PDH Enterprises, LLC
PO Box 942
Morrisville, NC 27560
(919)208-5296

NEC Motor Calculations

Course #200

This course provides a review of the calculations associated with Article 430 of the National Electrical Code. Students successfully completing this course will be able to demonstrate knowledge of the most common topics and calculations within Article 430.

To receive credit for this course, each student must pass an online multiple choice exam of fifteen (15) questions. A passing score is 70% or better. Completion of this course and successfully passing the exam will qualify the student for **two (2)** hours of continuing education credit. All information necessary to complete the examination will be presented within this course document and within the 2008 version of the National Electrical Code or NEC.

Course Author:

Chris Barrow, PE

Motor calculations are some of the most challenging calculations that are performed when dealing with the NEC. While they are challenging, they are easier to understand if we deal with each section separately rather than as a whole. For the purposes of this course, we will concentrate on the more common calculations pertaining to motors rather than try and understand the entire article

If you have one available, you should also follow along with your NEC book. If you turn in your book to Article 430, you will see that there are 13 sections that deal with all of the code requirements for motors.

These sections are made easier to understand with the addition of some easy to use tables and formulas for sizing overcurrent protection, conductors, and motor full load currents. It also contains a very useful chart that gives a graphical depiction of all of the relevant code sections. It is Figure 430.1 and can be seen below:

General, 430.1 through 430.18	Part I
Motor Circuit Conductors, 430.21 through 430.29	Part II
Motor and Branch-Circuit Overload Protection, 430.31 through 430.44	Part III
Motor Branch-Circuit Short-Circuit and Ground-Fault Protection, 430.51 through 430.58	Part IV
Motor Feeder Short-Circuit and Ground-Fault Protection, 430.61 through 430.63	Part V
Motor Control Circuits, 430.71 through 430.74	Part VI
Motor Controllers, 430.81 through 430.90	Part VII
Motor Control Centers, 430.92 through 430.98	Part VIII
Disconnecting Means, 430.101 through 430.113	Part IX
Adjustable Speed Drive Systems, 430.120 through 430.128	Part X
Over 600 Volts, Nominal, 430.221 through 430.227	Part XI
Protection of Live Parts—All Voltages, 430.231 through 430.233	Part XII
Grounding—All Voltages, 430.241 through 430.245	Part XIII
Tables, Tables 430.247 through 430.251(B)	Part XIV

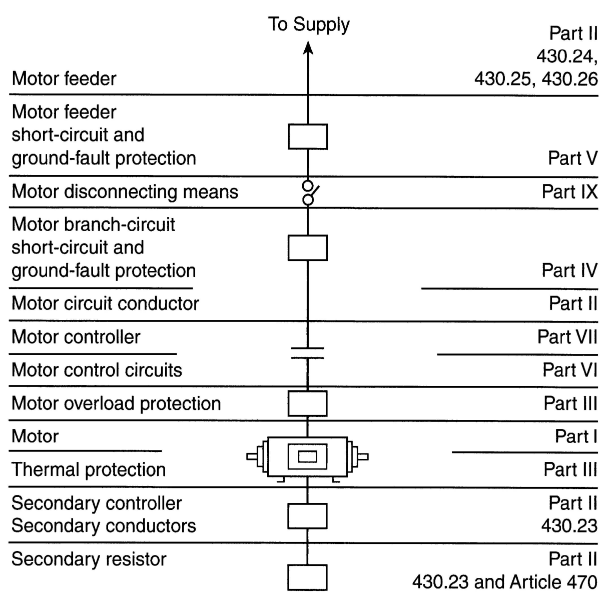


Figure 430.1 Article 430 Contents.

In this one diagram, we can find the correct part of the code needed to perform 95% of the motor calculations you will ever need. While it may seem overwhelming at first, it is actually quite easy to read and use. Let's take a look at the most relevant sections to this course in a little more detail.

