Graduate Student Teaching Award
Nomination Package

Bruno Abreu Calfa
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February 6, 2015

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Nomination Letter

February 1, 2015

To whom it may concern,

It is a great pleasure to write this letter to support the nomination of my student Bruno Calfa for Graduate Student Teaching Award. I have been very fortunate to have Bruno as one of my Ph.D. students. I have been extremely pleased and excited with his performance in research as well as in his teaching. He is a truly outstanding student who has high standards.

In research, Bruno has addressed in collaboration with Dow Chemical, the planning and scheduling of a batch process for manufacturing of multiple products. He has also addressed the problem of generating from historical data scenarios that are inputs to stochastic programming models. He has also investigated data-driven approaches to reformulate chance or probabilistic constraints into algebraic constraints. More recently, he has developed a comprehensive formulation for production planning of process networks that accounts for various types of contracts for the purchases of raw materials and for price elasticity in the sales of the chemicals. As a result of his research, Bruno will have produced 4 excellent technical publications plus a survey paper on process flexibility. He has also presented his work at several annual AIChE and INFORMS meetings.

What in my opinion sets Bruno apart from most graduate students is that aside from doing an outstanding job in research, he has also done a superb job in teaching. He has shown unusual devotion and dedication to education as he has been teaching assistant for more than 3 semesters, which is the requirement in our department. He is very passionate about teaching and making sure students learn the fundamentals, while keeping high standards. One of the major contributions of Bruno in education has been to help integrate computing in the undergraduate chemical engineering curriculum through Matlab, a powerful high-level computing language and interactive environment for mathematical modeling, algorithm development, data visualization, and data analysis. There is no specific course on Matlab in chemical engineering so what Bruno has been doing for several semesters is to be the teaching assistant who teaches sophomore, junior and senior students about the use of Matlab in special sessions and acts as a consultant to them. Thanks to Bruno this has allowed instructors in courses like 06-262 Mathematical Methods of Chemical Engineering, 06-261 Fluid Mechanics, 06-321: Chemical Engineering Thermodynamics, 06-364 Chemical Reaction Engineering, and 06-464 Chemical Engineering Process Control to have students use Matlab for their homework assignments and projects. In recognition to his outstanding job as the teaching assistant of Matlab Bruno received in 2012 the “Mark Dennis Karl Outstanding Teaching Award” from the Department of Chemical Engineering at Carnegie Mellon University.
Bruno also did an outstanding job as a TA in my undergraduate course, 06-421 Chemical Process Systems Design, that involved a project dealing with the design of cellulosic bioethanol plant via hydrolysis and for which Bruno was in charge of introducing the students to the process simulator Aspen, aside from supervising three design groups.

Bruno’s commitment and enthusiasm for teaching is evidenced by the fact that he completed the Future Faculty Program at the Eberly Center, and that he maintains his own teaching portfolio and website and has created extra teaching material for several courses. Based on all these contributions to education Bruno has been offered a postdoctoral position at the University of Wisconsin-Madison for developing educational materials on process technology and process design.

Finally, I should mention that another important contribution of Bruno has been to help me to raise awareness to the College of Engineering and Department of Mathematics about the weaknesses in the education of our students in the area of mathematics. Specifically, the problem is that most of our students currently place out of the courses 21-120 Differential and Integral Calculus and 21-122 Integration and Approximation, which means that they only take the two courses, 21-259 Calculus in Three Dimensions and 06-262 Mathematical Methods of Chemical Engineering, during their four years of study in chemical engineering. Bruno attended a meeting with Dr. Annette Jacobson, Education Dean of CIT and a number of faculty from the Department of Mathematics to provide them with feedback about the weaknesses that he has observed of the undergraduate students in their mathematical background.

In summary, Bruno is clearly an outstanding Ph.D. student who is very bright, and who has made not only very significant contributions in research but also in education. I am very happy to give Bruno my strongest support for his nomination for the Graduate Student Teaching Award. He is clearly a highly deserving award recipient.

Yours sincerely,

Ignacio E. Grossmann
Recommendation Letters

Recommendation Letter 1 (2012 Alumna)

Elizabeth (Betsy) Cole
CIT Chemical Engineering 2012

February 4, 2015

Eberly Center for Teaching Excellence and Educational Innovation
ATTN: Graduate Student Teaching Award Selection Committee
5000 Forbes Avenue
Cyert Hall, Room 125
Pittsburgh, Pennsylvania 15213-3815
eberly-ctr@andrew.cmu.edu

To the members of the Graduate Student Teaching Award Selection Committee:

I was fortunate enough to have Bruno Abreu Calfa as my TA for three semesters as an undergraduate chemical engineering student. I attended office hours on a regular basis and sought help from Bruno frequently. I highly recommend him for the Graduate Student Teaching Award, given his superior qualifications.

Bruno has a real passion for what he does. He clearly enjoys his own studies of chemical engineering, mathematics, and programming, and he wants to share his love of learning with students. This enthusiastic attitude is what makes Bruno so successful and well liked as a TA. His face lights up when he explains concepts to students, and students can tell that Bruno truly enjoys learning, teaching, and helping.

By his upbeat approach and infectious enthusiasm, Bruno creates a positive learning environment for students, because he himself clearly enjoys learning. He does not just believe that the student-teacher relationship goes one way – he firmly believes that teachers can learn from their students too. This love of learning that Bruno imparts to his students is what makes them excited about learning as well.

Bruno is very encouraging in his teaching style. He never demeans anyone or makes anyone feel stupid for not knowing the concepts. If a student does not know something, Bruno will take the time to explain it to him or her, while using real-world examples to illustrate the point. The fact that Bruno does not just use theory to help explain fundamental chemical engineering and mathematical concepts is crucial. The use of real, physical examples truly helps students comprehend the subject matter, in a way that they can understand.
One of the key characteristics of a successful teacher is that he or she must know how to engage all students – from the beginners to the more experienced, from the apathetic to the eager, and from the visual to the auditory learners.

Bruno is able to do this effectively, because he knows how to explain concepts in the right level of detail. He can teach something to beginners by explaining the basics in a way that they can understand, but he can also help more experienced students by taking their thinking to the next level. In office hours, he internally assesses the skill level of those present, and then pairs up students who have similar questions, encouraging students to work with one another, while also taking the time to work one-on-one with those students who have more fundamental questions.

He never lets a student feel discouraged or lets a question go unanswered. Bruno takes the time to patiently work through the issues. However, he never just simply gives out the answers to homework problems. He knows that there is much more to learning than that. If students have a question on a problem, he guides them through an analysis of what they need to think about to solve the problem, drawing on material covered in lecture and using real-world examples to which they can relate. He helps students to think logically when they are stuck, and he never gives up in making sure that students see the value and importance of what they are learning.

Bruno is very well organized. He always prepares lecture slides and handout materials ahead of time and has them ready to pass out during class. These really serve to reinforce the concepts he explains. Bruno recognizes that not all students learn in the same way, and so by speaking during class, writing on the board, encouraging students to take notes, and providing handouts, he really covers the entire learning spectrum of students.

In addition, Bruno is always very generous with his time and is a very accessible TA. He goes above and beyond in order to help students. He always makes time for students, even after formal office hours are over. If office hours end and not all the issues are resolved, he offers to meet with students again, on his own time, to help them understand the problem sets or lecture material. He also makes himself available via email, to answer questions.

One specific way that Bruno helped me was by offering a series of sessions, developed of his own volition and on his own time, in Excel and VBA Programming in the Spring of 2012. I attended these sessions, and I found them to be incredibly valuable. Bruno prepared lecture materials, as well as exercises to help us learn the concepts. He would teach for part of the session, and then he would let us practice the skills he just demonstrated on computers in the computer lab. He saw a need to teach students about a specific software and programming language, and he took the time to prepare and hold these sessions for students to learn. Bruno did not have to organize these sessions, nor did he have to put as much time and energy into helping us learn, but he did.

Because of all the reasons I have given, I feel very confident in recommending Bruno Abreu Calfa for the Graduate Student Teaching Award for this year.

Sincerely,

Elizabeth (Betsy) Cole
Recommendation Letter 2 (2012 Alumnus, M.S.)

Scott Kolodziej

January 31, 2015

Graduate Student Teaching Award Selection Committee
c/o Hilary Schuldt, Associate Director
Eberly Center for Teaching Excellence
Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh, PA 15213

Dear Graduate Student Teaching Award Selection Committee,

As a colleague of Bruno Calfa, I have always viewed his dedication to education and teaching to be beyond exceptional – an ideal to strive for if never equaled. During 2010 - 2012, we shared an advisor and an office in the department of chemical engineering at Carnegie Mellon University, and in this time I witnessed the exceptional amount of time, effort, skill, and character Bruno put into his work as a graduate teaching assistant. I would like to recommend Bruno for the Graduate Student Teaching Award without reservation and with the utmost confidence.

During our first semester at CMU, Bruno and I were teaching assistants for Chemical Engineering Design, the senior capstone project. Bruno dedicated many hours of his time – far more than even the best teaching assistants that I am familiar with – to help students understand the material. He was always available to students and made an effort to spend as much time as was needed for them to understand the material. Even outside of office hours, Bruno would readily invite students to his office to discuss homework and other material that they had questions about. Because of this level of concern and dedication, Bruno truly blurred the line between teaching assistant and mentor to many.

In successive semesters, Bruno was appointed to be the Math Software Teaching Assistant, a newly created role to fill a growing need for instruction in this area within the department. This role would have been challenging for any graduate student, as it required a broad knowledge of mathematical software (including Excel, VBA, MATLAB, and other programming languages and software platforms), and was accountable for the entire department rather than students in a single course. To address these difficulties, Bruno again made himself extremely available and accessible to students, regardless of schedule. Going above and beyond his duties, Bruno also created tutorials, slides, and example source code that he used during open help sessions. These sessions were held late so as to not conflict with courses during the day and for several hours to allow students to come and go as needed, once again focusing on the students’ needs.

Bruno was so successful in this position that he received the Department of Chemical Engineering’s Mark Dennis Karl Outstanding Teaching Award in 2012 and was chosen to continue in this role for three consecutive semesters. He has additionally made the tutorials he developed freely available for students everywhere to benefit from.

That students feel supported and respected by Bruno goes without saying. He continuously has a friendly demeanor, even when under stress, and can seemingly relate to students from a plethora of backgrounds. He naturally finds common ground and empathizes with students while maintaining an appropriate level of professionalism.

Once again, I feel Bruno is an excellent teacher and educator, and I cannot recommend him for this award with enough enthusiasm. It is rare for a graduate student to dedicate as much time and effort as Bruno has to education and teaching, and even amongst those who do, Bruno is an exception above.

With my highest recommendation and regards,

Scott Kolodziej
Graduate Student Researcher
Texas A&M University
Department of Computer Science and Engineering
Recommendation Letter 3 (2012 Alumna)

To the Graduate Student Teaching Award Committee:

As a former student under Bruno Calfa’s guidance, it is my pleasure to recommend Bruno for Carnegie Mellon University’s annual Graduate Student Teaching Award.

I was an undergraduate student double majoring in Chemical Engineering and Biomedical Engineering from 2008–2012. I first met Bruno in the context of my Process Control class, where he was a teaching assistant for the term. After that course, he continued to connect with and teach students both in an official and an unofficial capacity in many of my Chemical Engineering courses. When I reached out to him later in my studies regarding a roadblock when coding in Matlab — despite him not being the TA for the respective course — he was responsive and eager to help. Bruno was one of the few people I’d ever met who was truly invested in students’ learning, not just in their grades. He was passionate about the subject, had the technical expertise to understand it, and had the drive to teach it.

Bruno is not just a teaching assistant or a graduate student teacher. Bruno is a full-fledged teacher because of his actions: he can and does teach. He taught me, mentored me, and cared about my learning throughout the many years that I knew him at CMU. He was able to teach me when I became stumped and could not learn through notes, in textbooks, or via my own problem solving. He followed up when I or others fell off the radar. He even had that skill to reframe the problem when a student is struggling like only the most experienced professors are able to do. When students were struggling, he took special care to review the material from several perspectives until he found the one that each student connected with. I owe much of what I learned in my Chemical Engineering degree to Bruno’s efforts.

In addition, Bruno always seeks feedback about his teaching and probes his students with thoughtful questions on how to improve. In fact, he still seeks feedback from me to improve his performance, a former student, even though I have since graduated from Carnegie Mellon over two years ago.

Bruno deserves to be honored for his excellent work as a graduate student teacher. I respect him because he surpassed his defined role as a teaching assistant and became a true teacher. I know it is his passion to professionally pursue the role of teaching in this technical field. Furthermore, from experience, I can assert that future students will benefit from his teachings. An acknowledgement of Bruno’s success in teaching thus far will help him to achieve his professional goal and will help future students’ education.

For these reasons and more, I advocate that Bruno be recognized by Carnegie Mellon University’s annual Graduate Student Teaching Award

Sincerely,

[Signature]

Celia Ludwinski
2015 February 5
Dear committee,

I am writing this letter to recommend Bruno Abreu Calfa for the Graduate Student Teaching Award. I was his student throughout my undergraduate life as a chemical engineering student, and I really appreciate his help and support.

In the “Chemical Engineering Thermodynamics” class, Bruno held office hours and review sessions for exams. He is knowledgeable about the material and always makes sure I understand the root of my problem. He did not only answer my questions but also gave advices on how to solve particular problems and strategies that could help me further build up my knowledge.

Bruno was also the TA for my “Mathematical Methods of Chemical Engineering” and “Process Control” classes. He held Tutorials on MATLAB and Simulink in the chemical engineering computer cluster so that we could practice and learn better. He started from the basic techniques and presented examples that we could refer to in the homework. He put a lot of effort in preparation so that his classes were well-structured and organized.

