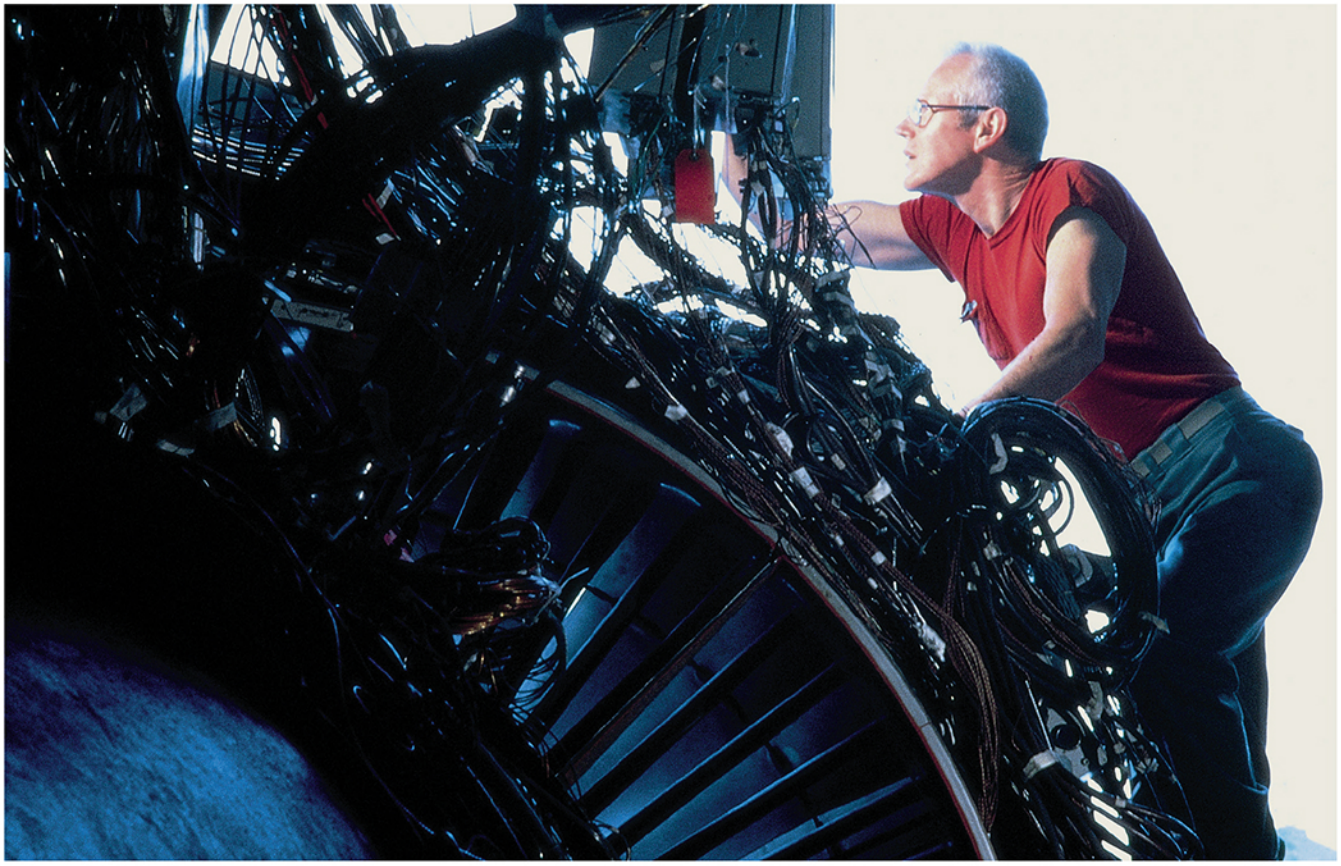
Aviation Maintenance Technician Series

Dale Crane

General

Fourth Edition



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Aviation Supplies & Academics, Inc.
NEWCASTLE, WASHINGTON

Aviation Maintenance Technician Series: General
Fourth Edition
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First Edition published 1993. Fourth Edition published 2017.

