
AC 2012-5290: THE USE OF COMPUTER-BASED TEAM ASSIGNMENTS AS AN EFFECTIVE TOOL IN TEACHING MECHANICS

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The Use of Computer-Based Team Assignments As an Effective Tool in Teaching Mechanics

Abstract

The authors explore and discuss how computer-based assignments (CBAs) are used to promote both a better understanding of engineering mechanics through application of concepts and the development of teamwork and technical writing skills in engineering students at their institution. CBAs start as early as in Statics, the first course in mechanics, and are continued through Mechanics of Materials, a junior-level course. In addition to applying the subject matter from the course through the use of computers to solve relevant, practical, usually open-ended problems, the students learn to work in teams, albeit sometimes with groans and pains. They also develop and improve their technical writing skills in generating the formal technical reports that are required by the CBA, and are occasionally asked to demonstrate technical presentation skills, again with computer-aided audio-visual support. The authors present data in this paper to explore how effective CBAs are in achieving the learning outcomes regarding concept application, teamwork, and technical writing in those mechanics courses.

Introduction

The importance of integrating the use of computers in learning and teaching engineering mechanics has been demonstrated and heralded in the literature.¹⁻⁶ Students benefit from “instructional activities involving [them] in doing things and thinking about what they are doing.”⁷ The emphasis in this paper is on the use of computer-based assignments (CBAs) as an auxiliary learning tool for students. The main purpose of the CBAs is to have students make connections between concepts and how they are applied and thereby learn to enjoy mechanics. To complete CBAs, students use the power of the computer to solve an open-ended problem with practical implications. The CBAs also encourage teamwork and collegiality among students, allowing them the opportunity to interact with the faculty, graduate students, and other undergraduate students in proposing solutions to the assigned problem. Another very important reason for the CBAs is to promote and improve technical writing in support of writing across the curriculum.

The mechanics course is not a computer programming course, but students are expected to have familiarity with programming applications of mathematical analysis software packages such as Excel, MathCAD, Matlab, or similar programs.⁸⁻¹⁰ Students are not required to use any particular software. They are free to write their own programs or choose any software to solve their given problem. Students who are not as familiar with programming and mathematical analysis software packages are able to learn from their teammates. Whichever programming method they select as a team, the students are involved in the learning process as they apply concepts presented in class to solve the problems. This makes the CBAs an active learning strategy that the instructor deems an effective tool in teaching mechanics.

For the purpose of this paper, effective is defined as producing the instructor’s desired effects of prompting students to apply mechanics concepts successfully and develop teamwork and

technical writing skills. This paper examines student grades in mechanics courses that use CBAs to explore how effective this active learning strategy is in achieving the desired results.

The Computer Based Team Assignment

When the course is taught from any one of a list of available textbooks^{11,12}, ample problems that are specific or suitable for computer-based assignments are given at the ends of most chapters. In the past seven years, however, one of the authors has taught his mechanics courses from class lecture notes and handouts^{13,14}, and provided CBA's from a range of topics, such as:

- a. Vector algebra – addition and multiplication;
- b. Particle equilibrium;
- c. Equivalent Force and Moment Systems;
- d. Reactions for plane trusses and frames;
- e. Analysis of a three-bar truss;
- f. Geometric properties of lines, areas, or masses;
- g. Equilibrium of an object on a rough inclined plane; and
- h. Shear force and bending moment diagrams for cantilevers and simple beams.

Some typical CBA's are shown in the Appendix.

For the data presented in this paper, students were organized into teams of four or five persons, with each team having approximately equal academic strength based on the performance of the student members on the prerequisite test, given in the first week of class, or the most recent exam. To the extent possible, the teams also reflect diversity of major, gender, and even nationality. Teams are shuffled and students are assigned to different teams from one assignment to the next, in order to maximize networking in the class. Sometimes, students are allowed to make up their own teams, but diversity is still required. For example, in a Statics class of 25 students in Fall 2011, students divided themselves into 5 teams, each with two men and three women, from at least two majors, most of whom were mechanical and chemical engineering students, with a few civil and electrical engineering majors.

