COMPUTER-AIDED ENGINEERING
Ph.D. QUALIFIER EXAM – FALL 2017

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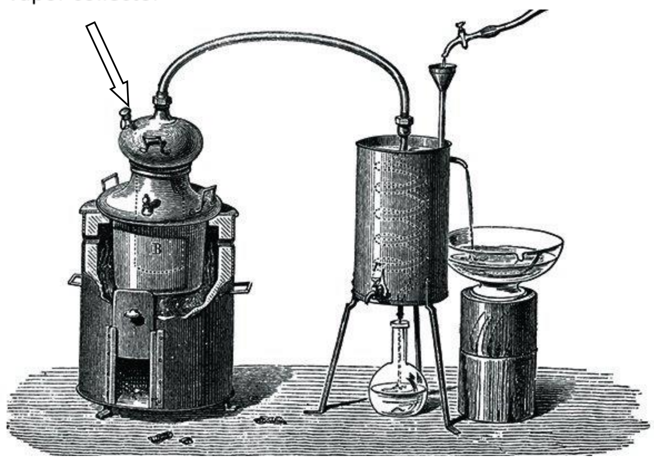
- All questions in this exam have a common theme: ***Natural Disasters***
- Answer all questions.
- Make suitable assumptions when data is not available or when you do not follow a question. State your assumptions clearly and justify.
- Show all steps and calculations.
- ***During ORALS, you will be given an opportunity to tell us how CAE fits into your doctoral research. Please come prepared to make this opening statement.***

GOOD LUCK!

Question 1 - Geometric Modeling

Suppose that you have joined the International Engineering Coalition, an organization for disaster relief. You are given a task to design a vapor collector for the water distilling system, shown in the sketch.



You want to use Bézier surface patches to model a portion of the vapor collector.

1.1) You are given the following 3 x 3 array of control points to design Patch 1 of the surface:

Patch 1:

(1 17 2)	(3 17 6)	(6 17 5)
(1 14 1)	(3 14 6)	(6 14 5)
(1 11 2)	(3 11 3)	(6 11 4)

Identify the order of a Bezier patch with the above control points, and write down the equation of the Bezier surface patch in a matrix form.

1.2) For the design of Patch 2, you are provided some of the control points as follows.

Patch 2:

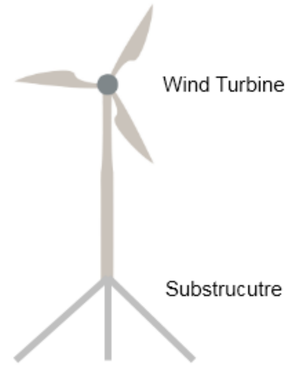
(1 23 3)	(3 23 8)	(6 23 7)
$\mathbf{P}_3$	$\mathbf{P}_4$	$\mathbf{P}_5$
$\mathbf{P}_1$	$\mathbf{P}_2$	(6 17 5)

To ensure the C^0 and C^1 continuity between the two patches, what are the coordinate values of $\mathbf{P}_1$, $\mathbf{P}_2$, $\mathbf{P}_3$, $\mathbf{P}_4$, and $\mathbf{P}_5$? Explain how you decide the values in detail and show calculations.

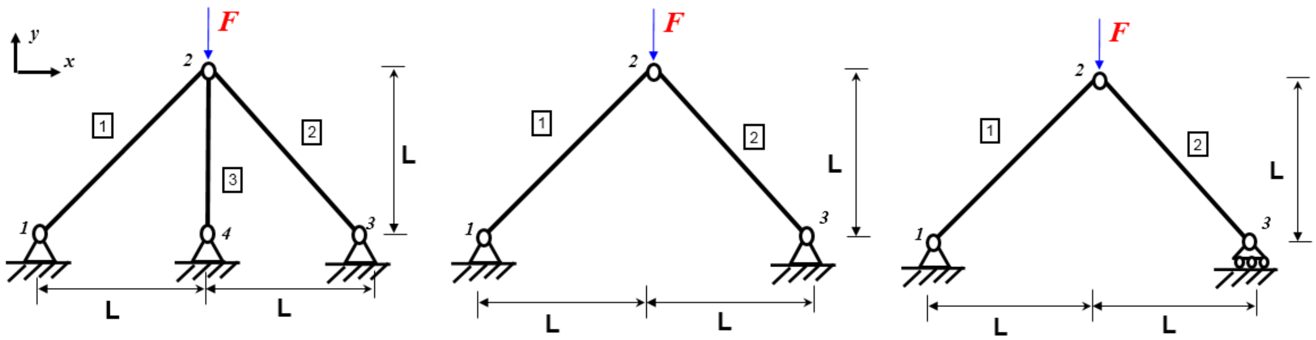
1.3) Calculate the unit normal vector of Patch 1 at point (1,17,2).