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ASA-AMT-G4-PD
ISBN 978-1-61954-518-2

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PREFACE

Aviation maintenance technology has undergone tremendous changes in the past decades. Modern aircraft, with their advanced engines, complex flight controls, and environmental control systems, are some of the most sophisticated devices in use today, and these marvels of engineering must be maintained by knowledgeable technicians. The Federal Aviation Administration, recognizing this new generation of aircraft, has updated the requirements for maintenance technicians and for the schools that provide their training. The FAA has instituted an Aviation Maintenance Technician Awards Program for technicians and their employers to encourage technicians to update their training.

New technologies used in modern aircraft increase the importance of maintenance technicians having a solid foundation in such basic subjects as mathematics, physics, and electricity. The *Aviation Maintenance Technician Series* has been produced by ASA to provide the needed background information for this foundation and to introduce the reader to aircraft structures, powerplants, and systems.

These texts have been carefully designed to assist a person in preparing for FAA technician certification, while at the same time serving as a valuable reference for individuals working in the field. The subject matter is organized into the categories used by the FAA for the core curriculum in 14 CFR Part 147, "Aviation Maintenance Technician Schools" and for the Subject Matter Knowledge Codes used in the written tests for technician certification. These categories have been rearranged in the ASA series to provide a more logical progression of learning. For example, in the General textbook the basic subjects are covered first, then the technical subjects common to both airframe and powerplant certification, and finally the maintenance publications, forms, and records that are so important.

The author and publisher of the *Aviation Maintenance Technician Series* wish to express our appreciation to the various manufacturers, aviation maintenance technician schools, and FAA personnel who have assisted us in producing this coordinated training series. Special appreciation goes to Terry Michmerhuizen of Western Michigan University School of Aviation Sciences for his valuable assistance in editing these texts.

Dale Crane

About the Author and Editors

Dale Crane (1923 – 2010) was involved in aviation for more than 50 years. He began his career in the U.S. Navy as a mechanic and flight engineer in PBYs. After World War II, he attended Parks Air College. After college, he worked as an instrument overhaul mechanic, instrument shop manager, and flight test instrumentation engineer. Later he became an instructor and then director of an aviation maintenance school.

Dale was active as a writer of aviation technical materials, and as a consultant in developing aviation training programs. ATEC presented to Dale Crane their special recognition award for "his contribution to the development of aviation technicians as a prolific author of specialized maintenance publications." He also received the FAA's Charles Taylor "Master Mechanic" award for his years of service in and contributions to the aviation maintenance industry, and the recognition of his peers for excellence as a leader and educator in aircraft maintenance, and aviation safety advocate.

Terry Michmerhuizen, technical editor for the previous editions, is an Associate Professor at the College of Aviation, Western Michigan University. He obtained his A&P Certificate in 1974, and received his IA rating in 1994. He has a Bachelor of Science in Mechanical Engineering Technology and a Master's Degree in Management. He was employed for 18 years at an aerospace hydraulic manufacturing and repair facility. He also worked 14 years as a certification engineer at a large FAA-authorized repair station for corporate aviation.

Sean Fortier is technical editor for the Fourth Edition; he is the Associate Dean and Chair of the Applied Aviation Science Department in the College of Aviation at LeTourneau University. He studied electrical engineering at Colorado University before transferring to Moody Bible Institute's Aviation program, earning his Airframe and Powerplant Certificate, Private Pilot Certificate, and FCC General Radiotelephone Operator License in the process of obtaining his Bachelor of Science in Missionary Aviation Science. Sean started his time at LeTourneau in 1994 in the aviation maintenance technology program, focusing on teaching aircraft electrical systems and avionics. In 1998 he earned his Master's Degree in Systems Technology from Louisiana State University Shreveport.

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MATHEMATICS 2

Why Study Mathematics?

Mathematics is an exact science that gives us the basic language for all technology, and without it, aviation as we know it could not exist. We use mathematics daily for a variety of tasks, from figuring our paycheck to determining the strength of a riveted joint.