Each team is required to prepare and submit a formal technical report, complete with a cover page, bibliography, and appendices. Students are told at the time that the assignment is issued that grading shall consider technical content and format, style and grammar, correct use of engineering and scientific terminology and phraseology, and proper citation of references. For a 100 point grading scheme, points are awarded as follows:

- Cover Sheet and TOC (5)
- Purpose (5)
- Scope and Limitations (5)
- Theory (15)
- Solution Algorithm and Macro-Flowchart (10)
- Input/ Output Specifications (10)
- Inputs/ Outputs for Sample Problem (20)
- Discussion, Conclusions and Recommendations (10)
- Citations and List of References (5)
- Appendices- Program Listings, etc. (10)
- Grader's Overall Impression (5)

In this paper, CBA scores have been scaled down to a maximum of 20 points to ease comparison with exam data.

Some teams function quite well from the start. They meet early, choose a leader, identify and assign tasks, and work out a schedule to complete the assignment and the written report in the given time, usually three to four weeks. Some of the other teams do not fare as well. Some students complain that they cannot get along because of different work habits, and may even give excuses such as “We cannot find one another,” or “We cannot find a time to meet because of our different class and work schedules.” Sometimes, an unspoken underlying problem may be relating to and working with persons of a different gender, religion, or nationality. Many of these problems are resolved by encouraging the students to be proactive in communicating with team members, occasionally scheduling time in class for team meetings, and offering extra credit for students who attend and learn invaluable soft skills from free Engineering Futures (EF) sessions conducted by the student chapter of Tau Beta Pi, the Engineering Honor Society (www.tbp.org). The EF sessions are offered by TBP as a service to the engineering community and develop people and interpersonal skills, such as how to schedule and conduct efficient meetings and, most importantly, how to function as a productive member of a team. Students are also forewarned that impromptu quizzes and regular exams may contain questions directly related to the CBAs in order to prevent complete procrastination.

Results

Data from two classes of 26 primarily sophomore students in Statics are plotted in Figures 1 and 2 for average CBA and exam scores. Similar data are presented in Figures 3 and 4 for two classes of 17 junior students in Mechanics of Materials. The data are taken from one of the author’s course records but, to protect student privacy, names and identification numbers have been removed. Grades on course exams and CBAs have been averaged separately and compared. The line graphs and scatter plots provide the basis for determining the effectiveness of CBAs in causing students to apply mechanics concepts successfully and develop teamwork and technical writing skills.

The first observation in comparing average exam and CBA scores by student is that CBA scores are considerably higher than exam scores. This is a noteworthy trend because exams are structured to gauge knowledge and comprehension primarily, whereas CBAs focus on application.¹⁵ So, higher CBA scores suggest that students are achieving the goal of applying concepts successfully. The effect of the teamwork component in CBA grades cannot be ignored, however.

Figure 1 shows that 42% of Statics students score a 70 or higher, on average, for CBAs and exams or score 65 or lower for both. This trend only confirms the obvious – that students who do well on exams will also do well on applying exam concepts in a CBA and vice versa. The remaining 58% of Statics students scored higher than 70% on the CBAs, but lower than 65% on exams. This introduces a second type of student - low exam scorers who were likely helped to high CBA scores by the academically stronger members of their teams. This becomes even clearer in Figure 2, which shows a wide range of exam scores within each CBA team (as indicated by the team CBA score on the x axis) and a great deal of scatter in the plot ($R^2=0.13$).

