M.E. Ph.D. Qualifier Exam
Spring Semester 2002

GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Semester 2002

Computer-Aided Engineering
EXAM AREA

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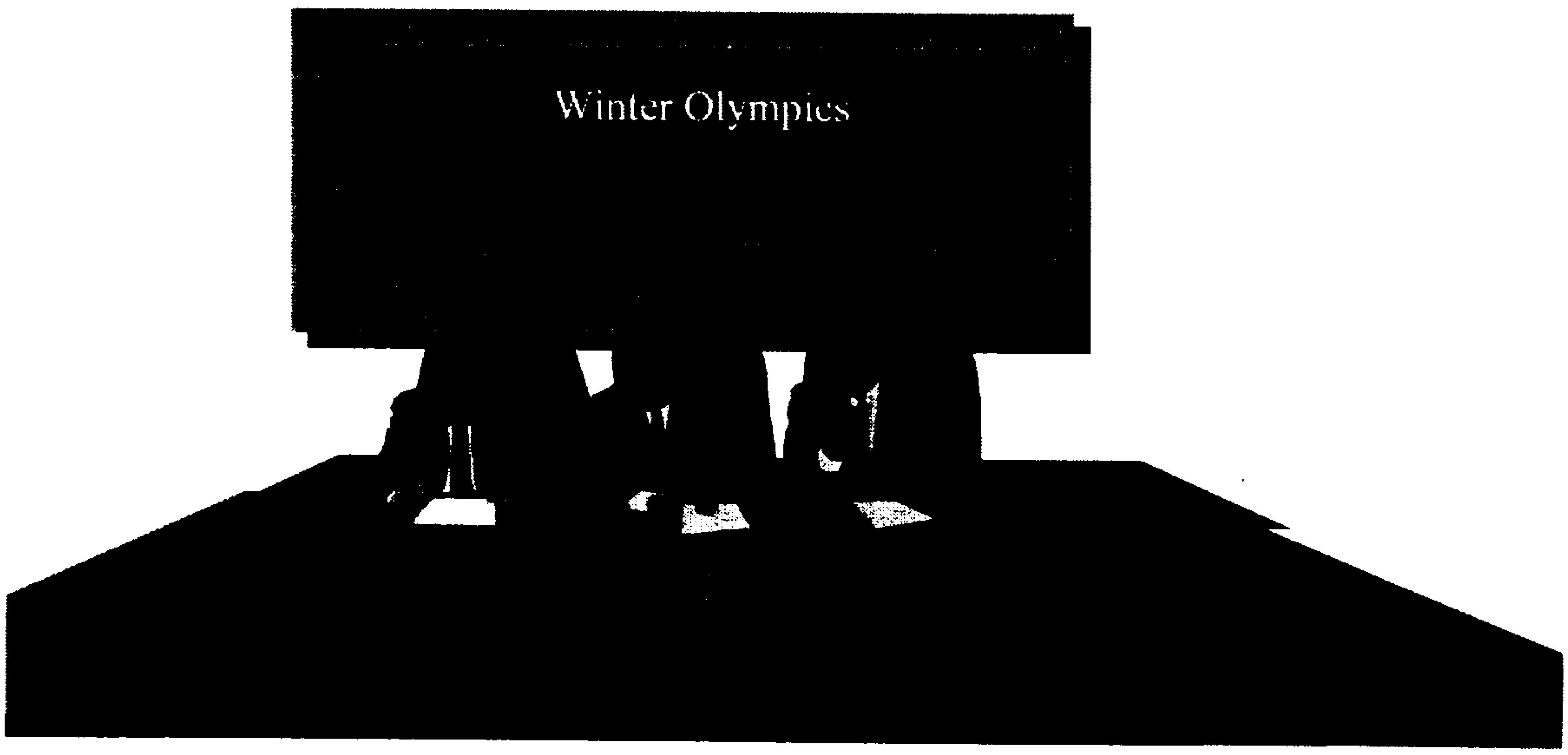
Assigned Number **(DO NOT SIGN YOUR NAME)**