Bruno always tries to help in his free time even in other subjects. Once our project in “Biomedical Engineering Product Design” class requires us to build some macro and VBA in Excel. One of our teammates asked Bruno for help. He responded promptly to our questions and actually took out time to teach us in person. In my opinion, Bruno loves to help others and see them succeed; “TA” is not just a job for him, it is who he is.

I am very glad to share my thoughts as a student and a friend of Bruno. If you have any additional questions or need additional information, please feel free to contact me anytime.

Sincerely,

Jocelyn Zhao
To Whom It May Concern:

It is my sincerest pleasure to give Mr. Bruno A. Calfa my highest recommendation for the Carnegie Mellon University Graduate Student Teaching Award. I came to know Bruno while I was an undergrad at CMU studying Biomedical and Chemical Engineering and have only positive things to say about my interactions with Bruno.

For Bruno, being a TA was more than just a departmental requirement and it showed through his willingness to not only host scheduled office hours, but meet with students one-on-one, step in and “teach” our classes when our professors were away, and even go as far as to create supplemental instruction courses on ChemE related software to supplement our in class learning. Not being programing savvy, Bruno’s willingness to go above and beyond allowed for me to expand my knowledge beyond what I gained inside the classroom to a level which allowed me to excel on my homework, exams, and class projects. Today, I find myself using many of the programing shortcuts, especially in Excel to excel (yes, pun intended) in my current work. Because of Bruno’s ability to teach in a manner that allowed for me to master the concepts, I am now able to teach my coworkers many of these tips and tricks.

All in all, Bruno is an intelligent individual with a passion and extraordinary ability to transfer that knowledge to anyone who seeks out his help. Because of Bruno’s dedication and commitment to teaching, I was fortunate to be able to build upon the engineering knowledge I gained in the classroom with real-world programing knowledge which I continue to not only leverage in my current work, but also share with others. I hope you consider Bruno’s application favorably as he has clearly demonstrated teaching excellences at the undergraduate level by fostering a culture of teaching excellence.

Please do not hesitate to reach out with any questions.

Sincerely,

Kathryn A. Kukla
CIT C/o 2012
Recommendation Letter 6 (2012 Alumnus, M.ChE.)

To whom it may concern:

I am writing to give my highest recommendation to my former teaching assistant, Bruno Calfa, for the graduate teaching assistant award. He was my teaching assistant for chemical engineering process control in 2011. He was always positive, passionate in teaching, and knowledgeable.

I was able to find him all the time when I needed help even though it is not his set office hour. He always walked me through step by step on the problems that I have puzzled. If I could not figure it out, he patiently tried different approach until I was through.

Not limiting himself to help students as a TA, he was always willing to help others with his knowledge. I also took advanced optimization course and he attended the course since the instructor was his advisor and his research is related. Again, whenever I had question, he tried to answer the question patiently so that I was able understand the concept.

In addition, he also provided few extra teaching sessions for students who wanted to learn programing language and few software interfaces. He created the tutorial himself with few examples which helped me to utilize the software in academia.

Bruno Calfa is an accessible and warm-hearted teaching assistant who always take teaching as his pleasure. I believe he is the right candidate for the graduate student teaching award. If you have any question or need more information, please feel free to call me at XXX-XXX-XXXX or email me at shihyun@ufl.edu.

Sincerely,

Shihyun Ahn
Chemical Engineering
University of Florida
1006 Center Drive Building 723 Room 118
Gainesville, FL 32611
shihyun@ufl.edu
Dear Graduate Student Teaching Award Committee,

This letter is in support of Bruno Abreu Calfa’s application for the Graduate Student Teaching Award.

As a 2013 graduate of CMU’s Departments of Chemical and Biomedical Engineering, and a current doctoral student in Georgia Tech’s School of Chemical and Biomolecular Engineering, I have had the privilege of working with Bruno both as his student and his colleague. Working with him in these roles afforded me several opportunities to observe his exemplary character and commitment to teaching.

In the spring of my senior year, Bruno served as a Teaching Assistant for Chemical Engineering Process Control. For the duration of the course, Bruno took great care to make himself available and approachable to students. Bruno held his office hours in the chemical engineering computer cluster, which is where nearly all ChemE students work on their assignments. Because of this, the apparent barrier which deters many students from asking for help was greatly reduced, and Bruno was typically found on rotation from computer to computer, assisting multiple students simultaneously.

In particular, I remember one occasion in which I was struggling to pass information between MATLAB and Simulink. My endeavor was not part of the original assignment, but I felt it necessary to improve my understanding of the tools, and to develop a more elegant solution to the problem at hand. Inevitably, I hit a wall in my efforts. Although it was beyond the scope of the class, and certainly beyond what was expected from a teaching assistant, Bruno was very generous with his time; he sat down with me and helped me to work through the issues I had inadvertently created for myself.

When I entered the graduate program at the Georgia Institute of Technology and became a TA myself, I found that Bruno’s commitment to his students was far greater than I had realized during my limited time under his tutelage. When I was struggling to clearly explain a particular concept (mass balances with recycle streams) to my own students, I once again turned to Bruno for guidance. Bruno sent me an entire lecture that he had developed for a recitation, as well as a general outline of his lesson plan. Bruno’s teaching materials were clear and well organized, and both my students and I greatly benefited from his efforts, despite being over 500 miles away. I have since learned that Bruno has made all of his supplemental teaching materials available on his website.

Those who have taught know that it is easy to help high-performing students – the cases in which a simple push in the right direction will suffice. On the other hand, it can be frustrating and sometimes even demotivating to work with those students who struggle with the fundamentals. However even a cursory glance through the topics of Bruno’s extra teaching materials illustrates his eagerness to help students grow and develop the foundational basics to be successful in their classes and careers.

Bruno’s generosity with his time, and his enthusiasm for teaching have also helped me in my professional research. Last year, I found that I suddenly needed to run and modify computer code written in FORTRAN 77. In my experience, there are two barriers to programming: getting the compiler and code running on your computer, and actually learning the programming language. Fortunately, Bruno already had an organized list of FORTRAN references and tutorials on both fronts. He spent several hours corresponding with me to help troubleshoot the problems I encountered. With Bruno’s assistance, I was running statistical thermodynamics simulations in a new-to-me language in less than a day.

I cannot imagine another candidate more deserving of the Graduate Student Teaching Award. Bruno has made it his mission to be an outstanding educator, and every interaction I have had with him has reflected his dedication and drive to realize that ideal.

Harrison B. Rose
Graduate Research Assistant
School of Chemical & Biomolecular Engineering
311 Ferst Drive, N.W.
Atlanta, Georgia 30332-0100 U.S.A.
harrison.rose@chbe.gatech.edu

January 20th, 2015
To whom this may concern,

My name is Sara Saheb Kashaf and I am a Carnegie Mellon ‘14 alumna. During my chemical engineering studies at Carnegie Mellon University, I was frequently faced with challenging coursework which was often supplemented with TA sessions by Bruno. Bruno was the Math Software TA during Fall 2011 and Spring 2013. However, even when Bruno was not the TA for the course, he reached out to my classmates and me and generously offered his time and expertise when he saw us struggling with coursework. During my years at Carnegie Mellon University and in my postgraduate program, I have never encountered a TA with such a broad knowledge in chemical engineering who is so organized and so dedicated to helping his students succeed.

With every session as the Math Software TA, Bruno was always organized and he was extremely well-prepared with carefully drafted documents that perfectly summarized the concepts. Moreover, he gave presentations that were coupled with exercises, which we could attempt during the sessions. While we attempted the exercises, he approached each of us when we were having trouble and even went beyond the session hours to help us resolve these issues. Given the rigor of the computational coursework, his help was essential to our performance in numerous chemical engineering courses.

However, beyond his formal TA obligations, Bruno placed a lot of time and effort into helping us succeed and making sure we were dealing with the stress of the chemical engineering program. I have never encountered a TA who cares so much about his students’ well-being. I think such TA support is essential in counteracting the stress culture at CMU. When we were struggling with concepts or the computational aspects of our courses, Bruno took so much time outside of his normal PhD and TA obligations to guide us. For example, he met with us multiple times to help us reason through and implement our ideas for Transports lab. My peers and I were surprised to see that he skipped meals and stayed with us for hours to make sure that we were getting the help we needed. Similarly, for another class project, he stayed up often until 2am or 3am on multiple days to explain to us concepts and to guide us in implementing our projects. I think few chemical engineering students would deny that Bruno has been one of the best TAs we have ever encountered, with regards to his one-on-one instructions, his review sessions, and his support for our well-being.

I strongly support Bruno’s application to the Graduate Student Teaching Award as I really think he has gone beyond his TA obligations in working with the chemical engineering department to provide us with an education that would allow us to succeed after Carnegie Mellon. I believe he deserves this recognition for his work. If you have any further questions, please don’t hesitate to contact me at ss2228@cam.ac.uk.

Sincerely,

Sara Saheb Kashaf
To whom it may concern,

My name is Katia Bazzi, and I graduated with a bachelor's degree in Chemical Engineering from Carnegie Mellon in May 2014. Today, I am a Flow Assurance Engineer at ExxonMobil. Over the many years of my college career, Bruno Calfa has made a major positive impact as a mentor, colleague, and TA through many instances.

In Fall 2012, I asked Bruno if I could shadow his studies as a PhD student so that I could learn about his research. He accepted and served as a phenomenal mentor. While shadowing him, I learned about deterministic and stochastic programming (and their applications with Dow Chemical). He was very patient and taught me a tremendous amount. Throughout college, he stands out as one of the best mentors I've had.

From Fall 2012 to the end of my college career, he played a dominant role in TAing many of my courses. Specifically, he was well known as the “Matlab TA.” Whenever students ran into major bugs or problems with their code, they would email Bruno about it. He always found time in his busy schedule to meet with students one-on-one and teach them how to approach the issues they were experiencing. Personally, I can't think of a TA at CMU that has invested this much time and effort into their students. It was very inspiring.

Lastly, in Fall 2014, I was working on a unit operations final project. There was one point where I ran into a major dead end - I was in the undergraduate lounge on a Sunday and messaged Bruno on gchat. He met with me early Monday morning and spent a great amount of his time showing me best practices on how to approach problems like this.

Overall, I've learned a great deal from Bruno, and I hope he pursues academia further (and becomes a professor!) so that he can inspire more students like myself. Bruno was extremely accessible and supportive. He created a respectful learning environment, and was organized with his formal and informal teaching sessions.

Feel free to contact me if you have any questions about my recommendation.

Best,

Katia Bazzi
katia.bazzi@exxonmobil.com
Dear Committee for Graduate Student Teaching Award,

I am writing this letter of recommendation in support of Bruno Calfa’s nomination for the Graduate Student Teaching Award.

I got to know Bruno as a teaching assistant while taking a class (06-421, Chemical Process Systems Design). In class, he did not only help us with weekly assignments but also guided us for the project final report as the designated TA. Through this experience, I have become familiar with Bruno as a teaching assistant. Accordingly, I am writing this letter because I believe that he is highly qualified to be a recipient of the teaching award.

Bruno was an exceptional TA, for he was always available to us even outside the lectures and office hours. He often communicated with the students via e-mails. In the class, he helped us with assignments by reviewing the concepts covered in lectures and guiding us the directions for the homework. For the final report, he helped us with interpreting the problem statements and specific requirements and provided additional resources. I still remember that on the night before the project deadline, he even stayed in the undergraduate cluster with us, answering last-minute questions. He made us feel that we can always count on his help. However, he did not just tell us what to do and supply the answers. Rather, he made us to think about the problem and guided us to the right direction to reach a solution. He was patient and encouraging TA, who treated us with respect.

In closing, I enthusiastically recommend that Bruno Calfa to be selected as a recipient of the Graduate Student Teaching Award.

Sincerely,

Siwon Choi
Department of Chemical Engineering
Massachusetts Institute of Technology
siwonc@mit.edu
Recommendation Letter 11 (Student, Class of 2016)

February 1, 2015

Dear Members of the Selection Committee:

It is with great pleasure that I write to you in support of the application of Bruno Abreu Calfa for Carnegie Mellon University’s Graduate Student Teaching Award. I am a third-year Chemical Engineering Undergraduate at CMU. I first met Bruno in Spring 2014 during my sophomore year, when he served as the TA for one of my classes, 06-262: Mathematical Methods of Chemical Engineering. Since then I have had the good fortune to have him as TA for a second class, 06-321: Chemical Engineering Thermodynamics, in Fall 2014. Bruno is well-known by the professors and students of the Department of Chemical Engineering for his passion for teaching, his understanding of the learning needs of students, and his activism for incorporating computational software with the Chemical Engineering curriculum. I have never encountered a TA that rivals Bruno in terms of teaching aptitude and character.

Although I only met him in Spring 2014, I have known of Bruno as a resource since Spring 2013, when he served as Math Software TA for the Chemical Engineering department. I first got to know Bruno through the emails he sent out to all Chemical Engineering undergraduates. The first things I noticed from these emails were his friendly demeanor and accessibility. Bruno has always been very approachable. He makes it clear that the undergraduates should feel free to ask questions or schedule a meeting any time. I distinctly remember one occasion where I sent a long email at 10 p.m. with questions about a Math Methods problem set due the next day. Although I had little hope of getting a response in time, Bruno replied promptly and thoroughly. Even after he retired the role of Math Software TA, he encouraged undergraduates to continue to ask him for help if needed. He was happy to serve as an unofficial math software TA. Bruno genuinely enjoys helping students to understand material.