1.4) Out of the above 18 control points, which ones will be on the two surfaces themselves (i.e. the surfaces precisely pass through the points)?

2) Finite-Element Analysis



Hurricane Irma rolled into Georgia on Sep., 2017 and a substructure of an offshore wind turbine was partially broken. You are asked to analyze the substructure using finite element formulation. Initially, the substructure is designed to support the given load of F = 100 kN as shown in Figure (a). In the "simplified" model, the substructure is assumed to be made of three bar elements and the area of member 3 is A=100 mm^2. Also, the members 1 and 2 have an area of cross-section of $A/\sqrt{2}$. Assume that the Young's modulus of the material is E = 200 kN/mm^2 and the height and span of the substructure is L = 10 m as shown in Figure (a).



(a) Substructure of a wind turbine (b) Question 2 (Damaged Structure) (C) Question 3

2.1 Determine the deflection at node 2 of the undamaged substructure Figure (a).

- Use minimum number of finite elements.
- State all of your assumptions clearly.
- Show the boundary conditions and loading conditions.
- Write down the element and assembly stiffness matrices
- Show all steps.

2.2 Now assume that member 3 is totally broken and detached from the original substructure due to the hurricane as shown in Figure (b). Find the load that would generate the same deflection at node 2 as that from Question 1.

2.3 Assume that additional damage has occurred on the foundation at node 3. Now, node 3 can freely move in the *x*-direction and is restricted to move in the *y*-direction as shown in Figure(c). Without solving the problem, discuss the effect of this change in your solution process. Also, discuss whether you can determine the deflection at node 2.

Element Stiffness Matrix

$$[K]=\frac{EA}{L}\begin{bmatrix} l^2 & lm & -l^2 & -lm \\ lm & m^2 & -lm & -m^2 \\ -l^2 & -lm & l^2 & lm \\ -lm & -m^2 & lm & m^2 \end{bmatrix}$$

where E, A, and L are the Modulus of Elasticity, Area of cross-section, and Length of the element respectively; l and m are direction cosines.

Question 3: Numerical Methods

Multiple worldwide massive solar storms have hit the earth, a so-called second Carrington event more massive and extensive than the first. A worldwide disaster has occurred. Internet is down. Most communications are down. Petroleum production has stopped. You have a sample of vehicles that have been converted to biodiesel, and they have been driven around to estimate their fuel efficiency. You are given the vehicle's mass. You also know that having tires properly inflated improves efficiency. A tire gauge is available so that the ratio of the tire pressure to proper inflation pressure can be calculated for each vehicle.

E= efficiency, M=Mass and T=Tire Inflation Pressure Ratio

Your task is to come up with a numerical approach to predict the efficiency, given the follow data:

> E= 10 mpg, M=2000 kg, T=1.1,
> E=9 mpg, M= 2200 kg, T=0.9
> E=13 mpg, M= 1600 kg, T=1.0,
> E=7 mpg, M= 1600 kg, T=0.85,

3.1) From the perspective of numerical methods, what type of problem is this?

3.2) Describe the equations or algorithm you would use to predict E, given M and T. Note: it is not necessary to perform the actual computations; to save some time, you can simply describe the computations symbolically. Describing the algorithm using Matlab code would also be an acceptable answer. If you made any assumptions in your approach, clearly discuss them.

3.3) Do you see any potential numerical issues in the given data? If so, explain the issues and discuss what you would do to address those issues.