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

COMPUTER-AIDED ENGINEERING
Ph.D. QUALIFIER EXAM – Spring 2002

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

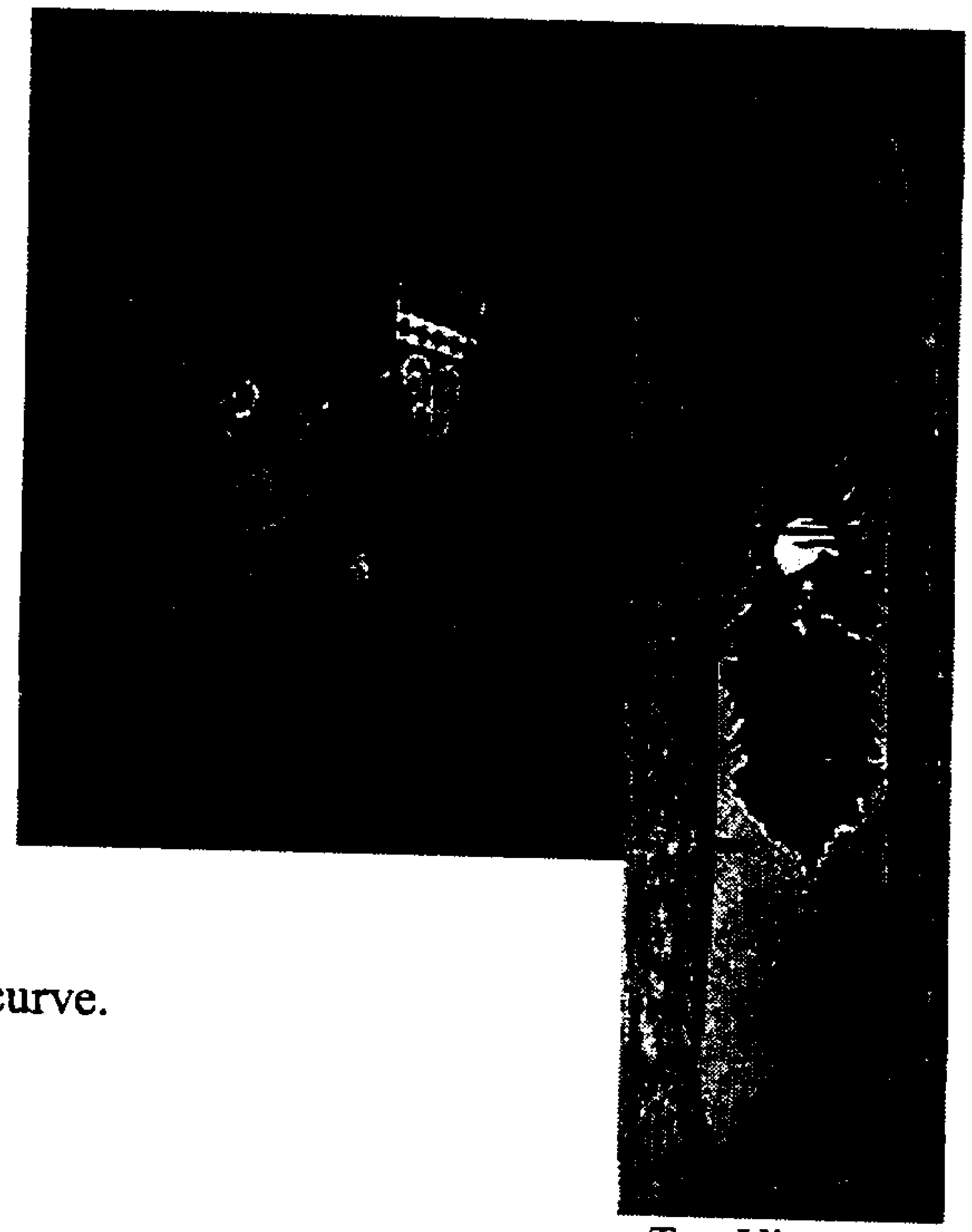
Bras, Fulton, Rosen, and Sitaraman (Chair)



- All questions in this exam have a common theme: ***Winter Olympics***
- 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



Top View

The US snowboarders really exceeded everyone's expectations at the 2002 Winter Olympics by receiving many medals. Great snowboard designs! Your challenge in this question is to develop geometric models of snowboards.

Given: Equations for **Bezier curves** are

$$b(u) = \sum_{i=0}^{n} B_{i,n}(u)\vec{P}$$

$$B_{i,n}(u) = \binom{n}{i} u^i (1-u)^{n-i}$$

where: **P** are the control vertices that define the Bezier curve.

a) Given the equation for a Bezier curve above, derive the equations for linear, quadratic, and cubic Bezier curves.

b) Assume the sketch below is a side view of a snowboard. On a copy of the sketch, draw the control vertices and control polygons for a quadratic Bezier curve, a linear Bezier curve, and a cubic Bezier curve, from back to front. Indicate how you will ensure G^1 continuity between the curves.

