Key Objectives
K = Knowledge
S = Skills

<table>
<tr><th>Class #</th><th>Key objectives</th></tr>
<tr><td>1</td><td><u>Introduction to Optomechanical Engineering</u>
K: Definition of Optomechanical engineering

<u>First order properties of lenses and mirrors</u>
K: First order optics
object, image, cardinal point relationship
magnification, image orientation</td></tr>
<tr><td>2</td><td><u>First order properties of lenses and mirrors</u>
S: Decompose rotation about one point to rotation about another point plus translation
S: Calculate image shift for rotation of optical system about an arbitrary point for object at infinity.</td></tr>
<tr><td>3</td><td><u>Image motion</u>
K: Use of optical invariant
S: calculate image shift for a general case of any element motion

<u>System LOS, RSS combinations</u>
K: understand issues for RSS combination
S: estimate rss combination for large number of parameters

<u>Technical Reports</u>
K: Approach and expectations for technical reports. Understand key issues:
- writing with a sense of audience and purpose
- organization
- writing reports that emphasize results, rather than process
- use of graphics, data
- use of appendices
S: Write quality, concise technical reports</td></tr>
<tr><td>4</td><td><u>Prisms</u>
K names, properties, and applications of common prisms
K definitions for technical reports
S: determine elliptical beam footprint onto a tilted plane (like a mirror)

<u>Mirror Matrices</u>
K definition of mirror matrices
S calculate mirror matrix for set of reflections
S determine mirror matrix from inspection
S apply mirror matrices to determine effects of prism rotations</td></tr>
<tr><td>5</td><td><u>Technical drawings: concepts</u>
K: Create 3-view orthographic projections of parts, assemblies
K: define datum surfaces, dimensions
K: use of control frames to specify tolerances and alignment of surfaces</td></tr>
<tr><td>6</td><td><u>Engineering design using to Solid Works</u>
S creating a solid model of a simple assembly
S create solid models of optical components
S mate mechanical mount and optical surfaces to optomechanical assemblies

<u>Drawing in Solidworks</u>
S: Create 3-view orthographic projections of parts, assemblies
S: Create cutaway views of parts, assemblies
S: Appropriately tolerance dimensions
S: Define datum surfaces</td></tr>
</table>

	S: Use control frames to specify tolerances and alignment of surfaces S: Design and specify threaded interfaces
7	<u>Tolerancing Optical Systems</u> K Systems engineering approach to tolerancing S build tolerance table, adjust for performance S define compensator for tolerancing S use rules of thumb for initial mechanical tolerancing
8	<u>Specification of Optical components</u> K lens centration, wedge what it means and how it relates to manufacturing S Specify lens wedge S Relate tolerance on radius of curvature to surface sag S Apply rules of thumb for setting requirements <u>Modeling in Solidworks</u> S Create assemblies S Methods of mating parts S Definition of threaded interfaces
9	<u>Machining and measurements</u> K common machining methods – limitations K common measuring methods – limitations S calculate effects of Abbe offset
10	<u>Statics</u> K Definition of force, moment, static equilibrium S create free body diagram S Apply static equilibrium to determine reaction forces S determine constraint conditions for simple cases K Familiarity with methods of joints and sections for frames and machines
11	<u>Stress and strain</u> K Understand normal and shear stress and strain, Poisson effect K Definition of material properties E, G, E_B, ν, σ_y, σ_{PEL} σ_{ULT} S Calculate elongation due to normal loads S Determine effective stiffness for combination of series – parallel load paths S Use bulk modulus to determine stiffness of constrained layer
12,13	<u>Deflections under loading</u> K Understand solid mechanics of deformations for beams with simple loading – axial, shear, torsion, bending S calculate I, J for simple geometry, look it up for more general cases S use tables to determine angular and lateral deflections of beams for simple loading S use superposition to determine beam deflections for more general cases S use superposition to solve problems that have overconstraint S apply Maxwell's reciprocity to simple cases S Calculate stiffness for simple geometry, determine resonant frequency S assess stability for Euler buckling
14	<u>Finite Element Modeling: theory and applications</u> K: Understand the calculations performed by FE code K: names and application of different types of elements K: Use of FE analysis to guide the engineering design process
15	<u>Thermal Distortions</u> K: Understand thermal expansion K: Know about materials with very low CTE S: Calculate thermal distortion for simple cases S: Apply material conductivity to determine thermal gradient, heat flux S: Apply thermal diffusivity to determine conductive time constant S: Athermalize using different materials, geometry
16	<u>Kinematic constraints</u> K Understand principles of kinematic constraint K Understand usefulness and limitations of semi-kinematics S Define kinematic and semi-kinematic interfaces S Calculate stiffness and stress for point contacts

