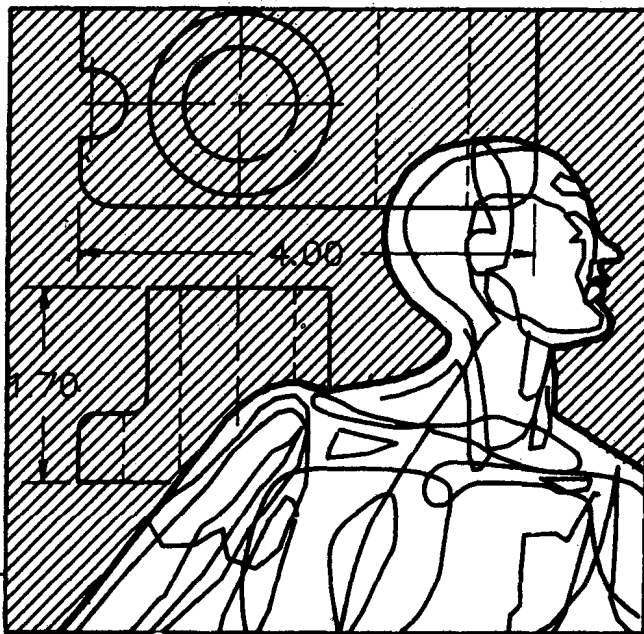


Engineering Design Graphics
Fifth Edition

JAMES H. EARLE

Engineering Design Graphics

Fifth Edition



JAMES H. EARLE

Texas A&M University



Addison-Wesley Publishing Company

Reading, Massachusetts • Menlo Park, California
Don Mills, Ontario • Wokingham, England • Amsterdam
Sydney • Singapore • Tokyo • Madrid • Bogotá
Santiago • San Juan

Sponsoring Editor: Donald Fowley
Production Supervisor: Laura Skinger
Production Coordinator: Ezra C. Holston
Text Designer: Designworks
Illustrator and Cover Designer: James H. Earle
Layout Artist: Lorraine Hodsdon
Editorial Assistant: Laurie McGuire

Library of Congress Cataloging-in-Publication Data

Earle, James H.

Engineering design graphics.

Includes index.

1. Engineering design. 2. Engineering graphics.

I. Title.

TA174.E23 1987 620'.00425 86-22269

ISBN 0-201-11641-3

Copyright © 1987 by Addison-Wesley Publishing Company, Inc. All rights reserved.
No part of this publication may be reproduced, stored in a retrieval system, or
transmitted, in any form or by any means, electronic, mechanical, photocopying,
recording, or otherwise, without the prior written permission of the publisher. Printed
in the United States of America. Published simultaneously in Canada.

ABCDEFGHIJ-HA-8987

Preface

Engineering Design Graphics covers the principles of engineering drawing, computer graphics, descriptive geometry, design, and problem solving for a college-level course. The fifth edition is a major revision of the previous edition, but it retains the same class-tested format and general sequence of topics.

Computer graphics

Two chapters, 10 and 38, are devoted to computer graphics. Chapter 10 provides a general introduction to the use of computer graphics in design and drafting and covers the fundamentals of AutoCAD Version 2.15 and its usage with microcomputers. Chapter 38 covers updated features of Version 2.5 that was released in late summer of 1986 and other applications of AutoCAD. Additionally, computer graphics techniques have been integrated throughout other chapters to offer an easy and natural transition from traditional graphics with a pencil to graphics by a computer.

AutoCAD software was selected as the example program to use because it is the most widely sold microcomputer software in the computer graphics field. Therefore, it is likely that more students will encounter AutoCAD in the industrial employment environment than any other software. The IBM XT/AT computer (and their compatibles) were chosen as the microcomputer because they too dominate the market.

Essentially all computer graphics principles have been presented in illustrations that use a two-step format and are supplemented with the prompts from AutoCAD that would be seen on the screen and the response from the user. By this means, the teacher and student will be able to cover the principles of computer graphics with the greatest ease.

Major topics

Other major areas in this text are communications, working drawings, descriptive geometry, and design

PREFACE

concepts. Each of these areas is important to the engineer, technologist, and technician.

Communications is covered as it relates to the presentation of ideas, three-dimensional concepts, data analysis, and pictorials. The methods of making working drawings are given in accordance with ANSI standards and include materials, tolerances, welding specifications, pipe drafting, and electric/electronics drafting. The design process is covered in Chapters 2 through 9 to illustrate the importance of engineering graphics in developing creative solutions to technical problems. Descriptive geometry is covered in Chapters 27 through 32. Vectors, nomography, empirical equations, and graphical calculus are other specialty areas receiving emphasis.