Besides Bruno’s friendliness and accessibility, he is respectful of all students. This was most evident from the review sessions taught by Bruno in Math Methods and Thermodynamics. He never considered any question a dumb question; he took the matter of helping an individual student understand a concept very seriously, even if a student asked a question that they would know the answer to if they had attended class. Beyond his offers of academic help, it was clear that Bruno cared about students’ success. In the middle of what many call the “sophomore slump” in Spring 2014, personally my worst semester academically, my class of Chemical Engineers was taking Fluid Mechanics, Math Methods, and Lab 1 (Analytical Chemistry) simultaneously. It was a stressful semester for most, when many sophomore chemical engineers questioned why they had chosen to major in Chemical Engineering. However, something that struck me about Bruno was his awareness for undergraduates’ struggles. At one point in that semester Bruno sent an email to the class with reminders of campus resources such as CAPS and Academic Development, as well as offering himself as a resource for general guidance. He also encouraged us to attend an event put on by Student Senate, “The First Lectures”, to hear a former student of his that had had similar struggles but who was now very successful. This was a simple gesture – just an email – but one that stuck out to me because it was genuine and at a time when our professors seemed oblivious to the “slump”. While my interactions with Bruno were largely
limited to review sessions, a few lectures, and frequent emails, Bruno was an excellent TA because it was easy to think of him as a peer.

Bruno’s passion for teaching is evident from the immense effort he put in and from his determination to continually improve. Besides his aforementioned effort to be accessible and helpful, it was obvious that he put significant effort into preparing for review sessions and the few lectures he gave us. Bruno made extensive tutorials on how to use MATLAB, Excel, VBA, Aspen – all important software to the Chemical Engineering profession – and compiled them on his website for students to access long after he was no longer TA. In addition to teaching the software functionality, he included coding examples with a Chemical Engineering application. Bruno is well-organized. Every lecture or review session that he taught was complete with a comprehensive PowerPoint presentation or LaTeX’ed notes and key examples that illustrated the most fundamental concepts. It was evident that Bruno wanted to continually improve because he elicited feedback from students after review sessions and lectures. When I consider Bruno in comparison to other TA’s I have had, Bruno demonstrates a unique willingness to go far beyond expectations.

Although many TAs and professors are passionate about teaching, Bruno is exceptional because his teaching methods are very effective. Thermodynamics was a difficult class because the professor derived seemingly five new equations every lecture. It was difficult to synthesize everything because the professor rarely circled back to ensure that we understood the definitions on which everything else was built. However, Bruno gave an excellent review session towards the end of the semester. He boiled down a semester of derivations and concepts into a few fundamental concepts that were important to understand before one could grasp everything else: chemical potential, fugacity, excess properties, and activity coefficients. He offered both a mathematical understanding and a physical interpretation that helped to cement the concepts in my mind. While this seems simple, it is difficult to distill the most important ideas from a textbook and an abundance of lecture notes and present them such that one learns and remembers them; note that this is very different than simply summarizing concepts which we should have already learned. Bruno’s review session enabled me to study effectively for the final and ultimately do well in the course.

Finally, I believe Bruno is deserving of this award due to his enhancement of the chemical engineering curriculum. Software, modeling, optimization, and programming are essential skills to any chemical engineer. However, besides a requirement to take an introductory computer science course, we are hardly formally taught programming and use of mathematical software in a chemical engineering context. Most of this we learn by doing. We are expected to develop a proficiency in these skills through a few projects, but most students are not skilled at using code and software to more efficiently solve problems. Bruno has single-handedly enhanced the chemical engineering curriculum here at CMU by advocating for more instruction in computational software and by providing instruction himself. It is no coincidence that every class for which Bruno is a TA has increased emphasis on mathematical software and coding. Given the university’s international renown for computer science, I think it is very much in the spirit of Carnegie Mellon that Bruno has advocated for increased instruction in mathematical software.
To be succinct, Bruno is an excellent Teaching Assistant. He works hard, loves to teach, and has made significant contributions to the undergraduate Chemical Engineering curriculum. Bruno’s aspirations to be a professor are well-placed; he would be an asset to any university faculty he joined. I strongly recommend him for the Graduate Student Teaching Award, with no reservations. If you have further questions regarding this recommendation, I can be reached via telephone at 941.914.1174 or via email at rmckinne@andrew.cmu.edu.

Sincerely,

Ryan McKinney
Chemical Engineering, Class of 2016
Carnegie Mellon University
To whom it may concern,

I highly recommend Mr. Bruno Calfa as a candidate for the Graduate Student Teaching Award. Bruno was a teaching assistant for my Mathematical Methods of Engineering class and my Thermodynamics II courses. Throughout his tenure, he exhibited professionalism and enthusiasm towards teaching, and possessed skills such as reliability, organization, motivation, and exceptional verbal and communication skills. Mr. Bruno had a wonderful rapport with all of his students and took so many initiatives towards ensuring the students grasped the major concepts.

Despite his busy schedule, Mr. Bruno was readily accessible to answer any questions, whether they involved help with the courses he assisted or MATLAB. He answered every question in a simple and understanding fashion, keeping in mind that students understood concepts at different paces.

During his tenure, Mr. Bruno took several initiatives such as organizing review sessions before exams, additional MATLAB sessions for help with assignments involving MATLAB, and utilizing his broad experience to advise students on internships and various career paths. During the review sessions, he implored the use of assessing and building on prior knowledge, which entailed using knowledge acquired in previous courses, mostly chemical engineering courses, and extending that knowledge to the present course. During office hours, Mr. Bruno implemented the use of problem solving tasks and critical thinking activities, which improved the students’ problem solving skills and how they generally approached questions, especially in Thermodynamics II.

Mr. Bruno had a successful experience in the courses I partook in. He performed his teaching duties in a respectable and organized manner. He was always well prepared for office hours and review sessions, and even impromptu sessions. I was particularly impressed with his strengths in relating to each and every student. He was fair and respectable of every student. In addition, he created an atmosphere that promoted learning and intellectual interactions.

In my opinion, Mr. Bruno is the ideal candidate for the Graduate Student Teaching Award. He has immense initiative, and great enthusiasm towards imparting knowledge. Along with his tremendous grasp of chemical engineering and his effective teaching strategies, Bruno is an exceptional role model for chemical engineers. He encompasses the ideal qualities of the modern day chemical engineer. Mr. Bruno would be the perfect candidate.

Sincerely,

Edna Fongod
January 28, 2015

To Whom It May Concern,

I highly recommend Bruno for the Graduate Student Teaching Award. I had the pleasure of having Bruno as a Matlab TA for Mathematical Methods for Chemical Engineers (Math Methods) during Spring 2014 and a TA for Chemical Engineering Thermodynamics (Thermo II) for Fall 2014.

Early on, it was evident that Bruno really cared about the student learning experience. Before my Math Methods class was assigned a homework problem that dealt with using Matlab, Bruno took the initiative to hold Matlab tutorials in the Chemical Engineering cluster. I found this to be extremely useful because although I had a background in programming, Matlab was a foreign language to me. Bruno’s tutorial was very clear and easy to follow for someone like myself who was new to Matlab syntax.

Not only does Bruno care about the student learning experience, but he also goes above and beyond to ensure that the student understands the material. For instance, a Matlab assignment was due soon for Math Methods and I had no clue as to where to begin. I knew immediately to ask Bruno for help. Even though Bruno was under the weather and could not make it to our meeting, he went the extra mile to meet with me on google hangout, which still gave me the opportunity to speak with him and ask questions. Because I experienced firsthand Bruno’s dedication to the student, it does not surprise me that he was a recipient of the 2012 Mark Dennis Karl Outstanding Graduate Teaching Award. He truly is the quintessence of an outstanding TA.

My experience with Bruno as a TA for Thermo II was just as good, if not better, than my Spring 2014 experience. Not only was Bruno able to help with regular homework questions, he also provided a great amount of assistance with the Matlab portion of the homework assignments even though it was not his specific title. Once the homeworks were graded and returned, he even provided solutions to the homework assignments using Matlab for those who were curious how to solve problems numerically. At the end of the semester, Bruno was kind enough to provide my class with a comprehensible, concise review on topics that my class experienced difficulty with.

Overall, Bruno created a welcoming environment for his students. There was never any hesitation regarding seeking help from him. He always responded to emails with swiftness and continuously made an effort to enhance the learning experience of his students. Again, I recommend Bruno without any reservations and I cannot think of anyone more deserving of this illustrious award.

Sincerely,

Yoyinsola Ibikunle

Yoyinsola Ibikunle
Dear Graduate Student Teaching Award Committee,

If anyone deserves a Graduate Student Teaching Award, it would be Bruno Calfa, as he has been an extraordinary TA here at Carnegie Mellon University. Bruno Abreu Calfa has been the Teaching Assistant for a number of my undergraduate chemical engineering courses in the past two years and I accredit many of my accomplishments in each of these classes to him.

I do not hesitate in stating that Bruno has been most helpful in my conquering a number of chemical engineering concepts, assignments, and even courses. He was the teaching assistant in my very first engineering course- Introduction to Chemical Engineering. Switching from a major in Biology to Chemical Engineering was quite a challenge for me, as I had to catch up in the engineering curriculum, while still taking the courses required for that semester. As a result I struggled in the beginning of Introduction to Chemical Engineering. Of all the TAs in this course, Bruno stuck out in his desire to help the students and his genuine enthusiasm for chemical engineering. I went to him countless of times for help with better understanding course material. Bruno was even willing to meet with me on Friday afternoons and Saturday mornings, just to make assure my understanding of difficult course material- something I will never forget. Because of Bruno, I was able to conquer Introduction to Chemical Engineering and end the course with an A.

A year later, I again had Bruno as a TA for Thermodynamics II. This was one of my most difficult classes to date and Bruno definitely helped in my understanding of the material throughout the semester. He showed mastery of the material during office hours and met with me to aid with homework assignments on the weekend. One time in particular stuck out to me- Even after weeks of travel and being ill, Bruno still came to campus to tutor me in the Thermodynamics material on a Saturday morning. That, to me, displayed an incredible amount of dedication to his students and his love for teaching.

Bruno always put the students’ needs first and does anything to ensure we get the help we need to succeed in class. Bruno has expressed his genuine care for our clear understanding of material by offering numerous review sessions and Matlab tutorials, independent of class expectations. His supplemental help has offered so many of us further explanation to concepts we have struggled with in class.

Without a doubt, Bruno has been the most instrumental and supportive chemical engineering TA for the Carnegie Mellon University chemical engineering class of 2016. His love for teaching and his selfless desire to help others make him an extraordinary teaching assistant and an exceptional being. Because of this, it is quite easy to affirm that if anyone deserves a Graduate Student Teaching Award, it would be Bruno Calfa.

Anthonia Raphael-Chicke  
Carnegie Mellon University c/o 2016  
B.S. Chemical Engineering | Biomedical Engineering

[Signature]

1/3/15
2 February 2015

To Whom It May Concern:

I am writing on behalf of Bruno Abreu Calfa in order to recommend him for the Graduate Student Teaching Award. I have had the pleasure of having Bruno as a teaching assistant for two courses, and I felt that his aid was an invaluable asset to both of the classes. In addition to his office hours, he went above and beyond what was required of his position by offering extra help with MATLAB. Besides this software aid being useful in these courses, MATLAB has been useful in other classes and will continue to be an important tool in future careers. Bruno also went out of his way to organize review sessions for final examinations. These review sessions were always well put together and well thought out. He displayed an incredible amount of insight into the material by condensing the course in such a way that he covered the most important and useful elements. Furthermore, Bruno always remained approachable and created an environment in which it was comfortable to ask for help.

It is also important to note that Bruno has displayed his dedication to teaching through completing programs such as the Future Faculty Program at Carnegie Mellon. His exceptional work as a teaching assistant has previously been recognized through the Mark Dennis Karl Outstanding Teaching Award, which he received in 2012. In my opinion, Bruno is the ideal candidate for the Graduate Student Teaching Award and exhibits all of the qualities necessary to be distinguished with this honor.

Sincerely,

Danielle Maly

Danielle Maly
To whom it may concern,

I am writing this recommendation letter because Bruno Calfa would be an excellent candidate for the graduate student teaching award. Bruno has been a TA in my Introduction to Chemical Engineering, Mathematical Methods of Chemical Engineering, and Chemical Engineering Thermodynamics classes. In that time he has shown a great interest and enthusiasm for the material he teaches as well as an investment in the success of his students.

In every class I have taken where he has acted as the TA he was very accessible and supportive. His office hours were incredibly helpful both with completing assignments and understanding key concepts. He was also more than willing to meet with us outside of his designated office hours if that time did not work for us (even on weekends). Additional if there was no time to meet he was quick about responding to emails.

Regarding learning activities and teaching strategies, Bruno had several very effective ones. He was good at explaining things step by step in an understandable way. Particularly, when it comes to learning how to use new software. He would bring his laptop into class and instruct us to do the same so that we could practice as he showed us how to use a new program. He was instrumental part of my learning of the software that chemical engineers have to use. He was not only well versed in the software; he was good at instructing others in how to properly use it. The review sessions he held before many of our exams where also very effective in helping to figure out what areas I should focus on when studying.

In his individual class sessions Bruno was very organized. Whenever he gave a lecture come in with a very well thought out and organized presentation. These presentations were generally very easy to follow and we usually got through all of the material he was supposed to cover that day.

Overall, Bruno has always been an exemplary TA. He effectively created an environment in which all students felt respected and able to ask questions. He was organized, accessible, supportive and just generally good at teaching. He would be an excellent candidate for the Graduate teaching award.

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Onyenma Enwereji
Carnegie Mellon University class of 2016
B.S. Chemical Engineering | Biomedical Engineering
NSBE Chapter Membership Chair
Booth Chair, Astronomy Club
*** Here is my email recommendation for you : ***

Dear Selection Committee,

My name is Maximilien Vachon and I am a sophomore chemical engineering student at CMU. I had the chance to have Bruno Abreu Calfa as my T.A. for 06-100 Introduction to Chemical Engineering and would like to recommend him for the Graduate Student Teaching Award, which he rightly deserves.

When I started that class during the fall of 2013, I wasn't sure that I wanted to major in Chemical Engineering. At the end of the semester, though, I was hooked and it is in no small part due to Bruno Calfa. He was really an amazing role model of what chemical engineering could lead to. He made great efforts to show students how the principles we learn as chemical engineering students can be applied to a wide variety of fields, from his own field of industrial optimization to climate models and pretty much every product made in the world.

