THE ENGINEERS' MANUAL

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PREFACE.

THIS work originated from the conception that the practicing engineer or engineering student would welcome a consolidation of the formulas and constants for which he is accustomed to search through several volumes and that the application of each formula might be explained more concisely than in texts devoted exclusively to the process of derivation. With this end in view those engineering formulas, mathematical operations and tables of constants which appear to be most useful are presented in systematic order and in a size of book designed to fit the pocket.

Each formula is preceded by a statement in which its application, the symbology of the involved physical quantities and definite units of measurement are indicated. It is believed that this method of presentation increases the speed of selection and understanding of a desired formula and insures greater accuracy of substitution since data units of any kind may be converted into specified units by reference to the table of conversion factors. The sequence of the formulas is based generally upon their order of derivation so that the understanding of a formula may be enlarged by inspection of the formulas which precede it. All catchwords, symbols and formulas are printed in full face type and each formula or group of formulas is numbered to facilitate reference to the text or cross reference between formulas.

For the practicing engineer the aim throughout has been to enable him to obtain results quickly and accurately even in a branch of engineering to which he can give little attention. For instructional purposes the object has been to present a summary of the important relations which may be derived from fundamental principles so that the student may give his undivided attention to the sources of engineering knowledge, the evolution of engineering formulas and their applications. It is suggested that class room exercises devoted to the derivation of the stated formulas be given to increase the student's comprehension of the origin of his working formulas and of the mathematical operations which intervene as well as to create discrimination between those relations which are fundamental, derived and empirical. In the solution of problems original data may be given in terms of units not specified in the formulas and for conditions not definitely prescribed in the text.

The writer wishes to express his obligations to his assistants for their coöperation in preparing the work, to Mr. C. H. Sutherland and Mr. A. L. Brown and to Professors H. B. Phillips and W. V. Lyon for many effective suggestions and reading of proof. While every effort has been made to insure accuracy of statement in both formulas and tables experience indicates that in texts containing so many symbols and numbers minor errors may still exist and the authors will be grateful for notice of them.

RALPH G. HUDSON.

CAMBRIDGE, MASS.,
November, 1916.

MATHEMATICS

ALGEBRA

1 Powers and Roots

$a^n = a \cdot a \cdot a \cdot \ldots$ to n factors. $\qquad a^{-n} = \frac{1}{a^n}$.

$a^m \cdot a^n = a^{m+n}$; $\frac{a^m}{a^n} = a^{m-n}$. $\qquad (ab)^n = a^n b^n$; $\left(\frac{a}{b}\right)^n = \frac{a^n}{b^n}$.

$(a^m)^n = (a^n)^m = a^{mn}$. $\qquad (\sqrt[n]{a})^n = a$.

$a^{\frac{1}{n}} = \sqrt[n]{a}$; $\quad a^{\frac{m}{n}} = \sqrt[n]{a^m}$. $\qquad \sqrt[n]{ab} = \sqrt[n]{a}\sqrt[n]{b}$; $\sqrt[n]{\frac{a}{b}} = \frac{\sqrt[n]{a}}{\sqrt[n]{b}}$.

$\sqrt[n]{\sqrt[m]{a}} = \sqrt[mn]{a}$.

2 Operations with Zero and Infinity

$a \cdot 0 = 0$; $a \cdot \infty = \infty$; $0 \cdot \infty$ is indeterminate, see page 37.

$\frac{0}{a} = 0$; $\frac{a}{0} = \infty$; $\frac{0}{0}$ " " " " 37.

$\frac{\infty}{a} = \infty$; $\frac{a}{\infty} = 0$; $\frac{\infty}{\infty}$ " " " " 37.

$a^0 = 1$; $0^a = 0$; 0^0 " " " " 37.

$\infty^a = \infty$; ∞^0 " " " " 37.

$a^\infty = \infty$, if $a^2 > 1$; $a^\infty = 0$, if $a^2 < 1$; $a^\infty = 1$, if $a^2 = 1$, see also page 37.

$a^{-\infty} = 0$, if $a^2 > 1$; $a^{-\infty} = \infty$, if $a^2 < 1$; $a^{-\infty} = 1$, if $a^2 = 1$, see also page 37.

$a - a = 0$; $\infty - a = \infty$; $\infty - \infty$ is indeterminate, page 37.