Today, a knowledge of mathematics is more important than ever before. All aircraft, engines, and the systems they contain must obey the laws of physics, and only by using the tools of mathematics are engineers able to design equipment that follows these laws. And only by understanding and using mathematics are we as technicians able to maintain this equipment so it will continue to function properly.

The miracle of modern engineering and production is possible only because of computers that quickly and accurately make the vast number of mathematical computations that are needed. Pocket-size calculators help to take the boredom out of mathematics and free the technician to concentrate on the practical use of this science.

In this section, we begin with a review of the number systems commonly used and progress through the four basic procedures in arithmetic, through a discussion of common and decimal fractions, percentage, ratio and proportion, powers and roots, signed numbers, and trigonometry, and conclude with mathematical sequences and practical problems.

To gain the most from this chapter, work all of the study problems by hand and check your answers with a pocket calculator; then check with the answers in the back of this chapter. By practicing the old-fashioned way of working problems, you will sharpen your skills and better understand the mathematical process.

Numerals

Numerals are the symbols used in mathematics to represent values. We are most familiar with the Arabic numerals, but Roman numerals have some special functions.

Arabic Numerals

Practically all modern mathematics are performed with Arabic numerals. This series of ten symbols is thought to have been developed by the Hindus in India and introduced in Europe by the Arabs.

Arabic numerals. The symbols 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9 used to represent values in the decimal number system.

The ten symbols may be arranged in such a way that they represent any quantity we want, and we use Arabic numerals, also called digits, in both the decimal and binary number systems.

The ten Arabic numerals are: 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9.

Roman Numerals

Roman numerals were used in an ancient number system, and are occasionally used as the chapter numbers in some books and on some of the more decorative clock faces. Seven capital letters represent numbers, and combinations of these letters may be used to make up any value we want. Mathematical manipulation of these numerals is too awkward for us even to consider here.

The seven Roman numerals and their Arabic equivalent are seen in Figure 2-1.

Roman	Arabic
I	1
V	5
X	10
L	50
C	100
D	500
M	1,000

Figure 2-1. *Comparison of Roman and Arabic numerals*

Number Systems

Decimal System

The number system used every day in aviation maintenance is the decimal system. It is based on the ten Arabic numerals, and we can arrange these ten digits so they represent any value we want. We do this by observing the position the digits occupy in the string of digits. The value of the digits in a decimal number is determined by their placement relative to the decimal point.

The easiest way to understand the decimal system is to use a number line, Figure 2-2. The center of the number line is marked with a small dot similar to a period used in writing. This is called the decimal point or, more generally, just "the decimal."

1,000,000 100,000 10,000 1,000 100 10 1 (.) .1 .01 .001 .0001 .000 01 .000 001

Figure 2-2. *On the number line, all numbers to the left of the decimal point are whole numbers, and all numbers to the right of the decimal point are fractional parts of a whole number.*

$$
\begin{array}{rcl}
50{,}000 & = & 5 \cdot 10{,}000 \\
2{,}000 & = & 2 \cdot 1{,}000 \\
400 & = & 4 \cdot 100 \\
90 & = & 9 \cdot 10 \\
6 & = & 6 \cdot 1 \\
\hline
52{,}496 & &
\end{array}
$$

Figure 2-3. *Place values for numbers greater than 1 in the decimal system*

The digit in the first place to the left of the decimal point has a value between 1 and 9. The digit in the second place has a value between 10 and 90, and the digit in the third place has a value between 100 and 900. This continues on, with each place to the left increasing the value by ten times.

To find the exact value of any number, just add all of the place values to the left of the decimal point. For example, we can break the number 52,496 down as shown in Figure 2-3.

In the United Kingdom, the decimal is placed above the line (·), but in the United States the decimal is placed on the line (.), and the raised dot (·) is used to indicate multiplication. All numbers to the left of the decimal point are numbers greater than 1, and those to the right of the decimal are fractions, or numbers less than 1.

