SPECIALIZED
TELEVISION ENGINEERING

TELEVISION TECHNICAL ASSIGNMENT

POSITIVE AND NEGATIVE NUMBERS; EXPONENTS AND SQUARE ROOT

705D

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FOREWORD

To the average person a number always has a positive quality; that is, to most people "zero" is the ultimate in smallness—they have no concept of a number that could represent a value of less than zero. They deal with such numbers, however, in daily life. We constantly hear the expression, as referring to a business, "operating in the red". Thus, if a business operated at a loss of $1,000, it could just as well be stated that there was a "negative profit" of $1,000—that is, the profit was $1,000 *less than zero.*

In television video (picture) amplifiers there is frequently used a "cathode coupled" stage in which a tube is used in a special type of circuit to feed the pictures signal to a transmission line. Such an amplifier stage may have a "gain" of .5 *or less than unity.* Since unity (1) gain or amplification means that the output signal is equal to the input signal, a gain of less than unity indicates a *negative quantity or loss* of signal amplitude.

As another example: The kinescope (picture tube) of a television receiver may have applied to its second anode a *positive potential* of 7,500 volts with respect to its cathode which, normally, is considered the zero reference point in a tube. At the same time, the control grid may operate with a *negative potential* of 30 volts with respect to the same cathode. Thus, with respect to the cathode, we could express these as: anode potential, + 7,500 volts; grid potential - 30 volts. Since these voltages are opposite in direction from 0 potential, the voltage applied between anode and grid is actually 7,530 volts.

From the above it will be seen that a negative number can represent a *very real quantity.* Contact with a *negative potential* of 1,000 volts with respect to ground will knock you just as far as similar contact with a *positive potential* of 1,000 volts! Since you will be dealing with such examples of positive and negative quantities daily in your radio and television work, a proper concept of such numbers is essential.

The second major topic in this assignment is "Exponents." The proper use of exponents *greatly simplifies* the expressing of very large and very small quantities and provides a "shorthand" method of dealing with such quantities in problems.

For example, how much simpler it is to write: $5 \times 10^{-7} \times 7 \times 10^{15} = 35 \times 10^{8}$ than to write: $.0000005 \times 7{,}000{,}000{,}000{,}000{,}000 = 3{,}500{,}000{,}000$!

These are typical of the numbers you will encounter in radio and television calculations. For example, in compensating the frequency response of a video (picture) amplifier stage, you must measure the tube output capacity which may be 9 μμF and then possibly compensate the load circuit with 35 μH. Expressed in units for purposes of calculation, these would be .000000000009 Farad and .000035 Henry, respectively. How much easier to write 9×10^{-12}F and 35×10^{-6}H. And how much easier to keep the decimal point correct!

This assignment is not difficult—but *it is extremely practical and important*. What you learn in studying the next few pages, you will use during all the years of your professional career. Isn't it worth the few hours of serious study it takes to learn it well?

E. H. Rietzke,
President.

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TELEVISION TECHNICAL ASSIGNMENT

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Mathematics is the tool of the engineer. The study of radio circuits is nothing more than the study of alternating currents at radio frequencies, and the study of alternating current theory and practice is impossible without the use of certain basic mathematics. The calculations necessary in the handling of practical radio engineering problems are not difficult but they must be thoroughly understood. The ability to use the essential mathematics, to work the problems incident to the design of workable equipment, and to follow a technical explanation of the operation of a circuit is the distinguishing qualification of an engineer as contrasted with the mechanic.

All of the mathematical work in this course of study has been carefully selected and prepared with the practical application always the foremost consideration. No part of it is non-essential and no part should be skipped over without being thoroughly understood. A careful thorough study of this early work will pave the way for excellent progress throughout the entire course.

The student should conscientiously work *all* the exercise problems as he comes to them. In no work is the saying, "Practice makes perfect", more applicable than in the study of applied mathematics.

THE POSITIVE NUMBER.--The positive number is the number used and understood in common arithmetic and is any number greater than zero. Positive numbers may be added, subtracted, multiplied, or divided and the answer is positive, with one exception, that exception being in the case of a larger number subtracted from a smaller number, such as 5 - 8. This will be explained in the following paragraph. If a number is not preceded by a sign, it is always understood to be positive.

THE NEGATIVE NUMBER.--Common arithmetic recognizes only the positive number. There are many occasions, however, where it becomes necessary to recognize numbers less than zero, as in the above example of a larger number subtracted from a smaller. The answer would certainly be less than zero. Consider the case of a man who has ten dollars in cash and has debts amounting to twenty dollars. He actually owns ten dollars less than nothing. His financial condition would be expressed as -10. Thus the answer in the case of a larger number subtracted from a smaller is always expressed as a negative number and preceded by the minus sign.

If a positive number is thought of as a force acting in one direction on a point, and a negative number as a force acting on the same point in the opposite direction, the point being zero, these numbers may be expressed as in Fig. 1.

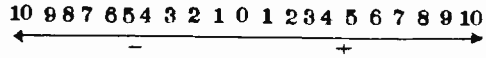

Fig. 1.--Representation of positive and negative numbers by two opposite directions in space.

It is apparent that since the negative number has an effect opposite to that of the positive number, one will counteract an equal amount of the other. For example: The sum of a +6 and a -6 is zero, as one counteracts the effect of the other. If it is desired to add a -8 to a +5, the latter will counteract only the amount of the former equal to itself, and there will be a remainder of -3. Thus, the sum of a +5 and a -8 is -3. The sum of a +8 and a -3 will be +5. Therefore, a rule may be made as follows:

RULE 1: *When adding two numbers of unlike signs, subtract the smaller from the larger, and the answer will take the sign of the larger.*

Example: $4 + (-8) = -4$

$(-4) + 8 = 4$

In adding several positive and negative numbers, first add all the positive numbers, next add all the negative numbers, and then work according to Rule 1.

Example: Add, 4, -8, -6, 14, 2, -5,

4	-8	
14	-6	20 + (-19) = 1
2	-5	
20	-19	

Exercises

Add,

1. 16, -2, -27, -8, 4.

2. -3, 27, 13, -42, 20.

3. 15, 28, -14, -6, -10.

4. -6, -8, 2.5, 28.7, -10.6.

5. -25, -37, -14, 102, 16.

6. 24, -78, 41, 32, -17.

7. -16, 42, 76, -124, 314.

8. -27.5, 16 2/3, -14 1/2, -17.9.

9. 26.32, -.98, 44, -76.1.

10. 3.276, -14.928, -.764, 19.73.

