GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Semester 2003

Computer-Aided Engineering
EXAM AREA

Assigned Number (DO NOT SIGN YOUR NAME)

* Please sign your **name** on the back of this page —

Answer 3 of the 4 questions.

COMPUTER-AIDED ENGINEERING

Ph.D. QUALIFIER EXAM – Fall 2003

GEORGE W. WOODRUFF SCHOOL OF MECHANICAL ENG.
GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GA 30332-0405

Bras, Fulton, Rosen (Chair), and Sitaraman

- All questions in this exam have a common theme: ***Airplanes***
- Answer **3 out of the 4** questions. Indicate which questions you want graded.
- 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.***

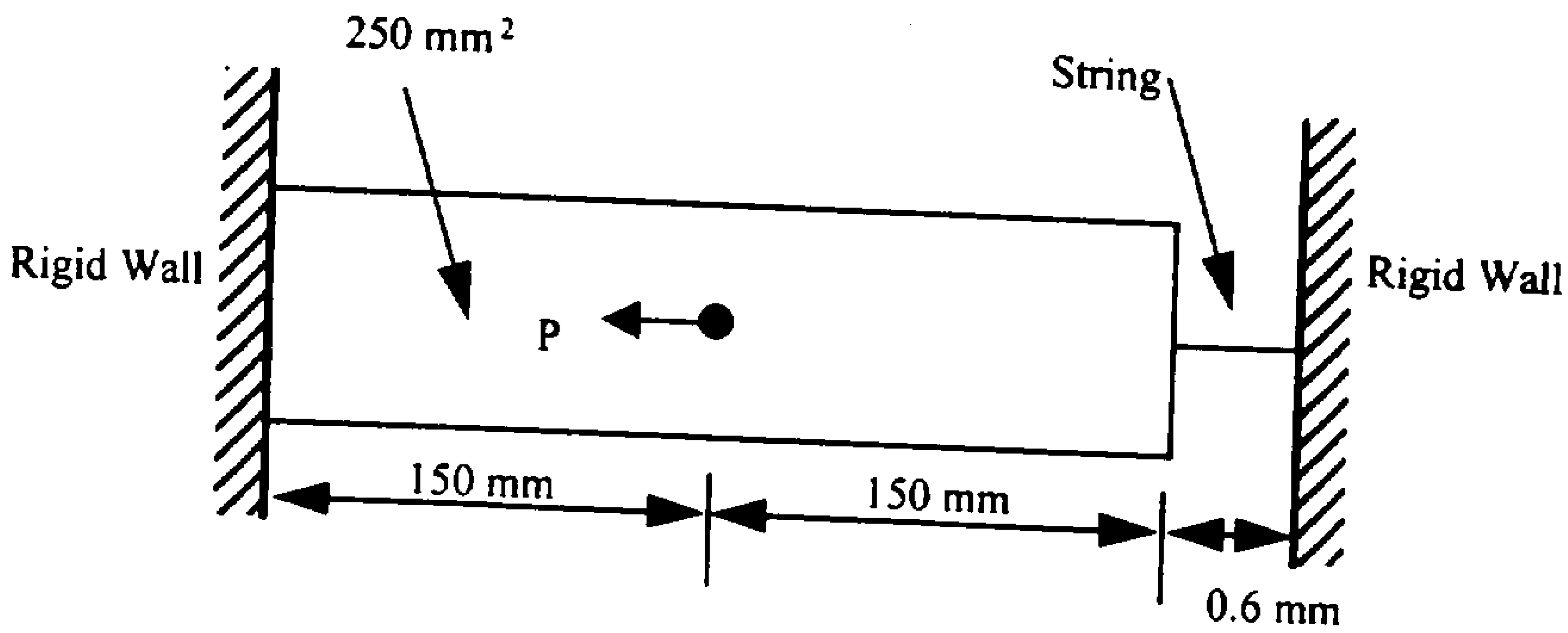
GOOD LUCK!

Answer 3 of the 4 questions.

Question 1
Finite Element Modeling

In an aircraft structure, a rod having a cross-section area of 250 mm^2 and a length of 300 mm is attached to a rigid wall on the left side and is attached to a string on the right side. The string has a stiffness of 10,000 N/mm in tension and ***has no stiffness against compression.*** A load P=35,000 N is applied as shown in the figure below. Assume E= 15,000 N/mm^2 for the rod.

