Undergraduate Research Endowed Grant
Application Cover Sheet

Please type. Faculty mentors should submit completed application to the Undergraduate Research Office.

Proposed Title for Research Investigating the Emission Spectra of Narrow Line Seyferts and Low-Ionization Nuclear Emission Region Galaxies through CLOUDY Simulations

Application Checklist:

In the preparation of this Undergraduate Research Grant Application each of the following was completed:

☒ Meet eligibility requirements as given on page 1 of this form

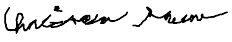
☒ Met with my faculty mentor to develop and or review letter of application/project description

☒ Included relevant references and citations with letter of application/project description

☒ Sought out the advice of Writing Center staff, as necessary

☒ Included the following items with my application materials
- Unofficial student transcript
- Student letter of application
- Faculty mentor research statement

In the preparation of my Undergraduate Research grant application, I have followed the steps outlined above. I understand that incomplete applications, or those that do not follow the specified application instructions, will influence the type of evaluative feedback received from the selection committee and may not be considered by the selection committee. *If I am selected to receive an Undergraduate Research grant, I understand that the Undergraduate Research Program may use my application as an example for future applicants*.



Student signature

09/29/2016

Date

Mentor signature

Date

Student Applicant Information

Full Name (first middle last) Christopher Ross Greene

Signature _____

Student Elon ID (Datatel) Number 1905958 ***(applications will not be accepted without the Datatel ID #)***

Campus Box 7599 Local Phone 9192579435

Major(s) Physics and Music

Year in school Senior e-mail cgreene11@elon.edu

Please check all of the following that apply to you.

☐ Honors Fellow ☒ Elon College Fellow ☐ Lumen Scholar ☒ SURE Scholar

☐ Previous Undergraduate Research Scholarship/Grant recipient; Which one?_____

I am applying for the following scholarship/grant (**select only 1**).

☒ Rawls ☐ Glen Raven ☐ Sinclair

☒ Wise ☐ Watts ☐ Sustainability

Faculty Mentor Information

Name _____

Signature _____

Department _____

Campus Box _____ Phone _____

e-mail _____

Faculty mentor should submit the completed application electronically in one file to the Undergraduate Research Program (millerp@elon.edu).

B. Project Description

1) Background and Rationale

One of the biggest questions in astronomy and astrophysics is "How do galaxies evolve?" Because of the large time scales involved in the formation of galaxies, the only way to learn about the formation of galaxies is through studying galaxies outside the Milky Way by observation and simulation. In the late 20th century astronomers began observing and investigating galaxies that contain supermassive black holes in their center that produce more light than all of the stars within the galaxy. These galaxies are hosts active galactic nuclei (AGN), which is a particular stage of galactic evolution. An active galactic nucleus is divided into several regions, based mainly on the distance from the central black hole. One of the outermost regions of an AGN is the narrow line region, which typically have a diameter on the order of 100,000,000 times the distance from the Earth to the Sun. I will be running simulations of the narrow line region of a specific type of AGN galaxy. With the data from these simulations, I will make graphs that show how bright the region is at different wavelengths of light. For example, a graph may show that the narrow line region may have brighter blue light than red light. The results from my research should provide a greater insight into the structure of the narrow line region, which can be used in conjunction with other research to help answer the question of galactic evolution.

A noteworthy characteristic of the NLR in Seyfert galaxies is the similarity between their emission spectra. In many older models, this meant that the ratio of ionizing photons to particles (known as the ionization parameter) was nearly constant. Groves et al. 2004 established a new paradigm for modeling the narrow line region in Seyfert galaxies. In the past, photoionization models did not account for the effects of dust and radiation pressure on the emission spectra. Interstellar dust also absorbs photons, meaning that it can prevent all the atoms in gas clouds in the NLR from ionizing and producing a complete emission spectrum. Groves et al. introduced dusty, radiation pressure-dominated photoionization models, which were shown to accurately fit observed data without the introduction of arbitrary assumptions and parameters. After using dusty models became prevalent, researchers looked into what the shape of the dust cloud takes.