The digit in the first place to the right of the decimal point has a value between $^{1}/_{10}$ and $^{9}/_{10}$, and the digit in the second place has a value between $^{1}/_{100}$ and $^{9}/_{100}$. The value of the digits becomes smaller by a factor of ten for each place the digit is to the right of the decimal point (*see* Figure 2-4). The number 347.69 can be broken down as we see in Figure 2-5.

For whole numbers greater than 1, the decimal point is normally omitted, and for numbers less than 1, a zero is normally placed before the decimal point.

0.1	=	1/10
0.01	=	1/100
0.001	=	1/1,000
0.000 1	=	1/10,000
0.000 01	=	1/100,000

Figure 2-4. *Place values for numbers smaller than 1 in the decimal system*

300.	=	3 · 100
40.	=	4 · 10
7.	=	7 · 1
0.6	=	6 · 0.1
0.09	=	9 · 0.01
347.69		

Figure 2-5. *Place values for mixed numbers in the decimal system*

Binary System

All data used by digital computers is represented with only two electrical conditions, OFF or ON. This can also be LOW or HIGH, or NEGATIVE or POSITIVE. Computers can do many different things when they are commanded by combinations of these two conditions.

To get the most value from digital computers, we must be able to reduce all of the data we use to a series of numbers, and since the computer recognizes only two conditions, we use the binary number system. This system uses only two symbols, 0 and 1. These are called bits (**BI**nary digi**TS**).

In the binary system the value of the bits doubles as they progress from right to left. The values of the first ten bits, reading from right to left, are: 1, 2, 4, 8, 16, 32, 64, 128, 256, and 512, as shown in Figure 2-6.

Decimal	Binary place values										Binary
	512	256	128	64	32	16	8	4	2	1	
1	0	0	0	0	0	0	0	0	0	1	0000000001
10	0	0	0	0	0	0	1	0	1	0	0000001010
97	0	0	0	1	1	0	0	0	0	1	0001100001
152	0	0	1	0	0	1	1	0	0	0	0010011000
312	0	1	0	0	1	1	1	0	0	0	0100111000
1,000	1	1	1	1	1	0	1	0	0	0	1111101000

Figure 2-6. *Conversion between the binary and decimal system*

To find the binary equivalent of a decimal number, start with the left side of the chart and subtract the binary place values from the decimal number. Proceeding to the right, every time a place value goes into the decimal number, put a 1 for the place value. When a place value does not go into the decimal number, put a zero for that place value. For example, the binary equivalent of 152 is 10011000:

- 152 – 128 = 24, so 1 goes in the 128 column
- 64 is greater than 24, so 0 goes in the 64 column
- 32 is greater than 24, so 0 goes in the 32 column
- 24 – 16 = 8, so 1 goes in the 16 column
- 8 – 8 = 0, so 1 goes in the 8 column
- There is nothing left, so 0 goes in the 4, 2, and 1 columns

Any zeros to the left of the first 1 may be omitted without changing the value of the binary number.

To find the decimal equivalent of a binary number, add all of the place values in which there is a 1. The decimal equivalent of 0100111000 is 312.

- Start at the right and add the place values in which there is a 1
- 0 + 0 + 0 + 8 + 16 + 32 +0 + 0 + 256 = 312

Arithmetic

Arithmetic is essentially the branch of mathematics in which we use addition, subtraction, multiplication, and division to solve problems that may contain positive and negative numbers and zero.

The pocket calculator has just about spoiled us for working arithmetic problems the old-fashioned way, but it is a good idea to review a few principles. Practicing may prevent some common mistakes.

Addition

addition. The process of finding the combined value of two or more numbers.

Addition is the process of finding the combined values of two or more numbers, their sum. The symbol for addition is the plus sign (+).

