MDESIGN concept – White Paper

The following chapters list the modules of MDESIGN concept.

The chapters which are closely linked with U.S. standards are aligned by the symbol ⊕. They have been developed in cooperation with Robert L. Mott. More information can be obtained from the text book “Machine Elements in Mechanical Design” by Robert L. Mott, Prentice Hall Publishers.
The modules related more closely to European standards are denoted by the symbol ⊗.

Group 1: Beams, Shafts, Columns, and Mohr's Circle

1-1 ⊗ **Beam Calculations** Basic beam stress analysis

1-2 ⊗ **Shaft Calculation - Base** Comprehensive shaft analysis/fatigue

1-3 ⊗ **Statically Determinate Beams** General purpose beam analysis

1-4 ⊗ **Statically Indeterminate Beams** Various indeterminate beam types

1-5 ⊕ **Shafts - U.S. Standards:** Focused on shafts carrying gears

1-6 ⊕ **Column Analysis:** Given a proposed design of a column, the module analyzes load-carrying capacity using Euler or Johnson method; Calculates the allowable load on the column using approaches in Sections 6-6 and 6-7 of the book.

1-7 ⊕ **Column Design:** Modelled on the procedures from Section 6-10 of the book; only solid circular columns are illustrated, calculating minimum required diameter.

1-8 ⊕ **Combined Stresses & Mohr's Circle:** Modelled on Section 4-4 of the book, the software uses input data for given stresses on an element in a known x-y orientation, computes combined stress data and displays the Mohr's circle results.

Group 2: Shaft-Hub Connections

2-1 ⊗ **Splined Shaft Connections** Related to book Section 11-5

2-2 ⊗ **Parallel Key Connections** Related to book Sections 11-2 to 11-4

2-3 ⊗ **Split Hubs** European Standards

2-4 ⊗ **Split Lever Hubs** European Standards

2-5 ⊗ **Tapered Connections** Figure 11-14 of the book

2-6 ⊗ **Clamping Device Joints** Related to Figure 11-10 of the book

2-7 ⊗ **Cylindrical Press Fit Connections** Related to Section 13-8 of the book

2-8 ⊕ **Parallel Keys – U.S. Standards:** Modelled on Sections 11-2 to 11-4 of the book, the software uses input data for given for shaft size, torque transmitted, design factor, length of the hub and materials for key, shaft, and hub to calculate the minimum required key length and installation dimensions for the keyseat in the shaft and the keyway in the hub.

2-9 ⊕ **Woodruff Keys:** Modelled on Sections 11-2 to 11-4 of the book, the software uses input data for given shaft size, torque transmitted, design factor, length of the hub and materials for key, shaft, and hub to determine the proper size of key from Table 11-3 of the book and calculate the design stresses and required areas, the shaft keys at depth, hub keys at length, and the resulting effective length of the key. See Figure 11-3(e) in the book.

Group 3: Bolts and Pins

3-1 ⊗	**Cross Bolts**	Called *Clevis Joint* or *Lug Joint* in the book Related to Section 3-21 and Figure 3-26
3-2 ⊗	**Guiding Pins**	Sometimes called *dowel pins*, used for precise Location and alignment
3-3 ⊗	**Longitudinal Pins**	Sometimes called *pin keys*; Figure 11-3(d) In the book
3-4 ⊗	**Transverse Pins**	See Figure 11-9 of the book

Group 4: Screw Connections

4-1 ⊗	**Bolted Joints**	European Standards
4-2 ⊗	**Power Screws**	European Standards
4-3 ⊗	**Moment Loaded Joints**	European Standards

4-4 ⊕ **Bolt Specifications:** Modelled on the book's Section 19-4, the software uses input data for clamping force, number of bolts, and related data to calculate the required diameter for the bolts and reports the nearest larger standard size and the recommended tightening torque.

4-5 ⊕ **Bolted Connections:** Modelled on Section 20-3 of the book and Figure 20-4 concerning a moment-loaded bolted connection. Given the applied load, the distance from the line of action of the load to the center of the bolt pattern, and the pattern of bolts, the software calculates the required diameter of the bolts and the nearest standard diameter.

4-6 ⊕ **Power Screws – U.S. Standards:** Modelled on Section 17-2 of the book, the software uses input data for the load to be moved, the distance moved, and the travel time, and calculates the required diameter of the screw, the standard screw size, the driving torques, and the power required to drive the screw.

Group 5: Gears

5-1 ⊗	**Spur Gears, Gear Rack**	European Standards
5-2 ⊕	**Spur Gears, U.S. Standard**	Relevant to the book's Section 9-11

5-3 ⊕ **Helical Gears, U.S. Standard** Relevant to the book's Section 10-5

5-4 ⊕ **Bevel Gears, U.S. Standard** Relevant to the book's Section 10-10

5-5 ⊕ **Worm Gears, U.S. Standard** Relevant to the book's Section 10-13

5-6 ⊗ **Splines – ANSI B92.2M** Metric splines – geometry - European

Group 6: Belt, Chain Drives

General Note: All modules in this group contain catalogs of many sizes and types of belts or chains from which the user or the program chooses one. All catalog data are in metric dimensions except for Module 6-5, V-Belts, U.S. Standard and Module 6-6, Roller Chains – ISO 10823. German DIN standards are used throughout.

