be mounted to the surface of a structure, with associated couplings, connectors, boxes, and fittings for the installation of electrical conductors.

    (a) True
    (b) False

23. Fixture wires shall not be used for branch-circuit wiring, except as permitted in other articles of the *Code*.

    (a) True
    (b) False

24. The *NEC* requires a lighting outlet on the wall in clothes closets.

    (a) True
    (b) False

25. Motor controllers and terminals of control circuit devices shall be connected with copper conductors unless identified for use with a different conductor.

    (a) True
    (b) False

26. Portable or transportable equipment with a self-contained power supply, such as battery-operated equipment, could potentially become an ignition source in hazardous (classified) locations.

    (a) True
    (b) False

27. In Class I, Division 1 locations, a multiwire branch circuit can be protected using single-pole breakers.

    (a) True
    (b) False

20. Each vented cell of a battery, as it relates to storage batteries, shall be equipped with _____ that is(are) designed to prevent destruction of the cell due to ignition of gases within the cell by an external spark or flame under normal operating conditions.

(a) pressure relief
(b) a flame arrester
(c) fluid level indicators
(d) none of these

21. Sealing compound shall be used in Type MI cable termination fittings to ____.

(a) preventing the passage of gas or vapor
(b) excluding moisture and other fluids from the cable insulation
(c) limiting a possible explosion
(d) preventing the escape of powder

22. The phase converter disconnecting means shall be _____ and located in sight from the phase converter.

(a) protected from physical damage
(b) readily accessible
(c) easily visible
(d) clearly identified

23. Electric space-heating cables shall not extend beyond the room or area in which they _____.

(a) provide heat
(b) originate
(c) terminate
(d) are connected

24. Constructed, protected, or treated so as to prevent rain from interfering with the successful operation of the apparatus under specified test conditions defines the term _____.

(a) raintight
(b) waterproof
(c) weathertight
(d) rainproof

25. Receptacles, receptacle housings, and self-contained devices used with flat conductor cable systems shall be _____.

(a) rated a minimum of 20A
(b) rated a minimum of 15A
(c) identified for this use
(d) none of these

26. Wiring on luminaire chains and other movable parts shall be _____.

(a) rated for 110°C
(b) stranded
(c) hard-usage rated
(d) none of these

27. When service equipment has ground-fault protection installed, it may be necessary to review the overall wiring system for proper selective overcurrent protection _____.

(a) rating
(b) coordination
(c) devices
(d) none of these

28. In mobile/manufactured homes, portable appliances could be _____, if these appliances can be moved from one place to another in normal use.

(a) refrigerators
(b) range equipment
(c) clothes washers
(d) all of these

29. Fixed electric space-heating equipment shall be installed to provide the _____ spacing between the equipment and adjacent combustible material, unless it is listed for direct contact with combustible material.

(a) required
(b) minimum
(c) maximum
(d) safest

30. Flat conductor cable shall not be installed in _____.

(a) residential buildings
(b) schools
(c) hospitals
(d) any of these

31. An attachment plug and receptacle can serve as the disconnecting means for cord-connected _____.

(a) room air conditioners
(b) household refrigerators and freezers
(c) drinking water coolers and beverage dispensers
(d) all of these