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September 30th, 2008

Dear Student,

Thank you for picking up one of the Manhattan GMAT Strategy Guides—we hope that it refreshes your memory of the junior-high math that you haven't used in years. Maybe it will even teach you a new thing or two.

As with most accomplishments, there were many people involved in the various iterations of the book that you're holding. First and foremost is Zeke Vanderhoek, the founder of Manhattan GMAT. Zeke was a lone tutor in New York when he started the Company in 2000. Now, eight years later, MGMAT has Instructors and offices nationwide, and the Company contributes to the studies and successes of thousands of students each year.

These 3rd Edition Strategy Guides have been refashioned and honed based upon the continuing experiences of our Instructors and our students. We owe much of these latest editions to the insight provided by our students. On the Company side, we are indebted to many of our Instructors, including but not limited to Josh Braslow, Dan Gonzalez, Mike Kim, Stacey Koprince, Jadran Lee, Ron Purewal, Tate Shafer, Emily Sledge, and of course Chris Ryan, the Company's Lead Instructor and Director of Curriculum Development.

At Manhattan GMAT, we continually aspire to provide the best Instructors and resources possible. We hope that you'll find our dedication manifest in this book. If you have any comments or questions, please e-mail me at andrew.yang@manhattangmat.com. I'll be sure that your comments reach Chris and the rest of the team—and I'll read them too.

Best of luck in preparing for the GMAT!

Sincerely,

Andrew Yang
Chief Executive Officer
Manhattan GMAT

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ALGEBRAIC TRANSLATIONS

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Algebraic Translations

To solve many word problems on the GMAT, you must be able to translate English into algebra. You select variables and variable expressions to represent unknown quantities. Then you write equations to state relationships between the unknowns and any known values. Once you have written one or more algebraic equations to represent a problem, you can solve them to find any missing information.

> A candy company sells premium chocolates at $5 per pound and regular chocolates at $4 per pound. If Barrett buys a 7-pound box of chocolates that costs him $31, how many pounds of premium chocolates are in the box?

Be sure to make a note of what each variable represents. If you can, use meaningful letters as variable names.

To solve this problem, simply translate the words into algebraic equations:

<u>Step 1: Assign variables.</u>
If possible, designate only one variable, and use it to represent all unknown information.

Almost every word problem will refer to more than one quantity, but most solutions work best when they involve only one variable. Therefore, you should try to express all quantities in terms of a single variable—ideally, the "Ultimate Unknown" that the problem is asking for, but only if that Ultimate Unknown is a simple quantity.

In the problem above, the pounds of premium and regular chocolate must add to 7. Therefore, if you know one of the weights in pounds, you can subtract from 7 to find the other. We can assign the following:

p = number of pounds of premium chocolate
$7 - p$ = number of pounds of regular chocolate

You should also note that p is the Ultimate Unknown that the problem wants you to find. A good way to remind yourself is to write down "p = ?" on your paper.

Time is short during the GMAT, so you should not waste valuable seconds searching for one-variable expressions if you cannot nail them down right away. Instead, try using additional variables—but with an eye to finding substitutions that will ultimately reduce the number of variables to just one. In the chocolate problem, you could assign the following:

p = number of pounds of premium chocolate
r = number of pounds of regular chocolate

These two variables are related by the equation $p + r = 7$. Since the question is ultimately about p, you want a substitution that will eliminate r. Therefore, solve this equation for r:

$$r = 7 - p$$

Thus, there are p pounds of premium chocolate and $7 - p$ pounds of regular chocolate, and the problem has been successfully reduced to one variable. By the way, you *could* have used the letters x and y to represent the pounds of premium and regular chocolate, but if you use p and r, you will never forget which is which. Use meaningful letters if you can.

Step 2: Write equation(s).
If you are not sure how to construct the equation, begin by expressing a relationship between the unknowns and the known values in **words**. For example, you might say:

> "The total cost of the box is equal to the cost of the premium chocolates plus the cost of the regular chocolates."