6-1 ⊕ **Synchronous Belts:** Relevant to the book's Section 7-5. Belt profiles are similar to those shown in the book's Figure 7-18 with some of the sizes listed in the book's Table 7-4. Input data include the power to be transmitted, the rotational speeds of the input and output pulleys, the locations of the centers for the drive pulley and the driven pulley (called the *jockey pulley* in the software). The software calculates the smallest standard width of the belt, its length, pulley diameters and numbers of teeth, the actual center distance, and other operational and geometric factors. Analysis performed by the software is similar to that shown in the book's Example Problem 7-2.

6-2 ⊗ **Belt Contact:** Basic geometry of belt drives as shown in the book's Section 7-3.

6-3 ⊗ **Normal V-Belts:** Relevant to the book's Sections 7-3 and 7-4. Belt profiles are similar to those shown in the book's Figure 7-3. Analysis performed by the software is similar to that shown in the book's Example Problem 7-1.

6-4 ⊗ **Narrow V-Belts:** Relevant to the book's Sections 7-3 and 7-4. Belt profiles are similar to those shown in the book's Figure 7-6 but using European notations. Analysis performed by the software is similar to that shown in the book's Example Problem 7-1.

6-5 ⊕ **V-Belts, U.S. Standard:** Relevant to the book's Sections 7-3 and 7-4. Belt profiles are similar to those shown in the book's Figure 7-6, either 3V, 3VX, 5V, 5FX, 8V, or 8VX. Analysis performed by the software is similar to that shown in the book's Example Problem 7-1.

6-6 ⊕ **Roller Chains – ISO 10823:** Relevant to the book's Sections 7-6 and 7-7, using chain sizes in inch dimensions as listed in the book's Table 7-6 for general purpose power transmission. Analysis performed by the software is similar to that shown in the book's Example Problem 7-3.

Group 7: Roller Bearings

7-1 ⊕ **Ball and Roller Bearings** Relevant to the book's Chapter 14. Data from a comprehensive SKF catalog is accessible for 14 types of rolling contact bearings handling any combination of radial and thrust loads. Included are single and double row ball bearings or roller bearings, tapered roller bearings, angular contact bearings, and many more.

Group 8: Journals

8-1 ⊗ **Axial Journals** Thrust bearings – European Standards

8-2 ⊗ **Radial Plain Surface Bearings** Hydrodynamic bearings – European Standards

8-3 ⊕ **Plain Surface/Journal Bearings** Boundary lubricated bearings, as described in the book's Chapter 16, Section 16-5. After entering data for radial load, rotational speed, shaft diameter, and the ratio of length to diameter, the software calculates the *pV* value and recommends a suitable material for the bearing.

Group 9: Elastic Springs

9-1 ⊗ **Bellville Springs** European Standards

9-2 ⊗ **Torsion Springs** European Standards

9-3 ⊗ **Torsion Bar Springs** European Standards

9-4 ⊕ **Helical Extension Springs: U.S.** Modelled on the book's Section 18-6, the software uses input data for basic length dimensions and corresponding forces, estimated spring mean diameter, and material properties and calculates spring rate, required wire diameter, number of coils, and other details.

9-5 ⊕ **Helical Compression Springs: U.S.** Modelled on Section 18-3 to 18-6 of the book, the software uses input data for basic length dimensions and corresponding forces, estimated spring mean diameter, and material properties and calculates spring rate, required wire diameter, number of coils, and other details.

9-6 ⊕ **Helical Torsion Springs: U.S.** Modelled on Section 18-8 of the book, the software uses input data for required angular deflection and corresponding applied torques, proposed design for the end-extensions of the wire, estimated spring mean diameter, and material properties and calculates the spring rate, required wire diameter, number of coils, and other details.

Group 10: Materials, Strengths, Stresses

10-1 ⊗ **Material Data** European symbols and terms

Group 11: Tolerances & Fits

11-1 ⊕ **ISO Fit System:** Used for the fit between a shaft and the bore of its mating hole, and Modelled after the book's Sections 13-3 to 13-6, the software applies tolerance grades selected from the book's Tables 13-2 and 13-2M as illustrated in the book's Figure 13-4 to calculate the upper and lower deviation from the specified basic size, total tolerance, maximum size, minimum size, maximum clearance, and minimum clearance.

Group 12: Moments, Approximate Values

Note: This group of modules contains a variety of topics that are generally useful in mechanical design; assigning surface roughness values for mating parts, computing the moment of inertia for many shapes of plane areas, and computing the mass moment of inertia of solid bodies as used in dynamics analysis and applied in this book in Chapter 22 Motion Control: Clutches and Brakes.