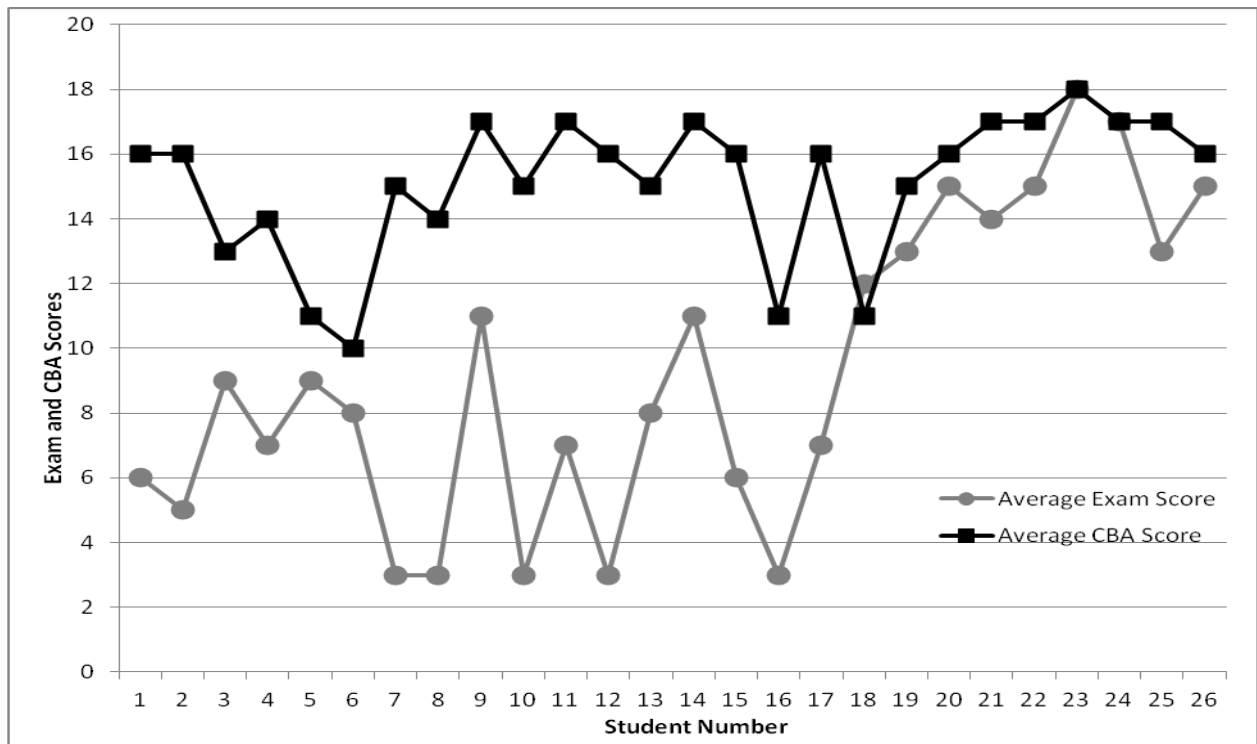


Figure 1. Average CBA and Exam Scores in Statics

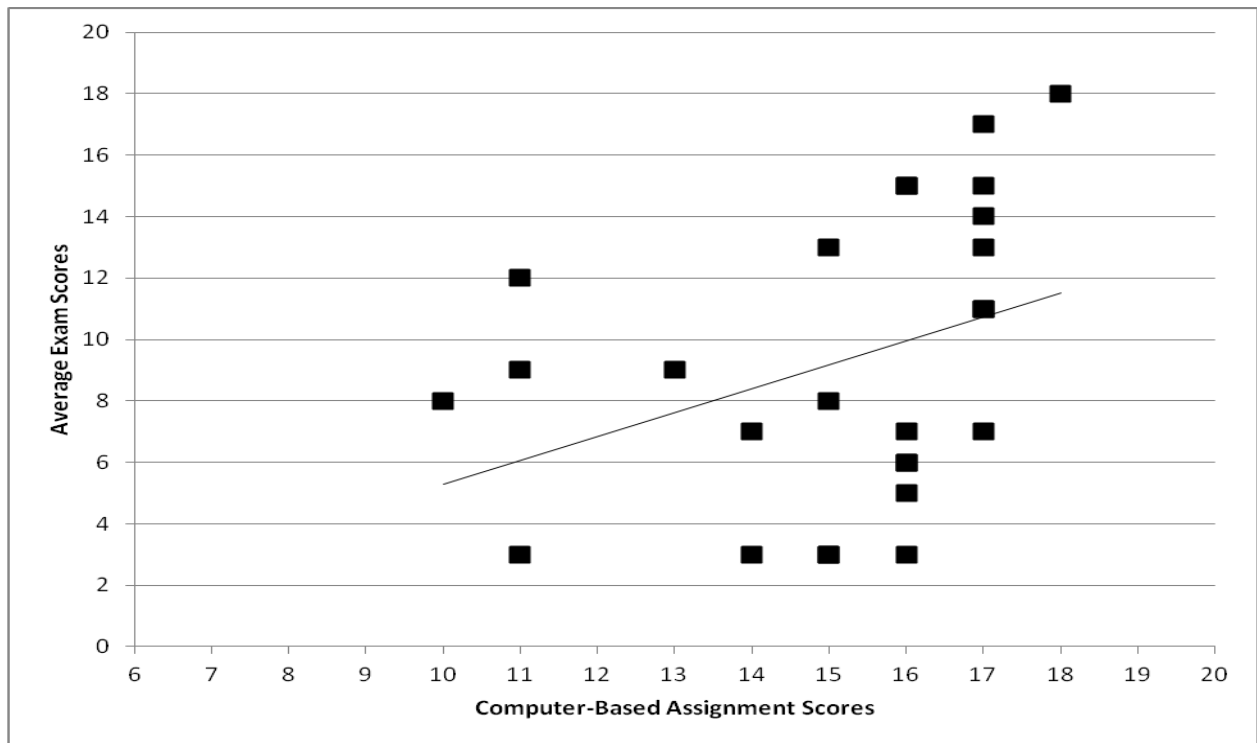


Figure 2. Scatter Plot of Average CBA and Exam Scores in Statics

So, students are developing teamwork skills. There is only one case in Figure 1 where a CBA score is lower than the exam score and the difference is only one point on the twenty point scale.

