

Introduction

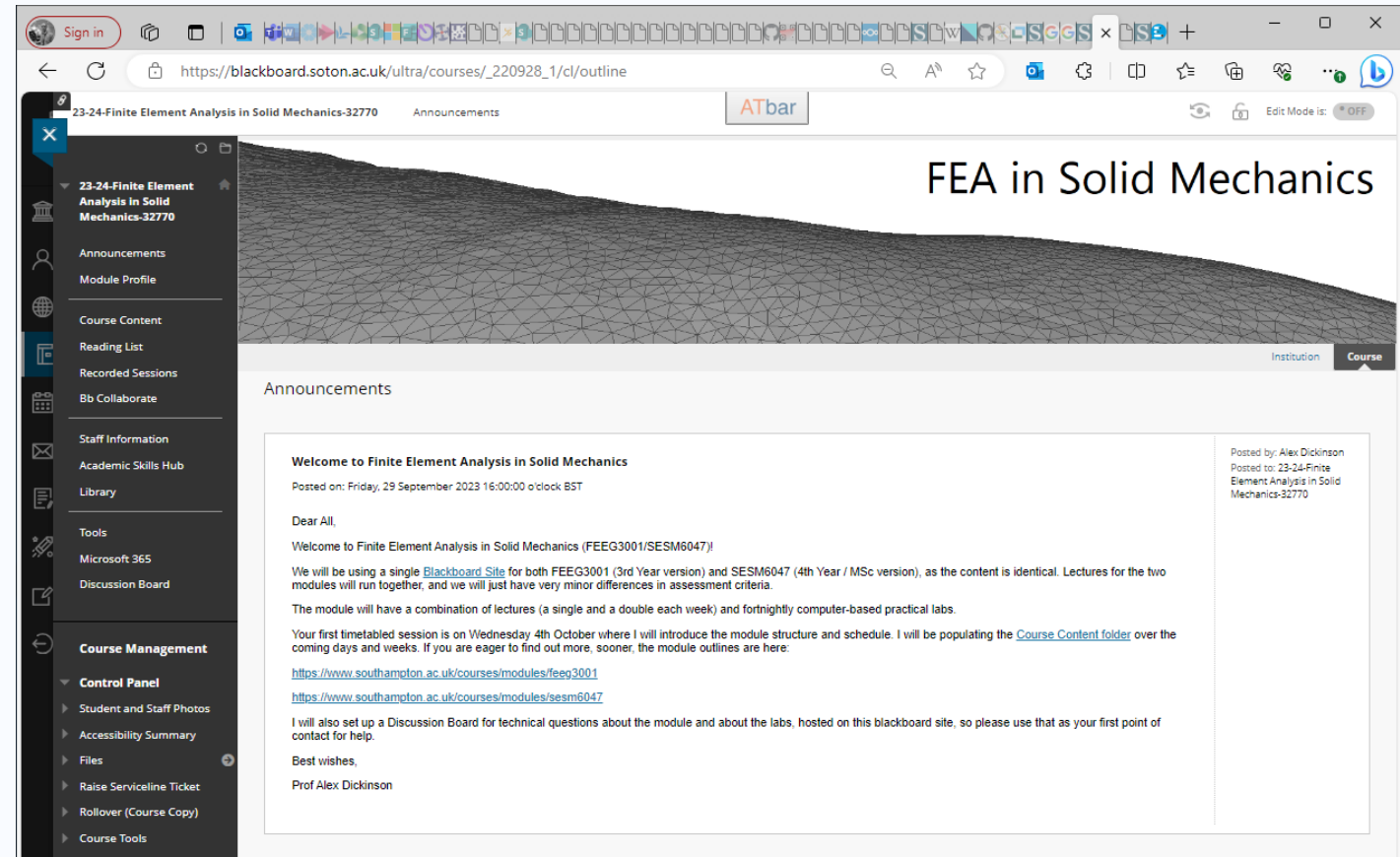
FEEG3001/SESM6047 FEA in Solid Mechanics

Prof A S Dickinson

1st October 2024

Welcome

- Who is in the room?
Backgrounds?
- Has everyone done at least one solid mechanics course?
 - Basic solid mechanics
 - Basic Matrix algebra (multiplication, transposes, ...)
- See the background maths lecture if needed



The screenshot shows a web browser displaying a Blackboard course page. The URL is https://blackboard.soton.ac.uk/ultra/courses/_220928_1/cl/outline. The course title is "23-24-Finite Element Analysis in Solid Mechanics-32770". The page features a sidebar with navigation links: Announcements, Module Profile, Course Content, Reading List, Recorded Sessions, Bb Collaborate, Staff Information, Academic Skills Hub, Library, Tools, Microsoft 365, and Discussion Board. The main content area has a header image of a wireframe mesh with the title "FEA in Solid Mechanics". Below the header, there is an "Announcements" section with a welcome message from Prof Alex Dickinson, dated Friday, 29 September 2023 16:00:00 o'clock BST. The message welcomes students to the course (FEEG3001/SESM6047) and provides information about the course structure, including a combination of lectures and computer-based practical labs. It also mentions a first timetabled session on Wednesday 4th October and provides links to the course content folder and a discussion board for technical questions.

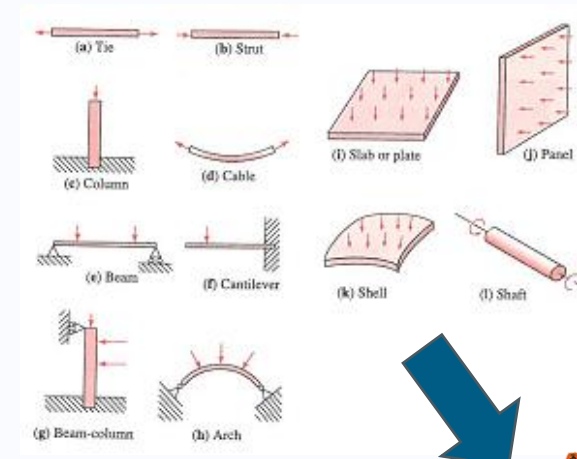
What is Finite Element Analysis (FEA)?