You *might* even write down a "Word Equation," halfway between English and algebra:

> "Total Cost of Box = Cost of Premiums + Cost of Regulars"

Then, translate the verbal relationship into mathematical symbols. Use another relationship, *Total Cost* = *Unit Price* × *Quantity,* to write the terms on the right hand side. For instance, the "Cost of Premiums" in dollars = (\$5 per pound)(p pounds) = $5p$.

Most algebraic translation problems involve only the 4 simple arithmetic processes: addition, subtraction, multiplication, and division. Look for totals, differences, products and ratios.

$$31 = 5p + 4(7 - p)$$

The total cost of the box

is equal to

the cost of the premium chocolates

plus

the cost of the regular chocolates

Note that many word problems, including this one, require a little basic background knowledge to complete the translation to algebra. Here, to write the expressions $5p$ and $4(7 - p)$, you must understand that *Total Cost* = *Unit Price* × *Quantity*. In this particular problem, the quantities are weights, and the units of those quantities are pounds.

Although the GMAT requires little factual knowledge, it will assume that you have mastered the following relationships:

- Total Cost = Unit Price × Quantity purchased
- Total Sales or Revenue = Unit Price × Quantity sold (essentially the same relation)
- Profit = Revenue – Cost
- Distance = Rate × Time (this relation will be covered in the next chapter)

Step 3: Solve algebraically.

$$31 = 5p + 4(7 - p)$$
$$31 = 5p + 28 - 4p$$
$$3 = p$$

Step 4: Evaluate the algebraic solution in the context of the problem.
Once you solve for the unknown, look back at the problem and make sure you answer the question asked. In this problem, we are asked for the number of pounds of premium chocolate in the box. This is the Ultimate Unknown. Notice that we wisely chose our variable p to represent the Ultimate Unknown. This way, once we have solved for p, there are no additional steps to take. If you use two variables, p and r, and accidentally solve for r instead of p, you might choose 4 as your answer. This is why you should always note what the Ultimate Unknown is at the beginning of the problem (e.g., by writing "p = ?").

Translating Words Correctly

When you write equations representing relationships between variables—even if those relationships are fairly simple—you must be careful to **avoid writing the relationships backwards**. For instance, if you see "A is half the size of B," you should write $A = \frac{B}{2}$, not the wrong way around as $\frac{A}{2} = B$. Likewise, "A is 5 less than B" is written as $A = B - 5$. This relation is often incorrectly represented as $A = 5 - B$ or as $A - 5 = B$.

Be ready to insert simple test numbers to make sure that your translation is correct.

Because the stakes are so high for each GMAT problem, it is often worth a **quick check with easy numbers** to see whether you have written a relationship in the correct direction. For example, if you see "A is 5 less than B," then select, say, $A = 2$ and $B = 7$ to satisfy that relationship. (Note that these numbers do not have to satisfy other conditions given in the problem; their only purpose is to test the relationship you are looking at.) Trying these numbers in each of the three different re-writings of the equation yields

$A = B - 5$	→	$2 = 7 - 5$	Correct!
$A = 5 - B$	→	$2 = 5 - 7$?	Incorrect!
$A - 5 = B$	→	$2 - 5 = 7$?	Incorrect!

This quick testing will confirm that you have indeed written the correct form of an equation, so that you can proceed with confidence. If you ever make these types of errors, then take the time to perform these quick tests. Many incorrect answer choices on the GMAT are derived from mistakes just like these!

Note also the **two uses of "less than."**

"A is 5 less than B" turns into an equation with a subtraction: $A = B - 5$

"A is less than B" turns into an inequality: $A < B$

The difference is whether you specify *how much* less than. "More than" works similarly.

Percents can be tricky:

"p is what percent of q?" turns into an equation with a new variable: $p = \left(\frac{x}{100}\right)q$.

Or you can write proportions: $\frac{p}{q} = \frac{x}{100}$. Either way, you need to solve for x.

Finally, note that not all statements should be translated one word or phrase at a time. Some translations require you to **view the statement *as a whole*** to write an appropriate equation. For instance, if you see "Justina bought twice as many apples as bananas at the market," then you should write $A = 2B$, ***not*** $2A = B$ (as you can check with easy numbers).

