

LOCATION: SWANSEA

LLEOLIAD: ABERTAWE

LEVEL 5

LEFEL 5

EXAMINATION PERIOD

CYFNOD ARHOLIADAU

MODULE CODE:
M5x02064: CAE & Stress analysis

TIME: 2 HOURS

ANSWER THREE OUT OF FOUR QUESTIONS

Equipment or materials required – None

Adnoddau neu ddefnyddiau sydd eu hangen – Dim

A formula sheet is provided for reference.

Calculators are permitted.

Assume 'g' = 9.81 m/s².

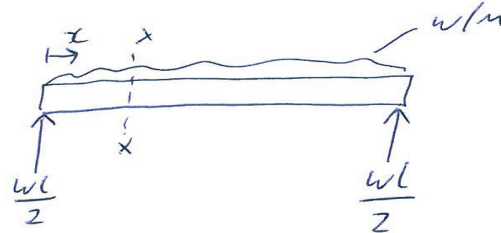
Continuation Sheet

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Question No	Question	Marks
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Q
1

1



$$M_{xx} = \frac{wlx}{2} - wx \cdot \frac{x}{2}$$

$$\therefore EI \frac{d^2 y}{dx^2} = \frac{wlx}{2} - \frac{wx^2}{2}$$

$$\therefore EI \frac{dy}{dx} = \frac{wlx^2}{4} - \frac{wx^3}{6} + A \quad * *$$

$$\therefore EI y = \frac{wlx^3}{12} - \frac{wx^4}{24} + Ax + B \quad *$$

WHEN $x=0, y=0 \therefore B=0$

WHEN $x=l, y=0 \therefore$

FROM *
 $0 = \frac{wl^3}{12} - \frac{wl^4}{24} + Al \therefore Al = \frac{wl^4}{24} \therefore A = \frac{wl^3}{24}$

FROM *
 $y = \frac{1}{EI} \left[\frac{wlx^3}{12} - \frac{wx^4}{24} - \frac{wl^3x}{24} \right]$

y_{max} WHEN $x = \frac{l}{2}$

$$\therefore y_{max} = \frac{1}{EI} \left[\frac{wl}{12} \left(\frac{l^3}{8} \right) - \frac{w}{24} \left(\frac{l^4}{16} \right) - \frac{wl^3}{24} \left(\frac{l}{2} \right) \right]$$

$$= \frac{1}{EI} \left[\frac{wl^4}{96} - \frac{wl^4}{384} - \frac{wl^4}{48} \right]$$

$$= -\frac{5wl^4}{384EI}$$

[8 MARKS]

Continuation Sheet

Module/Unit: CAE and Stress Analysis

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Question No

Question

Marks

(ii) FROM **

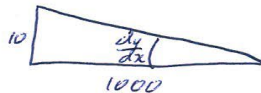
(2)

$$\frac{dy}{dx} = \frac{1}{EI} \left[\frac{wLx^2}{4} - \frac{wx^3}{6} - \frac{wL^3}{24} \right]$$

WHEN $x = 0$:

$$\left(\frac{dy}{dx} \right)_{\max} = \frac{1}{EI} \left(-\frac{wL^3}{24} \right) = -\frac{wL^3}{24EI} \quad [2 \text{ MARKS}]$$

(b) i) FIND $\left(\frac{dy}{dx} \right)_{\max}$:



$$\left(\frac{dy}{dx} \right)_{\max} = \frac{10}{1000} = \underline{0.01}$$

• FIND udl : $w = \frac{5000 \times 9.81}{5} = \underline{9810 \text{ N/m}}$

• $\left(\frac{dy}{dx} \right)_{\max} = -\frac{wL^3}{24EI}$

$$\therefore EI = \frac{wL^3}{24 \left(\frac{dy}{dx} \right)_{\max}} = \frac{9810 \times 5^3}{24 \times 0.01} = \underline{5.1 \text{ MNm}^3}$$

[5 MARKS]

(ii) IF $E = 210 \text{ GPa}$

$$I = \frac{5.1 \times 10^6}{210 \times 10^9}$$

$$= 2.4 \times 10^{-5} \text{ m}^4$$

$$= 2.4 \times 10^{-5} \times (100^4)$$

$$= \underline{2400 \text{ cm}^4}$$

FROM TABLE

BEAM = 254×101.6

MASS

PER

MASS = 22 kg/m

LENGTH =

$$\therefore \text{TOTAL MASS} = 22 \times 6.5 = \underline{143 \text{ kg}}$$

[5 MARKS]