Part I. General, 430.1 through 430.18

Most calculations dealing with a motor circuit are based off of the full load amperage (FLA) of the motor or motors connected. Therefore it is important that we start with the correct amperage. To determine this, the NEC provides several tables that are to be used to find the motor amperage. The code reference that explains this is as follows:

> **430.17 Highest Rated or Smallest Rated Motor**
> In determining compliance with Section 430.24, 430.53(B) and 430.53(C), the highest rated or smallest rated motor shall be on the rated full-load current as selected from Table 430.247, Table 430.248, Table 430.249, and Table 430.250

While there are a total of 6 tables that display motor full load currents, the two used most often are pictured in the tables below:

Table 430.248 Full-Load Currents in Amperes, Single-Phase Alternating-Current Motors
The following values of full-load currents are for motors running at usual speeds and motors with normal torque characteristics. The voltages listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 to 120 and 220 to 240 volts.

Horsepower	115 Volts	200 Volts	208 Volts	230 Volts
1/6	4.4	2.5	2.4	2.2
1/4	5.8	3.3	3.2	2.9
1/3	7.2	4.1	4.0	3.6
1/2	9.8	5.6	5.4	4.9
3/4	13.8	7.9	7.6	6.9
1	16	9.2	8.8	8.0
1 1/2	20	11.5	11.0	10
2	24	13.8	13.2	12
3	34	19.6	18.7	17
5	56	32.2	30.8	28
7 1/2	80	46.0	44.0	40
10	100	57.5	55.0	50

Table 430.250 Full-Load Current, Three-Phase Alternating-Current Motors
The following values of full-load currents are typical for motors running at speeds usual for belted motors and motors with normal torque characteristics.

The voltages listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 to 120, 220 to 240, 440 to 480, and 550 to 600 volts.

	Induction-Type Squirrel Cage and Wound Rotor (Amperes)							Synchronous-Type Unity Power Factor* (Amperes)			
Horsepower	**115 Volts**	**200 Volts**	**208 Volts**	**230 Volts**	**460 Volts**	**575 Volts**	**2300 Volts**	**230 Volts**	**460 Volts**	**575 Volts**	**2300 Volts**
½	4.4	2.5	2.4	2.2	1.1	0.9	—	—	—	—	—
¾	6.4	3.7	3.5	3.2	1.6	1.3	—	—	—	—	—
1	8.4	4.8	4.6	4.2	2.1	1.7	—	—	—	—	—
1½	12.0	6.9	6.6	6.0	3.0	2.4	—	—	—	—	—
2	13.6	7.8	7.5	6.8	3.4	2.7	—	—	—	—	—
3	—	11.0	10.6	9.6	4.8	3.9	—	—	—	—	—
5	—	17.5	16.7	15.2	7.6	6.1	—	—	—	—	—
7½	—	25.3	24.2	22	11	9	—	—	—	—	—
10	—	32.2	30.8	28	14	11	—	—	—	—	—
15	—	48.3	46.2	42	21	17	—	—	—	—	—
20	—	62.1	59.4	54	27	22	—	—	—	—	—
25	—	78.2	74.8	68	34	27	—	53	26	21	—
30	—	92	88	80	40	32	—	63	32	26	—
40	—	120	114	104	52	41	—	83	41	33	—
50	—	150	143	130	65	52	—	104	52	42	—
60	—	177	169	154	77	62	16	123	61	49	12
75	—	221	211	192	96	77	20	155	78	62	15
100	—	285	273	248	124	99	26	202	101	81	20
125	—	359	343	312	156	125	31	253	126	101	25
150	—	414	396	360	180	144	37	302	151	121	30
200		552	528	480	240	192	49	400	201	161	40
250	—	—	—	—	302	242	60	—	—	—	—
300	—	—	—	—	361	289	72	—	—	—	—
350	—	—	—	—	414	336	83	—	—	—	—
400	—	—	—	—	477	382	95	—	—	—	—
450	—	—	—	—	515	412	103	—	—	—	—
500	—	—	—	—	590	472	118	—	—	—	—

*For 90 and 80 percent power factor, the figures shall be multiplied by 1.1 and 1.25, respectively.