The undesired trend of high-achieving students not being able to navigate teamwork dynamics is not seen, then, because all teams were able to complete the assignment and apply the mechanics concepts satisfactorily. In addition to the trend connoting the accomplishment of teamwork and concept application goals, it also appears that students are meeting technical writing expectations, as evidenced by the relatively high average CBA scores.

Figures 3 and 4 show comparable trends with the somewhat smaller group of junior Mechanics of Materials students. In only one case is an exam score higher than a CBA score, excluding the grades of students 1 and 2 who must have received deductions for individual deficiencies since they are the only students with the CBA score they have (as opposed to a team score). So, the teams appear to work effectively, with only one team scoring less than 70% on a CBA, which also speaks to the accomplishment of technical writing goals. Despite a poor goodness of fit ($R^2=0.12$) in Figure 4, the trend is clear - low exam scorers were likely helped to high CBA scores by the academically stronger members of their teams and high exam scorers also earned relatively high CBA scores. Students are, then, accomplishing the instructor's concept application, teamwork, and technical writing goals.

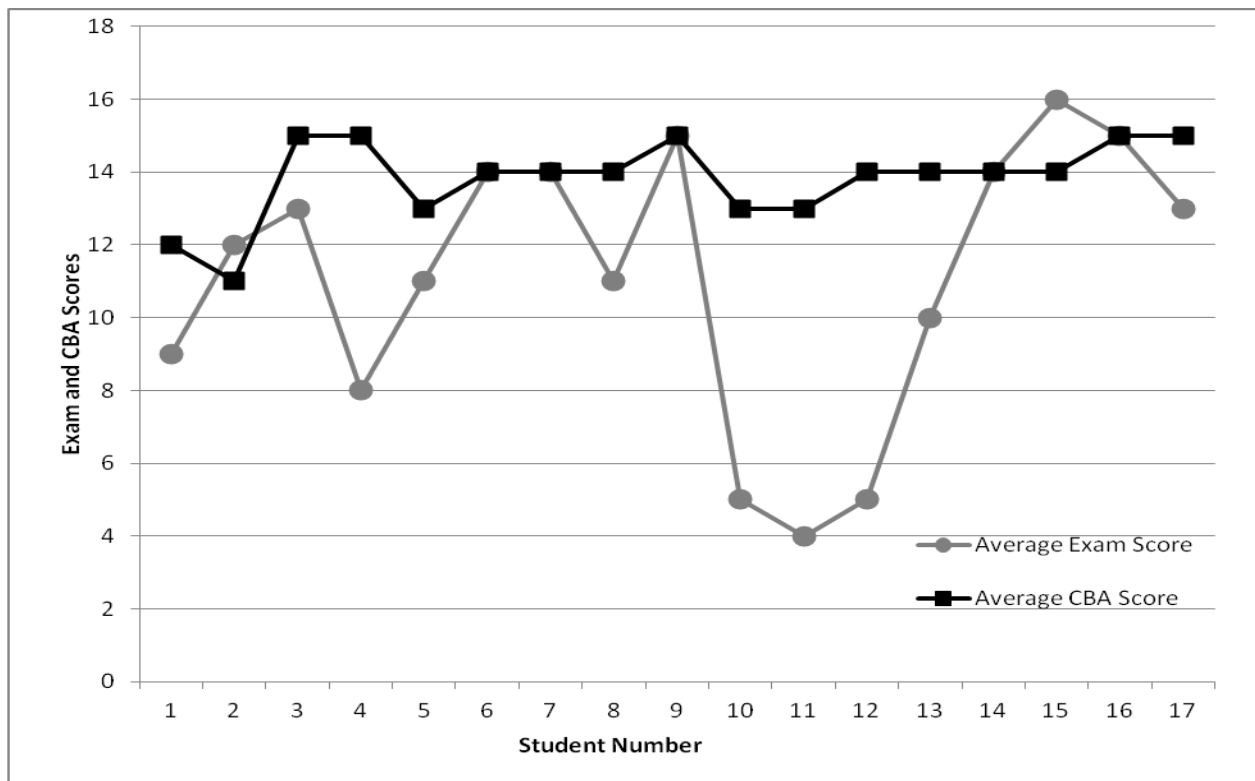