Referring to Fig. 1, it is seen that if a negative number is added to a positive number, it counteracts a certain amount of the positive number. On the other hand if it were desired to *subtract* a negative number, the effect would be reversed, that is, it would be the same as *adding* an equivalent amount to the positive number. This holds true also in the subtraction of a positive number; the effect will be that of adding an equivalent amount to the negative value.

It is seen that the subtraction of a negative number is the same as adding an equivalent positive number, and the subtraction of a positive number is the same as adding an equivalent negative number. This may be expressed in a rule as follows:

RULE 2: *When subtracting one number from another, change the sign of the subtrahend and add.*

This applies to the subtraction of either positive or negative numbers. (The "subtrahend" is the number that is to be subtracted. The number from which it is subtracted is called the "minuend". Any amount left over is the "remainder".) When both the numbers are of like sign after the sign of the subtrahend has been changed, the addition is arithmetic. Where the numbers have unlike signs after the change, the addition is in accordance with Rule 1.

Examples:

4 minus -6 = 10
-4 minus 6 = -10
-10 minus -2 = -8
10 minus 2 = 8

Simple rules for remembering the principles of addition and subtraction of positive and negative numbers are:

1. The addition of a positive number makes the value greater.
2. The addition of a negative number makes the value smaller.
3. The subtraction of a positive number makes the value smaller.
4. The subtraction of a negative number makes the value greater.

In connection with these rules it must be remembered that the larger the negative number, the smaller is its actual value.

Exercises

11. 280 - 320 = ?

12. -85 - 42 = ?

13. -102 - (-20) = ?

14. -80 - (-105) = ?

15. (27 + 18 - 40) - (82 - 14 + 20) = ?

16. 250 - (-20 + 30 - 65) = ?

17. 27 + 15 - (2.5 + 18.3 - 10.6) = ?

18. 150 - 25 - (100 + 240 - 80) = ?

19. (170 - 40 + 10) - 300 = ?

20. (150 + 60 - 28) - (34 + 16) - (-50 - 27) = ?

MULTIPLICATION AND DIVISION.—The rules for the multiplication and division of positive and negative numbers are similar, as follows:

RULE 3:—*When multiplying or dividing numbers having LIKE signs, the answer is ALWAYS positive. This is true if the signs are either both negative or both positive.*

Examples: 4 x 2 = 8 $\frac{4}{2} = 2$

-4 x -2 = 8 $\frac{-4}{-2} = 2$

RULE 4:—*When multiplying or dividing numbers having UNLIKE signs, the answer is ALWAYS negative.*

Examples: 8 x -2 = -16 $\frac{8}{-4} = -2$

-8 x 2 = -16 $\frac{-8}{4} = -2$

Exercises

21. 40 x 20 = ?

22. 60 x -30 = ?

23. 10 x -6 x -14 = ?

24. -25 x -6 x -4 = ?

25. 21 x 42 x -1 = ?

26. 42 ÷ -6 = ?

27. -40 ÷ -20 = ?

28. -35 ÷ 7 = ?

29. $\frac{350 \times -6}{-25 \times 2} = ?$

30. $\frac{420 \times 8}{-1} = ?$

ALGEBRAIC ADDITION.–The addition of quantities or forces, taking into consideration their signs, is called *algebraic addition.* In algebraic addition of forces the forces are always considered as acting in the same direction or in exact opposition, as determined by their signs. That is, if the sign of a number is changed, its effect on other numbers, considering the numbers as forces acting on a point, is exactly reversed. Two positive numbers act in exactly the same direction; two negative numbers act in exactly the same direction; a negative number and a positive number are in exact opposition. Algebraic addition is extensively used in calculations involving currents and voltages in a circuit.

EXPONENTS.-- A common use for positive and negative numbers is in working with numbers, (or letters in algebraic equations or formulas), having exponents.

The exponent of a number is a small figure placed above and to the right of the number, indicating the power to which the number is to be raised.

Examples: 10^3, 10^{-3}, Y^2, 8^n.

In example one, 10 is the number which is to be raised to the third power. This means that 1 is to be multiplied by the number, 10, as many times as is indicated by the exponent, as: 1 x 10 x 10 x 10 = 1,000 or 10^3. Since multiplying any number by 1 does not change its value, this may be stated as 10^3 = 10 x 10 x 10, or it may be stated that 10 is to be used as a factor in multiplication three times.

In example two, ten is again the number, but it is now raised to the negative third power. *This means that one is to be divided by the number raised to its third power, as:*

$$\frac{1}{10 \times 10 \times 10} = \frac{1}{10^3} = 10^{-3}$$

In the case of a number raised to its positive first power, as 5^1, this is equal to 1 x 5 or simply 5. It will be seen that any number raised to the first power is equal to itself, so the positive first power is not indicated. 10^1 is written simply 10.

In the case of a number raised to the negative first power, the power must be indicated, as a number raised to the negative first power is equal to the reciprocal of the number or one divided by that number. 10^{-1} means 1/10 and the negative one (-1) must be used as the exponent to indicate the division.

In the third example the letter Y is used in place of the number and is treated in the same manner. Y^2 = Y x Y.

In algebraic equations letters may be substituted for figures. In the same manner a letter may be used as an exponent to indicate some given power. Of course, if it is desired to find the exact numerical value of such a term, the actual numerical value which the letter represents must be substituted.

Examples: 4^n, X^y, etc. If y = 6, then $X^y = X^6$.

USE OF EXPONENTS.– In the practical use of exponents, two or more *like* numbers having exponents, may be multiplied by simply adding the exponents and affixing the resulting exponent to the common number.

Examples:

$8^4 \times 8^2 \times 8^3 = 8^{4+2+3} = 8^9$

$4^{-2} \times 4^{-3} \times 4^{-6} = 4^{-2-3-6} = 4^{-11}$

$5^{-6} \times 5^{-2} \times 5^4 = 5^{-6-2+4} = 5^{-4}$

Note in the above examples that *very careful attention must be given to the sign of the exponent.* It must also be remembered that these rules for the use of exponents apply only in the case of *like* numbers. $4^6 \times 5^0$ cannot be multiplied by adding the exponents and affixing to a common number. Such numbers must be raised to their respective powers individually and then multiplied.

Example: $2^3 \times 3^2 = 2 \times 2 \times 2 \times 3 \times 3 = 72$.