Join: **vevox.app** ID: **163-639-669**

Enter Text and
Press Send

What is Finite Element Analysis (FEA)?

- Field problems
- Boundary value problems
- Described by partial differential equations
 - Heat transfer
 - Fluid flow
 - **Structural analysis (deformation, stress)**
- An alternative to Free Body Diagrams
- When complexity in shape, loading, materials make analytical approaches inappropriate

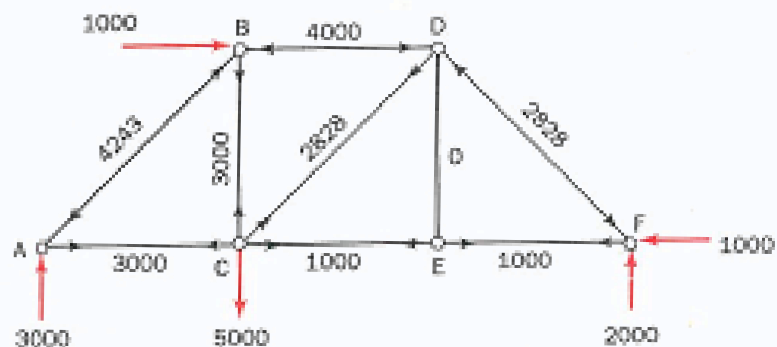


Benham et al



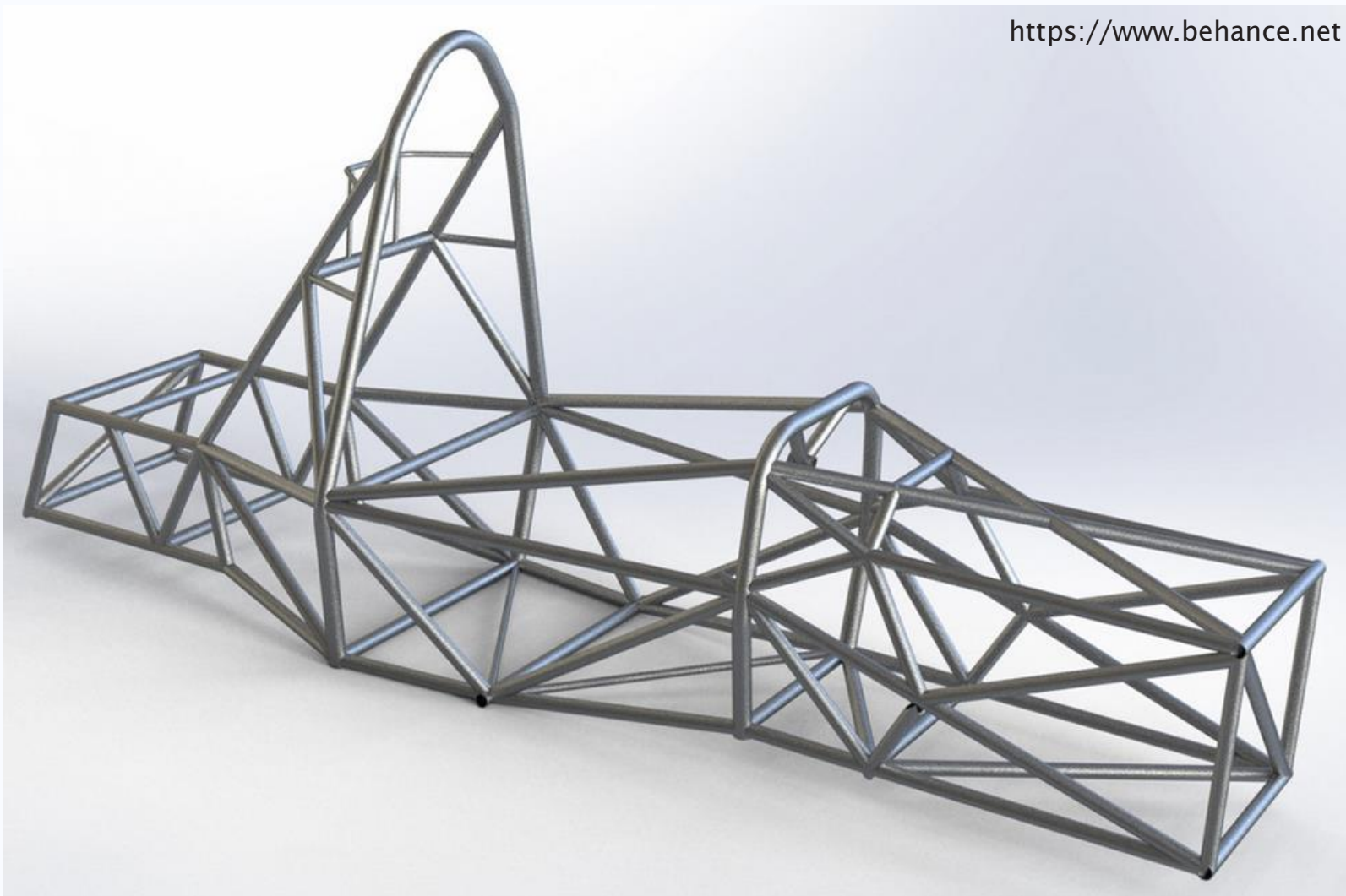
abcinfra.com

Complexity makes computation essential



Benham et al

<https://www.behance.net>



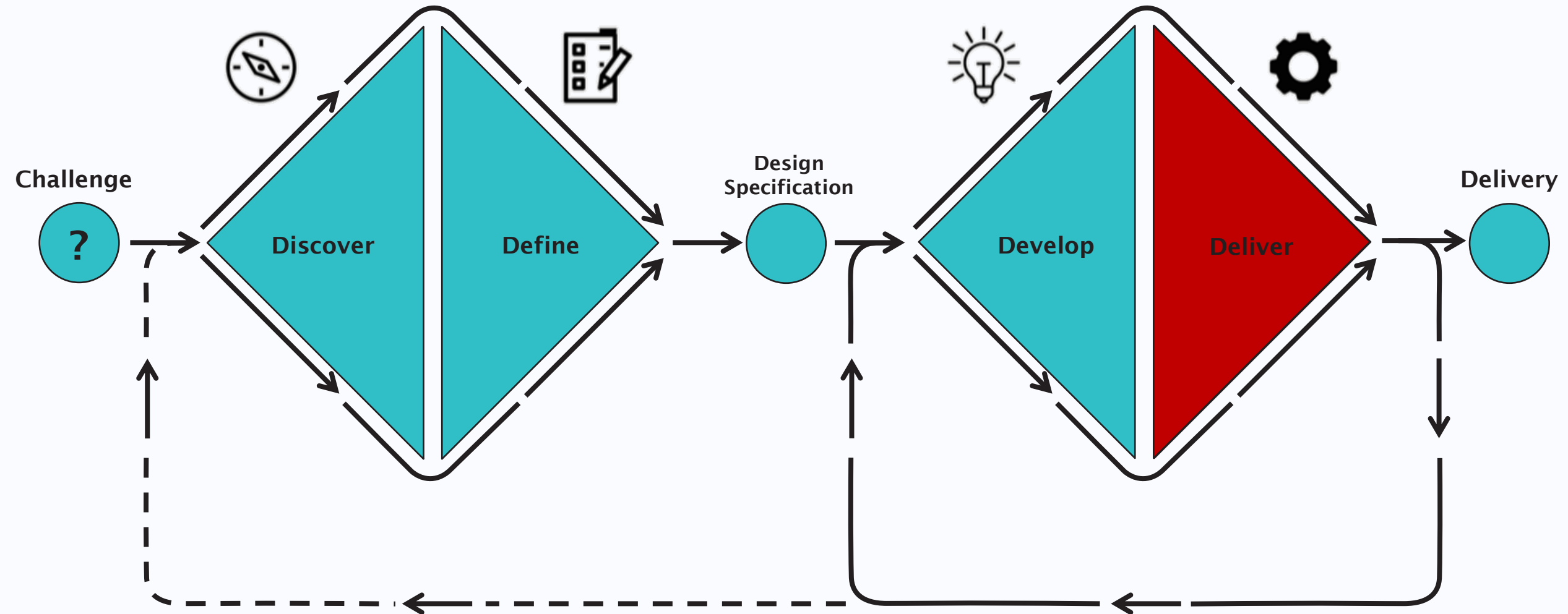
Complexity makes computation essential



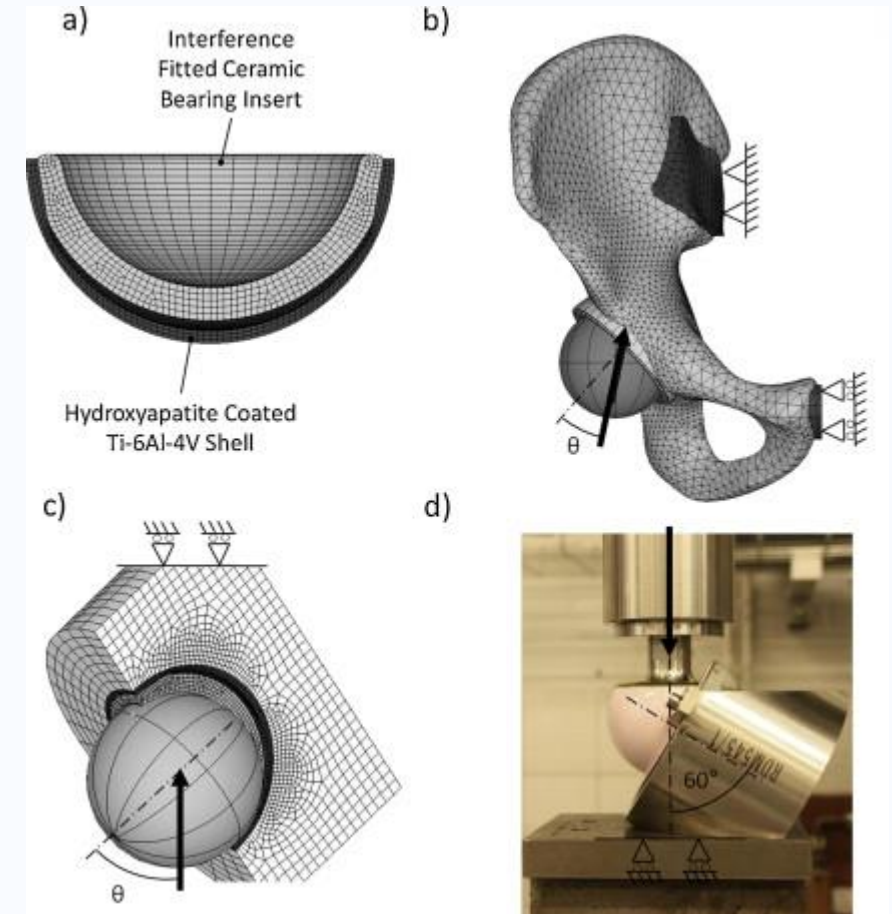
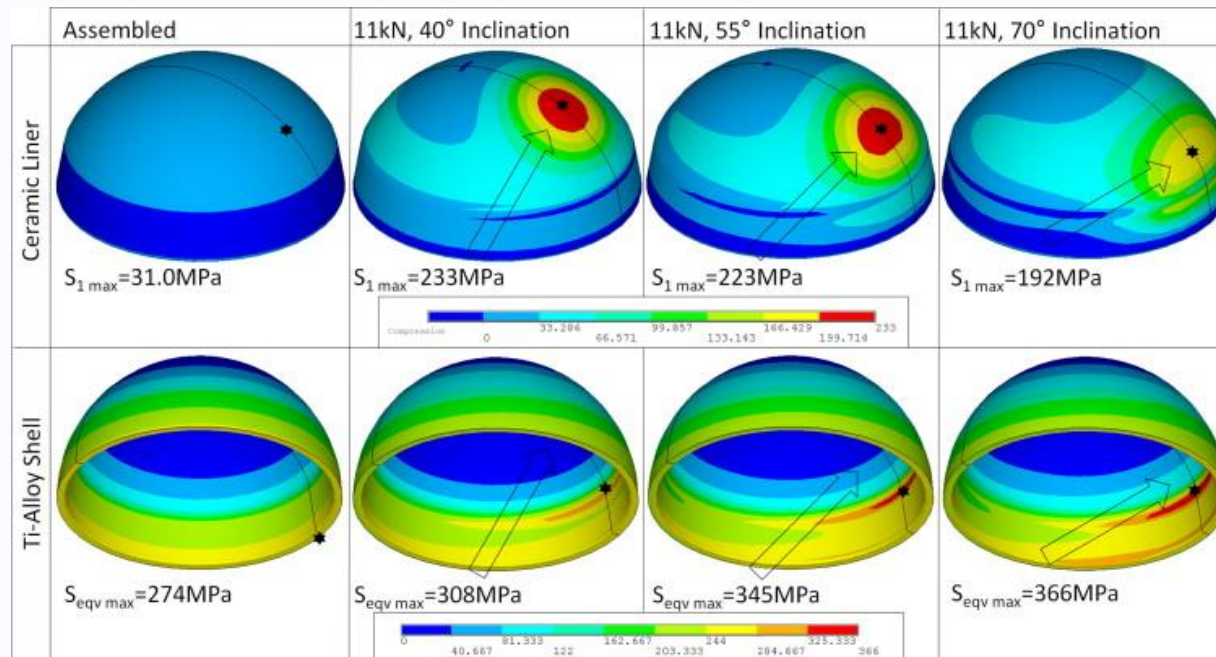
FEA in the design process:

