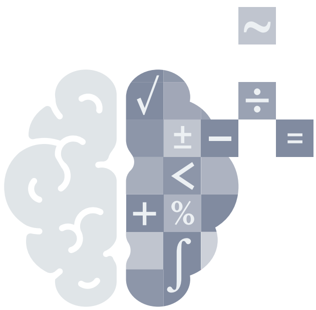
Mental Math for Pilots



Third Edition

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Mental Math for Pilots
Third Edition
by Ronald D. McElroy

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TABLE OF CONTENTS

INTRODUCTION

There may be a myriad of reasons why you decided to take a look at this book — perhaps simply because of the title or cover. Regardless of your reason, I want this study guide to help pilots sharpen their skills to better operate in the cockpit amid an ever-growing number of electronic gadgets designed to do our work for us. In short, because of the increased use of calculators and computers over the past few years, many of us either never learned or have forgotten the "tricks of the trade" that help us work math problems. Whether it's simple addition and subtraction or multiplication and division, we have become increasingly reliant on electronics to enhance, supplement, or even replace some of our piloting skills. Forget about being able to do square roots or simple calculus in our heads!

So, what happens? We tend to get sloppy and over-reliant on the airplane "black boxes!" Many times we don't recognize errors quickly enough or even at all! The more advanced we become with our technology, the more mentally inefficient and lazy we become.

In this book we'll study the areas where pilots have traditionally needed to have sharp mental math skills. These include such subjects as fuel planning, temperature conversions, reciprocal headings, turn radius, crosswind components, time-speed-distance problems, calculating true airspeed, and the 60-to-1 rule, plus many others.

My goal in writing this study guide is to encourage and help you to be a more professional and precise pilot. As a result, you will be better armed to stay ahead of the flight by using the black boxes to assist you in planning the flight rather than being in the position of asking, "What's it doing now?" Or, for those of you without fancy computers to use inflight, this study guide will teach you many of the mental math tools and shortcuts you will need to better fly and navigate. After all, the world of aviation is fast moving and multidimensional; we need all the help we can get just to fly from one airport to another.

Make a decision here and now to study and practice, practice, practice the mental math exercises discussed in this book. Once through—just scanning the exercises—won't do it for most people. Repetition is the key! Repetition is the key!

An additional benefit is in the area of career progression. Simply stated, this study guide may greatly improve your technical performance during each and every airline job interview you receive as you climb the ladder of an airline career. Don't underestimate the significance of this! With tens of thousands of qualified pilot applicants waiting for the chance, airlines can easily screen for the best of the best. So, include yourself in that category and be ready!

If airline interview preparation is your immediate goal, here are some suggestions:

1. Contact Cage Marshall Consulting at CageConsulting.com for professional airline interview preparation.
2. Build a personal study library to include: *FAR/AIM, ATP* and *Flight Engineer Test Prep* and the books *Checklist for Success: A Pilot's Guide to the Successful Airline Interview* and *Airline Pilot Technical Interviews.* Find everything you need to prepare at ASA's website, asa2fly.com.
3. Plan on 50 to 100 hours of study preparing for your interview. This may include technical study, a review of your own career, and administrative time preparing your application and reviewing your records. Don't wait to prepare! Start now!

I hope you enjoy my presentation of the material. But, as with *Airline Pilot Technical Interviews,* my success will be measured largely by the depth at which you are able to review and grasp the subjects discussed. I am sure you will learn something new that will help you fly the line a little better!

Ron McElroy

ABOUT THE AUTHOR

After writing his first book, *Airline Pilot Technical Interviews*, Ron McElroy noticed that many pilots were struggling to solve math problems in the cockpit without the use of calculators or even a pencil and paper to help. In *Mental Math for Pilots* Ron drew upon his many years as an instructor in the classroom and cockpit to capture these mental math struggles and provide solutions that are simple to use and practical for airborne contingencies. Many of his problem-solving techniques are borrowed from his own experiences ranging from computing ETAs for position reports to asking, "What's it doing now?" of the current generation of glass cockpit airplanes.