Part II. Motor Circuit Conductors, 430.21 through 430.29

430.22 Single Motor

Conductors that supply a single motor used in a continuous duty application shall have an ampacity of not less than 125% of the motor FLC rating as determined by 430.6(A)(1)

Therefore, we must multiply the full load current by 1.25 to determine the correct amperage or conductors will be sized for. From this number, we will use Table 310.16 to determine the correct wire size.

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

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.13(A).]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18	—	—	14	—	—	—	—
16	—	—	18	—	—	—	—
14*	20	20	25	—	—	—	—
12*	25	25	30	20	20	25	12*
10*	30	35	40	25	30	35	10*
8	40	50	55	30	40	45	8
6	55	65	75	40	50	60	6
4	70	85	95	55	65	75	4
3	85	100	110	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	150	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	190	230	255	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	355	420	475	285	340	385	600
700	385	460	520	310	375	420	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	450	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	520	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	560	665	750	470	560	630	2000

Part III. Motor and Branch Circuit Overload Protection

An overload condition is not a short-circuit nor is it a ground fault condition. It's basically an operating current that is just too high for the system conductors. Overload protection devices will interrupt a current that is too high, when it persists for too long. This time period is usually a matter of a few seconds. You must protect each motor branch circuit against overloading by a protection device sized no greater than the percentages listed as follows:

430.32 Continuous Duty Motors

Each motor used in a continuous duty application and rated more than 1 HP shall be protected against overload by one of the following means:

Service factor no less than 1.15 = 125% x FLC
Temperature rise not over 40° C = 125% x FLC
All other motors = 115% x FLC

Sometimes sizing based on these conditions results in an overload that trips too early to start the motor. In these cases, the code does allow the device to be increased in size. Modification of the value shall be permitted as in Section 430.32(C).

430.32(C) - Selection of Overload Device
Where the overload relay selected in Section 430.32 is not sufficient to start the motor or carry the load the next higher size overload relay shall be permitted to be used provided that trip current, current of the overload relay does not exceed the following FLC:

Service factor not less that 1.15 = 140% x FLC
Temperature rise not over 40°C = 140% x FLC
All other motors = 130% x FLC

Part IV. Motor Branch Circuit Short Circuit and Ground Fault Protection, 430.51 through 430.58

430.52 - Rating or Setting for Individual Motor Circuit
The motor branch circuit, short circuit and ground fault protection device shall comply with 430.52(B), 430.52(C), or 430.52(D) as applicable.

430.52(B) Be capable of carrying the starting current of the motor.

430.52(C) A protective device sized in accordance with Table 430.52 shall be used.

Table 430.52 Maximum Rating or Setting of Motor Branch-Circuit Short-Circuit and Ground-Fault Protective Devices

	Percentage of Full-Load Current			
Type of Motor	Nontime Delay Fuse[1]	Dual Element (Time-Delay) Fuse[1]	Instantaneous Trip Breaker	Inverse Time Breaker[2]
Single-phase motors	300	175	800	250
AC polyphase motors other than wound-rotor	300	175	800	250
Squirrel cage — other than Design B energy-efficient	300	175	800	250
Design B energy-efficient	300	175	1100	250
Synchronous[3]	300	175	800	250
Wound rotor	150	150	800	150
Direct current (constant voltage)	150	150	250	150

Exception 1: Calculation does not correspond to a standard device, the next higher standard size rating or possible setting shall be permitted.

Exception 2: Where the rating in Table 430.52 is not sufficient to start the motor the following can be used.

(A) Non-time delay fuse not exceeding 600 amps can be increased but cannot exceed 400% FLC.
(B) Time delay fuse shall be permitted to be increased but in no case may exceed 225% FLC.
(C) Inverse time circuit breaker shall be permitted to be increased but in no case exceed the following:
   1. 400% FLC of 100 amps or less
   2. 300% FLC greater than 100 amps

For fuses rated 601-6000 ampere, the multiplier cannot exceed 300%.