Figure 3. Average CBA and Exam Scores in Mechanics of Materials

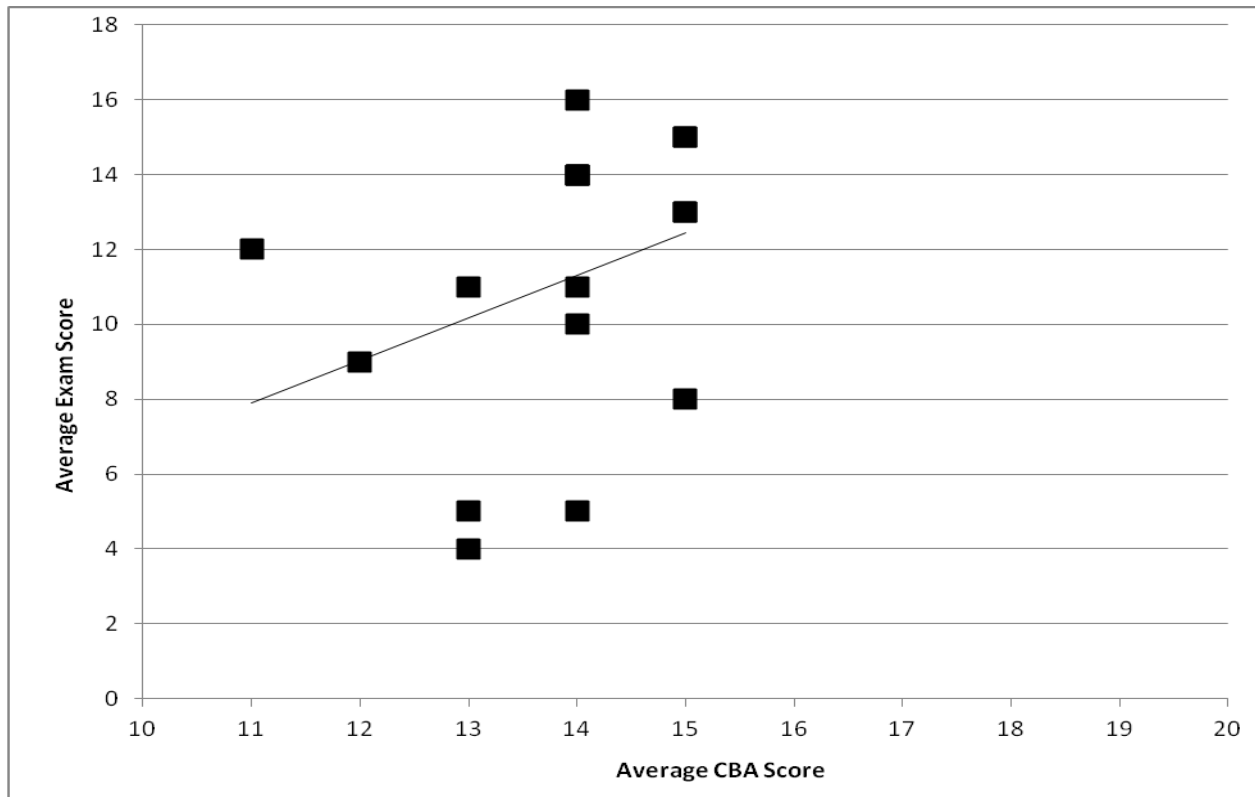


Figure 4. Scatter Plot of Average CBA and Exam Scores in Mechanics of Materials

What the plots do not show is that some students who start out unenthusiastic about working with other students, eventually develop team spirit and collegiality, and even buy into the instructor’s “propaganda” about the joy of mechanics! They learn how to use different software and how to select the most appropriate application for a particular task, and in the process also develop some research, technical reporting, and presentation skills.

Conclusions

Computer-based assignments are effective active learning tools for prompting students to apply mechanics concepts and develop teamwork and technical writing skills. Anecdotal evidence also suggests that they teach students to enjoy mechanics. Generally, sophomore and junior students scored relatively high on team computer-based assignments as compared to individual exams. In no instance did a student score significantly lower on a CBA than an exam, as would be expected if student teams succumbed to teamwork conflicts and challenges. This provides preliminary evidence that CBAs actively engage students in applying mechanics concepts and helps them to develop teamwork and technical writing skills.