12-1 ⊕ **Approximate Calculation of the Roughness Dimension:** Given a surface roughness value measured in the peak to valley system (R_z), the software calculates the approximate average roughness value, (R_a); and vice-versa. The conversion uses procedures defined in the German standard DIN 4678. The term R_a is sometimes called *AA*, the arithmetic average. Either micrometers or microinches may be used for roughness measurements. Refer to the book's Figure 13-3 for relationships between machining operations and surface roughness values that can be obtained.

12-2 ⊕ **Manufacturing Technique of the Roughness of the Surface:** The user selects a manufacturing technique from a drop-down menu and either average (R_a) or peak to valley (R_z) methods for roughness measurements. The software then reports back two ranges of roughness values: 1. Recommended upper and lower values; 2. Obtainable upper and lower values. The software uses values from the German standard 4766 and the results differ somewhat from those reported in the book's Figure 13-3 taken from Reference 8 in the book.

12-3 ⊕ **Moment of Inertia of Areas:** This module is an extension of the book's Appendix 1 and provides automatic calculation for the value of moment of inertia of areas. Any of nine common shapes can be selected and complete lists of commercially available shapes such as I-beams, angles, and channels are presented from German DIN standards. The user can select a standard size and the software calculates its area properties.

12-4 ⊕ **Mass Moments of Inertia:** This module is most closely related to the book's Chapter 22 Motion Control: Clutches and Brakes, especially Sections 22-4 and 22-5 in which the angular acceleration of rotating bodies is considered. It calls for input of dimensions for any combination of solid or hollow cylinders, spheres, or rectangular solids (parallelepipeds) along with their orientations and positions with respect to a specified coordinate system. After entering density also, the software calculates mass and mass moment of inertia of the object.

12-5 ⊕ **Mass Moments of Inertia – Elements:** This module is most closely related to the book's Chapter 22 Motion Control: Clutches and Brakes, especially Sections 22-4 and 22-5 in which the acceleration of rotating bodies is considered. The module is comprised of 14 separate sub-modules for different solid body shapes such as cylinders, cones, spheres, pyramids, and others. After entering dimensions and density, the software calculates mass and mass moment of inertia of the object.

Group 13: Welded Connections

13-1 ⊗ **Calculation of Welds** European standards

13-2 ⊕ **Welded Joints:** Modelled after the book's Section 20-4, the software calls first for identification of the general form for the weld pattern as shown in the book's Figure 20-8. Then the user enters pertinent dimensions, loads, the placement of the loads, and the allowable force per inch of weld leg length from the book's Table 20-3, reproduced in the software's input page. The output includes calculated forces, moments and torques on the weld and the required weld leg length size.

Group 14: Bonded Joints

14-1 ⊗ **Tensile Loaded Boned Joints:** A butt joint between two parts is analyzed to determine any of the variables for part width, part thickness, and applied force, after the strength of the adhesive and the other two variables are specified in the input data. If all variables are entered, the safety factor for the joint is calculated.

14-2 ⊗ **Tangential Loaded Bonded Joints:** A tangential loaded bonded joint, sometimes called a lap joint, is analyzed for its resistance to pulling free by a force acting tangential to the glued surface. Variables include the length of the sides of the glued plate and its width. If only one of those dimensions is entered, the minimum value of the other is calculated. If both are entered, the safety factor for the joint is calculated.

14-3 ⊗ **Torsional Loaded Boned Joints:** A cylindrical shaft of diameter *d* is to be glued into a hole in a hub having a length *b* and a torque is to be applied to the shaft. After specifying one of the two dimensions and an adhesive, the software calculates the other variable. If data for both the diameter and length are entered, the resulting safety factor is calculated.

Group 15: Clutches and Brakes

Note: All five modules in the group are Modelled after sections of Chapter 22 of this book.

15-1 ⊕ **Short Shoe:** Modelled after the book's Section 22-14. For the design shown in the book's Figure 22-17 and with all the basic dimensions entered along with the applied torque, the software calculates the required applied force, *W*.

15-2 ⊕ **Long Shoe:** Modelled after the book's Section 22-14. For the design shown in the book's Figure 22-19 and with all the basic dimensions, except the width of the brake pad, entered along with the applied torque, the software calculates the required width, a recommended preferred size for the width, *w*, the applied force, *W*, the frictional power, and the wear ratio.

15-3 ⊕ **Band:** Modelled after the book's Section 22-15. For the design shown in the book's Figure 22-20 and with all the basic dimensions entered along with the applied torque, the software calculates the required applied force, *W*, the frictional power, and the wear ratio.

15-4 ⊕ **Plate-type:** Modelled after the book's Section 22-11. For the design shown in the book's Figure 22-2(a), the user enters the applied torque, the normal force acting on the movable member, the rotational speed, the coefficient of friction, and an approximate value for the ratio of the outside radius to the inside radius of the friction pad. The software then calculates the required mean radius, actual inside radius, and outside radius, the frictional power, and the wear ratio.

15-5 ⊕ **Cone:** Modelled after the book's Section 22-13. For the design shown in the book's Figure 22-16, the user enters the applied torque, the coefficient of friction, the cone angle, and the value for the mean radius of the conical friction surface. The software then calculates the axial force required to press the two components together.