As a TA, he was immensely available and always ready to answer questions whether in person or via email. I recall an instance where I was having difficulties with MATLAB and Bruno Calfa patiently responded in great detail to all of my questions. Even after the fall of 2013, when he was no longer officially my TA, I still turned to Bruno Calfa for advice on which classes to take and how to start a chemical engineering career. Bruno Calfa really does believe that being a teacher is to be a guide and a mentor even after the student has finished the course.

Bruno Calfa was always extremely organized when teaching us and his lectures on MATLAB and global warming modelling were both rigorous and enjoyable to listen to. His approach, as always, was really focused on the student and he was very effective at communicating both his knowledge and his passion.

In light of these experiences and recognizing Bruno Calfa's passionate desire to be connected to his students, I believe he rightly deserves to receive the Graduate Student Teaching Award.

Sincerely,

Maximilien Vachon '17
Dear Graduate Student Teaching Award Committee:

I am writing this letter of recommendation to express my support of Bruno Calfa’s nomination for the Graduate Student Teaching Award. I write this recommendation freely and with the fullest support.

Mr. Calfa was my TA for 06-100: Introduction to Chemical Engineering in the Fall 2013 semester. I was first introduced to him in this position. In that capacity, he taught some lectures during Professor Kris Dahl’s absence and ran several MATLAB lectures during regularly scheduled class time.

Even since that initial introduction and experience, I have gotten to know Mr. Calfa as both a person and in a teaching capacity.

Throughout all my interactions with him and throughout all the time he served as my TA, he always made himself completely available to his students. He did absolutely everything in his power in order to help every single student succeed in any and all capacities that they wished to pursue. Just as an example, he once scheduled extra office hours to assist the students in the class because we were covering an extremely difficult topic that week. This was in addition to the normally scheduled office hours that he had held previously in the week. The fact that he was willing to spend his free time assisting students impressed me as this was going above and beyond the call of his job. He always made himself available to his students in order to help them succeed if they required his assistance.

With regards to his actual teaching style, despite being a doctoral student, Mr. Calfa’s understanding and explanations of the material was on part with the professor of the class. Unlike most TAs, who usually have inferior level of understanding and interpretations of the course material, Mr. Calfa was one of only two TAs whom I have ever had who was able to teach the class at the same level as the assigned professor (the other being Emily Daniels Weiss, who won the Mellon College of Science Hugh D. Young Graduate Student Teaching Award in 2014). If there was one word that I could describe Mr. Calfa’s teaching style, it would be “flexibility”. Whenever a student required a different manner to understand a particular piece of course material, he would make sure to break down the topic in as many different ways as possible and explain it at the most basic level until the student understood it. Mr. Calfa did this both in a one-on-one situation and when he was giving lectures. If he saw, either through body
language of the class or the amount and types of questions asked, that the class was not fully comprehending the material, he would adjust his lesson plans in order to make sure that everyone in the class understood the material. This is just one example of Mr. Calfa’s flexibility in terms of his teaching style, but I believe that this is a great illustration of what made Mr. Calfa such a successful TA. His flexibility with how he approached and explained the material such that any and all of his students fully understood impressed me beyond expression.

I hope the committee considers my recommendation to be of positive accord in Mr. Calfa’s favor as it deliberates whether or not he has earned this award.

If there are any questions, comments, or concerns regarding this recommendation, please do not hesitate to contact me.

Sincerely,

Vikramadhitya Cherupally
vcherupa@andrew.cmu.edu
Campus Relations Committee Chair, Student Dormitory Council
Bachelor of Science, Chemical Engineering, May 2017
3 February 2015

Dear Graduate Student Teaching Award Committee,

The purpose of this letter is to express my support for Bruno Calfa’s nomination for the Graduate Student Teaching Award.

Mr. Calfa was my Teaching Assistant for Introduction to Chemical Engineering in the fall of 2013. In addition to assuming regular TA duties, he also gave several in-class lectures to introduce MATLAB and some of its rudimentary chemical engineering applications to the class.

Although MATLAB was extremely difficult for a lot of the class to grasp, Mr. Calfa worked tirelessly with each student to make sure he or she understood the code, the result, and the concept behind the result. Often, he would host extra office hours to help the students, or even simply meet up whenever a student asked. My understanding of MATLAB grew tremendously under Mr. Calfa’s instruction and it has served me well in many of my classes.

Recitation and office hours with Mr. Calfa were definitely enjoyable and productive. He had a masterful knowledge of the subject and answered the class’ questions clearly and with much explanation. If any one student still did not understand, he would break down the problem in a different way. Mr. Calfa, unlike many other TA’s I have had, has never made me or anyone else feel inferior or unintelligent for having questions. Instead, he encourages questions and creates a relaxed and productive learning environment from which everyone can benefit.

Mr. Calfa’s intelligence, good humor, and patience set him apart from the rest of the TA’s. These traits coupled with the fact that he truly cares about his students, both in their academic and personal lives, is what allows him to connect with and teach his students so well. For all these reasons, I wholeheartedly support Mr. Calfa’s nomination for the Graduate Student Teaching Award.

Sincerely,

[Signature]

Dianna Li
diannal@andrew.cmu.edu
Dear Graduate Student Teaching Award Committee,

My name is John Kitchin, and I am a Full Professor in the Department of Chemical Engineering. I interacted closely with Bruno Calfa when he was the department's MATLAB TA in 2011. Bruno deeply cares about education, which is evident from his accomplishments during his service as a teaching assistant for the department. Below, I will elaborate on these accomplishments.

Bruno helped me implement a new culture in the department by adopting MATLAB as the standard software for scientific and engineering applications. Prior to this, a broad range of approaches ranging from pencil and paper to Matlab, Excel, Mathematica, and Mathcad were being used. This frustrated students, who never achieved substantial skills in any tool, and faculty who could not use sophisticated tools without losing the students. Bruno prepared and delivered a two-part introductory tutorial that was attended by sophomore, junior, and senior students. These tutorials have been used over and over, educating both faculty and students. Now, Matlab is the predominant tool used in the Department.

As part of this transition, I developed a units package for Matlab to aid in engineering calculations. Bruno was instrumental in developing the linear algebra aspects of the units package, as well as parts of the formatting code. For these accomplishments, Bruno was awarded the 2012 Mark Dennis Outstanding Teaching award. This is an award given to one graduate student per year in our department, and competition is always fierce. It was a pleasure to see Bruno win this award. His knowledge of mathematical tools and their applications is on par with many faculty, and his skill in developing and delivering tutorial materials on these topics is among the best I have ever seen. It was a pleasure working with Bruno on this, and it is safe to say I learned a lot from him in the process.

Bruno’s dedication to teaching goes beyond preparing and giving tutorials in mathematical tools. He has provided the faculty with valuable comments about his experience helping students with mathematical methods and computer programming. In particular, he has made suggestions in order to improve how mathematics is used across the curriculum, so that to ensure that it is presented in a logical order. Changing a curriculum is a slow process, but Bruno has seen his suggestions through over the past several years. In addition, Bruno organized a department-wide event about communication skills, in which an industrial speaker visited the campus and gave a talk on building a communication toolset. For undergraduates, this event was approved as an Experiential Learning requirement. No other graduate student in our department has done this before. This points to a significant characteristic of Bruno; not only does he like to learn about new things, he is extremely motivated to share them with others. This is the hallmark of someone destined for great teaching.

I will summarize by noting that Bruno’s accomplishments remind me of some of my own activities as a graduate student and young faculty member. I also organized events for students similar to the ones that Bruno organized. I also developed tutorial materials on math software, and have
pushed the department to integrate math software throughout the curriculum. Bruno is passionate about his work, and in providing the best opportunities for students to learn about engineering. I mention these to motivate a probable trajectory for Bruno in the future that mirrors my own trajectory: a faculty member. Bruno has demonstrated excellence in teaching, excellence in service, and excellence in research. It is clear he is interested in this path, as he has completed the Future Faculty Program at the Eberly Center, and has already begun preparing an impressive teaching portfolio. He will be an excellent colleague for some lucky faculty in the future.

In closing, I give my strongest recommendation for Bruno for the Graduate Student Teaching award. It would be a well-deserved recognition for his teaching achievements and contributions to the department.

Sincerely,

John Kitchin
Dear Committee Members:

I am delighted to provide this letter in strong support of Bruno Calfa, who is considered for a Graduate Student Teaching Award.

I met Bruno in 2009, shortly before he joined Carnegie Mellon University. The very first time that I met him, I asked him about his future plans. I sensed a great deal of excitement and passion in Bruno when he responded that he was planning to have a career in teaching as a university professor. Since then, Bruno has demonstrated careful planning and unparalleled ability towards meeting his goal.

I consider myself fortunate that Bruno was assigned as a Teaching Assistant to two of the courses that I taught at Carnegie Mellon: my Advanced Graduate Topics in Linear Optimization in Fall 2012 and my undergraduate Chemical Engineering Thermodynamics course in Fall 2014. I needed teaching material in both courses and Bruno was kind enough to put it together. I was very much impressed by the speed at which Bruno put together the material as well as the quality of the result. The material for my graduate course consisted of an introduction to programming languages C, C++ and Fortran. I was only interested in the Fortran part and that’s all that I asked for Bruno to prepare. After thinking a bit about the subject, Bruno pointed out that most of our students nowadays come to us with prior experience in C/C++ and have never heard of Fortran. He suggested that would help if Fortran was presented by contrasting it to these two other languages. The material that he presented was a great success for that course. This semester I am teaching a different graduate programming course and, once again, needed material on the same topic. I went back to Bruno’s material and found it has survived the test of time; I used it again. For my undergraduate Thermodynamics course last semester, I found myself teaching a new course for the first time, nearly 30 years after I had last seen this material myself as an undergraduate. I was in desperate need of good teaching assistants. I was fortunate that Bruno was assigned as a TA in my course. Not only did he help me think through the material that I was going to teach but he also prepared single-handedly a series of lectures and computational projects using ASPEN, a process simulator that our students wouldn’t have had the opportunity to be taught about had someone of the quality of Bruno not been assigned to TA for this course. Bruno also took the initiative to offer review lectures. The feedback that I received from students was that ‘he was terrific!’

During Bruno’s tenure in our department, he has become the go-to person for me and several other faculty and students when we need teaching material or ideas on how to prepare such
material. He offered to help teach students software such as MATLAB as well as help strengthen the applied mathematics part of our undergraduate curriculum.

In all my interactions with Bruno, he has impressed me as a deep thinker, fast learner, methodical, and above all, most effective and sincere teacher. Coming from a family of educators myself, I do not hesitate to say that Bruno is one of the most capable educators that I have ever met. He will be an enormously successful teacher. I am pleased to provide Bruno Calfa with my strongest possible recommendation for a Graduate Student Teaching Award.

Truly Yours,

Nick Sahinidis

Nikolaos V. Sahinidis
John E. Swearingen Professor
Recommendation Letter 22 (Associate Professor)

Carnegie Mellon

To whom it may concern:

I am happy to be writing a letter for Bruno Calfa for the graduate student teaching award. Bruno was one of my four teaching assistants for Introduction to Chemical Engineering in the fall of 2013. However, I don’t consider him a teaching assistant; I consider him more of a co-instructor. Bruno was a head teaching assistant. As such, he oversaw the duties of all of the other TAs to organize office hours, develop and carry out laboratory experiments, grade assignments, grade exams, etc.

In addition to his work as a head TA, Bruno was in charge of teaching freshmen how to use Matlab, a sophisticated computational mathematics package. He taught several tutorials while I was traveling as well as specialized presentations of Matlab in context. His lectures included a presentation on climate change and Matlab models of weather patterns. Bruno’s expertise in computational chemical engineering, in addition to his proactive efforts and general enthusiasm allowed the course and the students to excel. Students felt the same way as well:

“Bruno was always prepared for office hours. He didn’t just sit there and wait for us to show up with questions, he was great about putting together useful materials to make the most of the time. He also posted many things on blackboard so that we could work at our own pace. I never would have understood Matlab without him.”

“Bruno’s help with Matlab was great. With his tutorials and help, it allowed us to do work that felt much more sophisticated than what a freshman could do. He helped us perform at a higher level.”

Generally, Bruno is an exceptional educator. His concern for the students was palpable from the very beginning. He wanted the freshmen to get excited about Chemical Engineering, and he wanted to use his experience to put a “face” on the discipline. He talked about his experiences and guided many of the students in their own professional development. He also used every opportunity to improve his own skills, getting feedback from me and from the students. I think his dedication was obvious to everyone involved.

“Bruno is just a super TA. He always went above and beyond in every aspect.”
“I was really impressed that he asked us what we thought of his performance and how he could improve.”

In sum, I could not have asked for a better teaching assistant and educational partner as Bruno Calfa. He is the epitome of what we would want teaching assistants to be: enthusiastic, present, prepared, considerate and willing to utilize his complementary skills to enhance the education of the students. I sincerely hope that you will give him your top consideration for this award. It is rare in engineering – with all of the restrictions on graduate student time from research, travel and mentoring of junior graduate students – that we have teaching assistants that really take the time and energy to make such an impact.

Sincerely,

Kris Noel Dahl
February 4, 2015

Eberly Center for Teaching Excellence and Educational Innovation
125 Cyert Hall
Carnegie Mellon University
Pittsburgh PA 15213

Dear Sir or Madam,

This letter is to strongly recommend Bruno Calfa for the Graduate Student Teaching Award. I have known Bruno for many years as an excellent graduate student in the Chemical Engineering department. My primary interaction with Bruno was in his capacity as the TA tasked with helping students with the numerical computational program MATLAB. Bruno has been the “go-to” MATLAB expert in the department for several years and this service is above and beyond the duties expected of a typical graduate student in the department.