Part V. Motor Feeder Short Circuit and Ground Fault Protection, 430.61 through 430.63

For motor circuits that contain more than one motor or load, it is important that we correctly size the feeder as well. The feeder must be large enough to safely carry all of the connected loads, plus provide the necessary circuit protection to the system.

430.62 Rating or Setting – Motor Load
A feeder supplying fixed motor load(s) and consisting of conducting sizes based in 430.24 shall be provided with a protective device having a rating or setting not greater than the largest protective device plus the sum of the FLCs of the other motors in the group.

So how do we apply all of these code sections to a motor circuit? Well now that we have looked at the individual sections within the code, it is easier to understand if we apply it in logical steps to perform our calculations. The following guide is useful for most applications but may vary slightly for different motor sizing problems.

Motor Calculation Steps

1. Determine the motor full load current or FLC using Tables 430.247, 248, 249, or 250

2. Select the running overcurrent protection (heater overloads)
   Minimum 430.32(A)(1)
   Maximum 430.32(C)

3. Size the Branch Circuit Conductors

430.22 125% of FLC

4. Branch Circuit protection
   Article 430.52 tells us to use Table 430.52 for branch circuit protection device.

   Exception No. 1: If the calculation does not correspond to a standard device, the next higher standard size rating or possible setting shall be permitted.

5. Size the Feeder Conductor
   Article 430.24 If there is more than one motor, we increase the largest motor F.L.C. by 125% and then add the F.L.C. of the other motors.

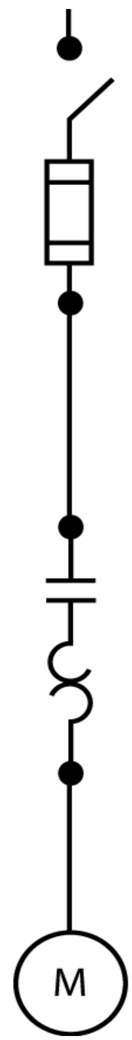
6. Feeder Protection
   430.62 This device cannot be greater than the largest branch circuit protection device plus the sum of the F.L.C. of the other motors.

   Note: One cannot go up on sizing protection for feeder--must go down if calculations do not correspond to a standard device.

   Note: The asterisk in 240.3(B) which limits #14 wire to a 15 amp device, #12 wire to a 20 amp device, and #10 wire to a 30 amp device does not apply to motors.

Single Motor Calculation Practice Problems

1. One 3 HP, 230 volt single phase AC motor with a temperature rise of 40° C using an inverse time breaker and THW conductors.