Objectives

The objective of this book is to support courses in which the student learns the various standards and techniques of preparing engineering drawings and specifications, learns how to read and interpret drawings by others, and learns how to solve three-dimensional technical problems that require the application of descriptive geometry and graphical analysis. Once the principles of preparing drawings correctly have been mastered, the student should be able to utilize these techniques in preparing drawings made by computer graphics methods. Above all, this textbook is designed to help students expand their creative talents and communicate their ideas in an effective manner.

Format

Engineering Design Graphics can be used as a self-instructional book enabling the student to work independently. Many problems are presented in a step-by-step sequence that shows the progressive steps in solving a problem and a second color is used to emphasize important points of construction. There are over 600 problems, many of which are new. These problems offer a range of assignments that can be solved by students to aid them in grasping principles covered in each chapter.

Revision features

The fifth edition of *Engineering Design Graphics* has been updated to reflect important developments in the

field, including the use of new tools and technologies, recent changes in governing standards, and others. In addition this revision has benefited in numerous ways from the close and continuous scrutiny of the author, colleagues at the author's and other institutions, and students. The opportunity to use the book over the course of several years has enabled us to refine and improve the material in hundreds of ways.

Some of the major revision features are

- the revision of several hundred illustrations to enhance clarity and student learning
- the inclusion of several hundred new drawings
- Chapter 10, "The Computer in Design and Drafting," replaces Chapter 37 from the fourth edition. This chapter is much changed in content: it provides a general introduction to the area of computer-aided design and drafting and then gives a detailed description of the AutoCAD software program and its application to engineering design graphics
- the insertion of computer graphics techniques in all appropriate chapters
- the addition of a new chapter, Chapter 38, which details the updated features of AutoCAD's Version 2.5 and offers some applications of these features to engineering design graphics
- the major rewriting of the chapter on tolerances (Chapter 22)
- the addition of many new problems
- the editing of existing material in all chapters, including: extensive updating of references, illustrations, and photographs; the enlargement of many problem illustrations from the fourth edition for easier student use; correction of minor inaccuracies that were brought to our attention by students, colleagues, and reviewers

Supplementary problems

Seventeen different problem books and teachers' guides are available to be used with this textbook. A listing of these books and their source is given on the page preceding the Preface. Twelve of the manuals have computer graphics problems on the backs of the problem sheets that allow the coverage of the problems by both computer and traditional methods with the same problem books.

PREFACE

Acknowledgments

We are grateful for the assistance of many who have influenced the development of this volume. We have been aided by the use of illustrations developed by the late William E. Street and Carl L. Svensen for their earlier publications. Many industries have furnished photographs and drawings that have been acknowledged in the legends where they are used. The Engineering Design Graphics staff of Texas A&M University has been helpful in making suggestions for the preparation of this book. Professor Tom Pollock provided valuable information on various metals and their designations.

We are indebted to Mary Ann Zadfar, Josef Woodman, and Joseph Oakley of Autodesk Inc. for

their assistance with AutoCAD. We appreciate the assistance and cooperation of Karen Kershaw of MEGACADD, INC. After our association with these individuals and their companies, it is easy to understand why they are leaders in their respective fields.

We are appreciative of the many institutions who have thought enough of our publications to adopt them for classroom use. It is an honor for one's work to be accepted by his colleagues. We are hopeful that this textbook will fill the needs of engineering and technology programs. As always, comments and suggestions for improvement and revision of this book will be appreciated.

College Station, Texas

J. H. E.

Contents

1. Introduction to Engineering and Technology	1		
1.1 Introduction	1		
1.2 Engineering graphics	2		
1.3 The technological team	2		
1.4 The engineering fields	5		
1.5 Technologists and technicians	12		
1.6 Drafters	13		
Problems	13		
2. The Design Process	15		
2.1 Introduction	15		
2.2 Types of design problems	15		
2.3 The design process	17		
2.4 Application of the design process to a simple problem	19		
Problems	24		
3. Problem Identification	26		
3.1 Introduction	26		
3.2 Design worksheets	26		
3.3 The problem identification process	27		
3.4 Automobile design—problem identification	28		
3.5 Hunting seat—problem identification	29		
3.6 Organization of effort	31		
3.7 Planning design activities	31		
Problems	33		
4. Preliminary Ideas	35		
4.1 Introduction	35		
4.2 Individual versus team	36		
4.3 Plan of action	36		
4.4 Brainstorming	36		
4.5 Sketching and notes	38		
4.6 Research methods	40		
4.7 Survey methods	40		
4.8 Hunting seat—preliminary ideas	41		
Problems	42		
5. Design Refinement	44		
5.1 Introduction	44		
5.2 Physical properties	44		
5.3 Applications of descriptive geometry	45		
5.4 Refinement considerations	46		
5.5 Hunting seat—problem identification	48		
Problems	50		
6. Design Analysis	55		
6.1 Introduction	55		
6.2 Types of analysis	55		