Understanding
the Problem

Developing Concept and
Detailed Designs

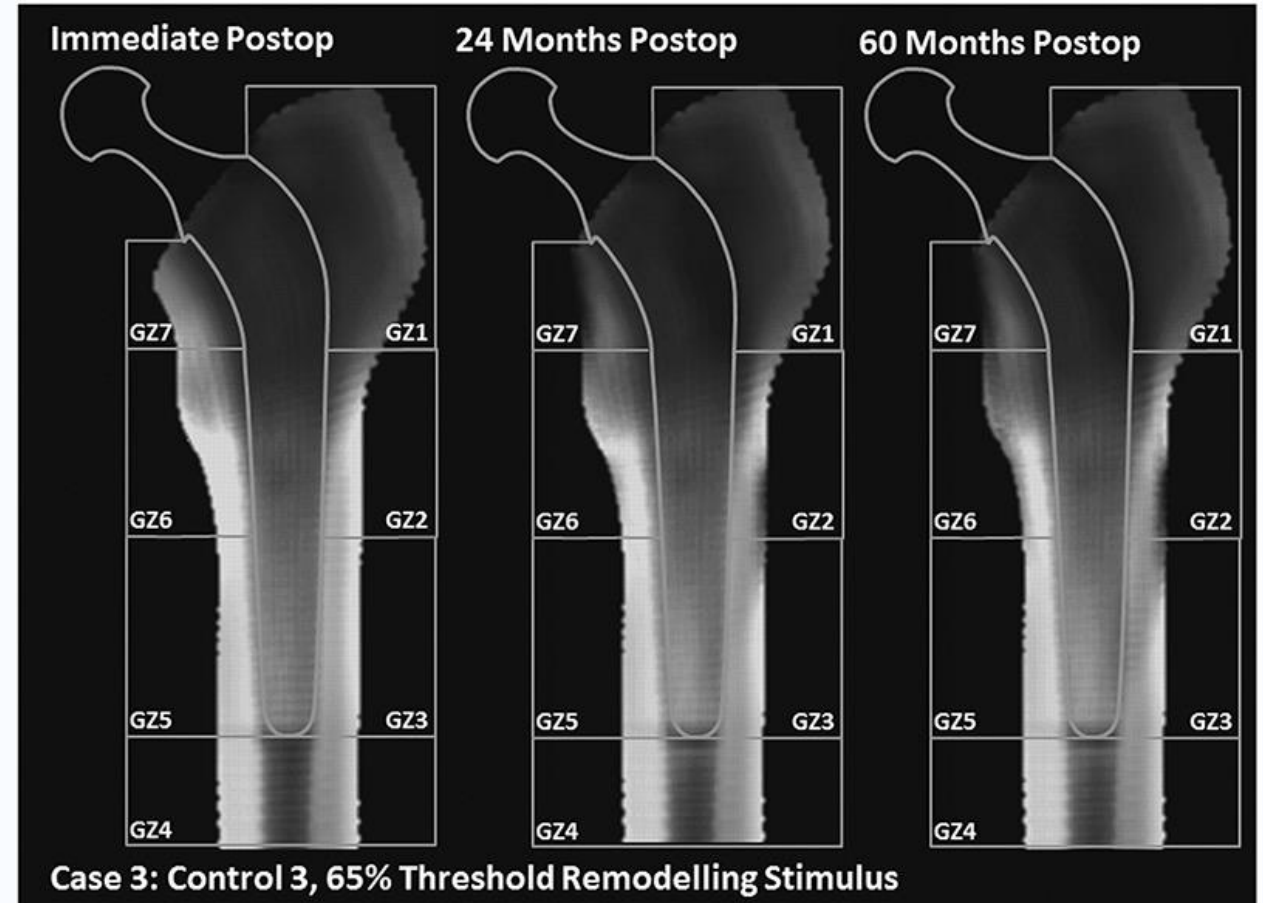
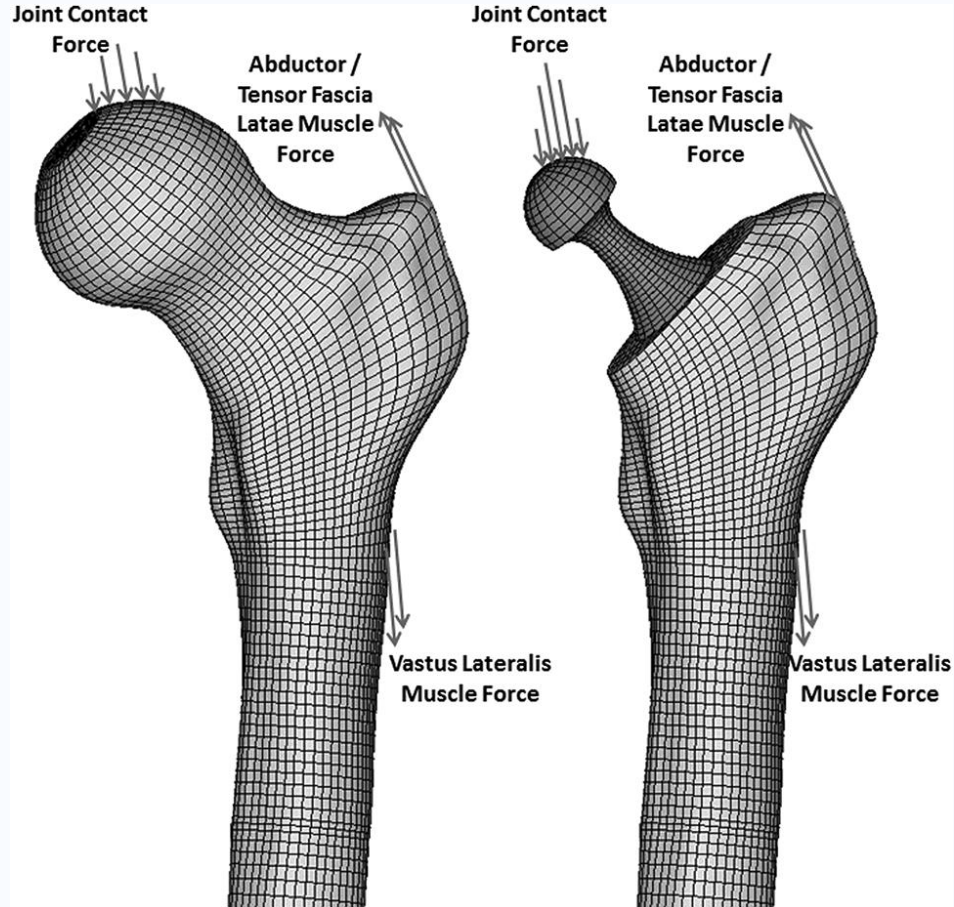