To find the sum, arrange the numbers in a vertical column with the decimal points all in a line, and combine the values of the numbers in each column. Since most whole numbers are written without a decimal point, just align the numbers with the least significant digits, the digits on the right, all in a straight vertical line. *See* Figure 2-7.

```
   64
   32
  736
+  9
```

Figure 2-7. *Arrangement of numbers for addition*

1. Arrange the numbers for addition, and combine the values of all of the digits in the ones column, the column on the right. When all of these digits are added together, they total 21. Twenty-one is 2 tens plus 1 one. Place the 1 below the ones column, and carry the 2 above the tens column. *See* Figure 2-8.
2. Combine the value of all of the digits in the tens column, including the 2 you just carried. The sum of these four digits is 14. This is 1 hundred, plus 4 tens. Put the 4 below the tens column and carry the 1 at the top of the hundreds column.
3. Now, combine the values of the digits in the hundreds column. This is 7 plus 1, or 8. Place the 8 below the hundreds column, and this gives the sum of the four numbers, which is 841.

```
  12
   64
   32
  736
+   9
  841
```

Figure 2-8. *The process of addition*

sum. The answer in an addition problem.

least significant digit. The digit on the extreme right in a decimal number.

The best way to check the accuracy of an addition problem is to add the numbers in a different sequence. If you added them the first time from the top number down, check by adding them from the bottom to the top.

Before leaving addition problems, there is one fact that will help in practical problems: It makes no difference in which order we add numbers.

```
  6      4      4
  4     19      5
 19      5      6
+ 5    + 6    +19
 34     34     34
```

Subtraction

Subtraction is the process of finding the difference between two numbers. The symbol for subtraction is the minus sign (–).

subtrahend. The number in a subtraction problem that is to be subtracted.

minuend. The quantity in a subtraction problem from which another quantity is to be subtracted.

difference. The amount by which one quantity is greater or less than another.The difference is the answer in a subtraction problem.

The number you begin with is called the minuend, and the number you subtract, or take away, from this is called the subtrahend. The answer is called the difference.

In Figure 2-9 we find the difference between 486 and 32. Place the subtrahend, 32, under the minuend, 486, with the least significant digits, the right-hand digits, lined up. Find the difference between the values of the digits in the ones column. 6 – 2 = 4. Place the 4 below the 2 in the ones column.

Find the difference between the values of the digits in the tens column. This is 8 – 3 = 5. Place the 5 below the tens column.

Since there is no number in the hundreds column of the minuend, just place the 4 in the answer in the hundreds column.

The difference between 486 and 32 is 454.

```
  486
–  32
  454
```

Figure 2-9. *This subtraction process does not involve borrowing.*

Some subtraction problems have digits in the subtrahend that are larger than those in the minuend, and we have to do some borrowing.

A

```
  12
  234
– 76
```

B

```
   2
  2 3(14)
– 76
   8
```

C

```
 1 (12)
 2 3 4
– 7 6
  5 8
```

D

```
  1
 2 3 4
– 7 6
 1 5 8
```

Figure 2-10. *This subtraction process does involve borrowing.*

A

```
  22
  365
x 124
 1460
```

B

```
  11
  365
x 124
 1460
 730
```

C

```
   365
 x 124
  1460
  730
+ 365
 45,260
```

Figure 2-11. *The process of multiplication*

multiplicand. The number in a multiplication problem that is multiplied.

multiplier. The number in a multiplication problem by which the other number, the multiplicand, is multiplied.

product. The answer in a multiplication problem.

In Figure 2-10, we see this situation:

A. We want to find the difference between 234 and 76.

B. Six ones is larger than 4 ones, so we must borrow 10 ones from the 3 in the tens column. This gives us 14 ones, and 6 from 14 leaves 8. Place the 8 in the ones column of the answer.

C. Seven is larger than 2, so we must borrow 10 tens from the hundreds column to get 12 tens. Seven from 12 gives us 5 tens in the answer.

D. We had to borrow 10 tens, or 1 hundred from the 2 hundreds, so we have 1 left in the hundreds column. Place a 1 in the hundreds column of the answer.

To check a subtraction problem, add the subtrahend to the difference, and if the problem has been worked correctly, the sum will be the same as the minuend.