Exercises

Combine and simplify,

31. $4^6 \times 4^8 \times 4^2 = ?$

32. $6^2 \times 6^{-4} \times 6^{-3} = ?$

33. $15^{-3} \times 15^{-7} \times 15^4 \times 15^2 = ?$

34. $8^4 \times 8^6 \times 8^8 \times 8^{-10} = ?$

35. $5^3 \times 5^4 \times 4^2 \times 5^{-6} \times 4^{-4} = ?$

36. $3^2 \times 3^{-6} \times 3^{-4} \times 3^8 = ?$

37. $2^2 \times 3^{-3} \times 2^4 \times 4^2 = ?$

38. $6^{-1} \times 6^2 \times 4^2 \times 7^3 = ?$

39. $15^{-3} \times 20^2 \times 15^{-1} \times 15^4 = ?$

40. $7 \times 7^2 \times 7^{-1} \times 6^2 \times 2^{-2} = ?$

DIVISION.—Two or more *like* numbers having exponents may be divided by *subtracting the exponent* of the divisor from the exponent of the dividend, and affixing the remainder as the exponent of the common number to form the quotient.

Examples: $6^5 \div 6^2 = 6^3$

$4^9 \div 4^{-3} = 4^{12}$

(*Note:* $9 - (-3) = 9 + 3 = 12$)

$18^{-6} \div 18^4 = 18^{-10}$

(*Note:* $-6 - 4 = -10$)

At this point it is well to point out a common error in handling numbers having exponents. For example, $10^2 \div 10^2$.

Subtracting the exponents, $2 - 2 = 0$. Thus the answer will be 10^0 or 10 to the zero power. 10^2 is 100, therefore $10^2 \div 10^2 = 100/100 = 1$. It will be seen that $10^0 = 1$. In fact *any* number raised to its zero power equals 1. The common error is to consider the answer as being zero.

Since $1/10^3 = 1 \times 10^{-3}$, a number having an exponent, when used in the denominator of a fraction, may be transferred to the numerator by merely changing the sign of the exponent. Thus $4 \times 10^3/2 \times 10^5$ may be written $4 \times 10^3 \times 10^{-5}/2$. The denominator 2 cancels (divides) into the 4 in the numerator and the expression may be written, $2 \times 10^3 \times 10^{-5}$. Since the numbers having exponents, 10^3 and 10^{-5}, are *like* numbers, they may be multiplied by adding their exponents. $3 + -5$ equals -2, therefore the simplified form is 2×10^{-2}. Since 10^{-2} means $1/(10 \times 10)$ then the expression may be finally written $2 \times 1/(10 \times 10) = 2/100 = .02$. It particularly should be remembered that only numbers having exponents may be handled in this manner, and that only the sign of the exponent is changed. In this problem the numerical value 2 below the line was cleared by division into the number 4.

Exercises

41. $8^3 \div 8 = ?$

42. $15^4 \div 15^{-1} = ?$

43. $6^{-5} \div 6^{-7} = ?$

44. $8^{10} \div 8^{12} = ?$

45. $12^{-6} \div 12^4 = ?$

46. $\frac{8^4 \times 8^3}{8^5} = ?$

47. $\frac{6^{-3} \times 6^4}{6^{-2}} = ?$

48. $\frac{9^3 \times 9^{-7} \times 9^{-2}}{9^{-8}} = ?$

49. $\frac{8^4 \times 8^{-2} \times 8^{-3}}{8^{-1}} = ?$

50. $\frac{14^5}{14^{-2} \times 14^{-4}} = ?$

Another problem involving similar procedure: $18 \times 10^{-4} \times 10^6 / 9 \times 10^{-3}$. Dividing the 9 in the denominator into the 18 in the numerator, the expression becomes $2 \times 10^{-4} \times 10^6 \div 10^{-3}$. Bringing the 10^{-3} from below the line to above the line, it becomes 10^3. The entire expression is then equal to: $2 \times 10^{-4} \times 10^6 \times 10^3$. All the numbers having exponents being the same, (10), multiply by adding the exponents. The sum of -4, 6, 3 = 5. The answer is 2×10^5.

It will be observed in the above problems that 10 was selected as the number having the exponent. Any number may, of course, be handled by this method, but 10 is the most commonly used number occurring in radio work (and in most mathematics) because the use of 10 raised to some positive or negative power facilitates the handling of very large numbers or very small decimals.

Example: 15,000,000,000 times 300,000 = 4,500,000,000,000,000. Since 15,000,000,000 = 15 multiplied by 10 nine times, it may be written 15×10^9. Likewise, 300,000 equals 3 multiplied by 10 five times, therefore equalling 3×10^5. The problem may then be reduced to the very simple form of $15 \times 3 \times 10^9 \times 10^5 = 45 \times 10^9 \times 10^5$. The exponents are added and affixed to the common number 10, and the answer becomes 45×10^{14}, which is exactly the same as the answer previously obtained but in a much simpler and compact form. Since very large figures are constantly occurring in radio mathematics, this simplicity is very desirable.

The same principle is used to simplify the handling of decimals. For example, $.0004 = 4/10 \times 10 \times 10 \times 10 = 4/10^4$. It can therefore be written 4×10^{-4}. *Any decimal may be converted into a whole number times 10 raised to some negative power* by simply moving the decimal point to the right as many places as may be necessary and multiplying the whole number obtained by 10 raised to a negative power equal to the number of places the decimal point was moved to the right.

Example: $.0000436 = 436 \times 10^{-7}$, This also may be expressed as 4.36×10^{-5} by moving the decimal point only 5 places to the right, and such form is very often advantageous. In particular, the latter form is useful when using a slide rule, where it is desired to keep the numerical values of the figures to be multiplied or divided small so as to simplify the placing of the decimal point in the answer.

Examples in simplifying large numbers and decimals:

$$14,960,000,000 = 1496 \times 10^{7}$$
$$= 149.6 \times 10^{8}$$
$$= 14.96 \times 10^{9}$$
$$= 1.496 \times 10^{10}$$
etc.

$$2,670,000,000,000 = 267 \times 10^{10}$$
$$= 26.7 \times 10^{11}$$
$$= 2.67 \times 10^{12}$$
$$= 0.267 \times 10^{13}$$
etc.

$$.000000000027 = 27 \times 10^{-12}$$
$$= 2.7 \times 10^{-11} \text{ etc.}$$

$$.0005 = .5 \times 10^{-4} = 0.5 \times 10^{-3} \text{ etc.}$$

A problem showing the use of the foregoing examples follows:

$$\frac{2000 \times 6 \times 10^{-8} \times 43 \times 10^{-9}}{14 \times 10^{7} \times .000003 \times 10^{-3}} = ?$$

Rearranging,

$$\frac{2 \times 10^{3} \times 6 \times 10^{-8} \times 4.3 \times 10 \times 10^{-9}}{14 \times 10^{7} \times 3 \times 10^{-6} \times 10^{-3}}$$

Multiplying,

$$\frac{51.6 \times 10^{-13}}{42 \times 10^{-2}}$$

Dividing 51.6 by 42 and bringing 10^{-2} above the line and changing the sign of the exponent, $1.228 \times 10^{-13} \times 10^{2}$

$$1.288 = 1288 \times 10^{-3}$$
(Move decimal 3 places to right)

$$1228 \times 10^{-3} \times 10^{-13} \times 10^{2}$$
$$= 1228 \times 10^{-14}$$

This answer may also be written .00000000001228 but it will then be very unwieldly.