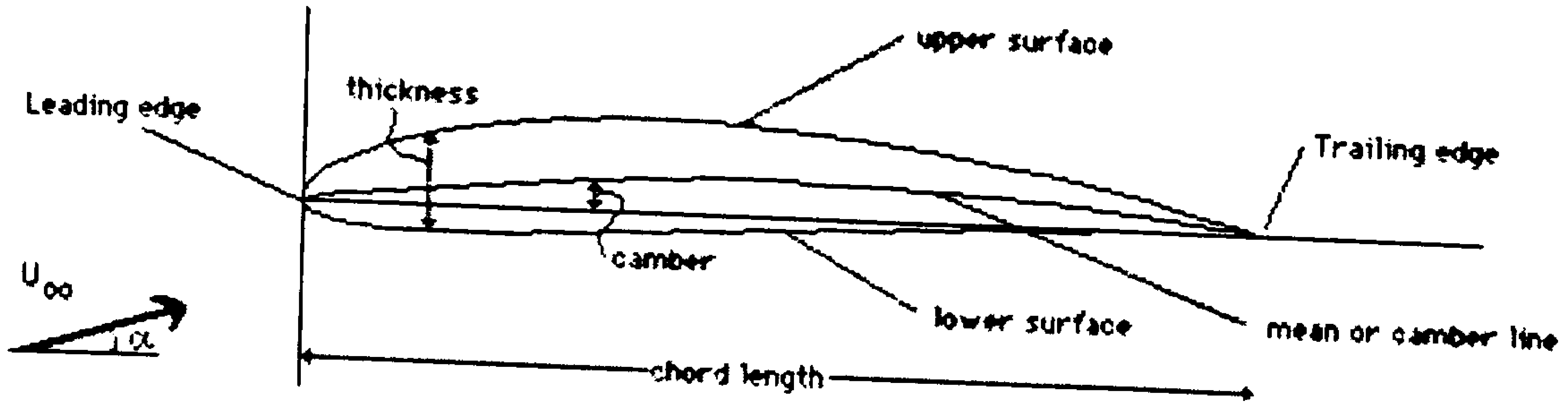
- Using finite-element formulation, determine the displacement at the point where the force is applied and the reaction forces at the walls.
- Assume that the force vector is now rotated by 180° and is applied in the opposite direction (facing the string side). Determine the displacement at the point where the force is applied.



Answer **3** of the 4 questions.

Question 2

Geometric Modeling + Numerical Methods



Consider the airfoil shown above. In this question, we will investigate various properties of airfoils such as this. For the class of airfoils known as 4-digit NACA airfoils, the upper surface and lower surface are described by fourth-degree polynomials:

$$y(x) = a + bx + cx^2 + dx^3 + ex^4 \qquad (1)$$

Two important quantities that are closely related to airfoil shape are the lift and drag forces that occur when air flows over the airfoil. Lift is proportional to the lift coefficient, C_L, while drag is proportional to C_L^2. To a first approximation, the lift coefficient is a cubic function of the ratio of airfoil thickness to chord length (see figure).

Given these relationships, answer the following questions:

a. Mass properties are important quantities that can be computed from CAD models. Describe how you would compute the area and moments of inertia of airfoil shapes (just 2-D).

b. Compute the area of a 4-digit NACA airfoil where the upper and lower surfaces are described by Eqn. 1.

It is often the case that a compromise needs to be achieved between lift and drag characteristics of an airfoil. To investigate this trade-off, it is necessary to understand how lift and drag change as a function of airfoil shape and parameters, such as thickness, chord length, leading and trailing edge radii, camber line shape, etc.

c. Graph the relationship between lift and drag. I am looking for you to show a qualitative understanding of this relationship, not to calculate any numbers.