Step 4: Branch Circuit protection
Article 430.52 ______________

Step 3: Size the Branch Circuit Conductors
430.22 125% of FLC ______________

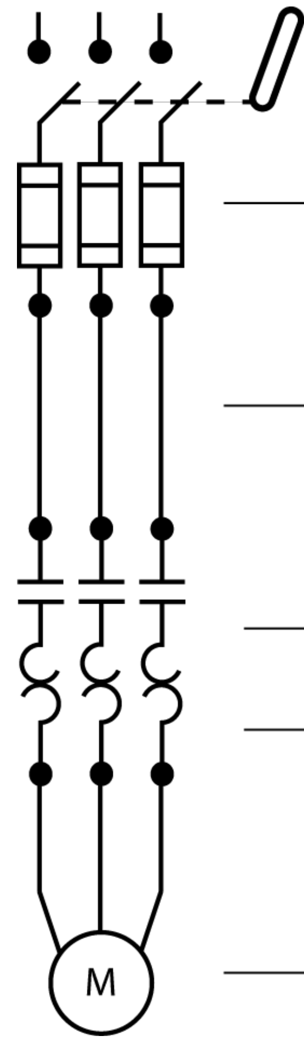
Step 2: Running Overcurrent Protection

Minimum 430.32(A)(1) ______________

Maximum 430.32(C) ______________

Step 1: Motor FLC
Tables 430.247, 248, 249, or 250 ______________

2. One 60 HP, 460 volt three phase AC motor with code letter H using inverse time breaker and THHN conductors.



Step 4: Branch Circuit protection
Article 430.52 ______________

Step 3: Size the Branch Circuit Conductors
430.22 125% of FLC ______________

Step 2: Running Overcurrent Protection

Minimum 430.32(A)(1) ______________

Maximum 430.32(C) ______________

Step 1: Motor FLC
Tables 430.247, 248, 249, or 250 ______________

For motor circuits with more than one motor, the calculations are a little different. Basically the calculations are performed as before with the individual motor circuit calculations performed first. The difference is when we size the feeder conductors and over current protection for them.

Looking at the code reference, we will see that it doesn't matter if we have several motors or motors with different types of loads. The feeder calculations are performed the same way.

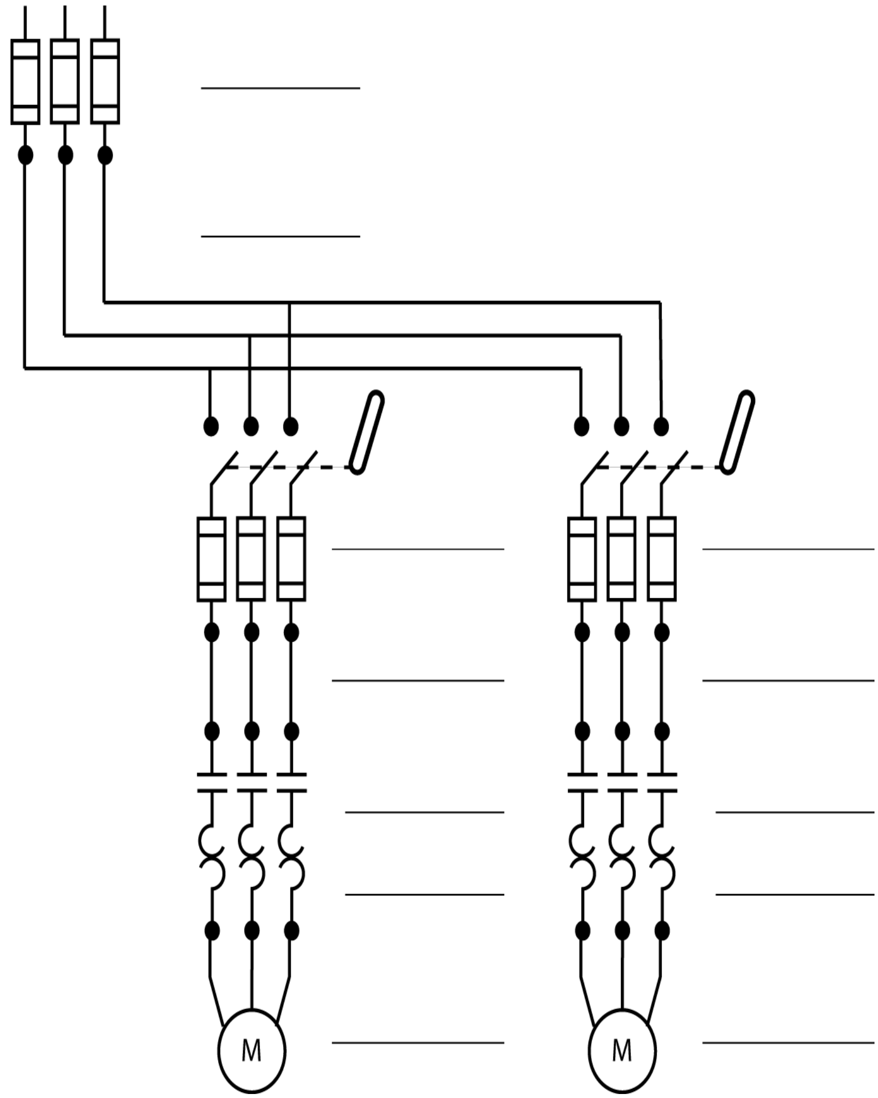
> **430.24 Several Motors or a Motor(s) and Other Load(s)**
> Conductors supplying several motors, or a motor(s) and other load(s), shall have an ampacity not less than 125% of the full-load current rating of the highest rated motor plus the sum of the full load current rating of all the other motors in the group, as determined by 430.6(A), plus the ampacity required for the other loads.