FEA in the design process:



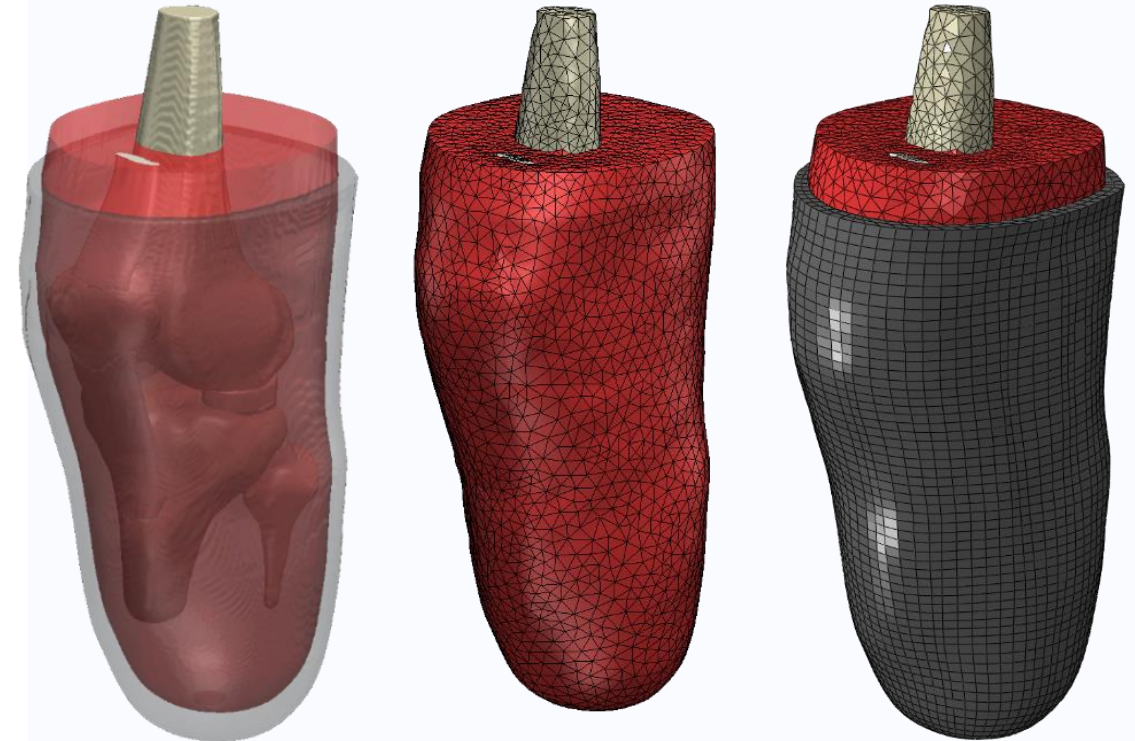
Dickinson, A. S. et al (2014). *Med Eng & Physics*. 36(1) 72-80 <https://doi.org/10.1016/j.medengphy.2013.09.009>

FEA in research?



