

**DISCUSSION OF THE PRECISION  
OF MEASUREMENTS: WITH  
EXAMPLES TAKEN MAINLY  
FROM PHYSICS AND ELECTRICAL  
ENGINEERING**

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649563067

Discussion of the Precision of Measurements: With Examples Taken Mainly from Physics and Electrical Engineering by Silas W. Holman

Except for use in any review, the reproduction or utilisation of this work in whole or in part in any form by any electronic, mechanical or other means, now known or hereafter invented, including xerography, photocopying and recording, or in any information storage or retrieval system, is forbidden without the permission of the publisher, Trieste Publishing Pty Ltd, PO Box 1576 Collingwood, Victoria 3066 Australia.

All rights reserved.

Edited by Trieste Publishing Pty Ltd.  
Cover @ 2017

This book is sold subject to the condition that it shall not, by way of trade or otherwise, be lent, re-sold, hired out, or otherwise circulated without the publisher's prior consent in any form or binding or cover other than that in which it is published and without a similar condition including this condition being imposed on the subsequent purchaser.

[www.triestepublishing.com](http://www.triestepublishing.com)

**SILAS W. HOLMAN**

**DISCUSSION OF THE PRECISION  
OF MEASUREMENTS: WITH  
EXAMPLES TAKEN MAINLY  
FROM PHYSICS AND ELECTRICAL  
ENGINEERING**



©

DISCUSSION  
OF THE  
PRECISION OF MEASUREMENTS.

*WITH EXAMPLES TAKEN MAINLY FROM*  
PHYSICS AND ELECTRICAL ENGINEERING.

*White* BY  
SILAS W. HOLMAN, S.B.,  
ASSOCIATE PROFESSOR OF PHYSICS,  
MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

FIRST EDITION.  
FIRST THOUSAND.

NEW YORK:  
JOHN WILEY & SONS,  
68 EAST TENTH STREET.  
1894.

Ms. A. 9. 1. 7



*Jurian fund*

*80.12*  
*2094*  

---

*7*

COPYRIGHT, 1894,  
BY  
SILAS W. HOLMAN.

ROBERT DEARBORN,  
Electrotyper,  
444 & 446 Pearl Street,  
New York.

FANNIS BROS.,  
Printers,  
220 Pearl Street,  
New York.

## PREFACE.

---

THE material presented in this volume is the outcome of several years' teaching of the subject. In a less complete form it was prepared for lecture notes and was printed in pamphlet form, but not published, by the Massachusetts Institute of Technology in 1888, having appeared in the *Technology Quarterly* and in the *Electrical Engineer* in 1887.

In this revised form, the author has felt that it perhaps possessed sufficient completeness and originality to be of interest or value to students and teachers, and therefore to merit publication.

In venturing to urge the importance of the subject as a course of study for engineers and for students of physics or other pure sciences, the author would suggest the value of the attitude of mind produced by it. One who has in any reasonable degree mastered its methods, although he may never apply them directly, will not only have increased his power to intelligently scrutinize experimental results, but will have acquired a tendency to do so. And it is perhaps not too much to hope that he may acquire a notion of a judicious distribution of effort which, with the best of results to himself, he may carry into quite other matters.

SILAS W. HOLMAN.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,  
BOSTON, September, 1892.

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000

1000



# CONTENTS.

## PRECISION OF MEASUREMENTS.

	PAGE
Introductory.....	I
<b>DIRECT MEASUREMENTS.</b>	
Direct Measurements.....	4
Indirect Measurements.....	4
Quantities: Independent, Conditioned.....	5
Sources of Error.....	5
Errors of Single Observations.....	6
Variable Part.....	6
Constant Part, Constant Error.....	7
Elimination of Constant Error.....	7
Corrections.....	8
Example I. <i>A, B, C</i> . Distance by Steel Tape.....	9
Determinate and Indeterminate Errors.....	10
Residuals.....	11
Accuracy or Error of Result.....	13
Deviations.....	14
General Law of Deviations.....	15
Mean: Best Representative Value.....	16
Deviation Measure.....	16
Average Deviation.....	16
Example II.....	18
Places of Figures in <i>d.m.</i> ; and Negligible Amounts.....	20
Best Value of <i>n</i> .....	22
Other Deviation Measures.....	23
Special Law of Deviations.....	24
Precision Measure of Result.....	25
To Make Residuals Negligible in <i>P.M.</i> .....	26
Criterion.....	26
Best Value of Residuals: Equal Effects.....	27
Fractional Deviation, Fractional Precision.....	29
Mistakes.....	30