CONTENTS

6.3	Graphics and analysis	56	9.8	Systems design problems	113
6.4	Functional analysis	56	9.9	Product design	117
6.5	Human engineering	59			
6.6	Market and product analysis	63	10.	The Computer in Design and Drafting	120
6.7	Physical specifications analysis	63	10.1	Introduction	122
6.8	Strength analysis	63	10.2	Computer-aided design	122
6.9	Economic analysis	63	10.3	Some applications of CAD	123
6.10	Model analysis	66	10.4	CAD/CAM	124
6.11	Hunting seat analysis	68	10.5	Hardware systems	125
	Problems	72	10.6	CAD software	128
7.	Decision	74	10.7	AutoCAD computer graphics	129
7.1	Introduction	74	10.8	Starting up	130
7.2	Types of presentations	74	10.9	Experimenting	130
7.3	Organizing a presentation	75	10.10	Shutting down	130
7.4	Visual aids for presentation	76	10.11	Drawing layers	131
7.5	The group presentation	80	10.12	Setting screen parameters	132
7.6	The technical report	81	10.13	Utility commands	134
7.7	Organization of a technical report	82	10.14	Basics of drawing lines	134
7.8	Decision	87	10.15	TRACE command	135
	Problems	89	10.16	Drawing circles	136
8.	Implementation	90	10.17	Drawing arcs	137
8.1	Introduction	90	10.18	Enlarging and reducing drawings	137
8.2	Working drawings	90	10.19	Erasing lines	138
8.3	Specifications	90	10.20	CHANGE command	139
8.4	Assembly drawings	91	10.21	FILLET command	140
8.5	Miscellaneous considerations	91	10.22	POLYLINE (PLINE) command	140
8.6	Implementation—hunting seat	92	10.23	PEDIT command	141
8.7	Patents	95	10.24	CHAMFER command	143
8.8	The preparation of patent drawings	98	10.25	HATCH command	144
8.9	Patent searches	101	10.26	Text and numerals	145
8.10	Questions and answers about patents	101	10.27	Text style	145
	Problems	104	10.28	Moving and copying drawings	146
9.	Design Problems	106	10.29	Mirroring drawings	147
9.1	Introduction	106	10.30	Snapping to objects (OSNAP)	147
9.2	The individual approach	106	10.31	ARRAY command	147
9.3	The team approach	106	10.32	Blocks	148
9.4	The selection of a problem	107	10.33	Dimensioning	149
9.5	Problem specifications	107	10.34	Dimensioning arcs and circles	150
9.6	Scheduling team activities	107	10.35	Dimensioning angles	151
9.7	Short design problems	109	10.36	Toleranced dimensions	152
			10.37	Oblique pictorials	152
			10.38	Isometric pictorials	152
			10.39	Plotting	153
			10.40	Grid rotation	155