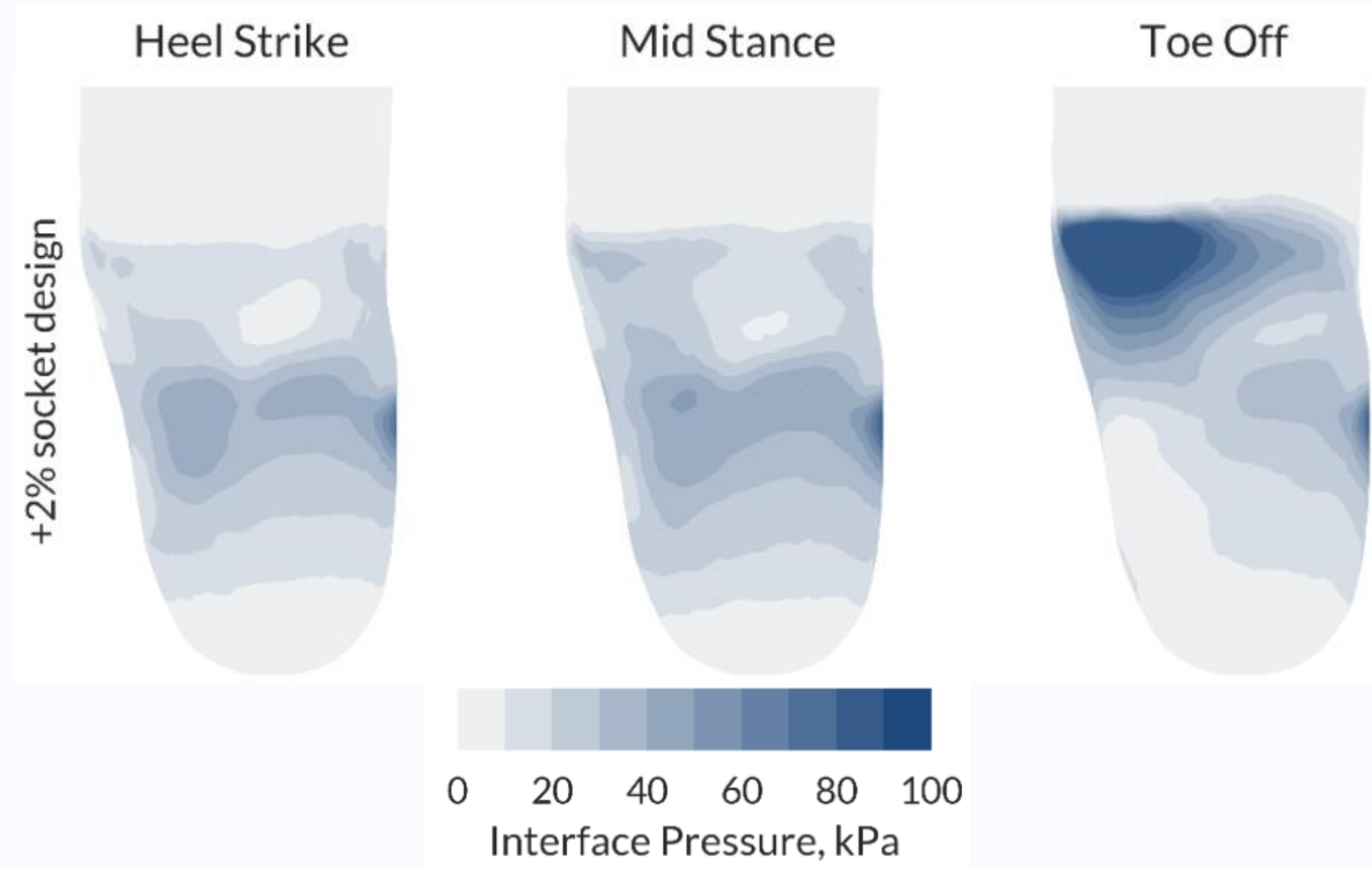
Dickinson, A. S. (2014). *J Biomech Eng.* 136(4) 041008 <https://doi.org/10.1115/1.4026256>

FEA in research?



Steer J.W. et al (2020). *Prosthet Orthot Intl.* <https://doi.org/10.1177/0309364620967781>

FEA in research?



Steer J.W. et al (2020). *Prosthet Orthot Intl.* <https://doi.org/10.1177/0309364620967781>

Warning

- Knowing a bit of FEA is dangerous
- FEA in CAD software is also dangerous
- This course will get you started
- but please develop a healthy scepticism



This Course:

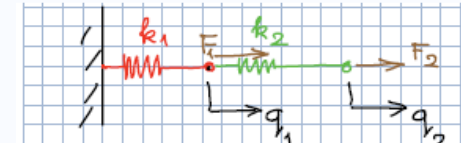
- What is behind the method?
- How is it formulated?
- How do we link these to code for practical implementation?
- First statics, then dynamics (low amplitude vibration)
- We will build you a construction kit filled with elements you can use for a variety of problems
- We will use the Principle of Minimum Total Potential Energy (PMTPE)