> **430.62 Rating or Setting – Motor Load**
> A feeder supplying fixed motor load(s) and consisting of conducting sizes based in 430.24 shall be provided with a protective device having a rating or setting not greater than the largest protective device plus the sum of the FLC of the other motors in the group.

To make it clear, work through the examples below paying special attention to the requirements for the feeder.

Multi-Motor Practice Problems

3. One 15 HP, 230 volt three phase AC motor code letter A. One 5 HP, 230 volt three phase AC motor code letter F. Using inverse time breaker and type TW conductors.



Step 6: Size Feeder Protection
Article 430.62

Step 5: Size Feeder Conductors
Article 430.24

Step 4: Branch Circuit protection
Article 430.52

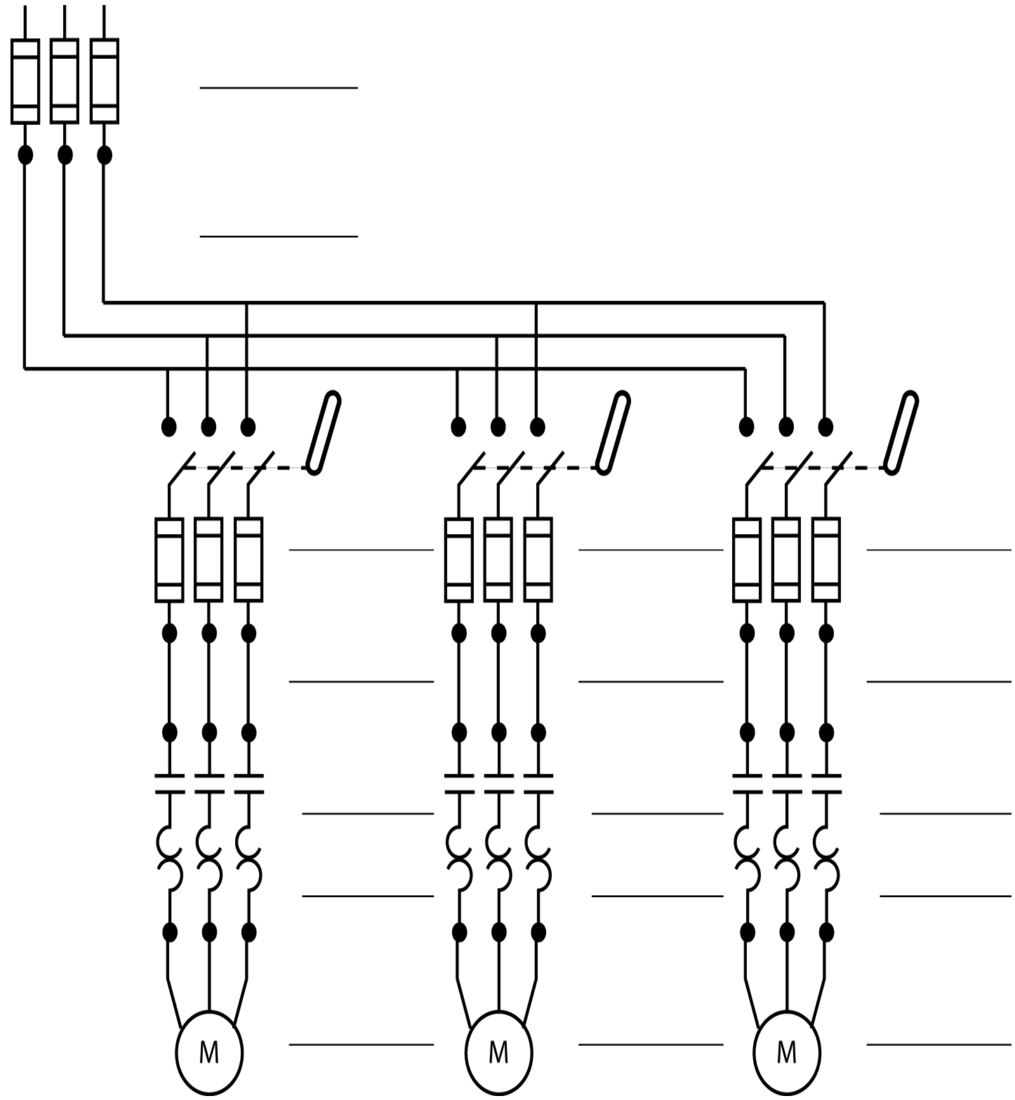
Step 3: Size the Branch Circuit Conductors
430.22 125% of FLC