CONTENTS

10.41	Applications	156	
10.42	Summary of AutoCAD	157	
11.	Drawing Instruments		158
11.1	Introduction	158	
11.2	Pencil	158	
11.3	Papers and drafting media	159	
11.4	T-square and board	160	
11.5	Drafting machines	161	
11.6	Alphabet of lines	161	
11.7	Horizontal lines	161	
11.8	Vertical lines	162	
11.9	Drafting triangles	162	
11.10	Protractor	163	
11.11	Parallel lines	164	
11.12	Perpendicular lines	164	
11.13	Irregular curves	165	
11.14	Erasing	165	
11.15	Scales	165	
11.16	Metric scales	169	
11.17	The instrument set	171	
11.18	Ink drawing	173	
11.19	Solutions of problems	177	
	Problems	179	
12.	Lettering		180
12.1	Lettering	180	
12.2	Tools of lettering	180	
12.3	Gothic lettering	181	
12.4	Guidelines	181	
12.5	Vertical letters	183	
12.6	Inclined letters	184	
12.7	Spacing numerals and letters	185	
12.8	Mechanical lettering	185	
12.9	Lettering by computer	186	
	Problems	188	
13.	Geometric Construction		189
13.1	Introduction	189	
13.2	Angles	189	
13.3	Triangles	190	
13.4	Quadrilaterals	190	
13.5	Polygons	190	
13.6	Elements of circles	190	
13.7	Geometric solids	191	
13.8	Constructing triangles	192	
13.9	Constructing polygons	192	
13.10	Hexagons	192	
13.11	Octagons	193	
13.12	Pentagons	193	
13.13	Bisecting lines and angles	194	
13.14	Revolution of figures	195	
13.15	Enlargement and reduction of figures	195	
13.16	Division of lines	195	
13.17	A circle through three points	195	
13.18	Parallel lines	197	
13.19	Points of tangency	197	
13.20	Line tangent to an arc	197	
13.21	Arc tangent to a line from a point	198	
13.22	Arc tangent to two lines	199	
13.23	Arc tangent to an arc and a line	200	
13.24	Arc tangent to two arcs	200	
13.25	Ogee curves	203	
13.26	Curve of arcs	203	
13.27	Rectifying arcs	204	
13.28	Conic sections	204	
13.29	Ellipses	205	
13.30	Parabolas	207	
13.31	Hyperbolas	208	
13.32	Spirals	208	
13.33	Helixes	209	
13.34	Involutes	209	
	Problems	210	
14.	Multiview Sketching		217
14.1	The purpose of sketching	217	
14.2	Shape description	217	
14.3	Six-view drawings	219	
14.4	Sketching techniques	219	
14.5	Three-view sketch	220	
14.6	Circular features	220	
14.7	Isometric sketching	224	
	Problems	228	
15.	Multiview Drawing with Instruments		232
15.1	Introduction	232	
15.2	Orthographic projection	232	
15.3	Alphabet of lines	233	
15.4	Six-view drawing	236	
15.5	Three-view drawing	238	
15.6	Arrangement of views	238	
15.7	Selection of views	239	
15.8	Line techniques	239	
15.9	Point numbering	241	
15.10	Line and planes	241	

CONTENTS

15.11	Alternate arrangement of views	241	17.8	Partial views	289
15.12	Laying out the three-view drawing	242	17.9	Offset sections	289
15.13	Two-view drawings	242	17.10	Revolved sections	289
15.14	One-view drawings	245	17.11	Removed sections	291
15.15	Incomplete and removed views	246	17.12	Broken-out sections	292
15.16	Curve plotting	246	17.13	Phantom (ghost) sections	293
15.17	Partial views	247	17.14	Conventional breaks	293
15.18	Conventional revolutions	247	17.15	Conventional revolutions	293
15.19	Intersections	248	17.16	Auxiliary sections	297
15.20	Fillets and rounds	249	Problems	297	
15.21	Left-hand and right-hand views	253			
15.22	First-angle projection	253			
Problems	254				
16. Auxiliary Views	263		18. Screws, Fasteners, and Springs	302	
16.1	Introduction	263	18.1	Threaded fasteners	302
16.2	Folding-line approach	263	18.2	Definitions of thread terminology	302
16.3	Auxiliaries projected from the top view	264	18.3	Thread specifications (English system)	303
16.4	Auxiliary from the top view—folding-line method	265	18.4	Using thread tables	306
16.5	Auxiliaries from the top view—reference-line method	266	18.5	Metric thread specifications (ISO)	306
16.6	Auxiliaries from the front view—folding-line method	267	18.6	Thread representation	309
16.7	Auxiliaries from the front view—reference-plane method	268	18.7	Detailed UN/UNR threads	309
16.8	Auxiliaries from the profile view—folding-line method	269	18.8	Detailed square threads	310
16.9	Auxiliaries from the profile—reference-plane method	269	18.9	Detailed Acme threads	311
16.10	Auxiliaries of curved shapes	269	18.10	Schematic representation	313
16.11	Partial views	271	18.11	Simplified threads	314
16.12	Auxiliary sections	271	18.12	Drawing small threads	314
16.13	Secondary auxiliary views	272	18.13	Nuts and bolts	315
16.14	Elliptical features	272	18.14	Drawing square bolt heads	317
Problems	274		18.15	Drawing hexagon bolt heads	317
17. Sections	281		18.16	Drawing nuts	318
17.1	Introduction	281	18.17	Drawing nuts and bolts in combination	319
17.2	Sectioning symbols	282	18.18	Cap screws	320
17.3	Sectioning assemblies	284	18.19	Machine screws	320
17.4	Full sections	284	18.20	Set screws	320
17.5	Parts not section-lined	286	18.21	Miscellaneous screws	322
17.6	Ribs in section	287	18.22	Wood screws	323
17.7	Half-sections	287	18.23	Tapping a hole	323
			18.24	Washers, lock washers, and pins	324
			18.25	Pipe threads	325
			18.26	Keys	325
			18.27	Rivets	326
			18.28	Springs	327
			18.29	Drawing springs	328
			Problems	329	