Lego.com

Course Overview

- Three lectures per week
 - One applications / examples / practicalities talk
 - Two theory
- One computing lab class every two weeks
- Coursework worth 50%
 - Assignment based on simulations from labs
 - Quizzes on Blackboard – formative or summative?
- Final assessment worth 50%
 - Exam, mixed long and short answer Qs



$$U = \frac{1}{2} k_1 q_1^2 + \frac{1}{2} k_2 (q_2 - q_1)^2$$

$$V = -W = -(F_1 q_1 + F_2 q_2)$$

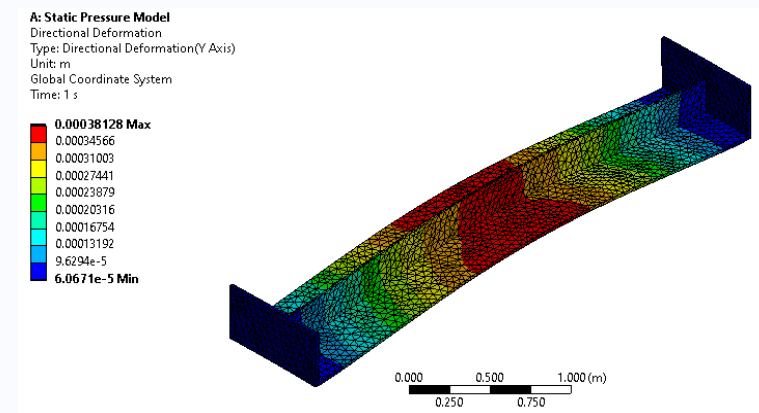
$$\Pi = U + V$$

$$= \frac{1}{2} k_1 q_1^2 + \frac{1}{2} k_2 (q_2 - q_1)^2 - (F_1 q_1 + F_2 q_2)$$

Equilibrium $\Rightarrow \delta \Pi = 0$, $\Pi = \Pi(q_1, q_2, \dots)$

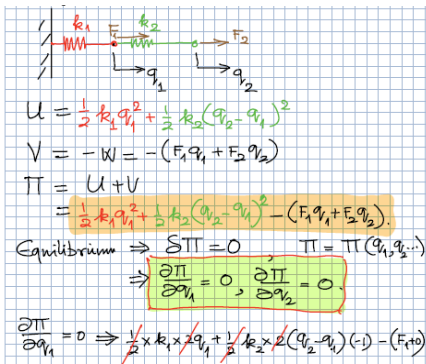
$$\Rightarrow \frac{\partial \Pi}{\partial q_1} = 0, \frac{\partial \Pi}{\partial q_2} = 0$$

$$\frac{\partial \Pi}{\partial q_1} = 0 \Rightarrow \frac{1}{2} \times k_1 \times 2 q_1 + \frac{1}{2} k_2 \times 2 (q_2 - q_1) (-1) - (F_1 + 0)$$



Course Overview

Commencing	30/09/2024	07/10/2023	14/10/2023	21/10/2023	28/10/2023	04/11/2023	11/11/2023	18/11/2023	25/11/2023	02/12/2023	09/12/2023	06/01/2024
Week	1	2	3	4	5	6	7	8	9	10	11	12
Lectures	1 to 3	4 to 6	7 to 9	10 to 12	13 to 15	16 to 18	19 to 21	22 to 24	25 to 27	28 to 30	31 to 33	34 to 36
Topic	1: PMTPE	1: PMTPE	2: Rods	Beams	3: Beams	4: Dynamics	4: Dynamics	4: Dynamics	5: Trusses	5: Trusses	6: Frames	Dimensions
Session 1	Intro	Assembling, Solution	Combining Rods & Springs	Rod Questions	Beam Assembly, Solution	Lagrange, Hamilton, 1, 2 DOF Systems	Dynamic Beams, Solving Dynamics	Trusses, CS	Frames, CS	Const. Strain Tris	MCQs, Exam Conditions	Revision
Session 2	PMTPE, [K], Springs	Elastic Rods [K]	Distributed Loads	Rod Questions, Beam SFs: HCs	Distributed Loads	Dynamic Rods, Reporting FEA	Mode Shapes, Rods, Shafts, Strings	TM, Assembly	Frames and Stress Calculations	Const. Strain Tris	4-Node Rectangles	Revision
Session 3	Lab 1 intro	Shape Functions	Lab 2 intro	Beam [K]	Lab 3 intro, Modal Demo	Beam Questions, Form. MCQs	Formative MCQs	Dynamics Ex.	Python Trusses Risk-Based FEA	Truss Ex.Stress Calc, Python	Revision	Q&A, Examples
Labs		Solid Static Models		Solid Modal and Buckling Models		Shell Models		3D Models? Help/Extra		Spare. Python/ANSYS comparison?		
Cours	Assigned 08/11/24, Submitted 29/11/24											

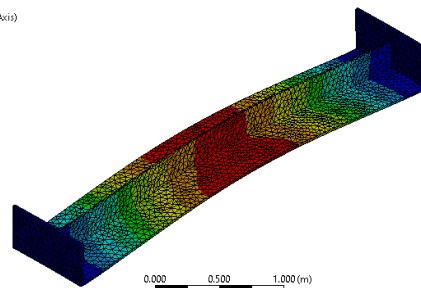


$U = \frac{1}{2}k_1q_1^2 + \frac{1}{2}k_2(q_2 - q_1)^2$
 $V = -W = -(F_1q_1 + F_2q_2)$
 $\Pi = U + V$
 $= \frac{1}{2}k_1q_1^2 + \frac{1}{2}k_2(q_2 - q_1)^2 - (F_1q_1 + F_2q_2)$
 Equilibrium $\Rightarrow \frac{\partial \Pi}{\partial q_1} = 0, \frac{\partial \Pi}{\partial q_2} = 0$
 $\frac{\partial \Pi}{\partial q_1} = 0 \Rightarrow \frac{1}{2} \times k_1 \times 2q_1 + \frac{1}{2} \times k_2 \times 2(q_2 - q_1)(-1) - (F_1)$