If you try to translate the equation word for word, you might get the incorrect version, because the word "twice" appears closer to "apples." Or you might wrongly think that $2A$ means "two apples." A represents the *number* of apples, which is *larger* than the number of bananas, B. So we must multiply the number of bananas by 2 to get the number of apples: $A = 2B$ is correct. The moral is this: always pay attention to the *meaning* of the sentence you are translating!

Using Charts to Organize Variables

When an algebraic translation problem involves several quantities and multiple relationships, it is often a good idea to make a chart to organize information.

One type of algebraic translation that appears on the GMAT is the "age problem." Age problems ask you to find the age of an individual at a certain point in time, given some information about other people's ages at other times.

Complicated age problems can be effectively solved using an Age Chart. Such a chart helps you keep track of one person's age at different times or several ages at one time.

The age chart does not relate the ages of the individuals. It simply helps you to assign variables you can use to write equations.

> 8 years ago, George was half as old as Sarah. Sarah is now 20 years older than George. How old will George be 10 years from now?

Step 1: Assign variables.
Set up an Age Chart to help you keep track of the quantities. Put the different people in rows and the different times in columns. Then assign variables. You could use two variables (G and S), or you could use just one variable (G) and represent Sarah's age as $G + 20$, since we are told that Sarah is now 20 years older than George. We will use the second approach. Either way, always use the variables to indicate the age of each person *now* (this way, you will not confuse yourself). Fill in the other columns by adding or subtracting time from the "now" column (for instance, subtract 8 to get the "8 years ago" column). Also note the Ultimate Unknown with a question mark.

	8 years ago	**Now**	**10 years from now**
George	$G - 8$	G	$G + 10 = ?$
Sarah	$G + 12$	$G + 20$	$G + 30$

Step 2: Write equation(s).
Write equations that relate the individuals' ages together. According to this problem, 8 years ago, George was half as old as Sarah. Using the age expressions in the "8 years ago" column, we can write the following equation:

$$G - 8 = \frac{G + 12}{2} \qquad \text{which can be rewritten as} \qquad 2G - 16 = G + 12$$

Step 3: Solve algebraically.

$$2G - 16 = G + 12$$
$$G = 28$$

Step 4: Evaluate the algebraic solution in the context of the problem.
In this problem, we are asked to find George's age in 10 years. In other words, $G + 10$ is the Ultimate Unknown. Since George is now 28 years old, he will be 38 in 10 years. The answer is 38 years.

Note that if we had used two variables, G and S, we might have set the table up slightly faster, but then we would have had to solve a system of 2 equations and 2 unknowns.

Prices and Quantities

Many GMAT word problems involve the total price or value of a mixed set of goods. On such problems, you should be able to write two different types of equations right away.

1. Relate the *quantities* or numbers of different goods: Sum of these numbers = Total.
2. Relate the total *values* of the goods (or their total cost, or the revenue from their sale):
   Money spent on one good = Price × Quantity.
   Sum of money spent on all goods = Total Value.

The following example could be the prompt of a Data Sufficiency problem:

> Paul has twenty-five transit cards, each worth either \$5, \$3, or \$1.50. What is the total monetary value of all of Paul's transit cards?

In a typical Price–Quantity problem, you have two relationships. The quantities sum to a total, and the monetary values sum to a total.

Step 1. Define variables

There are three quantities in the problem, so the most obvious way to proceed is to designate a separate variable for each quantity:

x = number of \$5 transit cards
y = number of \$3 transit cards
z = number of \$1.50 transit cards

Alternatively, you could use the given *relationship* between the three quantities (they sum to 25) to reduce the number of variables from three to two:

number of \$5 transit cards = x
number of \$3 transit cards = y
number of \$1.50 transit cards = $25 - x - y$ or $25 - (x + y)$

Note that in both cases, the Ultimate Unknown (the total value of the cards) is *not* given a variable name. This total value is not a simple quantity; we will express it *in terms of* the variables we have defined.

Step 2. Write equations

If you use three variables, then you should write two equations. One equation relates the *quantities* or numbers of different transit cards; the other relates the *values* of the cards.