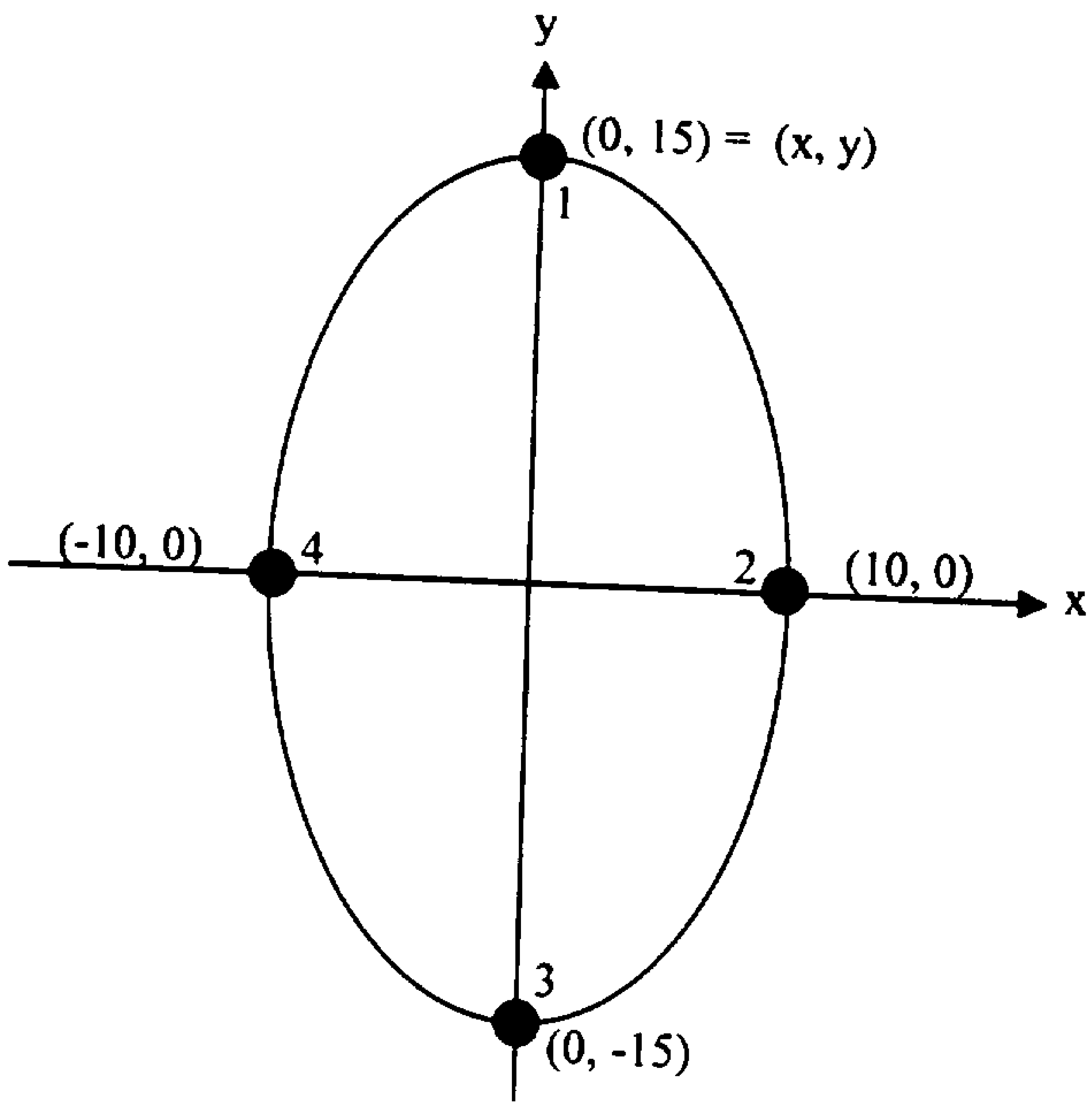
For our purposes, assume that lift is a function of four quantities: thickness to chord length ratio (*t/c*), leading edge radius, trailing edge radius, and camber line shape. Assume that drag is a function of the same quantities.

d. Assume that an airplane designer has specific targets for lift and drag forces as a function of airplane speed. In order to find a design that meets these targets, the designer must explore the quantitative relationships among lift and drag and must solve the equations to determine values (or ranges of values) for the four airfoil quantities. List some numerical methods (at least 2) that could be used to solve these equations to determine values for *t/c*, the edge radii, and camber line shape. For each numerical method listed, explain how it would be used to solve for the quantities and the advantages and limitations of the method.

Answer **3 of the 4** questions.

Question 3

Geometric Modeling



The oval cross-section of a passenger aircraft fuselage is to be defined by either cubic polynomial splines or cubic Bezier splines. The shape is symmetric about both the x and y axes and must go through the indicated control points (1, 2, 3, 4). It must also have at least C1 continuity at all control points. Develop the geometric model which satisfies these conditions based on:

a) cubic polynomial spline segments and

b) cubic Bezier spline segments

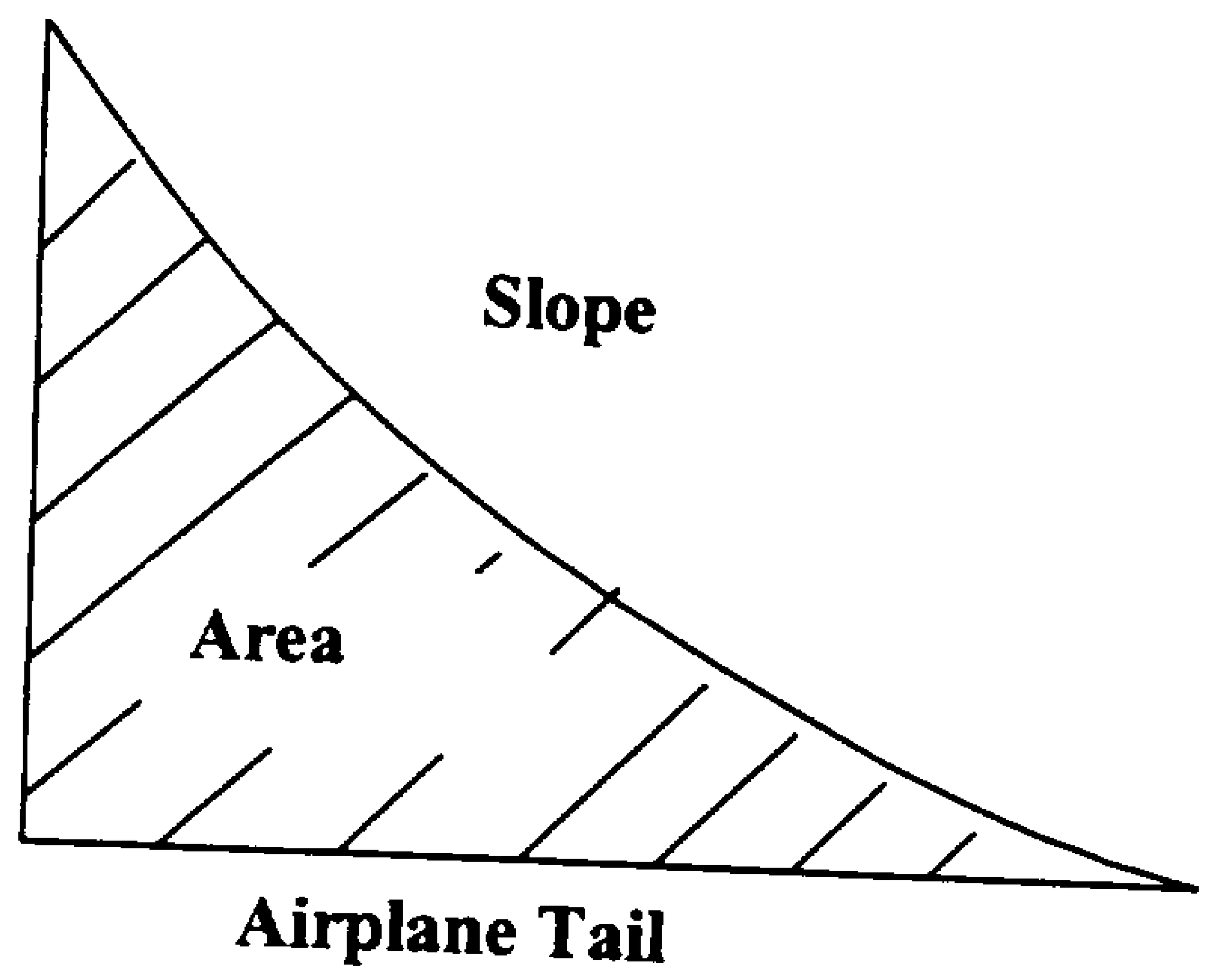
c) comment on the assets and liabilities of each approach relative to designing for interior fuselage space

You may add any points if needed to create these segments and take advantage of symmetry. The coordinates given above are based on feet.

Answer 3 of the 4 questions.

Question 4
Numerical Methods

In the figure below you see the tail of an airplane. The shape of the tail's slope is defined by the function $f(x,y) = -2x^3 + 12x^2 - 20x + 10$ and x ranges from 0 to 1.



a) Find the area (y) of the airplane's tail using the classical fourth order Runga-Kutta method for numerical integration. Assume the initial condition y = 1 at x = 0 and use a step size of 0.5.

b) Is the solution found under a) equal to the exact solution? Why or why not?

c) How many 2nd order Runga-Kutta methods are there?

d) Again find the area, but now using the Simpson rule for the integration. Compare and discuss your result with the result from a).

e) Explain how the Newton-Cotes family of quadrature rules for numerical integration of a function f(x) work. Name and explain two well-known methods that are part of this family.

f) What are some other methods to integrate a function f(x,y)?