Note that in solving such problems no large numbers or difficult decimals are handled at any time. Of course in actual practice some of the steps as outlined will be performed mentally so that the actual procedure is quick and simple.

POWERS OF TEN

The use of "Powers of Ten", or "Scientific Notation" as it is sometimes called, is a great time saver in radio work where very large and very small quantities are continually encountered. For example, in a single problem we may have frequencies of millions or thousands of millions of cycles per second and capacity values of a few millionths of a millionth of a farad. Such otherwise unwieldly numbers are handled with ease by rewriting each of then as a small number multiplied by an appropriate power of ten. Note the following:

$$10^{0} = 1$$
$$10^{1} = 10$$
$$10^{2} = 10 \times 10 = 100$$
$$10^{3} = 10 \times 10 \times 10 = 1,000$$
$$10^{4} = 10 \times 10 \times 10 \times 10 = 10,000$$

$10^5 = 10 \times 10 \times 10 \times 10 \times 10 = 100{,}000$

$10^6 = 10 \times 10 \times 10 \times 10 \times 10 \times 10$

$= 1{,}000{,}000$

A quantity to a negative power is equal to the reciprocal of the same number to a positive power of the same magnitude.

$10^{-1} = 1/10 = .1$

$10^{-2} = 1/10^2 = 1/(10 \times 10) = .01$

$10^{-3} = 1/10^3 = 1/(10 \times 10 \times 10) = .001$

$10^{-4} = 1/10^4 = 1/(10 \times 10 \times 10 \times 10)$

$= .0001$

$10^{-5} = 1/10^5 = 1/(10 \times 10 \times 10 \times 10 \times 10)$

$= .00001$

$10^{-6} = 1/10^6 =$

$1/(10 \times 10 \times 10 \times 10 \times 10 \times 10) = .000001$

Note that in the case of positive exponents of ten, the power indicates the number of places that the decimal point must be moved to the right, starting from its position following 1. In the case of negative exponents, the exponent indicates how many places the decimal point must be moved to the left, starting at its position after 1.

Thus, $10^7 = 10{,}000{,}000$
(Move decimal point seven places to right from 1.)

And, $10^{-3} = .001$
(Move decimal point three places to left from 1.)

When the number to be expressed in Scientific Notation is not a simple power of ten, the same idea may be applied by rewriting the significant figures of the given number, placing a decimal point after the first of these figures, and indicating as a multiplier 10 raised to a power equivalent to the number of places the decimal point was moved, positive exponents being indicated when the decimal point was moved to the left, negative when it is moved to the right.

For example, 5,000 can be regarded as $5 \times 1{,}000$ or 5×10^3. Or by the rule just mentioned, write the significant number 5, (decimal point understood to follow the 5) and indicate multiplication by 10 to a power equivalent to the number of places the decimal point was moved in going from 5,000 to 5, (3 places) giving the exponent a positive sign because the decimal point was moved to the left. Thus $5{,}000 = 5. \times 10^3$.

Additional examples follow: Note that the preferred practice is to write the decimal point after the first of the significant figures, but this is not mandatory, providing the exponent of ten is made to indicate the number of places the decimal point was actually moved.

$12{,}000 = 1.2 \times 10^4$ or $12. \times 10^3$

$310{,}000 = 3.1 \times 10^5$

$.021 = 2.1 \times 10^{-2}$ or $21. \times 10^{-3}$

$350{,}000 = 3.5 \times 10^5$

$251{,}000 = 2.51 \times 10^5$

$.09 = 9 \times 10^{-2}$

Solve by the use of powers of

ten:

$$\frac{12{,}000 \times 310{,}000 \times .021}{350{,}000 \times 251{,}000 \times .09} = ?$$

Rewriting in powers of ten:

$$\frac{1.2 \times 10^4 \times 3.1 \times 10^5 \times 2.1 \times 10^{-2}}{3.5 \times 10^5 \times 2.51 \times 10^5 \times 9 \times 10^{-2}}$$

$$= \frac{1.2 \times 3.1 \times 2.1 \times 10^{9-2}}{3.5 \times 2.51 \times 9 \times 10^{10-2}}$$

$$= \frac{7.812 \times 10^7}{79.065 \times 10^8} = .00988$$

Different powers of the same number may be multiplied by writing the number to the power indicated by the sum of the exponents.

Thus, $10^4 \times 10^5 \times 10^{-2} = 10^{9-2} = 10^7$

And, $10^5 \times 10^5 \times 10^{-2} = 10^{10-2} = 10^8$

Rewriting using the combined powers of ten:

$$= \frac{1.2 \times 3.1 \times 2.1 \times 10^7}{3.5 \times 2.51 \times 9 \times 10^8} = ?$$

Dividing both numerator and denominator by 10^7:

$$= \frac{1.2 \times 3.1 \times 2.1}{3.5 \times 2.51 \times 9 \times 10^1} = ?$$

Powers of ten may be transferred from denominator to numerator (or vice-versa) by changing the sign of the exponent

$$\frac{1.2 \times 3.1 \times 2.1 \times 10^{-1}}{3.5 \times 2.51 \times 9}$$

Performing the indicated arithmetic

$$= \frac{7.812}{79.065} \times 10^{-1} = .099 \times 10^{-1} = .0099$$

Ans.

Combining the powers of ten, shown in detail above, is usually accomplished in practice mentally, in one step, leaving only the arithmetrical calculation to be performed.

Note that the zero power of any quantity is unity (1). Thus 5×10^0 would mean 5×1, or 5.

Note that in radiowork accuracy to three significant figures is usually sufficient. Thus it is often convenient to "round off" values to three significant figures when rewriting in Scientific Notation:

$$.0053785 = 5.38 \times 10^{-3}$$

$$3{,}210{,}500 = 3.21 \times 10^6$$

(The above described practice of placing the decimal point after the first significant figure will be found convenient later in using logarithms, in which case the characteristic of the logarithm is identical with the exponent of the power of ten. For example:

$$\text{Log } .005378 = \text{Log } 5.378 \times 10^{-3}$$

$$= -3 + 0.72062$$

Note the recurrence of -3 as the power and as the characteristic. The use of logarithms and log tables will be taken up in the technical assignment on logarithms.