Since 1976, Ron has flown in nearly every area of aviation possible. He's been an Air Force test pilot at Edwards Air Force Base; a flight and ground instructor for the Air Force, several FBOs, and an aviation college; a charter pilot; a skydive pilot; a photo and chase plane pilot; and a simulator instructor and line pilot for two airlines. He currently works as an aviation consultant. Ron has flown over 200 types of aircraft in his career, from the Piper Cub to the Boeing 777, and the military T-38 to the C-17.

Ron has always maintained a multifaceted interest in all levels of teaching pilots about the technical aspects of their profession. Armed with his broad experience, he has provided a tremendous service to those pilots needing just a little help to start new careers as airline pilots or sharpen their skills as professionals. In his role of coaching aspiring airline pilots, Ron has discovered that technical preparation and mental math skills are key to successful airline interviews. Ron's teaching and techniques give all pilots a sharper edge.

CHAPTER 1

Taking the First Step

The root of mental math proficiency lies in the ability to grasp the basic concepts of addition, subtraction, multiplication, and division. The skill level you achieve is simply a reflection of how much work, or repetition, that you put into it. Starting now in your everyday activities of paying for gas or groceries, giving an allowance to your kids, keeping track of sports statistics or scores, or determining how much fuel to put in your aircraft try to do the calculations. A good starting point is to write the numbers (or formulas) on a piece of paper, study how you solve the problem, and then push the paper aside and repeat the problem by visualizing what you have just completed. This takes a little extra time and discipline, but repetition and effort is as necessary here as it is with any other skill.

When you discover that you need to calculate a solution to a math problem, first define the problem; i.e., what is the answer you need? Second, look for the right formula to use. Most of the formulas you will ever need are right here in this book. Third, rearrange the formula to solve for the answer that you need. And, fourth, plug in the numbers and solve.

The same is true of the problems in this study guide. If you need to first complete the problems with pen and paper, do it! Once you've completed the problem, set the paper aside and repeat the problem in your head until you feel comfortable that you can repeat the solution in a timely manner without cheating.

Many of the subject areas in this book will have practice questions. The answers are in Appendix C. In addition, there is a comprehensive test in Appendix B that will include different problems from all study areas. For all problems, try to be as accurate as possible. If you feel you need additional problems to solve, create some on your own. In fact, it will help increase your proficiency in solving problems to create your own problems.

I cannot overemphasize the importance and significance of having solid basic math skills. In most careers, having a slightly better-than-average skill will produce a noticeable increase in performance. That same philosophy is true in mental math skills for pilots. Therefore, Appendix A is available for extra study to review the basic concepts and techniques for solving simple and more complicated math problems we encounter while flying.

In Appendix A, the math skills that are reviewed include addition, subtraction, multiplication, division, squares, and square roots. In addition, there are problems to demonstrate simple and complex levels of proficiency, as well as practice problems for you to work.

The pilot population as a whole is no different in their math proficiency than in any other industry. Individual proficiency varies greatly. The remainder of this study guide relies on your ability to demonstrate basic math proficiency in order to understand and use the techniques and develop the skills necessary to increase your performance in the cockpit. Therefore, **I challenge you to review and assess your own math problem-solving skills, and make a commitment to study Appendix A.** If you are a new pilot your future employment may be at stake! If you are a seasoned veteran, your cockpit efficiency may improve significantly!

As a professional pilot you recognize the need to be at your top level of proficiency every time you fly. The preflight activities of flight planning, reviewing the weather, and checking the NOTAMs are a legal requirement of every flight. **However, the pilot skills you demonstrate are a reflection of the basic math skills and techniques you develop in a disciplined and focused strategy of study. This study guide is designed to help you be a more professional pilot!**

Study well. Good luck!

CHAPTER 2

Airborne Math Problems

Converting Hours and Minutes

I want to highlight the importance of the ability to convert hours and minutes as we normally read them from our watch into a more useful decimal value for use in math equations. Many pilots do not immediately recognize that one hour and fifteen minutes (1:15 or 1 + 15) **does not equal** 1.15 hours! Many have made the mistake of converting 1:15 to a decimal value of 1.15 (one point one five). The real answer is 1.25 hours!