CONTENTS

19. Gears and Cams	333	21.12 Dimensioning prisms	369
19.1 Introduction to gears	333	21.13 Dimensioning angles	370
19.2 Spur gear terminology	333	21.14 Dimensioning cylinders	370
19.3 Tooth form	335	21.15 Measuring cylindrical parts	371
19.4 Gear ratios	335	21.16 Cylindrical holes	371
19.5 Gear calculations	336	21.17 Pyramids, cones, and spheres	372
19.6 Drawing spur gears	337	21.18 Leaders	372
19.7 Bevel gear terminology	337	21.19 Dimensioning arcs	373
19.8 Bevel gear calculations	338	21.20 Fillets and rounds, and TYP	374
19.9 Drawing bevel gears	339	21.21 Curved surfaces	374
19.10 Worm gears	339	21.22 Symmetrical objects	375
19.11 Worm gear calculations	342	21.23 Finished surfaces	375
19.12 Drawing worm gears	342	21.24 Location dimensions	376
19.13 Introduction to cams	342	21.25 Location of holes	377
19.14 Cam motion	343	21.26 Objects with rounded ends	377
19.15 Construction of a cam	345	21.27 Machined holes	379
19.16 Construction of a cam with an offset follower	346	21.28 Chamfers	381
Problems	347	21.29 Keyseats	382
20. Materials and Processes	349	21.30 Knurling	382
20.1 Introduction	349	21.31 Necks and undercuts	383
20.2 Iron	349	21.32 Tapers	384
20.3 Steel	351	21.33 Dimensioning sections	384
20.4 Copper	351	21.34 Miscellaneous notes	384
20.5 Aluminum	351	Problems	386
20.6 Magnesium	352	22. Tolerances	388
20.7 Properties of materials	352	22.1 Introduction	388
20.8 Heat treatment of metals	353	22.2 Tolerance dimensions	388
20.9 Castings	353	22.3 Mating parts	389
20.10 Forgings	355	22.4 Terminology of tolerancing	391
20.11 Stamping	357	22.5 Basic hole system	392
20.12 Machining operations	357	22.6 Basic shaft system	392
20.13 Surface finishing	361	22.7 Metric limits and fits	392
21. Dimensioning	362	22.8 Preferred sizes and fits	394
21.1 Introduction	362	22.9 Example problems—metric system	396
21.2 Dimensioning terminology	362	22.10 Preferred metric fits—nonpreferred sizes	398
21.3 Units of measurement	363	22.11 Standard fits (English units)	398
21.4 English/metric conversions	364	22.12 Chain dimensions	399
21.5 Dual dimensioning	364	22.13 Origin selection	399
21.6 Metric designation	364	22.14 Conical tapers	400
21.7 Aligned and unidirectional numbers	365	22.15 Tolerance notes	400
21.8 Placement of dimensions	365	22.16 General tolerances—metric	400
21.9 Dimensioning in limited spaces	367		
21.10 Dimensioning symbology	368		
21.11 Computer dimensioning	368		