Exercises

Simplify and solve,

51. 2,345,000,000,000,000.

52. 6,400,000,000.

53. 8,750,000,000,000.

54. .00246

55. .0000078

56. .00000000003

57. .0000000987

58. .0002569

59. .00035 x .0000027

60. 265,000,000 x .0043 x .012 = ?

61. $\frac{.000027 \times .0003}{.000009} = ?$

62. $\frac{4{,}500{,}000 \times 63{,}000}{7{,}000{,}000{,}000} = ?$

63. $\frac{680{,}000 \times 42{,}000{,}000}{.007} = ?$

64. $\frac{.0000065 \times 24{,}000}{13{,}000 \times .006} = ?$

65. $\frac{18{,}000{,}000 \times 60{,}000}{70{,}000 \times .000025} = ?$

POWERS AND ROOTS OF NUMBERS HAVING EXPONENTS.--In raising a number having an exponent to a given power, it is only necessary to multiply the exponent by the power to which it is to be raised. Thus, $(10^4)^3 = 10^{12}$, $(10^5)^2 = 10^{10}$, $(10^{-3})^4 = 10^{-12}$. This may be seen from the following: 10^4 raised to the third power, $(10^4)^3$, means (10^4) (10^4) (10^4). Since $10^4 = 10 \times 10 \times 10 \times 10$, then $(10^4)^3 = 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10$. These are like numbers, each having a positive exponent of one, and the exponents added and affixed to the common number will equal 10^{12}. The same principle holds true with numbers having negative exponents: Thus, $(10^{-3})^4 = 10^{-12}$, due to The same reasoning as explained above in this paragraph.

The rule given in the preceding paragraph is reversed when it is desired to extract a root of a number having an exponent. In that case the exponent is divided by the root, and the resulting exponent is affixed to the number which is removed from beneath the radical.

Examples:

$$\sqrt{4^6} = 4^{6/2} = 4^3$$

$$\sqrt[4]{5^{12}} = 5^{12/4} = 5^3$$

$$\sqrt[3]{10^{-9}} = 10^{-9/3} = 10^{-3}$$

Suppose it is desired to extract the square root of the following decimal: $\sqrt{.000000002634}$. First convert to a whole number times ten to the correct negative power, $\sqrt{2634 \times 10^{-12}}$. Extract the square root of 10^{-12} by inspection and the result is $\sqrt{2634} \times 10^{-6}$. The number beneath the radical will now be treated as a whole number with no decimal part to consider. Decimals of this type are commonly experienced in alternating current problems at radio frequencies, in R.F. circuit calculations, etc. A somewhat similar problem of this sort,

$$\sqrt{16 \times 10^{-7} \times 4 \times 10^{-8}}$$

Simplified, this becomes

$$\sqrt{64 \times 10^{-15}}$$

If treated exactly as in the previous example it will become $\sqrt{64} \times 10^{-7.5}$. There is no simple way of raising a number to a fractional power, so that if treated in this manner the problem will become complicated instead of simplified. However, there is another solution. 64×10^{-15} is equal to 64 preceded by 13 ciphers. Suppose the decimal point is moved only fourteen places to the right. The expression will then become 6.4×10^{-14}. Thus, there is obtained $\sqrt{6.4 \times 10^{-14}}$, the answer becomes $\sqrt{6.4} \times 10^{-7}$. The problem is now simplified, and it is only necessary to extract the square root of 6.4 and multiply by 10^{-7}. The square root of 6.4 is equal to 2.529 which times 10^{-7} is 2.529×10^{-7}. Alternatively, the answer is 2529×10^{-10}. At no time was it necessary to handle difficult decimals.

Exercises

Simplify,

66. $(14^3)^6 = ?$

67. $(24^{-6})^3 = ?$

68. $(15^4)^{-3} = ?$

69. $(8^{-6})^{-2} = ?$

70. $(6^4 \times 6^3)^2 = ?$

71. $(5^7 \times 5^{-2})^{-1} = ?$

72. $\sqrt{14^6} = ?$

73. $\sqrt[3]{11^2 \times 11^4} = ?$

74. $\sqrt[5]{8^{-10} \times 7^5} = ?$

75. $\sqrt{6^4 \times 5^{-6} \times 4^2} = ?$

NOTE:--When handling very large numbers where accuracy to only the third or fourth significant figure is required, the numbers may be simplified; thus: 946,123,271,659,487 may be expressed as 946×10^{12}. The accuracy of the latter expression is to one-tenth of one percent, sufficiently accurate for most work. A practical example of such procedure in radio calculations is the common use of 3×10^8 meters per second as the speed of light or the velocity of propogation of electro-magnetic fields through space. The speed commonly accepted for accurate work is 299,920,000 meters per second, but this is so close to 300,000,000 that the error in the use of the latter is negligible for most practical work, and the velocity is therefore commonly taken as 3×10^8 meters per second.

Very often in formulas and problems fractional exponents will be used. Fractional exponents simply designate the extraction of roots. For example, $9^{1/2}$ means $\sqrt{9}$; $125^{1/3}$ means $\sqrt[3]{125}$; $87^{1/5}$ means $\sqrt[5]{87}$.

The numerator of a fractional exponent is not always 1. For example, $140^{3/5}$ reads 140 to the 3/5 power. This means that 140 is to be raised to the 3rd power and then the 5th root extracted. Thus, $140^{3/5} = \sqrt[5]{140^3}$. In a similar manner. $25^{3/2} = \sqrt{25^3}$; $47^{2/3} = \sqrt[3]{47^2}$.