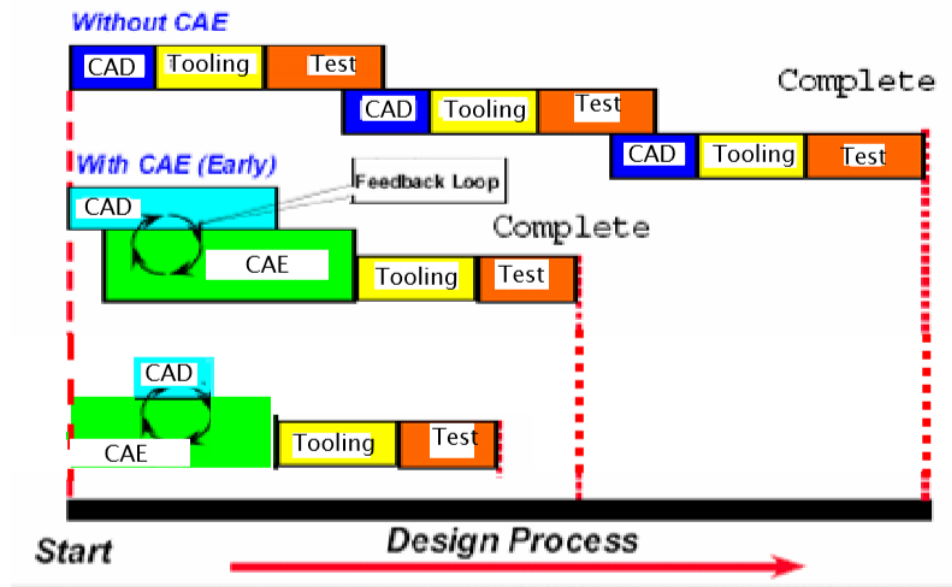
Q2

Discussion could include, but is not limited to, items such as the following:

- a) When carrying out some FEA the basic steps can be considered using the following acronym,
- **Split.** The first step that needs to be undertaken is to split the geometry down into finite elements (i.e. to create elements and nodes) so that mathematical assumptions can be made from one element to the next. As long as the distances between the nodes is small enough (i.e. the distance over which the assumption is being made), are small enough, then a close approximation can be obtained. At this stage then the element type (1D, 2D or 3D), order (1st or 2nd order) and density (size) needs to be considered.
 - **Interpret.** In order to be able to obtain a reasonable result in a reasonable amount of time the geometry needs to be approximated. Small details that add complexity to the analysis, but would not have an adverse effect on the analysis being undertaken in terms of run-time should be simplified or ignored. That is to say that the part needs to be 'idealised'
 - **Material.** Once the part has been simplified and meshed, then material information needs to be added. This may determine if a linear or a non-linear solver may be used (depending on if the material is linear or non-linear). Careful consideration needs to be given as to if the material actually used is the same as the material in the FE model. This may be a cause for poor correlation.
 - **Physical Property.** If 1D or 2D elements are used, then physical property information needs to be added to the model. That is to say, what is the section of any 1D elements (for example second moment of area, polar second moment of area, area and orientation)? If 2D elements are used then thickness of the elements needs to be considered. Again, this may be a cause for poor correlation to testing, for example, what is the manufacturing tolerance on a 2mm thick sheet of material? If 3D elements are being used, then this information is defined by the geometry of the elements.
 - **Loading.** Once the above information has been added to the FE model the solver will be able to calculate the stiffness matrix for the structure. From this, a set of simultaneous equations can be obtained. In order to solve these, then the loading and boundary conditions needs to be known. That is to say, how is the part loaded, in what direction, and how is it constrained? This can also be a source of poor correlation (probably the main cause for poor correlation). For example over what area is the force being applied (if the part is being loaded at a single node, then in theory the stress in this location would be infinite ($\text{stress} = \text{force} / \text{area}$)), in what direction? It is very easy to say a face is fixed in 6 degrees of freedom (i.e. it can not move at all), but this suggests that the part that the component is attached to is of infinite stiffness which will not be the case.