This past Fall, I wanted to develop a set of numerical exercises for the Freshman-level course “Introduction to Chemical Engineering (06-100)” that used MATLAB. There were two primary goals; one was to provide a design experience for the students and the other was to give them some background training in MATLAB as it is the main computational software used in the Chemical Engineering curriculum. This had not been attempted previously as the Intro students have little or no background in the matrix algebra that is the cornerstone of the software. Another challenge was the development of a design project that was sufficiently complex to allow for students’ creativity while remaining tractable for Intro students.

Bruno was a tremendous asset in the implementation of the design project. I met with him on numerous occasions to refine the problem statement and to set lectures that would give students the background needed to be successful. On his own time, Bruno tested various design solutions and drew up lecture material for the class. He also delivered four lectures to the class during recitation hours focused on use of matrix math, implemented in MATLAB, to solve systems of linear and non-linear equations. I of course attended these lectures and I was very impressed by his level of preparation and calm, confident lecture style. One very effective technique he incorporated into the lectures was the use of short quizzes to check how the students were following along. He would also follow up with revised material in later lectures based on students’ responses. The project went
very well for the students and most if not all of them were able to formulate and solve material balance problems using MATLAB by the conclusion of the project.

As described in his application, Bruno has won our department’s Mark Denis Karl Award for the top TA in the class. We have many outstanding TA’s in our department and I consider this to be a great honor. He has also been very responsive to student inquiries regarding MATLAB in other courses I have taught, notably the “Chemical Reaction Engineering” course (06-364). These inquiries can often be frustrating as students may ask to debug code rather than pose a specific question. Bruno was patient and thorough throughout.

Bruno Calfa is a gifted teacher that has gone well beyond what is expected of our TAs and is in my opinion the best TA we have had in the department in my 15 years at Carnegie Mellon. I understand that he is interested in pursuing a faculty position and this award would certainly strengthen his case. I recommend him for this award in the strongest possible terms.

Sincerely,

[Signature]

James W. Schneider
Professor, Chemical Engineering
Carnegie Mellon University
29 January 2015

Selection Committee
Graduate Student Teaching Award

Re: Recommendation Letter for Bruno Calfa

Dear Committee Members,

It is my pleasure to write in support of Bruno Calfa’s application for the Graduate Student Teaching Award. Bruno was one of two TAs for the class 06-262 Mathematical Methods of Chemical Engineering that I taught in Spring 2014, which had around 70 students. He did a spectacular job that went way beyond the usual responsibilities of a TA. For instance, Bruno initiated and taught two general Matlab tutorials at the beginning of the course, which were very well received by the students. He continued throughout the semester with further Matlab sessions on specific topics covered in homework, using materials that he prepared by himself. I plan to use those materials in the 06-262 class that I am teaching currently, which speaks to the long-term impact of Bruno’s efforts will have on this course. Bruno also gave lectures on the one or two occasions that I was out of town, which, again, were very well received by the students. Finally, Bruno made up his own summary of the course to help students prepare for their final exam. Bruno has all the qualities of a fantastic teacher and I recommend him in the highest possible terms for the Graduate Student Teaching Award. Contact me if you require further information.

Sincerely,

Dr. Aditya S. Khair
Assistant Professor of Chemical Engineering
Carnegie Mellon University
Teaching Philosophy

I strongly believe that the main role of an educator is to leverage students for their own success. An educator is a facilitator of learning, i.e., a person that helps students understand easy and difficult fundamental concepts that can be ultimately used to impact the world. Every discipline teems with important topics to be covered. However, to cope with the limited time in an academic term, I prepare teaching materials and lectures by carefully selecting relevant and indispensable topics that give the students the necessary basis to learn more challenging topics on their own in the future.

The different teaching styles and effectiveness among my professors have been instrumental in shaping my views on education. They form the basis of my teaching philosophy, which is to prepare students for the real world by taking two concrete actions:

1. effectively teach the fundamentals so that students can successfully use them to acquire more advanced knowledge in the future (life-long learning), and

2. assess the students’ progress by assigning homework and projects that require both individual and group work plus in-class presentations (communication skills).

When I teach, I experience personal joy and satisfaction from helping someone understand something I also understand. In addition to that main driver, I have realized that teaching is also a learning experience for me since each student has an individual approach to processing the material, which requires flexibility from the instructor’s part.

From a practical viewpoint, I believe that educators equip students with fundamental, yet incomplete knowledge about the world, and that constitutes their toolbox. From personal experience, students in general may not have the necessary maturity to comprehend this fact until after they graduate. Once they graduate, they will be able to use the tools and skills from their toolbox to help them tackle real-world problems. A key aspect to this toolbox is that students will know where to look for information when confronted with problems, and motivate them to keep always learning. For instance, when teaching concepts in Thermodynamics, such as fugacity and activity coefficients, I find it very useful for the students to not only present the mathematical definitions from a textbook, but I also make them aware of other sources of a different nature, such as handbooks and Internet sites. In addition, I also make use of practical examples related to chemical engineering applications where the concepts arise. This also gives me the opportunity to demonstrate how software tools (both general-purpose, such as MATLAB and Excel, and specialized process simulators) can be used to perform the required calculations in a professional setting.

In order to provide students with the tools and opportunities to hone their skills during classroom encounters, I have adopted the following student evaluation strategy. Students practice the concepts learned in class through homework assignments, and after enough content has been covered during the term I assign a group project. Students are expected to work in teams, divide up the tasks, and then present their work in front of the class, and possibly to an external audience, including professors and practitioners. All aspects of the group project bring students closer to real-world situations in which they will have to make decisions as a team to achieve a common goal. For example, the project guidelines I developed for a sample course syllabus concern flash calculations. The guidelines suggest three steps to
approach the problem: (1) data collection, (2) modeling and computer implementation, and (3) report writing and oral presentation. In all those steps, students are expected to divide up the tasks and at the same time be familiar with the overall work.

With regards to evaluating my teaching effectiveness, I ask students to do two feedback evaluations, one in the middle and another one at the end of the term. The advantage of having two evaluations during the term is illustrated with the following actual personal experience. The professor in the course 06-262 did a mid-term evaluation, and the students requested for more examples and MATLAB practice in class. As a teaching assistant and having to give a guest lecture a few days after the mid-term evaluation, I prepared two numerical exercises in addition to the lecture notes I had to cover provided by the professor. I gave the students five minutes to solve one of the exercises in class and on their own, and I demonstrated how to use MATLAB to solve the other exercise. Another self-evaluation tactic I use in every class is gauging the students’ understanding of the material by reviewing in the beginning of a class what was discussed in the previous class, and asking questions about what I just covered to check if students successfully follow the lecture.

As an educator, I will prepare students to tackle real-world problems by making use of assignments, such as homework and projects, that require both individual and team effort to achieve satisfactory results in communicating their work. Moreover, I would like to be able to take students on technical field trips. I find it to be very pedagogically beneficial for the students to see the concepts covered in class being applied in practice. They may inspire students even more about Chemical Engineering and, perhaps, significantly influence their professional careers. Lastly, I am interested in teaching all the courses I have served as a teaching assistant plus undergraduate special-topics or graduate-level courses related to computer programming and mathematical optimization.
Bruno Abreu Calfa

Education

2010–Present
Ph.D. Candidate in Chemical Engineering, Carnegie Mellon University, Pittsburgh, PA.

2004–2009
B.Sc. in Chemical Engineering, Pontifical Catholic University of Rio de Janeiro, Rio de Janeiro, Brazil.
Final-Year Project: Chemical Processes Data Treatment Through Data Reconciliation and Parameter Estimation

Professional Experience

2014
Summer Internship at The Dow Chemical Company, Midland, MI, USA.
Advanced Analytics group. Data mining and modeling to integrate historical and forecast data in the development of plausible planning scenarios.

2013
Summer Internship at The Dow Chemical Company, Midland, MI, USA.
R&D and Supply Chain intern in the Process Optimization group. Developed scenario tree generation methods that incorporate historical and forecast data.

Academic Experience

2007–2008
Exchange Undergraduate Student (EAP), University of California at Berkeley, CA, USA.
Took Upper Level courses in Chemical Engineering, Nuclear Engineering, Corrosion, and MATLAB Programming from Fall 2007 to Spring 2008.

2004–2007
Scientific Project Scholarship: Use of Biomass in Biosorption/Flotation Combined Process for Heavy Metals Removal, Pontificical Catholic University of Rio Janeiro, Brazil.
Project funded by CNPq (National Council for Scientific and Technological Development).

Awards

2012
Mark Dennis Karl Outstanding Graduate Teaching Award, Pittsburgh, PA, Carnegie Mellon University, Award given by the Department of Chemical Engineering at CMU to a student judged by the faculty to have done an outstanding job as a teaching assistant.

2009
Chemical Engineering Learning Incentive in Brazil Award, São Paulo, Brazil, Brazilian Association of Chemical Engineering (ABEQ in Portuguese), Award bestowed by PETROBRAS and ABEQ for the best student in Chemical Engineering of the Pontifical Catholic University of Rio de Janeiro in 2009.
Teaching Assistant Experience

- Chemical Engineering Thermodynamics, Fall 2014
- Mathematical Methods of Chemical Engineering, Spring 2014
- Introduction to Chemical Engineering, Fall 2013
- MS Excel and VBA Tutorials, Spring 2012
- MATLAB Tutorials, Fall 2011
- Chemical Engineering Process Control, Spring 2011
- Chemical Process Systems Design, Fall 2010

Computer Skills

- **Languages**: C, C++, Java, Fortran, VBA, C#, Python, R
- **Packages**: MATLAB, Maple, Mathematica
- **Platforms**: UNIX, Windows
- **Databases**: MS Access, MS SQL Server
- **Software**: AIMMS, GAMS, Aspen Plus, MS Word, MS Excel, MS PowerPoint

Community Service

2009 **Mathematics, Physics, and Chemistry Tutoring to Underprivileged Children, Rio de Janeiro, Brazil**, Center for Study and Action on Minors (NEAM, in Portuguese) at PUC-Rio, Taught middle- and high-school students from Rocinha and other favelas.

Languages

- **Portuguese**: Native
  *My mother language.*
- **English**: Fluent
  *Speaking, reading, and writing.*

Conference Presentations

2014 **2014 AIChE Annual Meeting**, *Atlanta Marriott Marquis and Hilton Atlanta, Atlanta, GA.*
Talk: Data-Driven Individual and Joint Chance-Constrained Optimization via Kernel Density Estimation.

Invited Talk: Data-Driven Individual and Joint Chance-Constrained Optimization via Kernel Density Estimation.

2013 **2013 AIChE Annual Meeting**, *Hilton San Francisco and Parc 55 Wyndham San Francisco – Union Square, San Francisco, CA.*
Talk: Multi-stage Scenario Tree Generation via Statistical Property Matching.

2013 **2013 INFORMS Annual Meeting**, *Minneapolis Convention Center, Minneapolis, MN.*
Invited Talk: Multi-stage Scenario Tree Generation via Statistical Property Matching.

2012 **2012 AIChE Annual Meeting**, *David L. Lawrence Convention Center, Pittsburgh, PA.*
Talk: Hybrid Bilevel-Lagrangian Decomposition Scheme for the Integration of Planning and Scheduling of a Network of Batch Plants.
2005  5th Scientific Initiation National Congress (V CONIC), UNIMONTE, Santos, SP, Brazil.

Publications


Teaching Responsibilities

The courses I served as a TA, my teaching responsibilities, and additional materials I prepared are listed below in chronological order:

- **06-421: Chemical Process Systems Design**
  - **Semester:** Fall 2010
  - **Responsibilities:**
    * Grade some of the assignments (rotation with other TAs);
    * Hold weekly office hours;
    * Grade the third memo (topic: Process Economic Evaluation);
    * Supervise three groups of 3-4 students in their process design project assignments (weekly or biweekly meetings).
  - **Additional Activities and Materials:**
    * Prepared handout on process economic evaluation;
    * Gave review lecture on process economic evaluation.

- **06-362: Chemical Engineering Process Control**
  - **Semester:** Spring 2011
  - **Responsibilities:**
    * Grade some of the assignments (rotation with other TAs);
    * Hold weekly office hours;
    * Supervise two groups of 4-5 students in a project involving laboratory experiments, and provide additional MATLAB and Simulink consulting.
  - **Additional Activities and Materials:**
    * Prepared and executed MATLAB and Simulink tutorials.

- **Math Software TA**
  - **Semesters:** Fall 2011, Spring 2012, Spring 2013
  - **Responsibilities:**
    * Provide help to students regarding computing;
    * Hold office hours;
    * Give software tutorials if requested by professors (e.g., involvement in a series of MATLAB tutorials as per the department’s decision to adopt it as the main computing software package, which was led by Prof. John Kitchin).
  - **Additional Activities and Materials:**
    * Prepared and executed tutorials on Microsoft Excel and Visual Basic for Applications (VBA);
* Developed and demonstrated in class a graphical tool in MATLAB for the McCabe-Thiele method for phase equilibria (06-361 Unit Operations of Chemical Engineering). Students were required to use the tool in homework assignments.

- **06-100: Introduction to Chemical Engineering**
  - **Semester:** Fall 2013
  - **Responsibilities:**
    * Hold weekly office hours;
    * Develop computational assignment and multiple-choice exam questions, and their solutions;
    * Give two guest lectures on air quality and climate change, prepare assignment and multiple-choice exam questions, and their solutions.

  - **Additional Activities and Materials:**
    * Gave a “Welcome to ChemE” presentation in the first week of class that included a brief history of the field, videos of chemical processes, high-level overview of the curriculum, and applications of chemical engineering;
    * Prepared introductory handouts and executed tutorials on MATLAB.

- **06-262: Mathematical Methods of Chemical Engineering**
  - **Semester:** Spring 2014
  - **Responsibilities:**
    * Grade some of the assignments (rotation with other TAs);
    * Hold weekly office hours;
    * Give a guest lecture on higher-order ordinary differential equations;
    * Give MATLAB tutorials that were focused on the topics covered in the course.