In other words, the numerator of a fractional exponent indicates the power *to which the number is to be raised and the denominator indicates the root to be extracted.*

Fractional exponents of like numbers are handled just as are whole number exponents. For example, $(20^{1/2})^2 = 20^1 = 20$. This may also be written $(\sqrt{20})^2 = 20$. This is apparent because the square of the square root of a number equals the number. Other examples,

1. $(27^{1/3})^4 = 27^{4/3} = \sqrt[3]{27^4}$

2. $(18^{3/4})^2 = 18^{6/4} = 18^{3/2} = \sqrt{18^3}$

3. $(14^3)^{1/2} = 14^{3/2} = \sqrt{14^3}$

4. $(125^{1/3})^{1/2} = 125^{1/6} = \sqrt[6]{125}$

5. $(20^{3/4})^4 = 20^{12/4} = 20^3$

6. $15^{-1/2} = \frac{1}{\sqrt{15}}$

7. $(25^2)^{-1/3} = 25^{-2/3} = \frac{1}{\sqrt[3]{25^2}}$

8. $(24^{-1/2})^{-1/2} = 24^{1/4} = \sqrt[4]{24}$

79. $(37^{-2})^{1/2} = ?$

80. $(76^{-1/2})^{-2} = ?$

81. $(42^3)^{-3/2} = ?$

82. $(18^{3/5})^5 = ?$

83. $(116^4)^{1/4} = ?$

84. $\frac{1}{(25^{1/2})^{-1}} = ?$

85. $\frac{1}{(25^{1/2})^2} = ?$

The examples above should be very carefully studied. It will be observed that when a number having an exponent, either fractional or whole, is to be raised to some power, either fractional or whole, the exponents are simply multiplied just as in examples previously discussed. Example 6 shows that the negative fractional exponent indicates exactly the same operation as the whole negative exponent, that is, the reciprocal of the number having the exponent.

Thus,

$$10^{-2} = \frac{1}{10^2} \qquad 10^{-1/2} = \frac{1}{10^{1/2}} = \frac{1}{\sqrt{10}}$$

It is simpler to write $8^{3/2}$ than $\sqrt{8^3}$ and the first method greatly facilitates the handling of numbers mathematically as shown in examples 1 to 8 above.

Exercises

76. $(65^3)^{1/4} = ?$

77. $(48^{3/2})^{1/5} = ?$

78. $(27^{4/3})^{1/4} = ?$

CONVERSIONS OF ELECTRICAL UNITS.--The use of 10 to some power is very useful in converting electrical units to milli-units, micro-units and micro-micro-units; also in converting from the small units to larger units. The electrical units commonly used and converted to milli- and micro-units are the ampere, volt, henry and farad. The latter unit, the farad, is also commonly expressed in micro-micro-farads.

The micro-unit is one millionth as large as a unit. Therefore with a value given in units, to convert into micro-units, it is necessary to multiply by one million, since there will be one million times as many of the smaller micro-units as of the original units. That is, one unit is equal to one million micro-units.

A micro-micro-unit is one-millionth of one-millionth of a unit or one-millionth of a micro-unit. Therefore to convert a unit to a micro-micro-unit value, multiply by a million times a million. To convert back from the smaller micro -and micro-micro-units, reverse the process and divide instead of multiplying.

To multiply by one million, multiply by 10^6. To multiply by a million times a million, multiply by 10^{12}. To divide by one million, multiply by 10^{-6}. To divide by a million times a million, multiply by 10^{-12}. The following conversion table will make this clear.

CONVERSION TABLE

Units to Milli-units:	Multiply	by	10^{3}
Units to Micro-units:	"	"	10^{6}
Micro-units to Micro-micro-units:	"	"	10^{6}
Units to Micro-micro-units:	"	"	10^{12}
Micro-micro-units to Micro-units:	"	"	10^{-6}
Micro-units to Units:	"	"	10^{-6}
Micro-micro-units to Units:	"	"	10^{-12}
Milli-units to Units:	"	"	10^{-3}

The conventional symbol for "micro" is the Greek letter, μ, pronounced "mu". For micro-micro, write $\mu\mu$.

A commonly used term is the millihenry, written MH, meaning 1/1000 henry. *The letter M in this case represents one-thousandth.* In some electrical work the term microfarad is written Mfd, but that is simply used as an abbreviation. The preferred symbol for microfarad is μF. Microhenry is written μH.

The micro-microfarad, $\mu\mu$F, is sometimes called a picofarad. Other commonly used terms are "megohm", (one million ohms); microhms, (ohms × 10^{-6}); kilowatts and kilovolts, (watts and volts multiplied by 1000, that is, one kilowatt = 1000 watts, one kilovolt = 1000 volts.

It is essential that the student thoroughly understand the conversion of units explained above. Future problem work will be greatly simplified by ability to convert units rapidly and accurately.

Exercises

86. .04 Amperes = ___ MA? ___ μA?
87. .74 " = ___ MA? ___ μA?
88. .006 " = ___ MA? ___ μA?
89. 27 μA = ___ MA? ___ Amps.?
90. 400 MA = ___ μA? ___ Amps.?
91. .6 Henry = ___ MH? ___ μH?
92. .006 " = ___ MH? ___ μH?
93. .55 " = ___ MH? ___ μH?
94. 500 $\mu\mu$F = ___ μF? ___ F?
95. .005 μF = ___ $\mu\mu$F? ___ F?
96. .04 Megohm = ___ Ohms?
97. .0006 Megohm = ___ Ohms?
98. 150,000 Ohms = ___ Megohms?
99. 450 Watts = ___ Kilowatts?
100. 2.37 Kilovolts = ___ Volts?
101. 27.45 Kilowatts = ___ Watts?
102. .0000000064 F = ___ μF? ___ $\mu\mu$F?
103. 25 $\mu\mu$F = ___ μF? ___ F?
104. 125 $\mu\mu$F = ___ μF? ___ F?

105. 14 µA = _____ MA? _____ Amps.?

SQUARE ROOT

The square root of a given number which multiplied by itself will equal the given number.

The indication that the square or second root of a number is to be extracted is the "Radical", $\sqrt{}$. The radical may be used to express the operation of extraction of other roots, such as the third or cube root, the fourth root, etc. For indication of other than the square root the radical is pre-fixed with a designating figure. For example, cube root is designated $\sqrt[3]{}$; fourth root is designated, $\sqrt[4]{}$, etc. The radical used without a designating figure indicates the extraction of the square root.

The extraction of the root of a number is the reverse operation to *raising that number to a given power.* For example, one may extract the square root of 4, $\sqrt{4} = 2$; or he may raise 4 to the second power, $4^2 = 16$. In the first case, the square root of 4 is 2, which multiplied by itself equals the given number, $2 \times 2 = 4$. In the second case the given number is multiplied by itself, 4×4, and the product is 16 or 4^2.

Extraction of the square root of a number is a comparatively simple process which will be explained in this assignment. Extraction of the higher roots is not such a simple process except by the use of logarithms which will be explained in a following assignment.

A problem in square root will be worked, each step being explained in detail. To extract the square root of 56431:

STEP 1: Write the number under the radical. $\sqrt{56431}$

STEP 2: Place the decimal point immediately over the decimal point of the number.