Modern day models often plot the spectral energy distribution (SED) using three different power law indices (the value that a number is raised to in a power law function), which provide the slopes connecting the different ranges of light (Tananbaum et al. 1979). The three power law indices used today are αx, which describes the slope of the x-ray spectrum of light, αuv, which connects light from the optical spectrum to light from the ultraviolet (UV) spectrum, and αox which connects the optical spectrum to the x-ray spectrum (Grupe et al. 2010).

In 1998, Grupe et al. noted that the spectral slopes αx and αox are correlated. Since then, multiple papers have commented on the correlations between the x-ray spectral slope αx and the ultraviolet spectral slope αUV and between the x-ray spectral slope and optical-to-x-ray spectral slope in the narrow line region of Seyfert galaxies. AGN with steeper αx tend to have weaker x-ray emission lines than AGN with flatter αx (Grupe et al. 2010). However, research into this correlation is lacking. Most research extending from Grupe et al. 2010 has been on the correlation between αox and the Eddington luminosity ratio, the ratio of the observed luminosity

of the object and the maximum luminosity the object can reach with the force of radiation pushing out and the force of gravity pushing in staying at equilibrium. One reason for this lack of research is due to the lack of simultaneous observations in the UV and X-ray band. Researchers observed the same AGN years apart, and AGN have been found to be variable in UV and X-ray bands. One of the biggest accomplishments of Grupe et al. 2010 was the compilation of observational data of 92 different AGN over the course of 5 years. This allows for better observational data that models can fit. This data allows for the establishment of average values for all three power law indices, which were given in the paper as both the mean and the median of the results. They noted that the median provided a more accurate representation than the mean.

Another potential type of AGN that is the subject of much research are Low-Ionization Nuclear Emitting Region (LINER) galaxies. The emission spectra of LINER galaxies produce lines that are typical of both AGN and their counterparts, star-forming regions, which are regions with extremely high rates of star formation, which is the primary source of emission lines for those regions. Scientists are uncertain if these galaxies are strictly AGN galaxies, star-forming galaxies, or some combination of the two. These regions contain emission line widths that are comparable to the lines produced by the NLR in Seyfert. While Seyfert galaxies are modeled using photoionization models, many researchers simulate LINERS using shock models (Heckman 1980). The reason for this difference is lack of understanding of the primary excitation mechanism for LINER galaxies, as they display properties of both star-forming regions and AGN galaxies.

In order to check the accuracy of their models, researchers compare ratios of certain emission lines in diagnostic diagrams. These diagrams can be used to classify the type of AGN based on their primary excitation mechanism, as well as act as a check for multiple parameters that we have to consider for our simulations. Taking into account this background, my research asks the question:

Does constraining the power law indices according to slopes derived from past research create an accurate model of Narrow Line Seyferts that can be used to simulate their properties across the AGN Sequence and can these models be extended to modeling emission lines from Low Ionization Nuclear Emitting Region (LINER) galaxies?

2) Methods

Using the data from Grupe et al. 2010, I will determine the average power law indices that will be used in the baseline spectral energy distribution that will be run through our simulations. To vary these indices in our models, I will use the data given from the same paper to determine if the correlations between the different power law indices are significant enough that linear regression slopes between the indices can be used to constrain the values. Because the data from the paper includes Broad Line Seyfert Galaxies, I will have to reduce the data by removing any sources that have a Full Width at Half Maximum (FWHM), which is the spectral width of the light wave at half of the maximum amplitude, greater than 2000 units. From there I will then look at the values for the power law indices and remove any of the sources that do not give α_x and α_{uv} values that have been corrected for galactic reddening. Then I will plot linear regression curves to and use the slopes to vary α_x, α_{ox}, and α_{uv}.

Once these slopes have been determined I will begin running simulations through the CLOUDY program. In the simulation, I will use the parameters established by Groves et al. 2004b to make the cloud that the light will be run through. These parameters include the metallicity, chemical abundances, hydrogen density, dust grain size distribution, dust grain composition, and ionization parameter. Once the simulations have been run, I will look at the predicted line emission ratios for a large variety of atomic transitions. Many of these ratios are between one ionized state of an element and the first two ionizations of hydrogen (Hα and Hβ). The most important of these ratios are those established by Baldwin, Philips, and Terlevich 1981. I will gather data on how these specific ratios change according to the model.