	PAGE
Criterion for Rejection of Doubtful Observations.....	30
Weights.....	31
Meaning of Estimated Accuracy of Direct Result.....	32
Forms of Problems on Accuracy of Result.....	33
Data Required to Substantiate Result.....	36
Planning of Direct Measurement.....	36
Solutions of Illustrative Problems in Direct Measurements.....	37
Example III. Weighing. Balance.....	37
Example IV. Voltmeter Calibration.....	41

#### INDIRECT MEASUREMENTS.

Estimate of Accuracy of Indirect Result.....	45
Error of Method.....	46
Check Methods.....	47
Relation between P.M. of Results and of Components.....	47
Types of Problems.....	47
General Formulæ.....	48
Notation.....	49
Separate Effects. I, II. Formulæ.....	49
Resultant Effects. III; 1, 2. Formulæ.....	50
Equal Effects. Formulæ.....	53
Application to Precision Discussions.....	54
Formulæ for General and Special Functions.....	55
Simple Functions.....	56
Separation into Factors which are Functions of Single Components.....	61
Separation into Groups.....	63
Criteria for Negligibility of $\delta$ in Components.....	67
Numerical Constants.....	70
Equal Effects. Demonstration.....	70
Estimated Precision Measures of Components.....	72
Components with Special Laws of Deviations.....	73
Preparation of Functions for Discussion.....	73
Simplification of Functions.....	75
Significant Figures.....	76
Rules for Significant Figures. 1-6.....	77
Examples V-XII.....	78
Demonstration of Rules ..	80
Forms of Problems on Accuracy of Result.....	84
Data Required to Substantiate Result .....	85
Planning of Indirect Measurement.....	85
Examples:—	
XIII—XVI. Value of $g$ by Simple Pendulum.....	86
XVII. Calorimeter.....	88
XVIII. Heat by Incandescent Lamp.....	89

CONTENTS.

vii

	PAGE
XIX. Volume of Sphere.....	90
XX. Value of $g$ by Simple Pendulum.....	90
XXI. Cosine Galvanometer.....	91
XXII. Continuous Calorimeter.....	94
XXIII. H. P. by Friction Brake.....	96
XXIV. Specific Resistance.....	98

BEST MAGNITUDES OF COMPONENTS.

Nature of Problems.....	100
For a Single Component.....	102
For Two Variable Components.....	104
Best Ratio, Procedure.....	104
Best Magnitudes.....	106
For Several Components.....	107
Best Ratio.....	107
Best Magnitudes.....	108
Approximate Solution by Equal Effects.....	108
Best Ratio.....	108
Best Magnitudes.....	109
Examples:—	
XXV. Best Deflection on Tangent Galvanometer.....	110
XXVI. Electrical Heating of Conductor.....	111
XXVII. Bar for Moment of Inertia.....	112
XXVIII. Modulus of Elasticity of Wooden Beam.....	115
XXIX. Specific Resistance of Wire.....	118
XXX. XXVIII by Another Method.....	118

SOLUTIONS OF ILLUSTRATIVE PROBLEMS.

Example XXXI. Calibration of Voltmeters.....	120
Example XXXII. Dynamo Efficiency by Stray-Power Method.....	122
Example XXXIII. Cradle Dynamometer.....	130
Example XXXIV. Tangent Galvanometer.....	138
Example XXXV. Electro-static Capacity. Thomson's or Gott's Method.....	159
Example XXXVI. Magnetometer.....	160
Example XXXVII. Battery Resistance and E. M. F.....	161

TABLES.

Sines, Cosines, Tangents.....	166
Constants.....	166
Squares, Cubes, Reciprocals.....	167
Logarithms.....	168
INDEX.....	171