STEP 3: *Starting at the decimal point* divide the number into groups of two figures each. $\sqrt{5'64'31'.}$

STEP 4: It will be seen that there is only one figure in the group on the left, namely 5. Treat this as a whole group as if it contained two figures. Find the largest square root which multiplied by itself, or squared, will not exceed the value of the first group. Since the first group is 5, the largest whole number that can be squared and not exceed 5 is 2. Write this in immediately *above* the first group.

$$\begin{array}{l} 2 \\ \sqrt{5\ 64\ 31.} \\ 4 \end{array}$$

STEP 5: Square this number (2) and place immediately below the first group (2×2)

STEP 6: Subtract this from the first group and write in the remainder.

```
  2      .
 √5 64 31.
  4
  1
```

STEP 7: Bring down the second group.

```
  2      .
 √5 64 31.
  4
 164
```

STEP 8: *Double the number above the radical* and bring it down as a *trial divisor* into the dividend 164.

```
   2      .
  √5 64 31.
   4
4/ 164
```

STEP 9: The next step is more difficult to explain and to understand, but when once understood, no more trouble will be experienced with problems of this type. An additional figure must be added to the trial divisor. This figure must be of such a value that the product of the *entire* divisor and this figure does not exceed the dividend. (In this case the dividend is 164. The *entire* divisor will be the trial divisor "4", and the additional figure to be found affixed to the right.) This figure may be found by trial, or it may be seen by inspection.

```
     2 3    .
    √5 64 31.
     4
 43/ 164
```

It is apparent that 4 will divide into 16 (the first two numerals of 164) four times. However, if four is affixed to the trial divisor (4) the entire divisor will be 44. 44 x 4 is *greater* than 164. Therefore the additional figure must be 3. This figure is placed above the radical *immediately over the second group* and also at the right of the trial divisor to complete the divisor.

STEP 10: Multiply the entire divisor (43) by the figure (3) found in step 9, place the product (129) beneath the dividend (164), and subtract to find the remainder which is 35.

```
     2 3    .
    √5 64 31.
     4
 43/ 164
     129
      35
```

STEP 11: Bring down the third group of figures (31) and affix to the remainder to form a new dividend (3531). Double the *entire* amount above the radical (23) and bring it down as a new trial divisor.

```
      2  3  .
    √5 64 31.
     4
  43/164
     129
  46/3531
```

STEP 12: Repeat "Step 9" with these new figures to find the figure to affix to the trial divisor and to place in the answer above the radical over the third group. A trial shows that 8 is too large. A second trial indicates that 7 is not too large. Therefore, affix 7 to the trial divisor (46) and to the amount (23) above the radical and multiply as in "Step 10", obtaining (3269). Then subtract to find the remainder as shown:

```
       2  3  7.
     √5 64 31.
      4
   43/164
      129
 467/3531
     3269
      262  Remainder
```

If accuracy to three figures is sufficient, the answer to this problem, $\sqrt{56431}$, may be taken as 237. If additional accuracy is desired ciphers may be added *in groups of two ciphers each* to the right of the decimal point and the operations as outlined above carried out to as many decimal places as desired.

If the original number of which the square root is to be extracted is a decimal, the procedure is the same except that the groups are pointed off to the *right of the decimal*. In all cases the groups are pointed off *from* the *decimal point*. Examples of the pointing off into groups of various types of numbers are shown.

As exercise problems, extract the square root of each example number below.

106. $\sqrt{43\ 21\ 76.}$

107. $\sqrt{6\ 54\ 31.\ 98\ 27\ 54}$

108. $\sqrt{8\ 67\ 52.}$

109. $\sqrt{.24\ 76\ 59}$

110. $\sqrt{55\ 43.\ 21\ 76}$

111. $\sqrt{.00\ 00\ 05\ 68\ 12}$

112. $\sqrt{3\ 64.\ 57\ 2}$

(In this case add a cipher to the last decimal group to make the group complete. A cipher added to the right of a decimal number does not change its value.)

It will be observed that in *all cases* the decimal point in the answer, which will be placed above the radical, should be placed *immediately above* the decimal point in the number of which the square root is to be extracted. The student should work sufficient problems of all types shown to become thoroughly familiar with this work.

ANSWERS TO EXERCISE PROBLEMS TECHNICAL ASSIGNMENT

1. -17
2. 15
3. 13
4. 6.6
5. 42
6. 2
7. 292
8. -43.23
9. -6.76
10. 7.314
11. -40
12. -127
13. -82
14. 25
15. -83
16. 305
17. 31.8
18. -135
19. -160
20. 209
21. 800
22. -1800
23. 840
24. -600
25. -882
26. -7
27. 2
28. -5
29. 42
30. -3360
31. 4^{16}
32. 6^{-5}
33. 15^{-4}
34. 8^{8}
35. 5/16
36. 1
37. 37.9
38. 32,928
39. 400
40. 441
41. 8^{2}
42. 15^{5}
43. 6^{2}
44. 8^{-2}
45. 12^{-10}
46. 8^{2}
47. 6^{3}
48. 9^{2}
49. 1
50. 14^{11}
51. $2345 \times 10^{12} = 234.5 \times 10^{13}$
    $= 23.45 \times 10^{14}$
    $= 2.345 \times 10^{15}$ etc.
52. 64×10^{8}
53. 875×10^{10}
54. $246 \times 10^{-5} = 24.6 \times 10^{-4}$
    $= 2.46 \times 10^{-3}$ etc.
55. 78×10^{-7}
56. 3×10^{-11}
57. 987×10^{-10} or 9.87×10^{-8}
58. $2569 \times 10^{-7} = 256.9 \times 10^{-6}$
    $= 25.69 \times 10^{-5}$
    $= 2.569 \times 10^{-4}$ etc.
59. $945 \times 10^{-12} = 94.5 \times 10^{-11}$
    $= 9.45 \times 10^{-10}$ etc.
60. 13674
61. 9×10^{-4}
62. 405×10^{-1} or 40.5
63. $408 \times 10^{13} = 40.8 \times 10^{14}$
    $= 4.08 \times 10^{15}$ etc.
64. 2×10^{-3}