The next stage of the research is to fit our model to existing observations. We will need a very large data set that is publicly available, as Elon does not have an observatory. As such, I will be using data collected from the most recent release of the Sloan Digital Sky Survey (SDSS). The SDSS provides the spectra of at least 1.5 million galaxies collected since it began in 2000. Furthermore, the data is publicly available, provided you understand the coding required to select your data. Using parameters determined by past research, I will take the data from galaxies to produce diagnostic plots that can be used in conjunction with our simulations to act as a check of the validity of our model.

After determining that our models are good fits for the NLR of Seyfert galaxies, we will adjust our models to simulate LINER galaxies, and then examine the data produced by the simulations to determine if we can accurately simulate them as well.

3) References

Baldwin, Phillips & Terlevich. 1981, *PASP Publications of the Astronomical Society of the Pacific*, 93, 5–5

Fischer, Crenshaw, Kraemer, Schmitt & Trippe. 2010, *The Astronomical Journal*, 140, 577–583

Groves, Dopita & Sutherland. 2004, *The Astrophysical Journal Supplement Series ASTROPHYS J SUPPL S*, 153, 75–91

Groves B, Heckman T, Kauffmann G. 2006. *MNRAS* 371:1559

Grupe, D., Beuermann, K., Thomas, H.-C.,Mannheim, K.,&Fink, H. H. 1998a, *A&A*, 330, 25

Grupe, D., Komassa, S., Leighly, K., Page, K., 2010, *ApJS*, 187, 64

Heckman, T. M. 1980, Astr. Ap., 87, 142

Jiang, Ho, Dong, Yang & Wang. 2013, *ApJ The Astrophysical Journal*, 770, 3–3

Khachikian & Weedman. 1974, *The Astrophysical Journal*, 192, 581–581

Nenkova, M., Ivezic, Ž., & Elitzur, M. 2002, *ApJ*, 570, L9

Netzer. Cambridge University Press, 2013,

Ryden & Peterson. Pearson , 2010,

Hönig S. F., Kishimoto M., 2010, *A&A*, 523, A27

Tananbaum, H., et al. 1979, *ApJ*, 234, L9

C. Responsibilities of the Student

Chris' proposal builds upon work that he started last year. During that time, Chris has attended research group meetings to learn the basics of the astrophysical code known as Cloudy, which is addressed in the research proposal of this document. Next semester, he will continue to build a solid foundation of the theoretical concepts in nebular astrophysics and test these concepts by performing plasma simulations. Chris already possesses many skills, such as navigating the command line of Unix systems and developing scripts, which are necessary to succeed in a field with an ever-growing dependence on numerical work.

Armed with the background knowledge necessary to conduct astronomy research, this grant would allow Chris to complete the logical next step by undertaking a high quality research project. His responsibilities reflect the proposed plan presented in the research proposal and fit into three broad categories:

1. **Develop working knowledge of running simulations on high performance clusters.** Cloudy has the ability to make use of multi-core processors, which drastically decreases the time required to complete a series of simulations. The research group already has access to a high throughput computing cluster located off campus. Chris will need to learn how to access this cluster, install Cloudy on his own workspace, and configure Cloudy so that it can run on the system. This will also require Chris to develop a basic understanding Bash scripting, which allows each user of the computing cluster to submit simulations to the queue.

2. **Maintain an online code repository.** Chris's project will require him to write code in the programming language Python. He will need to learn how to use the version control system known as Git, and create an online repository on Github, to manage all of the scripts he will write. This will allow others in the research group to make use of his scripts, allow his mentor to easily validate his work, and promote strong programming practices.

3. **Further investigation of Cloudy's capabilities.** While Chris will have a firm understanding of the theoretical underpinnings of Cloudy, the documentation of its capabilities is vast (~600 pages). Chris will need to develop the ability to quickly assess the problem at hand and then determine the appropriate tool in Cloudy best suited to solve it. Additionally, an online message board solely dedicated to Cloudy will assist Chris in investigating questions that other users have encountered and the path they took to solve them.

After successfully completing this work, Chris will formally document the results of the project and present them at the American Astronomy Society Meeting in Jan. 2017.