3 Binomial Expansions

$(a \pm b)^2 = a^2 \pm 2ab + b^2$.

$(a \pm b)^3 = a^3 \pm 3a^2b + 3ab^2 \pm b^3$.

$(a \pm b)^4 = a^4 \pm 4a^3b + 6a^2b^2 \pm 4ab^3 + b^4$.

$$(a \pm b)^n = a^n \pm \frac{n}{1}a^{n-1}b + \frac{n(n-1)}{1 \cdot 2}a^{n-2}b^2 \pm \frac{n(n-1)(n-2)}{1 \cdot 2 \cdot 3}a^{n-3}b^3 + \ldots$$

NOTE. n may be positive or negative, integral or fractional. When n is a positive integer, the series has $(n + 1)$ terms; otherwise the number of terms is infinite.

4 Polynomial Expansions

$(a + b + c + d + \ldots)^2 = a^2 + b^2 + c^2 + d^2 + \ldots + 2a(b + c + d + \ldots)$
$+ 2b(c + d + \ldots) + 2c(d + \ldots) + \ldots$

= sum of the squares of each term and twice the product of each term by the sum of the terms that follow it.

$(a + b + c)^3 = [(a + b) + c]^3 = (a + b)^3 + 3(a + b)^2c + 3(a + b)c^2 + c^3.$

5 Factors

$a^2 - b^2 = (a + b)(a - b).$

$a^2 + b^2 = (a + b\sqrt{-1})(a - b\sqrt{-1}).$

$a^3 - b^3 = (a - b)(a^2 + ab + b^2).$

$a^3 + b^3 = (a + b)(a^2 - ab + b^2).$

$a^4 + b^4 = (a^2 + ab\sqrt{2} + b^2)(a^2 - ab\sqrt{2} + b^2).$

$a^{2n} - b^{2n} = (a^n + b^n)(a^n - b^n).$

$a^n - b^n = (a - b)(a^{n-1} + a^{n-2}b + a^{n-3}b^2 + \ldots + b^{n-1}).$

$a^n - b^n = (a + b)(a^{n-1} - a^{n-2}b + a^{n-3}b^2 - \ldots - b^{n-1})$ if n is even.

$a^n + b^n = (a + b)(a^{n-1} - a^{n-2}b + a^{n-3}b^2 - \ldots + b^{n-1})$ if n is odd.

6 Ratio and Proportion

If $a : b = c : d$, or $\frac{a}{b} = \frac{c}{d}$, or $ad = bc$, then

$\frac{b}{a} = \frac{d}{c}$; $\frac{a}{c} = \frac{b}{d}$.

$\frac{a \pm b}{c \pm d} = \frac{a}{c} = \frac{b}{d}$; $\frac{a \pm c}{b \pm d} = \frac{a}{b} = \frac{c}{d}$.

$\frac{a + b}{a - b} = \frac{c + d}{c - d}$; $\frac{a + c}{a - c} = \frac{b + d}{b - d}$.

$\frac{ma}{mb} = \frac{nc}{nd}$; $\frac{ma}{nb} = \frac{mc}{nd}$.

$\frac{a^n}{b^n} = \frac{c^n}{d^n}$; $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \frac{\sqrt[n]{c}}{\sqrt[n]{d}}$; $\frac{a^{\frac{m}{n}}}{b^{\frac{m}{n}}} = \frac{c^{\frac{m}{n}}}{d^{\frac{m}{n}}}$.

If $\frac{a}{b} = \frac{c}{d} = \frac{e}{f} = \ldots$, then

$\frac{a}{b} = \frac{c}{d} = \frac{e}{f} = \ldots = \frac{a + c + e + \ldots}{b + d + f + \ldots} = \frac{pa + qc + re + \ldots}{pb + qd + rf + \ldots}$.

If $\frac{a}{b} = \frac{c}{d}$ and $\frac{e}{f} = \frac{g}{h}$, then $\frac{ae}{bf} = \frac{cg}{dh}$.

7 Constant Factor of Proportionality, *k*

If $y = kx$, y varies as x, or y is proportional to x.

If $y = \frac{k}{x}$, y varies inversely as x, or y is inversely proportional to x.

If $y = kxz$, y varies jointly as x and z.

If $y = k\frac{x}{z}$, y varies directly as x and inversely as z.