ANSWERS TO EXERCISE PROBLEMS TECHNICAL ASSIGNMENT

65. 617×10^{9} or 6.17×10^{11}

66. 14^{18}

67. 24^{-18}

68. 15^{-12}

69. 8^{12}

70. 6^{14}

71. 5^{-5}

72. 14^{3}

73. 11^{2}

74. 7/64

75. 1 19/125

76. $\sqrt[4]{65^{3}}$

77. $\sqrt[10]{48^{3}}$

78. $\sqrt[3]{27} = 3$

79. $37^{-1} = .027$

80. 76

81. $\frac{1}{\sqrt{42^{9}}}$

82. 18^{3}

83. 116

84. 5

85. 25^{-1}

86. 40 MA, 4×10^{4} μA

87. 740 MA, 74×10^{4} μA

88. 6 MA, 6×10^{3} μA

89. 27×10^{-3} MA, 27×10^{-6} A

90. 4×10^{5} μA, 4×10^{-1} A or 0.4 A

91. 600 MH, 6×10^{5} μH

92. 6 MH, 6×10^{3} μH

93. 550 MH, 55×10^{4} μH or 5.5×10^{5} μH

94. 5×10^{-4} μF, 5×10^{-10} F

95. 5×10^{3} μμF, 5×10^{-9} F

96. 4×10^{4} ohms

97. 600 ohms

98. 15×10^{-2} megohms

99. 45×10^{-2} KW

100. 2370 volts

101. 27450 W

102. 64×10^{-4} μF, 6400 μμF

103. 25×10^{-6} μF, 25×10^{-12} F

104. 125×10^{-6} μF, 125×10^{-12}F

105. 14×10^{-3} MA, 14×10^{-6} A

106. 657

107. 255.796

108. 294

109. .497

110. 74.45

111. .00238

112. 19.09

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TELEVISION TECHNICAL ASSIGNMENT

POSITIVE AND NEGATIVE NUMBERS; EXPONENTS; SQUARE ROOT

EXAMINATION

Show All Work:

1. The motor of the frequency control unit of the aural (sound) television transmitter rotates the condenser in the control unit in either a clockwise or counterclockwise direction, depending upon which way the frequency of the transmitter drifts from that of the crystal standard. Consider clockwise rotations of the motor as positive and counterclockwise as negative. In an hour's operation the motor makes the following rotations

   52, - 14, - 104, 47, - 86, - 21, 287.

   How many revolutions *net* has the motor turned in one hour's time, and in what direction?

   52 + 47 + 287 = 386

   −14 − 104 − 86 − 21 = −225

   386 − 225 = 161

   161 revolutions clockwise

2. Subtract (86 - 14 + 80 - 172) from (45 - 15 + 20 - 92).

   86 + 80 = 166   −14 − 172 = −186   45 + 20 = 65   −15 − 92 = −107

   −186 + 166 = −20   −107 + 65 = −42

   −42 − (−20) = −42 + 20 = −22

3. $\frac{40 \times -3 \times 2 \times -6}{5 \times -4} =$ $-\frac{40 \times 3 \times 2 \times 6}{20} = -72$

4. $\frac{10^7 \times 10^{-6} \times 10^{-6} \times 10}{10^{-7} \times 10^{-9} \times 10^{-15}} =$ $\frac{10^{8-12}}{10^{-31}} = \frac{10^{-4}}{10^{-31}}$

$= 10^{-4} \times 10^{31}$

$= 10^{31-4} = 10^{27}$

5. (a) The two capacitors have capacities expressed in farad as follows:

.000004 farad and .0000276 farad

Express the above as simple whole numbers times ten raised to some positive or negative power.

4×10^{-6} 2.76×10^{-5}

or 27.6×10^{-6}

or 276×10^{-7}

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T - POSITIVE AND NEGATIVE NUMBERS; EXPONENTS; SQUARE ROOT

EXAMINATION, Page 3.

5. (a) *(Continued)*

(b) Do the same for the following two numbers:

240,000,000 2.53

2.4×10^{8}
or 24×10^{7}

253×10^{-2}

6. In calculating the current in a complex electrical network, the following expression is encountered:

$$\frac{.002 \times 10^{4} \times 40000 \times 10^{-3}}{2000 \times 10^{5} \times 10^{7} \times .00002}$$

Evaluate this expression.

$$\frac{2 \times 10^{-3} \times 10^{4} \times 4 \times 10^{4} \times 10^{-3}}{2 \times 10^{3} \times 10^{5} \times 10^{7} \times 2 \times 10^{-5}} = \frac{8 \times 10^{8-6}}{4 \times 10^{15-5}}$$

$$= \frac{2 \times 10^{2}}{10^{10}} = 2 \times 10^{-8}$$

EXAMINATION, Page 4.

7. Express each of the following in units, micro-units, and micro-micro-units.

.00045 μf	6,000 μμf	4×10^{-8} F
450 μμf	0.006 μf	4×10^{-2} μf
4.5×10^{-10} F	6×10^{-9} F	4×10^{4} μμf

8. Express in units:

.08 MH = 0.00008 or 8×10^{-5} H.

18 milliamperes = 0.018 amperes

17.5 kilovolts = 17,500 volts

3.5 megohms = 3,500,000 ohms

25 microamperes = 0.000025 or 25×10^{-4} amps.

4,500 micromhos = 0.0045 mhos.

9. $(6400^{-3/2})^{1/3} = ?$ Express the answer as a simple number without an exponent.

$$= 6400^{-1/2} = \frac{1}{\sqrt{6400}} = \frac{1}{80}$$

10. (a) The area of a *square* plot of land for a transmitter site is given as 84,932 sq.ft. Find the length of each side of this plot of land.

```
        2  9  1 . 4
 2 √ 8 49 32.
     4
 49  4 49
     4 41
 581     8 32
         5 81
 5824    2 51 00
         2 32 96
```

291 ft (to 3 sig. fig)

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T - POSITIVE AND NEGATIVE NUMBERS; EXPONENTS; SQUARE ROOT

EXAMINATION, Page 5.

10. (a) *(Continued)*

(b) The area of a square plate in a vacuum tube is given as .4739 sq.in. Find the length of each side of this plate.

```
          .6   8   8  4
   6   √ .47  39
          36
 128      11 39
          10 24
 1368        11 5 00
             10 9 44
 13764          5 5 6 00
                5 5 0 56
```

0.688 in.

(c) A very fine wire of square cross section has an area of .000006894632 sq.in. Find the length of each side of the wire.

```
         . 0  0  2  6  2  5 / 7 6 3 1
  2   √ .00 00 06 89 46 32
                4
  46            2 89
                2 76
  522             13 46
                  10 44
  5245               3 02 32
                     2 62 25
  52507                40 07 00
                       36 75 49
  525,146                3,31,51,00
                         3,15,08,76
  5251,523                  16 42 24 00
                            15 75 45 69
  52,51,5261                   66,783,100
```

= 0.002625763 in.