D. Educational Benefits

Completing this project holds many educational benefits. First and foremost, I gain experience writing research proposals and grant applications, which is a skill that is required for graduate school and doing research professionally. I also gain experience with coding in Python and Linux based systems. Like most research projects, I learn how to approach a problem analytically, or in some cases determine what the problem/question is that we are trying to solve. I learn how to organize research and data files so that they are easy to access and simple to navigate. Because the field of astrophysics primarily relies on computer based simulations for research, knowing how to run computer programs and to code is a necessary skill. I am in the process of applying for graduate schools, so this project also helps me with the application process by honing my scientific writing skills and providing an example of my work for the schools to look at. In the past year of working on this research project, I have gained a deeper understanding of the field of astrophysics, which has aided my learning in the classroom. By learning how the research process is completed, I gain a respect and appreciation for the efforts of the great scientists and physicists of the past and the rigor that they had to conduct their research with.

E. Description of Planned Mentoring Relationship

Chris' proposed work directly aligns with the research of his mentor. As such, the mentor will be available and ready to offer advise during all stages of the proposed research:

The mentor will provide resources and examples to learn about high performance computing and script writing.

The mentor will work with the student to develop and write code.

The mentor will advise the student in the best practices in documenting research.

The mentor will be frequently available and meet with the student at least one hour per week.

The student will document their research using an electronic notebook that will be backed up online.

The student will regularly inform the mentor about their progress.

The student will spend at least 4 hours per week, per credit hour of PHY 499, performing work related to the project.

The student and mentor will read scholarly publications separately and then discuss the implications of the articles.

The student and mentor will meet at least once a week to reflect upon progress made since the previous meeting and converse about the way forward.

Chris T. Richardson

Elon University
Department of Physics
McMichael Science Building
Elon, NC 27244

Phone: (336) 278-6281
Email: crichardson17@elon.edu
Homepage: facstaff.elon.edu/crichardson17

Education

Ph.D. Program in Astrophysics, Michigan State University, 2008-2013.

M.S. Astrophysics, Michigan State University, 2010.

B.S. Physics and Applied Physics, Eastern Illinois University, 2008.

Minor: Mathematics
Honors: Magna Cum Laude, University Honors

Fields of Interest

Plasma Simulations, Nebular Astrophysics, Computational Astrophysics, Compact Objects, Physics and Astronomy Education

Academic Employment

Elon University, Department of Physics

Assistant Professor, Fall 2013 – Present

Michigan State University, Department of Physics and Astronomy

Postdoctoral Researcher, Jack Baldwin, Summer 2013

Research Assistant, Jack Baldwin, Spring 2011 – Spring 2013

Physics Tutor, Department of Physics and Astronomy, Spring 2011

Research Assistant, Ed Brown, Summer 2010 – Spring 2011

Research Assistant, Ed Brown, May – August 2009

Teaching Assistant, Fall 2008 – Spring 2010

Indiana University, Department of Physics

Research Experience for Undergraduates, Jim Musser, June – August 2007.

Eastern Illinois University, Department of Physics

Athletic Tutor in Physics, Mathematics, and Chemistry Cindy Tozer, 2006 – 2008.

Undergraduate Physics Grader, 2006 – 2008.

Undergraduate Physics Tutor, 2006 – 2008.

Research Assistant, Jie Zou, May – June 2006.

High School Physics Tutor, 2006 – 2007.

Undergraduate Research Students

Christopher Greene, 2015-Present

Elon College Fellow

Elena Meskhidze, 2013 - Present

Honors Fellow, Physics Department Research Award (2014), Summer Undergraduate Research Experience (2014), Lumen Scholar (2014-2016)

Emily Need, 2013 - 2014

Currently enrolled in Clemson University doctoral program in physics

Leadership Activities

Society of Physics Students Faculty Mentor, Elon University, 2014-Present

Physics & Astronomy Undergraduate Mentor, Women and Minorities in Physical Sciences (WAMPS), Monthly meetings with 3 students/year, Fall 2011 – Spring 2013

Member, Joint Institute for Nuclear Astrophysics (JINA) Journal Club, Michigan State University, Fall 2009 – Spring 2013