CONTENTS

22.17	Geometric tolerances	402	24.13	Freehand working drawings	449
22.18	Symbology of geometric tolerances	403	24.14	Castings and forged parts	449
22.19	Limit of size	403	24.15	Sheet metal drawings	449
22.20	Three rules of tolerances	404		Problems	451
22.21	Three-datum plane concept	404	25.	Reproduction Methods and Drawing Shortcuts	478
22.22	Cylindrical datum features	405	25.1	Introduction	478
22.23	Datum features at RFS	406	25.2	Reproduction of working drawings	478
22.24	Datum targets	408	25.3	Folding the drawing	481
22.25	Tolerances of location	408	25.4	Overlay drafting techniques	481
22.26	Tolerances of form	411	25.5	Paste-on photos	481
22.27	Tolerances of profile	412	25.6	Photo revisions	482
22.28	Tolerances of orientation	413	25.7	Stick-on materials	482
22.29	Tolerances of runout	414	25.8	Photo drafting	484
22.30	Surface texture	415	26.	Pictorials	486
	Problems	418	26.1	Introduction	486
23.	Welding	423	26.2	Types of pictorials	486
23.1	Introduction	423	26.3	Oblique pictorials	487
23.2	Weld joints	425	26.4	Oblique drawings	487
23.3	Welding symbols	425	26.5	Construction of obliques	488
23.4	Types of welds	426	26.6	Angles in oblique	489
23.5	Application of symbols	427	26.7	Cylinders in oblique	489
23.6	Groove welds	428	26.8	Circles in oblique	490
23.7	Surface contoured welds	429	26.9	Curves in oblique	491
23.8	Seam welds	429	26.10	Oblique sketching	492
23.9	Built-up welds	430	26.11	Dimensioned obliques	492
23.10	Welding standards	430	26.12	Isometric pictorials	493
23.11	Brazing	431	26.13	Angles in isometric	495
23.12	Soft soldering	431	26.14	Circles in isometric	495
	Problems	434	26.15	Cylinders in isometric	499
24.	Working Drawings	435	26.16	Partial circular features	500
24.1	Introduction	435	26.17	Measuring angles	501
24.2	Working drawings—inch system	435	26.18	Curves in isometric	502
24.3	Working drawings—metric system	438	26.19	Ellipses on nonisometric planes	502
24.4	Working drawings—dual dimensions	441	26.20	Surfaces of revolution	502
24.5	Laying out a working drawing	442	26.21	Machined parts in isometric	503
24.6	Title blocks and parts lists	443	26.22	Isometric sections	505
24.7	Scale specification	443	26.23	Dimensioned isometrics	505
24.8	Tolerances	443	26.24	Fillet and rounds	506
24.9	Part names and numbers	444	26.25	Isometric assemblies	506
24.10	Checking a drawing	444	26.26	Axonometric pictorials	507
24.11	Drafter's log	445	26.27	Axonometric construction	509
24.12	Assembly drawings	445	26.28	Perspective pictorials	509
			26.29	One-point perspectives	510

CONTENTS

26.30	Two-point perspectives	512	28.4	The true-length diagram	543
26.31	Three-point perspectives	515	28.5	Angles between lines and principal planes	543
26.32	Axonometric pictorials by computer	515	28.6	Slope of a line	544
26.33	Perspectives by computer	519	28.7	Compass bearing of a line	546
26.34	Overlay film	522	28.8	Contour maps and profiles	547
26.35	Photographic illustrations	523	28.9	Vertical sections	548
Problems	524		28.10	Plan-profiles	549
27. Points, Lines, and Planes	526		28.11	Edge view of a plane	550
27.1	Introduction	526	28.12	Dihedral angles	551
27.2	Orthographic projection of a point	527	28.13	Piercing points by projection	553
27.3	Lines	528	28.14	Piercing points by auxiliary views	553
27.4	Location of a point on a line	528	28.15	Perpendicular to a plane	553
27.5	Intersecting and nonintersecting lines	528	28.16	Intersections by projection	554
27.6	Visibility of crossing lines	530	28.17	Intersections by auxiliary view	554
27.7	Visibility of a line and a plane	530	28.18	Slope of a plane	554
27.8	Planes	531	28.19	Cut and fill	556
27.9	A line on a plane	531	28.20	Design of a dam	556
27.10	A point on a plane	531	28.21	Strike and dip	557
27.11	Principal lines on a plane	532	28.22	Distances from a point to a plane	559
27.12	Parallelism of lines	533	28.23	Outcrop	560
27.13	Parallelism of a line and a plane	534	28.24	Intersection between planes—cutting plane method	560
27.14	Parallelism of planes	534	28.25	Intersection between planes—auxiliary method	560
27.15	Perpendicularity of lines	535	28.26	Solution of descriptive geometry problems	562
27.16	A line perpendicular to a principal line	535	Problems	563	
27.17	A line perpendicular to an oblique line	536			
27.18	Perpendicularity involving planes	536	29. Successive Auxiliary Views	568	
27.19	A line perpendicular to a plane	536	29.1	Introduction	568
27.20	A plane perpendicular to an oblique line	536	29.2	Point view of a line	569
27.21	Perpendicularity of planes	537	29.3	Angle between planes	569
Problems	538		29.4	True size of a plane	570
28. Primary Auxiliary Views in Descriptive Geometry	541		29.5	Shortest distance from a point to a line	573
28.1	Introduction	541	29.6	Shortest distance between skewed lines—line method	573
28.2	Primary auxiliary view of a line	541	29.7	Shortest distance between skewed lines—plane method	573
28.3	True length by analytical geometry	543	29.8	Shortest level distance between skewed lines	574
			29.9	Shortest grade distance between skewed lines	575
			29.10	Angular distance to a line	577