  - **Additional Activities and Materials:**
    * Prepared complementary slides on Newton’s method and its implementation in MATLAB;
    * Prepared and executed review lecture for the final exam.

- **06-321: Chemical Engineering Thermodynamics**
  - **Semester:** Fall 2014
  - **Responsibilities:**
    * Grade some of the assignments (rotation with other TAs);
    * Hold weekly office hours;
    * Give an introduction Aspen Plus process simulator.

  - **Additional Activities and Materials:**
* Prepared and executed tutorials as well as homework assignment and solutions on Aspen Plus;
* Prepared and executed review lecture for the final exam.

In addition to the teaching responsibilities and activities listed above, I was also invited by professors in different semesters to hold tutorials on MATLAB (06-100 Introduction to Chemical Engineering and 06-623 Mathematical Modeling of Chemical Engineering Processes), MathCAD (06-221 Thermodynamics), and programming in C/C++ and Fortran (06-815 Advanced Topics in Linear Optimization), whose materials I prepared and made available to the students. All additional materials can be retrieved from my personal website: http://bacalfa.com/TA/ExtraMaterial/TAExtraMaterial.html.

Supporting Materials

This package contains a sample of the following supporting materials:

- MS Excel and VBA Tutorial (Appendix A). One of the three modules offered to undergraduate students in all years.

- Climate Change Guest Lectures (Appendix B). Two-part lecture materials taught in a freshman class.

- Review Lecture (Appendix C). Slides from a review lecture for 06-321 Chemical Engineering Thermodynamics.

Also, my Teaching Portfolio can be retrieved from the following address: http://bacalfa.com/CalfaBA-TeachingPortfolio.pdf.
Appendix A  MS Excel and VBA Tutorial: Spring 2012

This appendix contains one module of a three-part tutorial on Microsoft (MS) Excel and Visual Basic for Applications (VBA) that I prepared and presented to undergraduate students that ranged from sophomores to seniors. The three-part tutorial was held in six days, each with one-hour-and-half sessions at a computing laboratory in Baker Hall. The main motivation behind organizing this tutorial is the fact that MS Excel is ubiquitous in both industry and academia, and VBA extends its functionality to a great extent by allowing the user to create procedures and functions through programming. The website for the tutorial is available at http://bacalfa.com/TA/Excel_VBA/ExcelVBA.html.

For brevity, only the handout version of the slides presented is shown in the following pages. The supporting material contains module “3. Programming with VBA”, which assumes no prior knowledge of VBA and programming with macros—pieces of VBA code—in MS Excel. I reserved three days for Module 3 because it requires the introduction of a programming language that has a few significant differences from programming languages students may have learned before (e.g., MATLAB, Python). In the first lecture of Module 3, I mentioned to students many examples of applications in which VBA could be very useful to them (e.g., automating calculations and operations in MS Excel, calling external programs, such as MATLAB and process simulators, retrieving data from databases etc.). And interestingly, I personally experienced all those examples of applications in my two industrial internships.

I carried out the tutorial in a similar manner as the MATLAB tutorials that had been observed by colleagues at the Eberly Center for Teaching Excellence at CMU. I delivered Module 3 (and the two other modules) by alternating between slides and MS Excel in order to provide a live demonstration of the concepts. Before delving into VBA syntax, I taught students how to record macros, because it shows the automatically generated code from the user’s actions, and it naturally leads to the code editor (where the user writes VBA programs). I remember that the students had the same reaction of surprise as I had when I first did that myself; Excel automatically generated code for each action I took from the moment I started recording the macro until I stopped it. I told students this feature actually comes in handy when they are not sure how to code a certain operation in VBA. Throughout the tutorial, I gave students time to try out on their computers what I demonstrated on the screen. I also gave several good programming practices in VBA and in general. I finished the tutorial with a practical example in chemical engineering that involves calling MATLAB as an external program to perform calculations, and then reading back the results in VBA to be displayed in a spreadsheet.
MS Excel and VBA
Module 3: Visual Basic for Applications (VBA)
Bruno Abreu Calfa
Last Update: April 4, 2012

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1 Motivation
Why VBA?
• Visual Basic for Applications (VBA) is a programming language available in some of the MS Office packages
• VBA enables building user-defined functions, automating processes, and accessing Windows API and other low-level functionality through dynamic-link libraries (DLLs)
• The reason to program with VBA is to make some task easier or more reliable
• Programming languages make things easier because they are great at performing repetitive operations and following a logical path without getting tired or bored
• They make things more reliable because they slavishly follow your directions and never, ever get creative.

2 Recording Macros
Getting Started
• Macros are pieces of VBA code
• Be sure to enable the ‘Developer’ tab in the ribbon
• Go to: File → Options → Customize Ribbon and select the Developer tab

Automatic VBA Code Generation
• One of the ways of learning how to perform certain tasks in VBA is to “record a macro”
• After you are done recording it, you can see what commands correspond to your actions
• From the Developer tab, click on Record Macro (you can customize its name if you want) and hit OK
• Do some tasks and then click on Stop Recording
• To run/edit the macro, click on Macros and click on the respective button
• See file VBA_Examples.xlsm, worksheet “Recording”

3 VBA Programming: Basics
Definitions and Terminology (I)
• Code: You perform actions in VBA by executing VBA code. You write (or record) VBA code, which is stored in a VBA module.
• Module: VBA modules are stored in an Excel workbook file, but you view or edit a module by using the Visual Basic Editor (VBE). A VBA module consists of procedures.
• Procedures: A procedure is basically a unit of computer code that performs some action. VBA supports two types of procedures: Sub procedures and Function procedures.
Definitions and Terminology (II)
• **Objects:** VBA manipulates objects contained in its host application (Excel in this case). Examples of objects include a workbook, a worksheet, a range on a worksheet, a chart, and a shape.

• **Collections:** Like objects form a collection. For example, the Worksheets collection consists of all the worksheets in a particular workbook.

• **Object Hierarchy:** When you refer to a contained or member object, you specify its position in the object hierarchy by using a period (also known as a dot) as a separator between the container and the member. Example (all in one line):

  `Application.Workbooks("Book1.xlsx").Worksheets("Sheet1").Range("A1")`

Visual Basic Editor (VBE)
• To access the VBE, click on **Visual Basic** from the Developer tab or use the keyboard shortcut **ALT + F11**

• To insert a new **Module**, go to: **Insert → Module**

• **Project Explorer Window:** Displays a tree diagram that consists of every workbook that is currently open in Excel (including add-ins and hidden workbooks). Each workbook is known as a **project**.

• **Code Window:** Contains VBA code

• **Properties Window:** Allows you to change the properties of the item that is selected in the Project Explorer Window. To view it, go to **View → Properties Window** or hit **F4**.

Data Types
• Some of VBA’s data types: **Integer**, **Double** (double-precision real numbers), **String**, **Variant**

• The **Variant** data type can store any type of objects

• By default, if you don’t declare the type of a variable it will be **Variant**

• Good programming practice: use the **Option Explicit** statement to enforce the declaration of the variables types

• Use the keyword **Dim** to declare variables, for example:

  ```vba
  Dim x As Double, y As Single
  ```

Operators
• Operators and their precedence

<table>
<thead>
<tr>
<th>Operator</th>
<th>Operation</th>
<th>Order of Precedence</th>
</tr>
</thead>
<tbody>
<tr>
<td>- , + , / , * , ^</td>
<td>Unary operators</td>
<td>1</td>
</tr>
<tr>
<td>- , , and , or</td>
<td>Multiplication and division</td>
<td>2</td>
</tr>
<tr>
<td>+ , -</td>
<td>Addition and subtraction</td>
<td>3</td>
</tr>
<tr>
<td>= , &gt; , &lt; , &gt;= , &lt;=</td>
<td>Comparison</td>
<td>4</td>
</tr>
<tr>
<td>, , : , , , ,</td>
<td>Concatenation</td>
<td>5</td>
</tr>
</tbody>
</table>

• Use parentheses to enforce precedence, for example:

  ```vba
  x = 4 + 3 * 2
  y = (4 + 3) * 2
  ```

Logical Operators
• VBA’s logical operators are:

<table>
<thead>
<tr>
<th>Operator</th>
<th>What It Does</th>
</tr>
</thead>
<tbody>
<tr>
<td>And</td>
<td>Performs logical negation on an expression.</td>
</tr>
<tr>
<td>Or</td>
<td>Performs a logical disjunction on two expressions.</td>
</tr>
<tr>
<td>Not</td>
<td>Performs a logical conjunction on two expressions.</td>
</tr>
</tbody>
</table>

• For example, the following statement displays **True** when either Sheet1 or Sheet2 is the active sheet:

  ```vba
  MsgBox ActiveSheet.Name = "Sheet1" Or ActiveSheet.Name = "Sheet2"
  ```

Procedures: **Sub and Function**
• **Sub:** Consists of a series of statements and can be executed in a number of ways. Example of a **Sub** called **Test** that displays the string “Hello, world!” in a message box:

  ```vba
  Sub Test()
  MsgBox "Hello, world!"
  End Sub
  ```

To run it, click on the “play” button in the VBE toolbar or hit **F5**

• **Function:** Returns a single value (or possibly an array) and can be called from another VBA procedure or used in a worksheet formula. Example of a **Function** named **AddTwo**:

  ```vba
  Function AddTwo(arg1, arg2) As Double
  AddTwo = arg1 + arg2
  End Function
  ```

Complete Function Definition
• Explicitly define the arguments types and the return type

• Use the keywords **ByVal** and **ByRef** allow you to send arguments “by value” and “by reference” (default), respectively

• **ByVal** means that only the value of the argument is passed to the procedure

• **ByRef** means that the reference or pointer to the argument is passed to the procedure, and any local changes will affect the passed object. For example (try adding **ByVal** before the argument **a**):

  ```vba
  Option Explicit
  Sub Main()
  Dim x As Double, a As Double
  a = 1
  b = MyFunc(a) ' b receives the output of MyFunc and a is modified
  End Sub
  Function MyFunc(x As Double) As Double
  MyFunc = 2 * x
  x = x + 1
  End Function
  ```
Declaring Arrays
- An array of integers with 100 elements is declared as follows:
  ```vba
  Dim a(1 To 100) as Integer
  ```

  Where 1 is the lower index and 100 is the upper index.
- If you define the array with only the upper index, the lower index is 0 by default, so the following declarations have the same effect:
  ```vba
  Dim b(0 To 100) as Integer
  Dim c(100) as Integer
  ```

- Multidimensional arrays follow the same ideas:
  ```vba
  Dim d(1 To 10, 1 To 10) as Integer
  ```

Dynamic Arrays
- Useful when the size of the array is unknown a priori.
  ```vba
  Dim a() as Double
  ```

  Suppose the integer variable n contains the size, you can do:
  ```vba
  ReDim a(1 To n) ' Destroys array's values if existent
  ```

  Or
  ```vba
  ReDim Preserve a(1 To n) ' Keeps array's values if existent
  ```

4 Manipulating Objects and Collections
With-End With Constructs
- Enables you to perform multiple operations on a single object.
- For example, in the following code we avoided repeating `Selection.Font` in all statements:
  ```vba
  Sub ChangeFont()
      With Selection.Font
          .Name = "Cambria"
          .Bold = True
          .Italic = True
          .Size = 12
          .Underline = x1UnderlineStyleSingle
          .ThemeColor = x1ThemeColorAccent1
      End With
  End Sub
  ```

For Each-Next Constructs
- Enables you to iterate through all objects in a collection and perform some action on them.
- For example, in the following code the `MsgBox` function displays each worksheet's `Name` property:
  ```vba
  Sub CountSheets()
      Dim Item as Worksheet
      For Each Item In Worksheets
          MsgBox Item.Name
      Next Item
      End Sub
  ```

5 Controlling Code Execution
If-Then Constructs
- Used to execute one or more statements conditionally.
- For example, in the following code the `MsgBox` function displays a greeting message according to the time you execute the `Sub`:
  ```vba
  Sub GreetMe()
      If Time < 0.5 Then
          MsgBox "Good Morning"
      ElseIf Time >= 0.5 And Time < 0.75 Then
          MsgBox "Good Afternoon"
      Else
          MsgBox "Good Evening"
      End If
  End Sub
  ```

- The `ElseIf` and `Else` blocks are optional.

Select Case Constructs
- Useful for choosing among three or more options.
- For example, another way of coding the `Sub GreetMe()`:
  ```vba
  Sub GreetMe2()
      Dim Msg As String
      Select Case Time
          Case Is < 0.5
              Msg = "Good Morning"
          Case 0.5 To 0.75
              Msg = "Good Afternoon"
          Case Else
              Msg = "Good Evening"
      End Select
      MsgBox Msg
  End Sub
  ```
6 Looping Blocks of Instructions

For-Next Loops

- For example, calculate the sum of the square roots of the first 100 positive integers:

```vba
Sub SumSquareRoots()
    Dim Sum As Double
    Dim Count As Integer
    Sum = 0
    For Count = 1 To 100 Step 1
        Sum = Sum + Sqr(Count)
    Next Count
    MsgBox Sum
End Sub
```

- The `Step 1` is optional. You can use `Step -1` to loop "backward"

Do-While Loops

- For example, open a text file in the current directory and display its contents line-by-line:

```vba
Sub DoWhileFile()
    Dim LineOfText As String
    Open ThisWorkbook.Path & "\file.txt" For Input As #1
    Do While Not EOF(1)
        Line Input #1, LineOfText
        MsgBox LineOfText
    Loop
    Close #1
End Sub
```

- There are also Do Until loops

7 Working with Spreadsheets

7.1 Working with Ranges

Ranges: Basics

- A Range may be a single Cell or a collection of Cells
- Refer to cells in the same way you would do on a spreadsheet, i.e. the cell “A1” can be referred to as `Range("A1")` in VBA
- One of the most useful properties of a Range is its `Value`
- For example, the statement `Range("A1").Value = 1` will set the content of cell A1 in the active workbook and worksheet to 1

Copying and Moving Ranges

- We can make use of an `object variable` that represents an entire object, such as a range, a worksheet etc.
- To create an object variable, use the keyword `Set` after declaring the variable with `Dim`
- The following example copies a range of cells to another location:

```vba
Sub CopyRange()
    Dim Rng1 As Range, Rng2 As Range
    Set Rng1 = Worksheets("Ranges").Range("A1:A3")
    Set Rng2 = Worksheets("Ranges").Range("B1")
    Rng1.Copy Rng2
End Sub
```

- Similarly, the method `Cut` moves a range to another location

7.2 Working with Cells

Cells: Basics

- Cells objects are useful when reading/writing consecutive cells from/to a worksheet in a loop block
- The equivalent to `Range("A1")` is `Cells(1, 1)`
- Likewise for `Range` objects, use the `Cells` property `Value` to read and write values
- You can refer to cells relative to other cells by using the `Offset` property. For instance, `Cells(1, 1).Offset(2, 3)` refers to range D3.