Multiplication

Multiplication is a process in which one number is added to itself a given number of times.

Various symbols are used to indicate the multiplication process. These are the letter "x," or a small dot placed in the center of the space "·," or parentheses. Parenthesis are used in problems in which other functions must be applied to terms before they are multiplied.

$5 \times 8 \times 10 = 400$
$5 \cdot 8 \cdot 10 = 400$
$(3 + 2)\ (12 - 4)\ (6 + 4) = 400$

The number to be multiplied is called the multiplicand, and the number used to multiply is called the multiplier. The answer is called the product.

The multiplication problem $4 \cdot 3 = 12$ is the same as four added to itself three times: $4 + 4 + 4 = 12$.

When multiplying numbers having more than one digit, the way we arrange them is important. This is shown in Figure 2-11.

A. To multiply 365 by 124, begin by multiplying 365 by 4.

1. First, multiply 5 by 4. $5 \cdot 4 = 20$

   Place the 0 in the ones column of the answer and carry the 2 above the tens column.

2. Now, multiply 6 tens by 4 and add the 2 tens we carried.

   $4 \cdot 6 = 24 + 2 = 26$ (This is actually $(4 \cdot 60) + 20 = 260$.)

   Place the 6 in the tens column of the answer, and carry the 2 (200) above the hundreds column.

3. Multiply 3 hundreds by 4, and add the 2 hundreds we carried.

$4 \cdot 3 = 12 + 2 = 14$ (This is actually $(4 \cdot 300) + 200 = 1400$.)

Place the 4 in the hundreds column of the answer and the 1 in the thousands column. The answer for our first step is 1,460.

B. The second stage is to multiply 365 by 2 in the tens column (20).

1. Multiply 5 by the 2 in the tens column. $5 \cdot 2 = 10$ (This is actually $5 \cdot 20 = 100$.)

   Place the zero in the tens column and carry the 1 (10) above the tens column.

2. Multiply 6 tens by 2 tens, and add the 10 tens we carried.

   $6 \cdot 2 = 12 + 1 = 13$ (This is actually $(60 \cdot 20) + 100 = 1300$.)

   Place the 3 in the hundreds column and carry the 1 (100) above the hundreds column.

3. Multiply 3 hundreds by 2 tens, and add the 10 hundreds we carried.

   $3 \cdot 2 = 6 + 1 = 7$ (This is actually $(300 \cdot 20) + 1000 = 7000$.)

   Place the 7 in the thousands column.

C. The final stage is to multiply 365 by 1 in the hundreds column (100).

1. Multiply 5 by 1 hundreds. $5 \cdot 1 = 5$ (This is actually $5 \cdot 100 = 500$.)

   Place the 5 in the hundreds column.

2. Multiply 6 tens by 1 hundreds. $6 \cdot 1 = 6$ (This is actually $60 \cdot 100 = 6000$.)

   Place the 6 in the thousands column.

3. Multiply 3 hundreds by 1 hundred. $3 \cdot 1 = 3$ (This is actually $300 \cdot 100 = 30{,}000$)

   Place the 3 in the ten thousands column.

4. Add all the numbers we have just created to get the product of $365 \cdot 124 = 45{,}260$.

To check a multiplication problem, divide the product by the multiplier, and you should get the multiplicand.

$45{,}260 \div 124 = 365$

In a multiplication problem involving several steps of multiplication, the order in which the numbers are multiplied has no effect in obtaining the correct answer.

$6 \cdot 5 \cdot 9 \cdot 20 = 5{,}400$
$20 \cdot 5 \cdot 6 \cdot 9 = 5{,}400$
$9 \cdot 6 \cdot 20 \cdot 5 = 5{,}400$
$5 \cdot 20 \cdot 9 \cdot 6 = 5{,}400$

Division

dividend. The quantity in a division problem that is divided.

divisor. The quantity in a division problem by which the dividend is divided.

quotient. The answer in a division problem.

remainder. The number left in a division problem when the divisor does not go into the dividend an even number of times.