Step 2: Running Overcurrent Protection
Minimum 430.32(A)(1)

Maximum 430.32(C)

Step 1: Motor FLC
Tables 430.247, 248, 249, or 250

4. One 3 HP, One 5 HP and one *7.5* HP, 240 volt three phase squirrel cage full voltage starting motors. Using an inverse time breaker and THW conductors.



Step 6: Size Feeder Protection
Article 430.62

Step 5: Size Feeder Conductors
Article 430.24

Step 4: Branch Circuit protection
Article 430.52

Step 3: Size the Branch Circuit Conductors
430.22 125% of FLC

Step 2: Running Overcurrent Protection
Minimum 430.32(A)(1)

Maximum 430.32(C)

Step 1: Motor FLC
Tables 430.247, 248, 249, or 250

Answers to Single Motor Calculation Practice Problems

1. One 3 HP, 230 volt single phase AC motor with a temperature rise of 40°C using an inverse time breaker and THW conductors.

   Step 1: Motor FLC
   Use Tables 430.247, 248, 249, or 250 17 A
   Step 2: Running Overcurrent Protection
   Minimum 430.32(A)(1) 17 x 1.25 = 21.25 A minimum

   Maximum 430.32(C) 17x1.40 = 23.84A maximum
   Step 3: Branch Circuit Conductors
   430.22 size conductors at 125% of FLC
   17 x 125%- 21.25 = #12 THW
   Step 4: Branch Circuit Protection
   Using 430.52
   17A x 250% = 17 x 2.50 = 42.5 A or 45 amps

2. One 60 HP, 460 volt three phase AC motor with code letter H and autotransformer starting using inverse time breaker and THHN conductor.

   Step 1: Motor FLC
   Use Tables 430.247, 248, 249, or 250 77A
   Step 2: Running Overcurrent Protection
   Minimum 430.32(A)(1) 77 x 1.25 = 88 A minimum

   Maximum 430.32(C) 77 x 1.40 = 100 A maximum
   Step 3: Branch Circuit Conductors
   430.22 size conductors at 125% of FLC
   77 x 125% = 96.25A = #3 THHN
   Step 4: Branch Circuit Protection
   Using 430.52
   77A x 250% = 15.2 x 2.50 = 192.5 amps, use 200 amp device

3. One 20 HP, 460 volt three phase motor with service factor 1.15, Code letter V and full voltage starting using time delay fuse and THHN conductors.