So, here's the gauge. Since there are 60 minutes per hour, every 6 minutes is equal to one-tenth (0.1) hour. Thus, every multiple of 6 minutes is equal to the same multiple of tenths (0.1). And, if we desire greater accuracy, every 3 minutes is equal to one-twentieth (0.05) hour, or one-half the increment of 6 minutes.

You probably will not need more accuracy than a 3 minute interval in these conversions. Especially since it is the goal of this study guide to keep numbers and equations as simple and predictable as possible to allow reasonable mental math computations in the cockpit. However, just to be sure, I have constructed a short table of these intervals with their decimal equivalent for you to study and learn.

Table 2-1. Decimal equivalents of minutes in an hour.

Character	Decimal Equivalent
3 minutes	0.05 hour
6 minutes	0.10 hour
9 minutes	0.15 hour
12 minutes	0.20 hour

continued

Character	Decimal Equivalent
15 minutes	0.25 hour
18 minutes	0.30 hour
21 minutes	0.35 hour
24 minutes	0.40 hour
27 minutes	0.45 hour
30 minutes	0.50 hour
33 minutes	0.55 hour
36 minutes	0.60 hour
39 minutes	0.65 hour
42 minutes	0.70 hour
45 minutes	0.75 hour
48 minutes	0.80 hour
51 minutes	0.85 hour
54 minutes	0.90 hour
57 minutes	0.95 hour
60 minutes	1.00 hour

Reciprocal Headings

Seems a simple enough problem—yet, in the heat of battle you may freeze if you haven't practiced. Only two approaches are appropriate to get through this question: use a formula or visualize the headings on a compass rose.

Let's set up a practice table and work on using the formula.

Table 2-2. Initial headings versus reciprocal headings.

Initial Heading	Reciprocal Heading
090°	270°
011°	191°
222°	042°

Initial Heading	Reciprocal Heading
355°	175°
167°	347°
313°	**133°**

Or, to look at it another way:

Table 2-3. Formulas for reciprocal headings less than and greater than 180°.

When INIT HDG < 180°	INIT HDG + 200° – 20° = RECIP HDG°
When INIT HDG > 180°	INIT HDG – 200° + 20° = RECIP HDG°

Did you notice the change of the plus and minus signs between the formulas? We use two formulas because we will have initial headings either smaller than 180° or greater than 180° to begin the formula.

For example:

090° + 200° – 20° = 270°

or

222° – 200° + 20° = 042°

Be cautious in using this formula for certain ranges of headings that will initially give you an answer that is either greater than 360° or less than zero in the first step of adding or subtracting 200. After completing the second step of adding or subtracting the 20, your answer will be corrected back into the appropriate range of 001° to 360°. Also, don't forget that the last digit always remains the same when computing the reciprocal.

For example:

167° + 200° – 20° = 347°

or

191° – 200° + 20° = 011°

The second approach to figuring reciprocal headings—using the compass rose—comes simply with experience in flying on instruments. Study, visualize, and memorize the reciprocal cardinal compass headings. I recommend that you practice these reciprocals the next time you go fly. I believe you'll find it very productive and the more you work on it the easier it will become.

To change from °F to °C, subtract 32 from °F and then do the multiplication. For example, 77°F – 32°F = 45°F, or 9 × 5. Multiplying 5 × 5 gives you 25°C.

It's relatively easy to use this 5 = 9 or 9 = 5 matching as long as you know just a few markers along the way. Try a couple of problems on your own, they're simple enough to catch on quickly.

Technique 2

The second technique to calculate °F is to double the °C, subtract 10%, and add 32. Or, to calculate °C, subtract 32 from the °F, add 10% and divide the result by 2. This is not very difficult and results in much more accuracy.

°F = ([°C × 2] – 10%) + 32

°C = ([°F – 32] + 10%) ÷ 2

To use the previous example:

°F = 30°C × 2 = 60°C

60°C – 6 = 54°C

54°C + 32 = 86°F

And

°C = 86°F – 32 = 54°F

54°F + 5 = 59°F

59°F ÷ 2 = 29.5°C (or pretty close to 30°C)

Technique 3

The third way of estimating will get you in the ballpark for **lower** temperatures only. Either double the °C and add 30 to get °F, or subtract 30 from the °F and cut that in half to get °C.