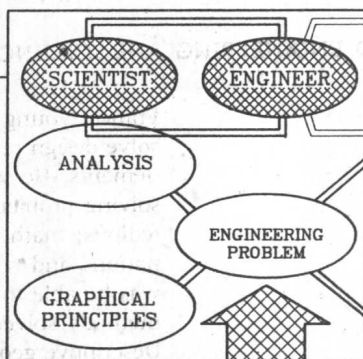
xvi CONTENTS

29.11	Angle between a line and a plane—plane method	577	
29.12	Angle between a line and a plane—line method	579	
Problems		579	
30.	Revolution	584	
30.1	Introduction	584	
30.2	True length of a line in the front view	584	
30.3	True length of a line in the top view	585	
30.4	True length of a line in the profile view	586	
30.5	Angles with a line and principal planes	587	
30.6	True size of a plane	587	
30.7	True size of a plane by double revolution	588	
30.8	Angle between planes	590	
30.9	Location of directions	591	
30.10	Revolution of a point about an axis	592	
30.11	Revolution of a right prism about its axis	593	
30.12	Angle between a line and a plane	595	
30.13	A line at a specified angle with two principal planes	595	
30.14	Revolution of parts on detail drawings	595	
Problems		597	
31.	Vector Graphics	600	
31.1	Introduction	600	
31.2	Basic definitions	600	
31.3	Coplanar, concurrent force systems	602	
31.4	Resultant of a coplanar, concurrent system—parallelogram method	602	
31.5	Resultant of a coplanar, concurrent system—polygon method	602	
31.6	Resultant of noncoplanar, concurrent forces—parallelogram method	603	
31.7	Resultant of noncoplanar, concurrent forces—polygon method	603	
31.8	Forces in equilibrium	603	
31.9	Truss analysis	606	
31.10	Noncoplanar structural analysis—special case	608	
31.11	Noncoplanar structural analysis—general case	609	
31.12	Noncurrent, coplanar vectors	609	
31.13	Nonconcurrent systems resulting in couples	609	
31.14	Resultant of parallel, nonconcurrent forces	612	
31.15	Resultant of parallel, nonconcurrent forces on a beam	613	
Problems		614	
32.	Intersections and Developments	618	
32.1	Introduction	618	
32.2	Intersections of lines and planes	618	
32.3	Intersections between prisms	621	
32.4	Intersection of a plane and cylinder	621	
32.5	Intersections between cylinders and prisms	624	
32.6	Intersections between two cylinders	625	
32.7	Intersections between planes and cones	625	
32.8	Intersections between cones and prisms	629	
32.9	Intersections between pyramids and prisms	629	
32.10	Intersections between spheres and planes	630	
32.11	Intersections between spheres and prisms	631	
32.12	Miscellaneous intersections	633	
32.13	Principles of developments	633	
32.14	Development of prisms	634	
32.15	Development of oblique prisms	635	
32.16	Development of cylinders	637	
32.17	Development of oblique cylinders	638	
32.18	Development of pyramids	639	
32.19	Development of cones	640	
32.20	Development of oblique cones	642	