Member, Sigma Pi Sigma (Physics Society), Eastern Illinois University, Spring 2008

Vice President, Astronomy Club, Eastern Illinois University, Fall 2007 – Spring 2008

Member, University Honors College, Eastern Illinois University, Fall 2004 – Spring 2008

Honors, Awards, and Fellowships

FR&D Re-Assigned Time Fellowship, Elon University, 2016

FR&D Summer Research Fellowship, Elon University, 2015

CATL Travel Grant, Elon University, 2015

FR&D New Faculty Summer Research Salary, Elon University, 2014

2nd Prize Poster Presentation, Cyber-Infrastructure Days, Michigan State University, 2012

Young Alumni of the Year Nomination, Eastern Illinois University, 2012-2013

Thomas A. Kaplan Award, Graduate Student Presentation of the Year, Michigan State University, 2011-2012

Center for Integration of Research, Teaching, and Learning (CIRTL) Exchange Program, 2012

Future Academic Scholars in Teaching (FAST) Fellowship, Michigan State University, 2010-2012

Graduated First in Class of Physics Majors, Eastern Illinois University, 2008

NSF Research Experience for Undergraduates, Indiana University, 2007

Lewis T. White Award in Mathematics, Eastern Illinois University, 2007

Dean's List, Eastern Illinois University, 2006

G.B. Dudley Award in Physics, Eastern Illinois University, 2006

Ranked in Top 100 Sophomores, Eastern Illinois University, 2006

Irvin L. Sparks Award in Physics, Eastern Illinois University, 2005

Continuing Education Scholarship, Eastern Illinois University, 2004 – 2007

Grants and Computing Time

"Theoretical Modeling of Emission-Line Regions in Star Forming Galaxies." PI: Chris Richardson, NSF XSEDE project (Trestles supercomputer cluster), 2014. 300,000 CPU-Hours. $ 14,500.

"Optimally Emitting Regions in Emission-Line Galaxies." PI: Chris Richardson, NSF XSEDE project (Trestles supercomputer cluster), 2013. 50,000 CPU-Hours.

Honors College Undergraduate Research Grant, Eastern Illinois University, 2006

Refereed Publications

**asterisk indicates undergraduate student*

*Meskhidze, H.**, **Richardson, C. T.**, "An Atlas of Starburst Galaxy Equivalent Widths", *ApJS* (submitted)

Richardson, C. T., Allen, J. T., Baldwin, J. A., Hewitt, P. C., Ferland, G. J., Crider, A.,*Meskhidze, H.**, "Interpreting the Ionization Sequence in Star-Forming Galaxy Emission Line Spectra", *MNRAS*, accepted pending small revisions

Richardson, C. T., Allen, J. T., Baldwin, J. A., Hewitt, P. C., Ferland, G. J., "Interpreting the Ionization Sequence in AGN Emission-Line Spectra", 2014, *MNRAS*, 437, 2376

Xiang, W., Ferland, G. J., Baldwin, J. A., Loh, E. D., **Richardson, C. T.**, "Detecting the Rapidly Expanding Outer Shell of the Crab Nebula: Where to Look", 2013, *ApJ*, 774, 112

Allen, J. T., Hewitt, P. C., **Richardson, C.T.**, Ferland, G. J., Baldwin, J. A., "Classification and Analysis of Emission Line Galaxies Using Mean Field Independent Component Analysis", 2013, *MNRAS*, 430, 3510

Richardson, C. T., Baldwin, J. A., Ferland, G. J., Loh, E. D., Kuehn, C., Fabian, A. C., Salome, P., "The Nature of the H_2 Emitting Gas in the Crab Nebula", *MNRAS*, 2013, 430, 1257

Richardson, C. T., O'Shea, B. W., "Assessing Gender Differences in Response System Questions for an Introductory Physics Course", 2012, *AJP*, 2013, 81, 231

Loh, E. D., Baldwin, J. A., Ferland, G. J., Curtis, Z. K., **Richardson, C. T.**, Fabian, A. C., Salome, P., "H_2 Temperatures in the Crab Nebula", 2012, *MNRAS*, 421, 789

Zou, J., Lange, X., **Richardson, C.**, "Lattice thermal conductivity of nanoscale AlN/GaN/AlN heterostructures: Effects of partial phonon spatial confinement", 2006, *JAP*, 100, 10, 104309-104309-8.