°F = (2 × °C) + 30

°C = (°F – 30) ÷ 2

An example:

2 × 10°C = 20 + 30 = 50°F

And

50°F – 30 = 20 ÷ 2 = 10°C

(Note that if you use this method, for example, to convert 104°F to °C you will get 37°C, not the correct 40°C.)

Here are some practice problems for each of the techniques discussed (Table 2-6). When given a temperature in either °C or °F, convert to the other scale using each of the three techniques and compare the differences. A more detailed and complete temperature conversion chart is available for reference in Appendix D, Table D-7.

Table 2-6. Practice problems for converting Celsius to Fahrenheit and Fahrenheit to Celsius.

°C	Technique 1	Technique 2	Technique 3	°F
12°C	?	?	?	Calculate °F
25°C	?	?	?	Calculate °F
0°C	?	?	?	Calculate °F
Calculate °C	?	?	?	40°F
Calculate °C	?	?	?	81°F
Calculate °C	?	?	?	72°F

Temperature Lapse Rate Deviations

The International Civil Aviation Organization (ICAO) has determined that the standard sea level temperature is 15°C, and that the standard temperature lapse rate is 2°C (or 3.5°F) per 1,000 feet change in altitude, up to 38,000 feet mean sea level (MSL). From this, you can determine deviations from the standard temperature for performance calculations during climb or cruise. The standard day temperature for each altitude is referred to with the term ISA (International Standard Atmosphere).

The moist adiabatic lapse rate is 2.5°C (4.5°F). Therefore, to estimate the possible cloud bases at an airport with a relatively close temperature/dewpoint spread, subtract the dewpoint from the actual temperature and then divide by the moist adiabatic lapse rate.

All of the practice problems in Table 2-7 use a straightforward method of solving for ISA temperature. Multiply the altitude, in thousands of feet MSL, by 2 (2°C temperature lapse rate); then, subtract from 15°C. For the first problem, 5 × 2 = 10; then 15°C minus 10°C equals 5°C, or the estimated standard temperature at 5,000 feet MSL. The rest of the problems are solved in the same manner. Compute the ISA temperature and deviation. To determine the standard deviation at those same altitudes, simply find the temperature difference between the actual and ISA temperatures.

Actual Temperature – ISA Temperature = Temperature deviation

Table 2-7. Practice problems for ISA temperature and temperature deviation.

Altitude	ISA Temp	Actual Temp	Temp Dev
5,000 MSL	?	20°C	?
8,000 MSL	?	15°C	?
FL 210	?	–10°C	?
FL 350	?	–60°C	?

For reference, I have included a sampling of ISA temperatures versus altitude from sea level up through FL370 in Appendix D, Table D-8.

What's the Pressure Altitude?

Sitting in the cockpit, if you set 29.92 inHg in your barometric altimeter, you would then be reading the standard day pressure altitude for your location. Simple enough, right?

However, a problem may occur when you must figure your pressure altitude based on a particular altimeter setting other than standard and using your local airport elevation.

This, again, is quite simple. For every 0.01 inHg altimeter setting, your pressure altitude reading changes 10 feet.

Q *The ATIS altimeter setting (QNH) is 29.79 inHg and the local airport elevation is 460 ft MSL. What is the pressure altitude?*

A *Pressure altitude equals 590 ft. The difference between 29.79 inHg and 29.92 inHg is 0.13 in, which converts to a difference of 130 ft pressure altitude. Since we need to add the 0.13 inHg to 29.79 inHg to equal the standardized 29.92 inHg, we also add the 130 ft to the airport elevation of 460 ft to figure the pressure altitude.*

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Since 1976, Ron McElroy has flown in nearly every area of aviation. He's been an Air Force test pilot, a flight and ground instructor, a charter pilot, a skydive pilot, a photo and chase plane pilot, and a simulator instructor and line pilot for two airlines. He currently works as an aviation consultant. Ron has flown over 200 types of aircraft in his career, from the Piper Cub to the Boeing 777, and the military T-38 to the C-17.

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