Recommendations

Instructors of courses in engineering mechanics should consider using computer-based team assignments as an auxiliary tool for prompting students to apply and enjoy engineering mechanics, while also developing teamwork and technical writing skills. Further research is also

recommended to study the effectiveness of CBAs on individual students. Such a study might focus on the evolution of individual student attitudes concerning mechanics, contributions to team assignments, and achievement on exams throughout the semester. A coordinated, multi-university study would be especially meaningful to also study effects in different academic settings.

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Appendix

SAMPLE CBAs

1. Statics Computer-Based Assignment: Resolution and Composition of Forces

In this exercise, each group should work as a team, without consulting members of other teams, to obtain, adapt, or write, test, and document one computer program for finding the components of a force or the resultant of two force components in a two-dimensional oblique or rectangular coordinate system. Your program should accept as input the magnitude and direction of each of the forces in the system, and then use *two different methods* to determine and print, as output, the magnitudes and directions of the components or the resultant. You should use at least four different examples, including at least two from class notes or texts, to demonstrate the versatility of your program. Your program should be documented in a formal technical report, and you may use the report format listed with the grading scheme as a guide.

2. Statics and Mechanics of Materials Combined Computer-Based Assignment: Equivalence and/or Equilibrium of 2-D Force and Moment Systems

In this CBA, each group has members from the Statics and Mechanics of Materials classes, who should work as a team, without consulting members of the other teams, but may get advice from the Instructional staff of both courses. Each Group should find, adapt, or write and document one computer program that can compare two different 2-D systems of forces and moments and determine whether they are equivalent or not, and if either system is in equilibrium.

Your input should allow for any mix of up to 5 force and moment vectors, each of which may be specified in any one of 4 different ways. The input for each force should include at least one point on its line of action. Your program should then reduce each system and print as output its equivalent system of one moment and/or one force acting at the origin of your coordinate system. *If possible*, you should reduce each system further to just one force, and print its magnitude and direction and the coordinates of a point on its line of action.

You should state clearly whether the two systems are equivalent, or not, and whether either system is in equilibrium, or not. You should illustrate the versatility of your program with at least 5 different examples, including at least 3 taken from text books and the class notes.

3. Statics and Dynamics Combined Computer-Based Assignment: Properties of Planar Systems of Slender Bars

For this exercise, each Group has members from the *Statics* and Dynamics classes. Members in each Group should work as a team to find, adapt, or write and document one computer program that can determine the properties of a system of interconnected slender uniform homogeneous bars, some of which may have straight, circular or semi-circular axes.

Your input should include the total number of bars and nodes in the system, and should provide the coordinates of each node, and the mass and connectivity of each bar. Your input should allow for any mix of up to 5 bar segments that are straight and inclined or parallel to either in-plane (x or y) coordinate axes; circular; or semi-circular, with their diameters parallel to either the x or y axis. Your program should compute and print out the system's total mass, the location of its center of mass, and its mass moments of inertia and radii of gyration about the two in-plane coordinate axes. You should illustrate the versatility of your program with at least 5 different examples, including at least 3 taken from text books and the class notes.

4. Statics Computer-Based Assignment: Beam Reactions

In this exercise, each Group should work as a Team, without consulting members of other teams, to obtain, adapt, or write, test, and document one computer program for finding the components of the reactions at the supports of your assigned beam, as shown below.

Your program should accept as input the number, coordinate locations and types of supports in the system, and the number and points of applications and directions or senses of the applied forces and/or moments (if any). The applied forces could be vertical, horizontal, or inclined at given angles or along given lines of action. You should allow for three *different support types* – *built-in, hinged or roller supports at prescribed orientations*. Your program should determine and print, as output, the magnitudes and directions of the components of the reactions at each support. You should use at least five different examples, including at least two from class notes or texts, to demonstrate the versatility of your program. Your program should be documented in a formal technical report, and you may use the report format listed with the grading scheme as a guide.

Table – Beam Assignments

Group # Beam Type
1	Cantilever beam supported from the left end
2	Cantilever beam supported from the <i>right</i> end
3	Simply supported beam with an overhang on the right
4	Simply supported beam with an overhang on the <i>left</i>
5	Simply supported beam with two overhangs