   Step 1: Motor FLC
   Use Tables 430.247, 248, 249, or 250 27 Amps
   Step 2: Running Overcurrent Protection
   Minimum 430.32(A)(1) 27 x 1.25 = 33.75 A minimum

   Maximum 430.32(C) 27 x 1.40 = 37.8 A maximum
   Step 3: Branch Circuit Conductors
   430.22 size conductors at 125% of FLC
   27 x 125% = 33.75A = #10 THHN

Step 4: Branch Circuit Protection
Using 430.52
27A x 175% = 27 x 1.75 = 47 amps, use 50 amp device

4. One 15 HP, 230 volt three phase AC motor code letter A. One 5 HP, 230 volt three phase motor code letter F. Using inverse time breaker and type TW conductors.

Step 1: Motor FLC, Use Tables 430.247, 248, 249, or 250
15 HP = 42 amperes
5 HP = 15.2 amperes
Step 2: Running Overcurrent Protection
15 HP: Minimum 430.32(A)(1) 42 x 1.15 = 48.3 A minimum
Maximum 430.32(C) 42 x 1.30 = 54.6 A maximum
5 HP: Minimum 430.32(A)(1) 15.2 x 1.15 = 17.48 A minimum
Maximum 430.32(C) 15.2 x 1.30 = 19.76 A maximum
Step 3: Branch Circuit Conductors, 430.22 size conductors at 125% of FLC
15 HP: 42 x l.25 % = 52.5 amps #6 TW
5 HP: 15.2 x l.25 % = 19.76 amps # 14 TW
Step 4: Branch Circuit Protection, Using 430.52
15 HP: 42 x 250% = 105 amps = 110 amp circuit breaker
5 HP: 15.2 x 250% = 38 amps or 40 amp circuit breaker
Step 5: Size Feeder Conductors, Use Article 430.24
15 HP: 42 amps x 1.25 = 52.5 A
5HP: = 15.2 A
total: = 67.7 A #4 TW
Step 6: Size Feeder Protection, Use Article 430.62
15 HP: 110 amp breaker 110 + 15.2 = 125.2 or 125 amp breaker

5. One 3 HP, one 5 HP and one 7.5 HP, 240 volt three phase squirrel cage full voltage starting motors. Using inverse time breaker and type THW conductors.

Step 1: Motor FLC, Use Tables 430.247, 248, 249, or 250
3 HP = 9.6 amperes
5 HP = 15.2 amperes
7.5 HP = 22 amperes
Step 2: Running Overcurrent Protection
3 HP: Minimum 430.32(A)(1) 9.6 x 1.15 = 11.04 A minimum
Maximum 430.32(C) 9.6 x 1.30 = 12.48 A maximum
5 HP: Minimum 430.32(A)(1) 15.2 x 1.15 = 17.48 A minimum
Maximum 430.32(C) 15.2 x 1.30 = 19.76 A maximum
7.5 HP: Minimum 430.32(A)(1) 22 x 1.15 = 25.30 A minimum
Maximum 430.32(C) 22 x 1.30 = 28.60 A maximum

Step 3: Branch Circuit Conductors, 430.22 size conductors at 125% of FLC

3 HP: 9.6 x l.25% = 12 amps #14 THW
5 HP: 15.2 x l.25% = 19.76 amps #14 THW
7.5 HP: 22 x l.25% = 27.5 amps #10 THW

Step 4: Branch Circuit Protection, Using 430.52
3 HP: 9.6 x 250% = 24 amps = 25 amp circuit breaker
5 HP: 15.2 x 250% = 38 amps or 40 amp circuit breaker
7.5 HP: 22 x 250% = 55 amps or 60 amp circuit breaker

Step 5: Size Feeder Conductors, Use Article 430.24

7.5 HP: 22 amps x 1.25	= 27.5 A
5HP:	= 15.2 A
3 HP:	= 9.6 A
total:	= 52.3 A #6 THW

Step 6: Size Feeder Protection, Use Article 430.62
7.5 HP: 60 A
60 A + FLC of 15.2 + 9.6 = 84.8 A
Therefore an 80 A circuit breaker is required

References:

The tables supplied in the course are referenced from the 2008 version of the National Electrical Code, NFPA 70