17	Introduction to Finite Element Modeling in SolidWorks K: Importance of mesh control, use of stress concentration factors. S: Create finite element model, including boundary conditions S: Apply load to FEM, determine deflections, stresses S: Use different types of elements in SolidWorks S: Use Solid Works finite element to predict lowest modes of vibration S: Use Solidworks FEM to establish buckling stability S: Apply thermal variations and gradients, determine stress and deflection S: Set mesh density to provide accurate deflections, stresses
18,19	Mechanical materials K: know approximate values of all common material constants for aluminum K: familiarity with special issues with common metals, knowledge of important constants Optical materials K: know approximate values of all common material constants for BK7 K: familiarity with special issues for common classes of materials K: know approximate values for material properties for common optical materials S: calculate change in focus due to temperature for simple optical systems S: athermalize mechanical distances, optical systems Adhesives K: Familiarity with classes of adhesives, issues, methods S: Calculate stiffness for elastomeric adhesives S: Calculate thermally induced stress for simple bonded joints
20	Fasteners K: Definitions of metric and English fasteners K: Familiarity with types and sources of specialty hardware S: Correctly call out holes for fasteners on a drawing S: Include fasteners in Solid Works models, assemblies, Bill of materials S: Use tables to find dimensions and torque settings for common fasteners S: Find and procure fasteners and specialty hardware Shock and Vibration K: Dynamic response for Mass-spring-damper system K: Definition of PSD, acceleration spectrum S: Estimate performance of vibration isolation system S: Estimate shock loading for simple case
21	Flexures and adjustments K: Understand 6 DoF constraints, adjustments K: understand use of flexures to constrain some and allow other degrees of freedoms K: use of flex pivots, blade flexures K: use of geometry, differential flexure for small motions. S: specify use of shims, preloaded screws push-pull screws for adjustments S: use liquid pinning for stable connection S: choose materials for flexures S: calculate stiffness for simple flexures
22	Stages and motion control K: Understand elements of any translation or rotation stage S: Calculate effect of angle coupled through Abbe offset S: trade off different issues and be able to choose stages - linear stage - rotary stage - tilt stage K: understand geometry of hexapod for motion control
24	Concepts for mounting optical elements K: understand how to define 6 DoF constraints S: choose between mounting concepts: clamping and bonding

	S: estimate thermal survival for bonded joints K: understand issues for choosing glass-metal interface - control of position and geometry, coupled with manufacturing tolerance - limit stress due to thermal and shock loading <u>Mounting of windows</u> K: mounting techniques for windows S: Calculate stresses for pressure windows <u>Mounting of prisms</u> K: issues with bonding or clamping prisms S: Calculate survivability for prisms
25	<u>Mounting of lenses</u> K: separate the functions of the mount: safe constraint and dimensional precision. S: design simple lens barrel for multiple lenses K: understand difference between mechanical and optical surfaces of a lens and how the mounting details accuracy K: understand the techniques used to achieve tolerances that are tighter than the machining precision <u>Data analysis in SAGUARO</u> S: operate SAGUARO, reading data and using canned modules
26	<u>Mirror mounts</u> K: understand basics for controlling mirror errors - fully constrain the rigid body degrees of freedom - don't over constrain and distort the mirror - allow thermal expansions - avoid applying moments K: sources of error for mirror mounts K: use of whiffle tree, flexures for axial support K: use of tangent, radial, and distributed lateral supports S: define simple bonded or clamped mount for small mirror S: estimate performance of simple bonded or clamped mirror mount S: estimate self-weight deflection for solid mirrors on simple supports <u>Modeling mirror distortion</u> S: create solid model, finite element model of simple mirror S: provide constraints, evaluate self-weight deflection S: export data from SolidWorks, perform Zernike fit