

# EML2322L – MAE Design and Manufacturing Laboratory

## EML2322L Top 100 Concepts

Following is a compilation of the most important concepts covered in EML2322L. The list is no substitute for reading the original material found on the course website. Rather, the list is meant to be used as a final checklist of whether you are ready for the final exam (and industry) with regard to your design and manufacturing knowledge.

### Part Design & Detail Drawings

1. Before finishing part design, consider attachment methods and clearance for assembly tools.
2. Are you sure other parts will not interfere with the one(s) you have designed?
3. Can manufacturing be simplified by combining multiple or splitting individual parts?
4. Can the design be simplified to reduce the number of manufacturing steps?
5. Can each feature on the part be made to the tolerance specified using machines you know how to use?
  
6. Include necessary dimensions and appropriately justified finish specs for manufacturing each part feature.
7. Include proper tolerances for each dimension and if unsure consult someone with more experience.
8. Specify properly sized clearance holes using close or free fit standards off the tap chart.
9. Select the correct type of thread (fine or coarse) for the chosen material.
10. Include all required information for threaded holes: (1) tap drill size and depth, (2) thread spec and depth, and (3) number of identical features on the part.
11. Denote part quantity and understand its effect on quoted cost per part.
12. Each drawing should have a consistent title block that includes the part name, designer's name, drawer's name, drawing scale, and revision number.
13. Each drawing should contain a tolerance table in the title block and a "NOTES:" section that includes units, material and quantity specifications, debur instructions, and other notes specific to the drawing.
  
14. Understand the two purposes of a tolerance table.
15. Dimensioning fundamentals summarized and illustrated in the [Dimensioning Rules](#) course document.
16. Define nominal size, basic size, and tolerance.
17. Understand the difference between bilateral, unilateral, and limit tolerancing.
18. Understand datum vs. chain dimensioning, and how each affects positional tolerance of target feature(s).
19. Understand the difference between fit and allowance, and how to dimension a shaft and bore accordingly.

### Assembly Drawings & BOMs

20. Assembly drawings should be so clear, complete, and uncluttered that a 10 year old could follow them.
21. Assembly drawings must include dims showing the location of different parts with respect to each other.
22. Never show individual part dimensions on assembly drawings (place those on detailed drawings instead).
23. Never show hidden lines in assembly views, but show all tangent edges.
24. Use exploded views when parts of an assembly are not clearly distinguishable by BOM balloon leaders.
25. A manufacturing BOM should contain a clearly formatted table with four columns: (1) unique and sequential item number, (2) part number, (3) part description, (4) quantity used in the assembly.
26. For each item in the BOM, there should be a balloon and leader clearly pointing to the corresponding part in the assembly drawing(s); this will require multiple views.
27. Label all BOM item numbers sequentially so there are no duplicates across all BOM sub-tables.
28. BOM fastener descriptions require three pieces of information: the thread specification, fastener length and head type (i.e. *1/4-20 x 0.5" button head cap screw* or *M6x1.0 x 25 hex head bolt*).

## Fastener Knowledge

29. Understand the sole purpose of a normal fastener is to clamp parts together; they are *not* designed to locate parts (that's the job of dowel pins and locating shoulders) or function as pivots and axles.
30. Understand how fasteners are intended to be loaded (i.e. tension) and how they are not (i.e. shear).
31. Understand basic fastener nomenclature (head, bearing surface, shank, thread crest, thread root, thread point, pitch, grip length, thread length, and overall length)
32. Understand the difference in metallurgy between cut and rolled threads and which process is used to produce *all* high quality fastener threads
33. Understand how to select the correct type of thread for use in stronger or weaker materials and *why* one type of thread is stronger than the other in each application.
34. Specify threaded hole notes and tap drill sizes based on Tap & Drill Chart standards (English & metric).
35. For blind threads, always specify at least one extra fastener major diameter for the tap drill depth.
36. Understand what keeps (and does not keep) fasteners tight, as well as how many more stress cycles a typical fastener can endure when properly torqued.
37. Understand how to calculate required fastener tightening torque for any size or grade fastener.
38. Never use smaller threads than necessary (i.e. avoid threads smaller than #6 or M4 whenever possible).
39. Specify threads to the proper depth (typically twice the nominal fastener major diameter, but never less than one or more than three fastener major diameters).
40. Never design for less than five threads of engagement and know how to calculate minimum part thickness given desired fastener size (i.e. pitch or TPI).
41. Understand the proper use of clearance fits (versus line or nominal fits) for normal fasteners and specify proper sized clearance holes using close or free fit standards off the tap & drill chart.