Division is the process of determining the number of times one number will go into another. The number to be divided is called the dividend, the number that is to go into the dividend is called the divisor, and the answer is the quotient. The symbols for division are ÷, and /.

Division can actually be thought of as a series of subtractions. We can find the number of times 7 will go into 56 by subtracting 7 from 56 until we get zero. Seven will go into 56 eight times. *See* Figure 2-12.

If the divisor does not go into the dividend an even number of times, the number left over is called the remainder.

42 ÷ 5 = 8, remainder 2

Long division is the term we generally use when the divisor has two or more digits. To solve a long division problem, we arrange it as we see in Figure 2-13.

1. Place the dividend under the division sign, and the divisor to the left of it.

   The 24 of the divisor will go into 136 of the dividend 5 times, with some remainder. Place the 5 above the 6. Multiply the 24 by 5, to get 120. Place the 120 below the 136.

   Subtract 120 from 136 to get 16 as the remainder for our first step.

2. Bring the 8 from the dividend down and place it after the remainder to give us a new dividend of 168.

   The 24 of the divisor will go into the new dividend 7 times. Place the 7 above the 8 and multiply the 24 by 7. Place the product of 168 below the new dividend and subtract. Since there is no difference, there is no remainder in this problem.

   Twenty-four will go into 1,368 fifty-seven times.

Division problems may be written in any of the ways we see in Figure 2-14.

```
56 – 7  =  49  (1)
49 – 7  =  42  (2)
42 – 7  =  35  (3)
35 – 7  =  28  (4)
28 – 7  =  21  (5)
21 – 7  =  14  (6)
14 – 7  =   7  (7)
 7 – 7  =   0  (8)
```

Figure 2-12. *Division is actually a series of subtractions. 56 ÷ 7 = 8*

```
      57
24)1368
   120
   168
   168
   000
```

Figure 2-13. *The process of long division*

24)1368 or 1368 ÷ 24

or $\frac{1368}{24}$

Figure 2-14. *Ways of writing division problems*

STUDY QUESTIONS: ARITHMETIC

Work all of these problems by hand, and then you may check your accuracy with a calculator.
Answers are found at the end of the chapter.

1. Find the sum of each of these columns of numbers:

a.	b.	c.	d.
321	65	7	936
66	681	47	72
59	6385	371	7931
6	83	849	365

2. Find the difference between each of these numbers:

a.	b.	c.	d.
458	756	5296	39
196	47	4805	18

3. Find the product in each of these multiplication problems:

a.	b.	c.	d.
248	1969	306	9841
62	142	212	77

4. Find the quotient and remainder of each of these division problems:

a. $3685 \div 92 =$ _____ remainder _____
b. $5694 \div 23 =$ _____ remainder _____
c. $148 \div 53 =$ _____ remainder _____
d. $98 \div 7 =$ _____ remainder _____

Aviation Maintenance Technician Series

General

Fourth Edition

Based on the original text by DALE CRANE
Edited by TERRY MICHMERHUIZEN *and* SEAN FORTIER

The *Aviation Maintenance Technician: General* is the first book in Dale Crane's *AMT Series*, textbooks created to set the pace for maintenance technician training and serve as an essential resource to pass the FAA Knowledge Exam. *General* covers the first section of the FAA's required curriculum, incorporating an introduction to aviation along with basic lessons on mathematics, physics, and electricity. As the student progresses, specific aviation concerns are addressed, including regulations, mechanic privileges, forms, aircraft hardware and tools. Study questions are included throughout, with answer keys printed at the end of each chapter.

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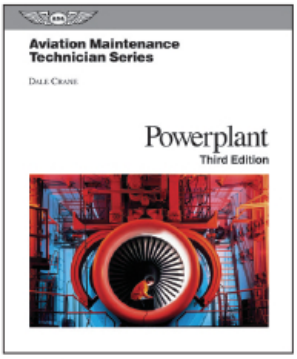

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