Invited Talks

"The Crab Nebula: Our Local Young Supernova Remnant", Triad Starfest, Guilford Technical Community College, March 2015.

"Exoplanets: Is there another Earth?", Tectonic Plates Science Cafe, Elon NC, November 2014.

"The Nature of the H_2 Emitting Gas in the Crab Nebula", Colorado University (Boulder), CIRTL Exchange Program, February 2012.

"Assessing Gender Differences in Think-Pair-Share Questions for an Introductory Physics Course", Colorado University (Boulder), CIRTL Exchange Program, February 2012.

"A Type Ia Supernova Lifetime: Simmers to Detonations", Eastern Illinois University Physics and Astronomy Seminar, 2010.

Conference Presentations

**asterisk indicates undergraduate student*

Richardson, C. T., Allen, J. T., Baldwin, J. A., Hewett, P. C., Ferland, G. J., *Meskhidze, H.**, "A New Interpretation for the Variation in Starburst Galaxy Emission Line Spectra", American Astronomical Society, 2015, AAS, 22542501

*Meskhidze, H.**, **Richardson, C. T.**, "An Atlas of Starburst Galaxy Equivalent Widths", North Carolina Astronomers' Meeting, 2014, Guilford Technical Community College, Jamestown, NC

Richardson, C. T., Allen, J. T., Baldwin, J. A., Hewett, P. C., Ferland, G. J., "The Physical Parameter Responsible for the Variation in AGN and Star Forming Galaxies Emission Line Spectra", 2014, The Fate of Gas in Galaxies, Durham University, England, UK

Richardson, C. T., Baldwin J. A., Ferland G. J., Loh, E. D., Kuehn, C. A., Fabian, A., Salomé, P., "Plasma Simulations of the H2 Emitting Gas in the Crab Nebula", American Astronomical Society, 2013, AAS, 22133006

Richardson, C., "The Structure of Laminar C/O Flames in Type Ia Supernovae at Low Densities", 2010, Joint Institute for Nuclear Astrophysics (JINA) Frontiers

Poster Presentations

**asterisk indicates undergraduate student*

Richardson, C. , Crider, A., *Kaiser, B.**, "Detecting HII Regions in Z=0.1 Galaxies with Multi-Band SDSS Data", IAUGA Meeting #29, #74.90

*Meskhidze, H.**, **Richardson, C. T.**, Ferland, G. J., "An Atlas of Starburst Galaxy Emission Lines", 2015, AAS Meeting #225, #251.06

Richardson, C. T., Allen, J. T., Baldwin, J. A., Hewett, P. C., Ferland, G. J., "Identifying the Physical Parameter Responsible for the Ionization Sequence in Star Forming Galaxies", 2014, North Carolina Astronomers' Meeting, Guilford Technical Community College

Richardson, C. T., Allen, J. T., Baldwin, J. A., Hewett, P. C., Ferland, G. J., "The Physical Parameter Responsible for the Variation in AGN and Star Forming Galaxies Emission Line Spectra", 2014, The Fate of Gas in Galaxies, Durham University, England, UK

Richardson, C. T., Allen, J. T., Baldwin, J. A., Hewett, P. C., Ferland, G. J., "Identifying the Physical Parameter Responsible for the Ionization Sequence in Star Forming Galaxies", 2014, AAS Meeting #223, #252.01

Richardson, C. T., Baldwin, J. A., Ferland, G. J., Loh E. D., Kuehn C. A., O'Dell C. R., Fabian, A. C., Salome, P., "Numerical Simulations of the H_2 Emitting Gas in the Crab Nebula", 2012, Cyber-Infrastructure days, Michigan State University, **2nd Place Award**

Richardson, C. T., Baldwin, J. A., Ferland, G. J., Loh E. D., Kuehn C. A., O'Dell C. R., Fabian, A. C., Salome, P., "The Nature of the H_2 Emitting Gas in the Crab Nebula", 2012, AAS Meeting #220, #431.12