## DFM Tips

42. Never design a part you can buy out of a catalog unless you can justify the time and cost to do so.
43. Design parts to take advantage of nominal raw material sizes.
44. Avoid designing mirror image (right or left hand) parts.
45. Use larger feature tolerances whenever possible.
46. Use fewer and/or coarser surface finish specifications.
47. Use fewer dimension datums.
48. Use nominal part / feature dimensions whenever possible.
49. Select materials intelligently in the following general order of importance: strength, machinability, cost; stated another way, always select the weakest material that is strong enough for the design.
50. Use thru-bolted holes when possible (as opposed to threaded if assembly space is not an issue).
51. Specify cone-bottomed holes (vs flat bottomed).
52. Make the part smaller.
53. Design for minimum raw-stock removal.
54. Avoid small, weak cutting tools (smaller than 0.25" dia. endmills; #6 or M4 fastener tap drills).
55. Design for favorable tool stiffness (small L:D ratios; under 3:1 for milling and 8:1 for drilling).
56. Design around standard cutter sizes (inch and metric) whenever possible.
57. Avoid fillets and chamfers unless you have functional justification for them.
58. Reduce the total number of parts in your assembly, or standardize required components.
59. Create designs that are explicitly simple; keep complexity intrinsic, buried, and invisible. If you (as the designer) think a concept is really complicated, you're probably right.
60. Treat each drawing you create as a resume. Good shops don't need your business. Your drawings always compete against others as good shops decide which jobs to accept.
61. Review the topics covered in the [DFM Examples](#) document.

## Design Process / Project Knowledge

62. Understand importance of data driven decisions, which is the concept behind evaluation matrices.
63. Understand why decision matrix objectives are weighted.

64. Understand why quantitative assessments are always preferred to qualitative assessments.
65. Understand importance of clear justification data.
  
66. List three reasons aluminum, plastic, steel, and wood are all suitable engineering materials and list three common applications of each.
67. Understand the definition of motor power and how it relates to useful work it can perform.
68. Understand the purpose of gears and why they are commonly used.
69. Understand different steering mechanisms and when each is appropriate.
70. Understand different mobile platform configurations and the necessary requirements of each.
71. Calculate linear velocity of a wheeled platform given wheel size, motor speed, and motor efficiency.
72. Calculate lifting torque required for an arm or a pulley given the geometry and weight of the load.

### **Design and Manufacturing Knowledge**

73. Understand the four common methods of mechanical power transmission and the pros/cons of each.
74. Understand the topics covered in the [Motor Mount](#) and [Wheel Hub Design Guides](#).
75. Understand equipment nomenclature for lathes (headstock, spindle, ways, tool post, cross slide, carriage, tailstock, bed), how many axes of motion a basic lathe possesses, and how the axes are identified.
76. Understand equipment nomenclature for milling machines (base, column, knee, saddle, table, spindle, quill, motor, overarm), how many axes of motion a basic mill possesses, and how the axes are identified.
77. Understand common lathe operations used in industry (turning, facing, profiling, chamfering, parting, threading, boring, drilling & knurling) and the tools used for each.
78. Understand the difference between end milling and face milling and the tools used for each.
79. Understand common drilling operations used in industry (reaming, tapping, counterboring, countersinking, centering, & spotfacing) and the tools used for each.
80. Understand the process and tools to produce a threaded hole in a workpiece using a milling machine.
81. Understand cutting operations performed on lathes and mills while making assigned parts.
82. Understand the difference between roughing and finishing cuts and what matters for each.
83. Understand from what two types of materials most cutting tools are made, and the one that is most commonly used for its higher toughness and lower cost.
84. Understand cutting dynamics and the dominant factors controlling how fast a cutting tool can rotate in a particular material, how deep it can cut per pass, and how fast it can feed across or into the workpiece.
85. Understand principal factors which affect optimal cutting speed and feedrate when machining (material composition, hardness, and thermal conductivity; depth of cut; efficiency of cutting fluid; stiffness and condition of machine; stiffness of workpiece, fixture, and tooling; desired finish quality; tool life).
86. Understand how to calculate speeds and feeds for drills and endmills used on CNC machines, and how and why these parameters must be scaled back when used on manual machines or in deep cut scenarios.
87. Understand what specific material properties cause the recommended surface speed ( $V$ ) for aluminum to be 2.5 times that for steel, and that of steel to be 3 times that for titanium.
88. Understand benefits of manual machines over CNC machines and vice-versa, as well as which types of parts are better suited for which type of machine.
89. Understand how to use measuring calipers and common reasons for improper measurements.
90. Understand the difference between accuracy and precision.
91. Understand square holes cannot be made using traditional processes.
92. Understand the three common types of electric arc welding and the pros/cons of each.
93. Understand water jet and abrasive water jet processes, the applications for each, and the advantages over traditional manufacturing methods.
94. Understand casting and forging processes, the applications for each, and how their material properties compare to traditional extruded billet material (such as those used to manufacture the assigned parts).
95. Understand process tolerances and how they are affected by feature size.
96. Understand the relationship between desired surface quality and relative manufacturing time.