Writing Values to Cells Iteratively

- The next code shows how to read integer numbers from a file and write them in the first column of a given worksheet:

```vba
Sub WriteDataToCells()
    Dim count As Integer, number As Integer
    Dim sheetName As String
    sheetName = "Cells"
    count = 1
    Open ThisWorkbook.Path & "\file.txt" For Input As #1
    Do While Not EOF(1)
        Input #1, number
        Worksheets(sheetName).Cells(count, 1).Value = number
        count = count + 1
    Loop
    Close #1
End Sub
```

- For-Next loops are also useful when reading/writing from/to worksheet cells
8 Applications

8.1 Calling MATLAB from VBA

Setup and Getting Help

- You can easily call MATLAB functions from VBA
- First, add the MATLAB reference in: Tools → References... → select “Matlab Application” and hit OK
- There is some documentation with examples in MATLAB’s Help (search for “Visual Basic”)
- Basic steps:
  - Create a “MATLAB object” (VBA function: CreateObject)
  - Put data in MATLAB’s workspace (VBA functions: PutFullMatrix, Execute)
  - Execute some routine, e.g. solving ODEs (VBA function: Execute)
  - Get data from MATLAB’s workspace (VBA functions: GetVariable, GetFullMatrix, Execute)

Example: Volume of a PFR

- The volume of a Plug Flow Reactor (PFR) is calculated by the following expression:
  \[ V = F_{A0} \int X \frac{dX}{r_A(X)} \]

  where \( V \) is the reactor volume, \( F_{A0} \) is the inlet molar flow of the limiting reactant A, \( X \) is the reaction conversion, \( r_A(X) \) is the reaction rate
- The value of \( F_{A0} \) and a table with \( r_A \) versus \( X \) data are given
- To compute \( V \), we need to numerically integrate the data
- You can call MATLAB’s trapz function to perform the integral and then retrieve the result to the worksheet
- See file VBA_Examples.xlsm, worksheet “MATLAB Example”
Appendix B  Guest Lectures on Climate Change: Fall 2013

This appendix contains the slides I prepared under the supervision of a subject-matter expert on climate change (Prof. Neil Donahue), and used during two lectures in the Introduction to Chemical Engineering freshman course. The two guest lectures were observed by colleagues at the Eberly Center at CMU, and were held in two days, each with fifty-minute long sessions. In addition to the slides, I also prepared two homework questions with solutions (not included), in which students were asked to perform basic calculations and use of MATLAB to practice the concepts discussed in the two lectures. I gave the lectures in two days, and each lecture lasted for fifty minutes.

The first set of slides (Part I) contains several graphics to illustrate the effects of greenhouse gases in the climate. The visuals also served the purpose of illustrating key concepts in climatology. In addition to pointing students to official websites about climate change, I made use of readily available online video clips to complement the material in the slides. The second set of slides (Part II) contains more of the mechanics of problem-solving in the context of climate change. It makes connections with topics covered in the course, such as concentrations, proportions, and the Ideal Gas Law. In addition, I explained how MATLAB can be used to solve the numerical examples in the slides.
06-100: Introduction to Chemical Engineering

Climate and CO₂ - Part I

September 23rd, 2013

Bruno Calfa
Prof. Kris Dahl

Outline

• Introduction to Climate Change
  – Definitions
  – Primary cause
  – Radiative Balance

• [CO₂] and Earth’s Temperature

• Anthropogenic CO₂ Emissions
  – Fossil Fuel Combustion
Global Warming and Climate Change

- Increase in average global temperatures
- Primary cause: greenhouse gases (GHGs)
- GHGs absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth’s surface, the atmosphere itself, and by clouds
- GHGs include primarily
  - Water Vapor (H₂O)
  - Carbon Dioxide (CO₂)
  - Nitrous Oxide (N₂O)
  - Methane (CH₄)
  - Ozone (O₃)
  - Fluorinated industrial gases (hydrofluorocarbons, HFCs, perfluorocarbons, PFCs, and sulphur hexafluoride, SF₆)

Relevant source: Intergovernmental Panel on Climate Change (http://www.ipcc.ch/)

Greenhouse Effect

- Atmospheric GHGs absorb radiation from planetary surface
- Re-radiation of absorbed radiation in all directions
- Warms the surface temperature, otherwise it would be too cold
- It is a natural phenomenon
Radiative Balance: 1\textsuperscript{st} Approximation

- Perfectly absorbing Earth
- Surface temperature: $T_s = 279 \, \text{K} = 5.85 \, ^\circ\text{C} = 42.5 \, ^\circ\text{F}$

Radiative Balance: 2\textsuperscript{nd} Approximation

- Part of solar radiation is reflected (mostly by clouds) $\Rightarrow$ albedo
- Surface temperature: $T_s = 255 \, \text{K} = -18.2 \, ^\circ\text{C} = -0.67 \, ^\circ\text{F}$

Values in W m\textsuperscript{-2}. Figure kindly provided by Prof. Neil Donahue.
Radiative Balance: 3rd Approximation

- Optical depth level 1 => radiates to space
- Surface temperature depends on the height of that level (air compression)
- $T_s = 284 \, K = 10.9 \, ^\circ C = 51.5 \, ^\circ F$

Values in W m$^{-2}$. Figure kindly provided by Prof. Neil Donahue.
**CO₂ and Earth’s Temperature**

- **Glacial Period**
  - Colder temperatures and glacier advances

- **Interglacial Period**
  - Warmer temperatures and between glacial periods

- **CO₂ presence**
  - 280 ppmv = interglacial period
  - 180 ppmv = glacial period

- Ice coring: [http://www.youtube.com/watch?v=oHzADl#XID8](http://www.youtube.com/watch?v=oHzADl#XID8)


---

**Rising Temperatures**

- Video from NASA’s Goddard Institute for Space Studies (GISS)

- As GHG emissions from energy production, industry and vehicles have increased, temperatures have climbed, most notably since the late 1970s

- Climate scientists use the concept of **radiative forcing**: 
  \[ \Delta F = \text{radiant energy received by Earth} - \text{energy radiated back to space} \]

- Main factors in radiative forcing
  - **Solar forcing**, which is exacerbated by a decrease in **albedo**
  - **Forcing due to atmospheric gases** as GHGs re-radiate energy back to the surface

- Greenhouse effect is natural, but it has been enhanced due to **anthropogenic activities**
  - **Fossil fuel emissions**
  - **Deforestation**

---

CO₂ Increase since Preindustrial is Anthropogenic

Figure kindly provided by Prof. Neil Donahue

CO₂ from Coal

Figure kindly provided by Prof. Neil Donahue
CO$_2$ from Coal + Oil

CO$_2$ from Coal + Oil + Gas

Figure kindly provided by Prof. Neil Donahue
**Air Quality at CMU**

- Center for Atmospheric Particle Studies (CAPS)
  - [http://caps.web.cmu.edu/members/index.html](http://caps.web.cmu.edu/members/index.html)
  - ChemE faculty
    - Prof. Neil Donahue (Chem)
    - Prof. Spyros Pandis (EPP)
    - Prof. Peter Adams (CivE, EPP)
  - Other faculty members
    - Prof. Allen Robinson (MechE, EPP)
    - Prof. Ryan Sullivan (Chem, MechE)
    - Prof. Albert Presto (MechE)
- Prof. Kris Dahl and I are very grateful for the ideas, materials and guidance from Prof. Neil Donahue in implementing the *Climate Change Module* in 06-100 (Introduction to Chemical Engineering).
Announcements

• Office Hours today
  – 2:30 pm – 4:00 pm
  – Cyert Hall B6A
• Friday Lecture (09/27)
  – Homework 4 and Recitation 3 due: beginning of class
  – Majors Information Session for Engineering Intro Courses
• Recitation 3 help material on Blackboard
  – Help slides + Additional information on part (d)
• Scott Institute for Energy Innovation
  – http://www.cmu.edu/energy/
  – Energy Experts ➔ By Topic Area
Outline

- Quantitative Analysis
  - Concentrations and fractions (emphasis on air)
  - Ideal gas

- Basic Calculations
  - Molecular weight of dry air
  - Mass of C corresponding to 1 ppm of CO₂ in the atmosphere (homework)

- Software Workshop
  - Reading and graphing pollution data in MATLAB
  - Plot CO₂ emissions in Mauna Loa (homework)

Concentrations and Fractions

- Mass- or mole-based concentrations
  \[
  \begin{align*}
  \frac{\text{\(\mu\)g}}{\text{m}^3} & \quad \text{mass of species} \\
  \text{mol} & \quad \text{mole of species} \\
  \frac{\text{mol}}{\text{m}^3} & \quad \text{volume of air}
  \end{align*}
  \]

- In air, fractions are usually expressed on a molar or volume basis (equivalent for ideal gases)
  \[
  \begin{align*}
  \% & \quad 1 \text{ part species per 100 parts solution} \\
  \text{ppm} & \quad 1 \text{ part species per } 10^6 \text{ parts solution}
  \end{align*}
  \]

Also ppmv (on a volume basis), ppb, ppt...

Example: 5 ppb of benzene in air means there are $5 \times 10^{-9}$ moles of benzene in 1 mole of air
Ideal Gas Law

- First of all, an “ideal gas” does not exist!
- Simple model of $P$-$V$-$T$ relations of a gas
  - Works well at low $P$ and high $T$
  - Neglects molecular size and intermolecular interactions
- In almost every case in environmental engineering, air can be treated as an ideal gas

\[ PV = nRT \]

or

\[ P\hat{V} = RT \]

where \( \hat{V} = \frac{V}{n} \) is the specific molar volume

Ideal Gas Mixtures

- Ideal gas law for species $i$

\[ p_i V = n_i RT \]

- Partial pressure and molar fraction

\[ p_i = \frac{n_i}{n} P = y_i P \]

- Average molecular weight of any mixture with $C$ components

\[ \overline{MW} = y_1 MW_1 + y_2 MW_2 + \ldots + y_C MW_C = \sum_{i=1}^{C} y_i MW_i \]
Exercise: MW of Dry Air

- Given the composition of air, calculate its molecular weight

<table>
<thead>
<tr>
<th>Species</th>
<th>MW [g mol⁻¹]</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N₂)</td>
<td>28</td>
<td>78.08</td>
</tr>
<tr>
<td>Oxygen (O₂)</td>
<td>32</td>
<td>20.95</td>
</tr>
<tr>
<td>Argon (Ar)</td>
<td>40</td>
<td>0.93</td>
</tr>
<tr>
<td>Carbon Dioxide (CO₂)</td>
<td>44</td>
<td>0.035</td>
</tr>
</tbody>
</table>

**Answer:**

\[
\overline{MW}_{\text{air}} = y_{N_2} \overline{MW}_{N_2} + y_{O_2} \overline{MW}_{O_2} + y_{Ar} \overline{MW}_{Ar} + y_{CO_2} \overline{MW}_{CO_2}
\]

\[
\overline{MW}_{\text{air}} = [(0.7808)(28) + (0.2095)(32) + (0.0093)(40) + (0.00035)(44)] \text{ g mol}^{-1}
\]

\[
\overline{MW}_{\text{air}} = 28.95 \text{ g mol}^{-1} \approx 29 \text{ g mol}^{-1}
\]

Homework: Problem 1

- Calculate the mass of C that corresponds to 1 ppm of CO₂ in the atmosphere

**Answer:** 2.2 Gt (giga tons) = 2.2 × 10⁹ t = 2.2 × 10¹² kg

- Hints:
  - Estimate mass or moles of the atmosphere
  - Calculate 1 ppm (amount of CO₂) from the answer above
  - Calculate mass of C (how many moles of C are in one mole of CO₂?)

- You may find useful to know
  - Mean radius of the earth: \( R = 6370 \text{ km} \)
  - Pressure at the surface: \( P = 1.01325 \times 10^5 \text{ Pa} = 1.01325 \times 10^5 \text{ N m}^{-2} \)
CO₂ Levels in MLO: Text Data

- Yearly CO₂ measurements in Mauna Loa (volcano in Hawai‘i)
  - Text file by the Earth System Research Laboratory (ESRL) at the National Oceanic & Atmospheric Administration (NOAA) (http://www.esrl.noaa.gov/)
  - Let’s plot the data to detect trends...

CO₂ Levels in MLO: Graph

- Yearly CO₂ measurements in Mauna Loa (volcano in Hawai‘i)
  - Text file by the Earth System Research Laboratory (ESRL) at the National Oceanic & Atmospheric Administration (NOAA) (http://www.esrl.noaa.gov/)
>> x = [2008 2009 2010 2011 2012 2013]
>> y = [310 350 370 400 410 440]
>> scatter(x, y)
or
>> scatter(x, y, 'fill')
or
>> scatter(x, y, markertype)
where markertype can be ‘o’, ‘+’, ‘*’, ‘d’ etc.