Numbers of cards: $x + y + z = 25$
Values of cards: $5x + 3y + 1.50z = ?$ (this is the Ultimate Unknown for the problem)

If you have trouble writing these equations, you can use a table to help you. The **columns** of the table are *Unit Price*, *Quantity*, and *Total Value* (with *Unit Price* × *Quantity* = *Total Value*). The **rows** correspond to the different types of items in the problem, with one additional row for *Total*.

In the *Quantity* and *Total Value* columns, but not in the *Unit Price* column, the individual rows sum to give the quantity in the *Total* row. Note that *Total Value* is a quantity of money (usually dollars), corresponding either to *Total Revenue*, *Total Cost*, or even *Total Profit*, depending on the problem's wording.

For this type of problem, you can save time by writing the equations directly. But feel free to use a table approach.

	Unit Price	×	*Quantity*	=	*Total Value*
\$5 cards	5	×	x	=	$5x$
\$3 cards	3	×	y	=	$3y$
\$1.50 cards	1.5	×	z	=	$1.5z$
Total	—		25		?

You can use a table to organize your approach to a Price–Quantity problem. However, if you learn to write the equations directly, you will save time.

Notice that the numbers in the second and third columns of the table (*Quantity* and *Total Value*) can be added up to make a meaningful total, but the numbers in the first column (*Unit Price*) do not add up in any meaningful way.

If you use the two-variable approach, you do not need to write an equation relating the *numbers* of transit cards, because you have already used that relationship to write the expression for the number of \$1.50 cards (as $25 - x - y$). Therefore, you only need to write the equation to sum up the values of the cards.

Values of cards: $5x + 3y + 1.50(25 - x - y) = ?$
Simplify → $3.5x + 1.5y + 37.5 = ?$

Here is the corresponding table:

	Unit Value	×	*Quantity*	=	*Total Value*
\$5 cards	5	×	x	=	$5x$
\$3 cards	3	×	y	=	$3y$
\$1.50 cards	1.5	×	$25 - x - y$	=	$1.5(25 - x - y)$
Total	—		25		?

All of the work so far has come just from the *prompt* of a Data Sufficiency question—you have not even seen statements (1) and (2) yet! But this work is worth the time and energy. In general, you should rephrase and interpret a Data Sufficiency question prompt as much as you can before you begin to work with the statements.

Hidden Constraints

Notice that in the previous problem, there is a **hidden constraint** on the possible quantities of cards (x, y, and either z or $25 - x - y$). Since each card is a physical, countable object, you can only have a **whole number** of each type of card. Whole numbers are the integers 0, 1, 2, and so on. So you can have 1 card, 2 cards, 3 cards, etc., and even 0 cards, but you cannot have fractional cards or negative cards.

As a result of this implied "whole number" constraint, you actually have more information than you might think. Thus, you may be able to answer the question with less information from the statements.

As an extreme example, imagine that the question is "What is x?" and that statement (1) reads "$1.9 < x < 2.2$". If some constraint (hidden or not) restricts x to whole-number values, then statement (1) is sufficient to answer the question: x must equal 2. On the other hand, without constraints on x, statement (1) is not sufficient to determine what x is.

When a variable indicates how many objects there are, it must be a whole number.

Recognizing a hidden constraint can be useful, not only on Data Sufficiency problems, but also on certain Problem Solving problems. Consider the following example:

> If Kelly received 1/3 more votes than Mike in a student election, which of the following could have been the total number of votes cast for the two candidates?
>
> (A) 12
> (B) 13
> (C) 14
> (D) 15
> (E) 16

Let M be the number of votes cast for Mike. Then Kelly received $M + (1/3)M$, or $(4/3)M$ votes. The total number of votes cast was therefore "votes for Mike" plus "votes for Kelly," or $M + (4/3)M$. This quantity equals $(7/3)M$, or $7M/3$.

Because M is a number of votes, it cannot be a fraction—specifically, not a fraction with a 7 in the denominator. Therefore, the 7 in the expression $7M/3$ cannot be cancelled out. As a result, the total number of votes cast must be a multiple of 7. Among the answer choices, the only multiple of 7 is 14, so the correct answer is (**C**).

Another way to solve this problem is this: the number of votes cast for Mike (M) must be a multiple of 3, since the total number of votes is a whole number. So $M = 3, 6, 9$, etc. Kelly received 1/3 more votes, so the number of votes she received is 4, 8, 12, etc. Thus the total number of votes is 7, 14, 21, etc.