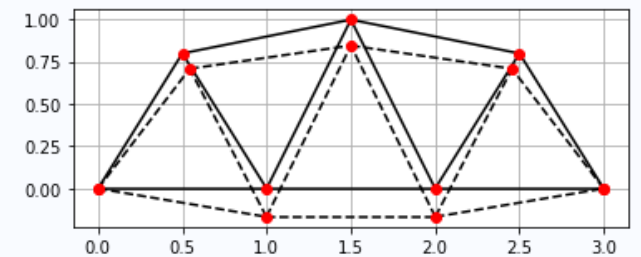
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A: Static Pressure Model
 Directional Deformation
 Type: Directional Deformation(Y Axis)
 Unit: m
 Global Coordinate System
 Time: 1 s

0.00038128 Max
 0.00034566
 0.00031003
 0.00027441
 0.00023879
 0.00020316
 0.00016754
 0.00013192
 9.6294e-5
 6.0671e-5 Min



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FEEG3001/SESM6047 FEA in Solid Mechanics

Computing Lab Arrangements

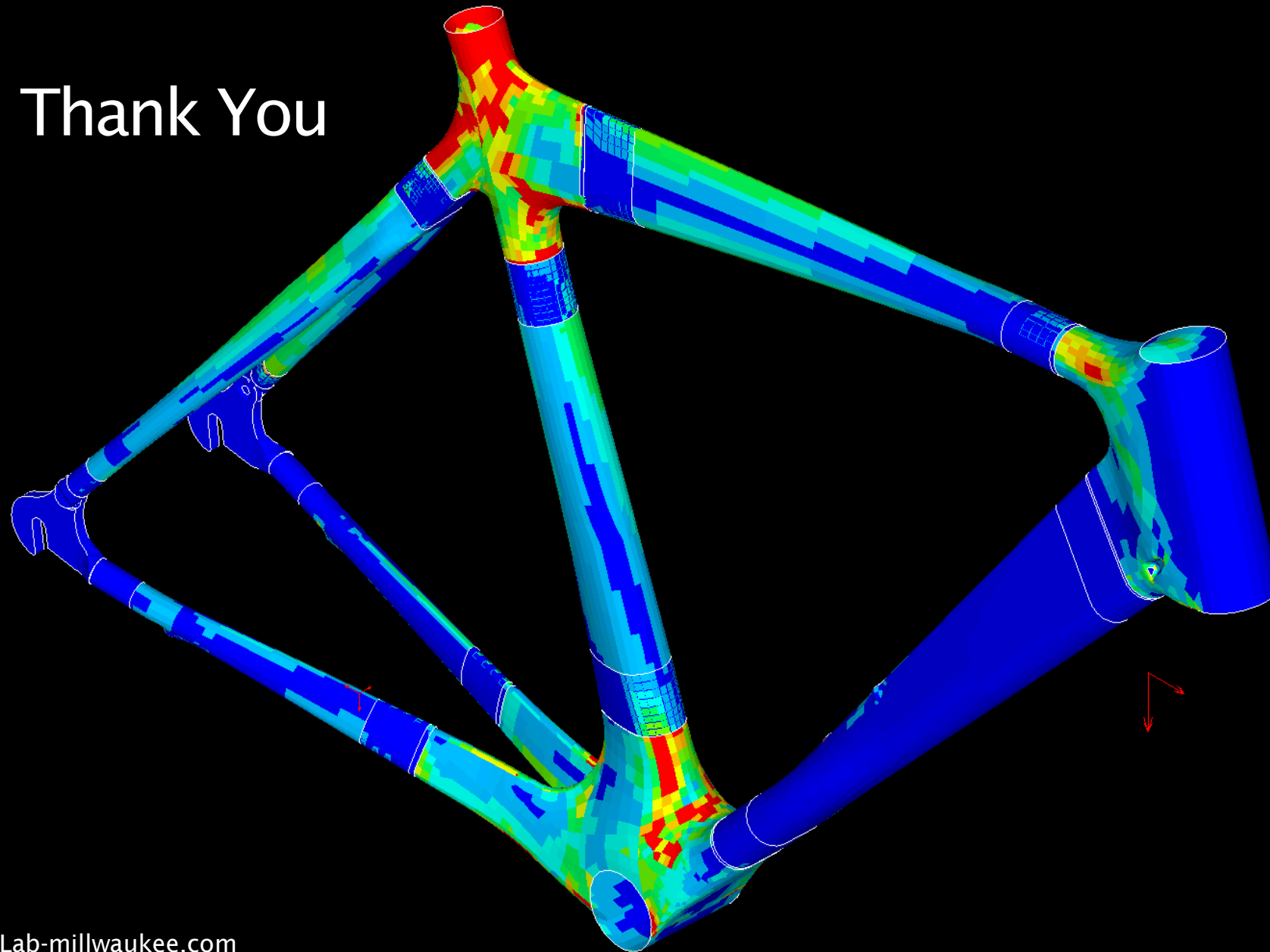
	Week	Task	Description	Application
1	2 (8-11 Oct)	ANSYS 1	Pre-processing, inc. Meshing and Element Types; Mesh Verification	Solid Ship Model 1
2	4 (22-25 Oct)	ANSYS 2	Post-Processing, Solvers and Solutions Model Validation	Solid Ship Model 2
3	6 (5-8 Nov)	ANSYS 3	Shell Model	Shell Ship Model
4	8 (19-22 Nov)	Help (labs, not assignment...)		
5	10 (3-6 Dec)	If desired, coding your own simple FE problems in Python		
	Summative Assessment:		Comparing Element Types and Appraising Results Briefing: 8 th November Submission: 29 th November (Blackboard Turnitin)	

How to do well on this course

- Try to see connections between the lectures and labs
- We don't solve the software model problems on paper, but you could
- Be meticulous!
 - with your terminology
 - your workings (maths)
 - and your data organisation (labs)
- Try not to panic!



Thank You



Lab-millwaukee.com