32.21	Development of warped surfaces	643	35.7	Introduction to graphical calculus	689
32.22	Development of transition pieces	643	35.8	Graphical differentiation	689
32.23	Development of spheres—zone method	645	35.9	Applications of graphical differentiation	690
32.24	Development of spheres—gore method	646	35.10	Graphical integration	693
32.25	Development of elbows	646	35.11	Applications of graphical integration	694
32.26	Development of straps	647	Problems	696	
32.27	Intersections and developments in combination	647			
Problems	649				
33. Graphs		652	36. Pipe Drafting		700
33.1	Introduction	652	36.1	Introduction	700
33.2	Size proportions of graphs	653	36.2	Welded and seamless steel pipe	700
33.3	Pie graphs	653	36.3	Cast-iron pipe	701
33.4	Bar graphs	654	36.4	Copper, brass, and bronze piping	703
33.5	Linear coordinate graphs	655	36.5	Miscellaneous pipes	703
33.6	Logarithmic coordinate graphs	662	36.6	Pipe joints	703
33.7	Semilogarithmic coordinate graphs	662	36.7	Screwed fittings	704
33.8	Polar graphs	664	36.8	Flanged fittings	706
33.9	Schematics	665	36.9	Welded fittings	706
Problems	666		36.10	Valves	706
			36.11	Fittings in orthographic views	710
34. Nomography		671	36.12	Piping systems in pictorial	711
34.1	Nomography	671	36.13	Dimensioned isometrics	713
34.2	Alignment-graph scales	671	Problems	716	
34.3	Concurrent scales	673	37. Electric/Electronics Drafting		717
34.4	Construction of alignment graphs with three variables	675	37.1	Introduction	717
34.5	Parallel-scale nomographs	675	37.2	Types of diagrams	717
34.6	N- or Z-graphs	680	37.3	Schematic diagrams connecting symbols	719
Problems	682		37.4	Graphic symbols	722
			37.5	Terminals	725
35. Empirical Equations and Calculus		684	37.6	Separation of parts	728
35.1	Empirical data	684	37.7	Reference designations	728
35.2	Selection of points on a curve	684	37.8	Numerical units of function	729
35.3	The linear equation: $Y = MX + B$	685	37.9	Functional identification of parts	730
35.4	The power equation: $Y = BX^M$	686	37.10	Printed circuits	731
35.5	The exponential equation: $Y = BM^X$	687	37.11	Shortcut symbols	731
35.6	Applications of empirical graphs	688	37.12	Installation drawings	732
			Problems	733	
			38. AutoCAD update		738
			38.1	Introduction	738
			38.2	The root menu	738
			38.3	POINT command	739
			38.4	POLYGON command	739

CONTENTS

38.5	Tangent options of the CIRCLE command	740	38.18	DIVIDE command	746
38.6	FILLET command	740	38.19	MEASURE command	747
38.7	DONUT command	741	38.20	OFFSET command	747
38.8	ELLIPSE command	742	38.21	SETVAR command	748
38.9	TEXT command	743	38.22	Dimensioning variables	748
38.10	SCALE command	743	38.23	Attributes	748
38.11	STRETCH command	744	38.24	Attribute listing (ATTTEXT)	752
38.12	ROTATE command	744	38.25	Digitizing with the tablet	753
38.13	Rotated rectangular arrays	744	38.26	SKETCH command	753
38.14	Mirrored text (MIRRTEXT)	745	38.27	Slide shows	754
38.15	BREAK command	745			
38.16	TRIM command	745	Appendixes		A-1
38.17	EXTEND command	745	Index		I-1



CHAPTER 1

Introduction to Engineering and Technology

Engineering graphics is the field of graphical problem solving and includes two areas of the design process: descriptive geometry and working drawings. Other areas that can be used for a wide variety of applications are nomenclature, graphical representation, technical illustration, technical writing, data analysis, and computer graphics. Graphics is one of the designer's primary methods of thinking, solving problems, and communicating ideas.

Descriptive geometry

1.1 Introduction

This book is devoted to the introduction of elementary design concepts of engineering and to the application of engineering graphics to the design process. Examples are given that have an engineering problem at the core and that require organization, analysis, problem-solving graphical principles, communication, and skill (Fig. 1.1).

Creativity and imagination are essential ingredients of the engineering profession. Albert Einstein said, "Imagination is more important than knowledge, for knowledge is limited, whereas imagination embraces the entire world . . . stimulating progress, or, giving birth to evolution" (Fig. 1.2).

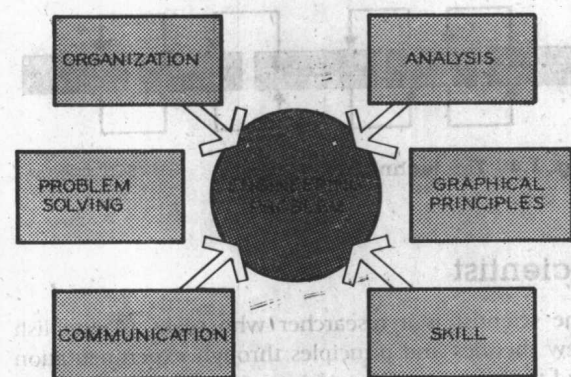


FIG. 1.1 Problems in this text require a total engineering approach with the engineering problem as the central theme.