Not every unknown quantity related to real objects is restricted to whole numbers. Many physical measurements, such as weights, times, or speeds, can be any positive number, not necessarily integers. A few quantities can even be negative (e.g., temperatures, x- or y-coordinates). Think about what is being measured or counted, and you will recognize whether a hidden constraint applies.

Problem Set

Solve the following problems with the four-step method outlined in this section.

1. John is 20 years older than Brian. 12 years ago, John was twice as old as Brian. How old is Brian?

2. Mrs. Miller has two dogs, Jackie and Stella, who weigh a total of 75 pounds. If Stella weighs 15 pounds less than twice Jackie's weight, how much does Stella weigh?

3. Caleb spends $72.50 on 50 hamburgers for the marching band. If single burgers cost $1.00 each and double burgers cost $1.50 each, how many double burgers did he buy?

4. Abigail is 4 times as old as Bonnie. In 6 years, Bonnie will be twice as old as Candice. If, 4 years from now, Abigail will be 36 years old, how old will Candice be in 6 years?

5. United Telephone charges a base rate of $10.00 for service, plus an additional charge of $0.25 per minute. Atlantic Call charges a base rate of $12.00 for service, plus an additional charge of $0.20 per minute. For what number of minutes would the bills for each telephone company be the same?

6. Ross is 3 times as old as Sam, and Sam is 3 years older than Tina. 2 years from now, Tina will drink from the Fountain of Youth, which will cut her age in half. If after drinking from the Fountain, Tina is 16 years old, how old is Ross right now?

7. Carina has 100 ounces of coffee divided into 5- and 10-ounce packages. If she has 2 more 5-ounce packages than 10-ounce packages, how many 10-ounce packages does she have?

8. Carla cuts a 70-inch piece of ribbon into 2 pieces. If the first piece is five inches more than one fourth as long as the second piece, how long is the longer piece of ribbon?

9. In a used car lot, there are 3 times as many red cars as green cars. If tomorrow 12 green cars are sold and 3 red cars are added, then there will be 6 times as many red cars as green cars. How many green cars are currently in the lot?

1. **32:** Use an age chart to assign variables. Represent Brian's age now with b. Then John's age now is $b + 20$.

	12 years ago	Now
John	$b + 8$	$b + 20$
Brian	$b - 12$	$b = ?$

Subtract 12 from the "now" column to get the "12 years ago" column.

Then write an equation to represent the remaining information: 12 years ago, John was twice as old as Brian. Solve for b:

$$b + 8 = 2(b - 12)$$
$$b + 8 = 2b - 24$$
$$32 = b$$

You could also solve this problem by inspection. John is 20 years older than Brian. We also need John to be *twice* Brian's age at a particular point in time. Since John is always 20 years older, then he must be 40 years old at that time (and Brian must be 20 years old). This point in time was 12 years ago, so Brian is now 32 years old.

2. **45 pounds:**
Let j = Jackie's weight, and let s = Stella's weight. Stella's weight is the Ultimate Unknown: $s = ?$

The two dogs weigh a total of 75 pounds.
$$j + s = 75$$

Stella weighs 15 pounds less than twice Jackie's weight.
$$s = 2j - 15$$

Combine the two equations by substituting the value for s from equation (2) into equation (1).

$$j + (2j - 15) = 75$$
$$3j - 15 = 75$$
$$3j = 90$$
$$j = 30$$

Find Stella's weight by substituting Jackie's weight into equation (1).

$$30 + s = 75$$
$$s = 45$$

3. **45 double burgers:**
Let s = the number of single burgers purchased
Let d = the number of double burgers purchased

Caleb bought 50 burgers:
$$s + d = 50$$

Caleb spent \$72.50 in all:
$$s + 1.5d = 72.50$$

Combine the two equations by subtracting equation (1) from equation (2).

$$\begin{array}{r} s + 1.5d = 72.50 \\ \underline{-\ (s + \quad d = 50)} \\ 0.5d = 22.5 \\ d = 45 \end{array}$$

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