c) Now think about a surface model of the snowboard. Your geometric model of the snowboard should be suitable for modeling the **nominal** snowboard shape. It should also be suitable for modeling a snowboard's **deformed** shape when in use. Assume that a finite element analysis will be used to generate deformed shapes. Propose **three different types of surfaces** (e.g., bicubic Hermite surface) that you could use to model the snowboard (hint: what types of curves/surfaces are used as shape functions in finite elements?).

d) For EACH surface type, identify at least **three characteristics** that of that surface type that you believe makes it suitable for modeling nominal and deformed snowboard shapes. In light of these characteristics, **evaluate** your three surface types. Explain their advantages and disadvantages (at least 3 of each). Based upon your evaluations, which surface type would you select? Explain your reasoning

Question 2

The sport of ice-sailing is considered for the Winter Olympics. In ice-sailing, a person sits on a catamaran-like (twin hull) or large surfboard-like deck that is mounted on large skates, typically in a triangular fashion. A single sail, similar like used for windsurfing is used for sailing across the ice. Speeds achieved in ice-sailing are much higher than those in regular water sailing. When viewing ice-sailing (or even regular catamaran sailing) you often see the "boat" being lifted of the ice on one side by the force of the wind. It is very important to know at what point the boat will tip over due to the wind.

In any sailing boat, whether on ice or not, the wind forces exerted from the sails on the mast vary as a function of the distance z above the deck of the boat according to the following function, where h is the total height of the mast:

$$dF/dz = 200 \left(z / (z+5) \right) e^{-2z/h} .$$

a) Calculate the total force of the wind on the mast using the classical fourth order Runga-Kutta method for numerical integration. Assume the total height of the mast h = 30 ft and use a step size of 15.

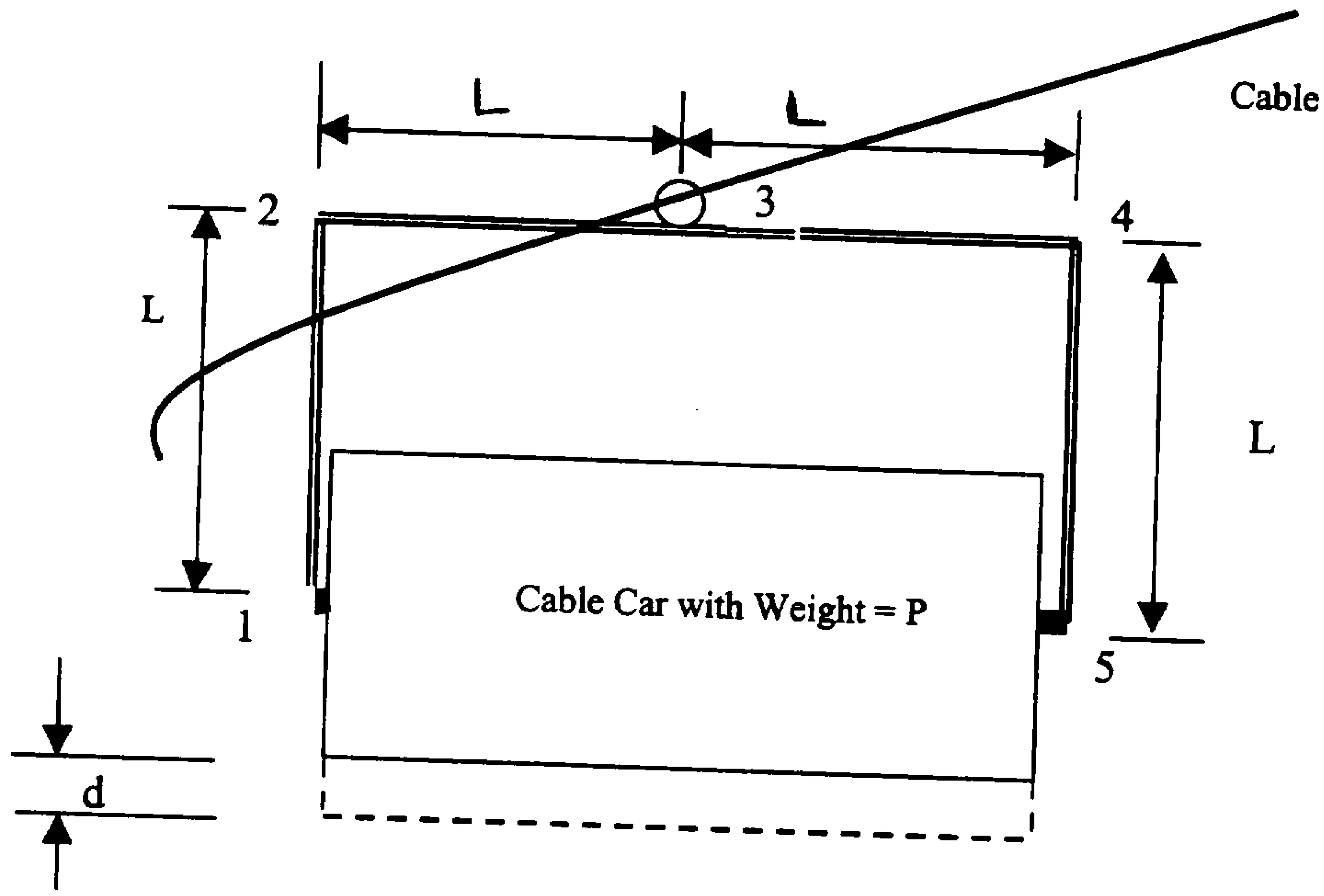
b) In what cases will the fourth order Runga-Kutta method give an exact solution?