- **Evaluate.** Once the model has been solved the analyst needs to evaluate their results. I.e. have any of the previous steps influenced the results? Does any of the information in the previous steps need to be updated? Using a computer to carryout FEA can only give approximate results. How appropriate is it to quote the results to many significant figures given the approximations that have been made? The results are computer generated, and like any computer generated information ‘garbage in = garbage out’!

b)



As can be seen in the above diagram, by moving FEA (CAE) so that it appears earlier in the design process, the amount of computer aided design (CAD) that is needed is significantly reduced to the point where conceptual work can be done with no CAD being necessary. Models can simply be produced and verified in an FE environment. If CAD is used, the designs produced are likely to be more efficient, delivered quicker and for less cost as major loadpaths etc would have been introduced to the design due to the early use of FEA, which is used to inform the design rather than relying on the experience and judgement of the CAD engineer.

Q3

Discussion could include, but is not limited to, items such as the following:

- a) Design problems are usually more vaguely defined than analysis problems. Analysis problems have only one answer, whereas the solution to a design problem is a system having specified properties, i.e. the ability to meet a specific need; there may be many possible devices to meet the need. Solving a design problem is usually an iterative process; as the solution to a design problem evolves, there may be continual refinement of the design. It may be the case that while implementing the solution to a design problem, the solution developed is found to be unsafe, too expensive, or will not work. Hence, design activity is cyclic or iterative in nature, whereas analysis problem solving is primarily sequential.
- b) 3 marks will be awarded to each of the following. One mark for the step definition and two for the discussion;
 1. **Define the problem;** This should start with a clear unambiguous definition of the problem. Once this has been done the problem definition should include;
 - i. Establish customer needs – what problem is the product solving?
 - ii. Develop problem statement – this should be broad enough not to preclude possible solutions but will specifically address the need identified.
 - iii. Criteria for success – this will involve input from many roles including managers, scientists, marketing and manufacturing.
 2. **Gather relevant information;** At this stage items such as the following could be considered;
 - i. Is the problem real and its statement accurate?
 - ii. Is there really a need for a new solution or has the problem already been solved?
 - iii. What are the existing solutions to the problem?
 - iv. What is wrong with the way the problem is currently being solved?
 - v. What is right with the way the problem is currently being solved?
 - vi. What companies manufacture the existing solution to the problem?
 - vii. What are the economic factors governing the solution?
 - viii. How much will customers pay for a solution to the problem?
 - ix. What other factors are important to the problem solution (such as safety, aesthetics & environmental issues)?
 3. **Generate multiple solutions;** At this stage items such as the following should be considered and used;
 - i. creative phase involving brainstorming,
 - ii. ‘synthesis’ of new ideas to solve design problem.
 - iii. Design teams should be free to take risks
 - iv. People from different disciplines should be involved

4. **Analyse and select solution;** At this stage the following analysis may be carried out;

- i. Functional analysis
- ii. Industrial design / ergonomics
- iii. Mechanical / strength analysis
- iv. Electrical / electromagnetic
- v. Manufacturability / testability
- vi. Product safety & reliability
- vii. Economic and market analysis
- viii. Regulations & standards

5. **Test and implement solution ;** At this stage items such as the following should be considered;

- i. Prototyping and test under real conditions. These can be used to correlate the analytical work carried out in step 4 to gain confidence in the work carried out at this stage. In addition, contemporary manufacturing techniques such as 3D printing.
- ii. Documentation. This may be particularly relevant if legislative testing is needed or if an audit is carried out on the final product to show what testing was carried out.
- iii. Apply for Patents to protect the design.

Q4

- (a) 3D sketch showing half cylinder of length L, including internal pressure p, wall thickness t, diameter d, and hoop stress acting on both diametrically opposing walls. Also, possibly includes 'projected area'.

Total *force* on half cylinder due to pressure = p x projected area = pdL

Resisting *force* owing to hoop stress in walls = $2\sigma_H \times Lt$ (i.e. stress x area)

Therefore, $2\sigma_H \times Lt = pdL$

Thus circumferential stress is defined as; $\sigma_H = \frac{pd}{2t}$

(6 marks)

- (b) Using appropriate equation from formula sheet, where all data given in SI units;

Change in diameter, $\Delta d = 1.245 \text{ mm}$

Change in length, $\Delta L = 0.469 \text{ mm}$

(4 marks)

- (c) (i) First determine internal pressure from change in volume equation;
 $p = 5003.61 \text{ N/m}^2$

Therefore, $\sigma_H = 0.782 \text{ MN/m}^2$ and, $\sigma_L = 0.391 \text{ MN/m}^2$

(6 marks)

- (d) Hoop stress will become 1.043 MN/m^2 and longitudinal stress 0.978 MN/m^2

(4 marks)