• Plot data measurements as scatter points
• Plot functions (models) as lines
Some Few Improvements...

% Data
x = [2008 2009 2010 2011 2012 2013];
y = [310 350 370 400 410 440];

% Fit 1st degree polynomial (straight line) through the data (trendline)
p = polyfit(x,y,1); % p = [p1 p2]

% Obtain R^2 value (Coefficient of determination)
rsq = rsquared(x,y,p);

% We will plot two sets of data on the same figure, so use hold on/off for every plot statement or hold all

% Plot data as scatter points
markersize = 100;
scatter(x,y,markersize,'fill')

% Plot trendline in black
plot(x,polyval(p,x),'k')

% Display trendline equation and R^2
xmiddle = mean(x);
ymiddle = mean(y);
% Note that p(2) is negative, so to make it pretty I add the negative sign
% in the string and display the absolute value of p(2)
% text(xmiddle,ymiddle-5,sprintf('[CO_2] = %g t - %g',p(1),abs(p(2))),'FontSize',14); % Tentative

% Change labels
xlabel('Year','FontSize',16)
ylabel('CO_2 Concentration [ppm]','FontSize',16)

% Change tick marks on x-axis
xticks, xticklabels, xgrid
Read Data from Text File

- Use MATLAB's function `dlmread`
  \[ M = dlmread(filename) \]
- \( M \) is a matrix with as many rows and columns there are in the text file whose name is `filename`
- Example: File “data.txt”
  
  | 2000 | 10 |
  | 2050 | 20 |
  | 2100 | 30 |
- Read data into variable called \( X \)
  \[ X = dlmread('data.txt') \]

Homework: Problem 2

- Given a text file (“CO2_MLO_data.txt” from NOAA ESRL) containing annually mean CO\(_2\) concentration measurements (ppm) in Mauna Loa (MLO), plot and fit a 2\(^{nd}\) degree polynomial to the data. Display the polynomial equation and the \( R^2 \) in the figure.

- Hints
  - You will have to ask `polyfit` to center and scale the \( x \) values, or MATLAB will issue a warning message
  - After centering and scaling, the polynomial coefficients are obtained with respect to the centered and scaled \( x \) values and not the original ones. So whenever you have to use the coefficients, make sure to use the centered and scaled \( x \) values.
Appendix C  Review Lecture: Fall 2013

This appendix contains the slides I prepared as part of my additional materials for a review lecture I gave before the final exam of 06-321 Chemical Engineering Thermodynamics. Before developing the slides, I contacted the students via Blackboard and asked them to suggest topics they wanted me to focus on in the review. After gathering requests, I designed the slides in such an order that made logical sense to me due to the connectivity between the subjects.

The first slide of the review contains a schematic that conveys an overview of why students learn thermodynamics, i.e., how it is linked to chemical engineering courses students would learn in the following semesters. It also shows “Material and Energy Balances” as the support of thermodynamics and, consequently, all remaining courses in the curriculum. I find it very beneficial that students are reminded of the big picture of the curriculum, and that all disciplines are actually connected and coexist in reality.

Throughout the slides, I number equations as they are labeled in the textbook used in the course in order to facilitate the lookup of additional information by students. I also put several citations of sections from the textbook that students could consult for further details. In terms of content, I provided not only equations that mathematically describe concepts and phenomena, but also their physical interpretation. A great example is fugacity; before showing a number of equations to calculate this quantity for different systems, I told students that it can be interpreted as the tendency of a species to escape a phase, thus being intimately connected to phase equilibria (central theme in thermodynamics). Throughout the session, before switching to new topics (e.g., from fugacity to solution properties), I would return to previous slides, review calculation methods, and progress by gradually increasing the complexity of models. For example, I started with ideal gas models (simple), then introduced the virial equation of state (real gas, intermediate difficulty), and finally discussed cubic equations of state (real gas, increased difficulty). As per request of the students, I illustrated the theoretical concepts and their equations with two very practical applications of thermodynamics: vapor-liquid equilibria and chemical reaction equilibria. I concluded the review session by solving a requested numerical problem on the blackboard.
06-321
ChemE Thermodynamics
Review Session

Bruno A. Calfa
December 6th, 2014
Chemical Potential

- Single-phase, open system (material can pass through boundaries)
  \[ nG = g(P, T, n_1, n_2, \ldots, n_i, \ldots) \]
- Total differential of \( nG \)
  \[
  d(nG) = \left[ \frac{\partial(nG)}{\partial P} \right]_{T,n} dP + \left[ \frac{\partial(nG)}{\partial T} \right]_{P,n} dT + \sum_i \left[ \frac{\partial(nG)}{\partial n_i} \right]_{P,T,n_{\neq i}}^\mu_i dn_i
  \]
  (chemical potential by definition)
- Interpretation
  - Partial molar free energy.
  - Form of potential energy that can be absorbed or released during a chemical reaction.
  - The total sum of chemical potentials is zero at chemical equilibrium or in phase equilibrium. See Chapter 11 (Sections 11.1 and 11.2).
Introducing Fugacity

- The Gibbs energy, and hence $\mu_i$, is defined in relation to internal energy (whose absolute value is unknown) and entropy.
- Less desirable characteristics of $\mu_i \Rightarrow$ fugacity.
- **Fugacity**: effective pressure of a real gas, which replaces the true mechanical pressure in accurate chemical equilibrium calculations. Potential quantity that characterizes equilibrium partitioning of mass.

\[
dG = VdP - SdT \quad (6.10)
\]
\[
dG_i^{iq} = V_i^{iq} dP = \frac{RT}{P} dP = RT \ln P \quad \text{(constant $T$)}
\]

Integration yields
\[
G_i^{iq} = \Gamma_i(T) + RT \ln P \quad (11.28)
\]

For a real gas, the following definition is given
\[
G_i = \Gamma_i(T) + RT \ln f_i \quad (11.31)
\]

Fugacity Coefficient

- Subtracting (11.28) from (11.31) gives
\[
G_i^R = G_i - G_i^{iq} = RT \ln \frac{f_i}{P}
\]

where $G_i^R$ is the residual Gibbs energy.
- By definition, the fugacity coefficient is the ratio $f_i/P$
\[
\phi_i \equiv \frac{f_i}{P} \quad (11.34)
\]

- Therefore, using equation (6.49),
\[
\frac{G_i^R}{RT} = \ln \phi_i = \int_0^P (Z - 1) \frac{dP}{P} \quad \text{(constant $T$)} \quad (11.35)
\]
- Can be integrated numerically (e.g., Trapezoid Method) if experimental data are available, or evaluated analytically if model for $Z$ is assumed.
Calculation of Fugacity: Pure Species (I/II)

• **Ideal Gas**
  
  \[ f_i^{1g} = P \quad \phi_i^{1g} = 1 \]

• **Pure Gas**
  
  – Virial equation of state up to second coefficient
    
    \[ \ln \phi_i = \frac{B_{ii} P}{RT} \]  
    
    (11.36)

  – Cubic equation of state
    
    \[ \ln \phi_i = Z_i - 1 - \ln(Z_i - \beta_i) - q_i I_i \]  
    
    (11.37)

  where

  \[ \beta_i = \frac{P_{r,i}}{T_{r,i}} \]  
    
    (3.53)

  Remember:

  \[ f_i = \phi_i P \quad q_i = \frac{\Psi \alpha(T_{r,i})}{\Omega T_{r,i}} \]  
    
    (3.54)

(see Table 3.1)

Calculation of Fugacity: Pure Species (II/II)

• **Pure Liquid**
  
  – Approximation to equation (11.43):
    
    \[ f_i = \phi_i^{\text{sat}} P_i^{\text{sat}} \exp \left[ \frac{V_i(P - P_i^{\text{sat}})}{RT} \right] \]  
    
    (11.44)

  \[ \ln \phi_i^{\text{sat}} = \int_0^{P_i^{\text{sat}}} (Z_i - 1) \frac{dP}{P} \]  
    
    (11.42)

where the exponential in (11.44) is known as Poynting correction factor.

– Need:
  
  • Values of \( Z_i' \) (experiments, equation of state, generalized correlation),
  
  • Liquid-phase molar volume \( V_i' \) (usually value for saturated liquid),
  
  • Value for \( P_i^{\text{sat}} \).
Fugacity of Species in Solution

- Analogous to the case of pure species. Interaction between different species is accounted for with mixing rules.

Real Gas Mixture
\[
\hat{\phi}_i^v = \frac{\hat{f}_i^v}{y_i P}
\]

Real Liquid Solution
\[
\hat{\phi}_i^l = \frac{\hat{f}_i^l}{x_i P}
\]

- Ideal Gas
\[
\hat{f}_i^{ig} = y_i P, \quad \hat{\phi}_i^{ig} = 1
\]

- Virial Equation of State up to Second Coefficient
\[
\hat{\phi}_k = \frac{P}{RT} \left[ B_{ik} + \frac{1}{2} \sum_i \sum_j y_i y_j (2\delta_{ij} - \delta_{ik}) \right]
\]  (11.64)

where \( \delta_{ik} = 2B_{ik} - B_{ii} - B_{kk} \)


Ideal Solution and Excess Properties

- By definition
\[
\mu_i^{id} = G_i(T, P) + RT \ln x_i \quad (11.75)
\]

- Lewis/Randall rule
\[
\hat{f}_i^{id} = x_i f_i \quad (11.83)
\]

Consequence:
\[
\hat{\phi}_i^{id} = \phi_i \quad (11.84)
\]

- Real liquid solutions are often more easily dealt with through properties that measure their departures from ideal-solution behavior rather than ideal-gas behavior.

- Analogously to a residual property \( M^\theta \), define \( M^E \) as an excess property
\[
M^E = M - M^{id} \quad (11.85)
\]

- The reason for not using the same formulation as gas is that there is no good, easy model for fugacity coefficient for liquid mixtures.
Excess Gibbs Energy and Activity Coefficient

- Manipulating equations,
  \[ G_i^E = G_i - G_i^{id} = RT \ln \frac{\hat{f}_i}{x_i \hat{f}_i} \]
  where we define the activity coefficient as follows
  \[ \gamma_i \equiv \frac{\hat{f}_i}{x_i \hat{f}_i} \]  \hspace{1cm} (11.90)

- Important result: ln \( \gamma_i \) is a partial property with respect to \( G^E/RT \):
  \[ \frac{G_i^E}{RT} = \sum x_i \ln \gamma_i \]  \hspace{1cm} (11.99)

- Several models for \( G^E/RT \), hence activity coefficients:
  - Margules
  - van Laar
  - Wilson
  - NRTL
  - UNIQUAC
  - UNIFAC

Application: Vapor-Liquid Equilibria (VLE)

- Equilibrium (isofugacity) condition:
  \[ \hat{f}_i^v = \hat{f}_i \]  \hspace{1cm} (11.48)

- Putting together the expressions for vapor and liquid fugacity in mixtures:
  \[ \hat{f}_i^v = \gamma_i x_i \hat{P}_i \]
  \[ \hat{f}_i^l = \frac{V_i^l}{RT} \left( \frac{P - \hat{P}_i^{sat}}{\hat{P}_i} \right) \]

  This is sometimes called the \( \gamma-\varphi \) approach to VLE.

- Rearranging, \( K \)-values (i.e., partition coefficients used in flash and distillation calculations):
  \[ K_i = \frac{y_i}{x_i} = \frac{\gamma_i \hat{P}_i^{sat} \exp \left[ \frac{V_i^l (P - \hat{P}_i^{sat})}{RT} \right]}{\hat{P}_i P} \]
Application: Chemical Reaction Equilibria

- Given general equilibrium reaction

\[ aA + bB \rightleftharpoons cC + dD \]

its equilibrium is determined by the equilibrium constant \( K \).

- By definition, we relate \( K \) and the standard Gibbs energy as follows:

\[ \Delta G^\circ = -RT \ln K \quad (13.11) \]

- The equilibrium is defined in terms of the fugacity of the components:

\[ K = \frac{\hat{f}_C \hat{f}_D}{\hat{f}_A \hat{f}_B} \frac{1}{P^o} (\hat{f}_A \hat{f}_B)^{a+b-c-d} \quad (see \ equation \ (13.25)) \]

- Using fugacity coefficients (typically in gas-phase reactions):

\[ \hat{f}_i = y_i \hat{\phi}_i P \]

\[ K = \frac{(y_C \hat{\phi}_C)^c(y_D \hat{\phi}_D)^d}{(y_A \hat{\phi}_A)^a(y_B \hat{\phi}_B)^b} \frac{P}{P^o} (\hat{f}_A \hat{f}_B)^{a+b-c-d} \quad (see \ equation \ (13.26)) \]

- Expressions for ideal gas mixture (13.28), liquid-phase (13.31) etc.

Extent of Reaction

- Also known as coordinate of reaction: \( \varepsilon \)

  - Extent to which the reaction has taken place.

\[ \frac{dn_i}{d\varepsilon} = \nu_i \varepsilon \quad (13.3) \]

where \( \nu \) is the stoichiometric coefficient of species \( i \) (positive if product, negative if reactant).

- Relationship between mole fraction and \( \varepsilon \) (see Section 13.1).

  - Single reaction

\[ y_i = \frac{n_i}{n} = \frac{n_{i0} + \nu_i \varepsilon}{n_0 + \nu \varepsilon} \quad (13.5) \]

  - Multiple reactions

\[ y_i = \frac{n_i}{n} = \frac{n_{i0} + \sum_j \nu_{ij} \varepsilon_j}{n_0 + \sum_j \nu_j \varepsilon_j} \quad (13.7) \]

where \( i \) indexes species and \( j \) indexes reactions.

- Procedure for ideal gas mixture: substitute \( y_i \) into expression for \( K \) and solve for \( \varepsilon \). See Examples 13.1, 13.2, and 13.3.