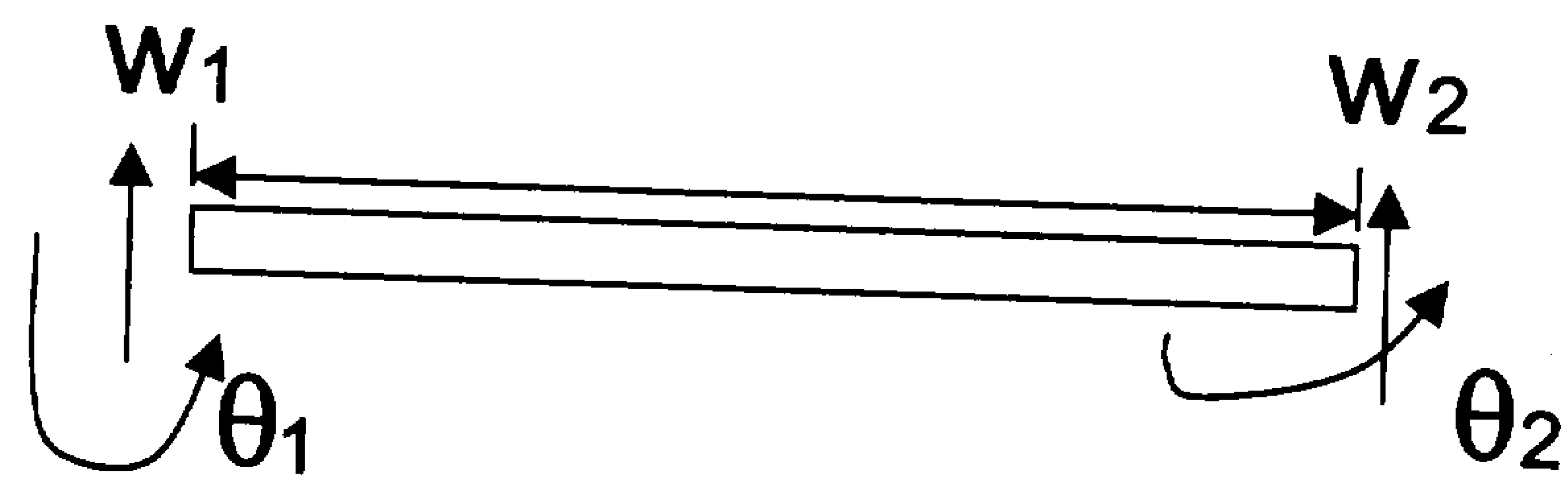
c) What are the differences between a second and fourth order Runga-Kutta method?

d) Name and describe at least four other methods for solving this problem.

Question 3

A ski cable car of weight P is supported by a beam frame shown below which hangs from the cable at point 3. The cable car can be considered rigidly attached to the frame at points 1 and 5. Assuming that the frame undergoes only bending behavior, determine the vertical displacement of the cable car *d* due to bending of the frame. All members of the frame have a length of L as shown in the figure and a flexural rigidity of EI. The beam bending stiffness matrix is given below for the indicated variables.





$$\frac{EI}{L^3}\begin{bmatrix} 12 & 6L & -12 & 6L \\ 6L & 4L^2 & -6L & 2L^2 \\ -12 & -6L & 12 & -6L \\ 6L & 2L^2 & -6L & 4L^2 \end{bmatrix}\begin{bmatrix} w_1 \\ \theta_1 \\ w_2 \\ \theta_2 \end{bmatrix}$$