Kuehn, C., Loh, E. D., Baldwin, J. A., Ferland, G. J., Fabian, A. C., **Richardson, C. T.**, Salome, P., O'Dell, B., "The Molecular Content of the Crab Nebula", 2012, AAS Meeting #219, #239.15

Richardson, C. T. and O'Shea, B. W., "Assessing Gender Differences in Think-Pair-Share Questions for an Introductory Physics Course", CIRTL Forum, 2011

Richardson, C., "The Structure of Laminar C/O Flames in Type Ia Supernovae at Low Densities", 2010, Joint Institute for Nuclear Astrophysics (JINA) Frontiers

Current Students

Elon University Unofficial Transcript

1905958 Christopher Greene

Course/Section and Title	Grade	Credits	CEUs	Repeat	Term
MUS*010 A Recital Attendance					Fall 2016
MUS*135 A Indiv Instruc Cello I					Fall 2016
MUS*318 A History of Jazz					Fall 2016
MUS*332 B Indiv Instr Saxphone III					Fall 2016
MUS*495 A Senior Seminar					Fall 2016
PHY*313 A Modern Astrophysics					Fall 2016
PHY*401 A Classical Mechanics					Fall 2016
PHY*499 CR Research/ELR					Fall 2016
MUS*471 IS Jazz Ambassadors Italy Tour	A	1.00			Summer Session I 2016
MUS*010 A Recital Attendance	S	0.00			Spring 2016
MUS*104 A Jazz Ensemble	A	1.00			Spring 2016
MUS*316 A Classic and Romantic Music	A-	4.00			Spring 2016
MUS*332 B Indiv Instr Saxphone III	A	2.00			Spring 2016
PHY*398 B Research Methods II	A	2.00			Spring 2016
PHY*404 A Electrodynamics II	A	4.00			Spring 2016
PHY*499 CR Research/ELR	A-	2.00			Spring 2016
REL*376 A Religion and Healing	A	4.00			Spring 2016
ECF*312 A Elon Coll Fellows Junior Sem	A-	2.00			Fall 2015
FNA*373 A Beyond Talent: Career Developm	A	4.00			Fall 2015
MUS*010 A Recital Attendance	S	0.00			Fall 2015
MUS*106 A Saxophone Ensemble	A	1.00			Fall 2015
MUS*130 A Indiv Instruc Clarinet I	A	1.00			Fall 2015
MUS*135 A Indiv Instruc Cello I	A	1.00			Fall 2015
MUS*232 B Indiv Instr Saxophone II	B+	2.00			Fall 2015

PHY*397 A Research Methods I	A	2.00	Fall 2015
PHY*403 A Electrodynamics I	A	4.00	Fall 2015
PHY*499 CR Research/ELR	A-	1.00	Fall 2015
MTH*359 A Differential Equations	A-	4.00	Spring 2015
MUS*010 A Recital Attendance	S	0.00	Spring 2015
MUS*104 A Jazz Ensemble	A	1.00	Spring 2015
MUS*112 A Materials of Music II	A	3.00	Spring 2015
MUS*114 C Aural Skills II	A	1.00	Spring 2015
MUS*120 BB Indiv Instruc Piano I	A	2.00	Spring 2015
MUS*135 A Indiv Instruc Cello I	A	1.00	Spring 2015
MUS*232 B Indiv Instr Saxophone II	A	2.00	Spring 2015
PHY*314 A Introduction to Modern Physics	A	4.00	Spring 2015
ANT*270 DV Japanese Culture/Society Film	A	4.00	Winter Term 2015
ECF*212 A Elon Coll Fellows Soph Seminar	A-	1.00	Fall 2014
MUS*010 A Recital Attendance	S	0.00	Fall 2014
MUS*104 A Jazz Ensemble	A	1.00	Fall 2014
MUS*106 A Saxophone Ensemble	A	1.00	Fall 2014
MUS*106 G World Percussion Ensemble	A	1.00	Fall 2014
MUS*111 A Materials of Music I	A	3.00	Fall 2014
MUS*113 A Aural Skills I	A	1.00	Fall 2014
MUS*132 B Indiv Instr Saxophone I	A-	2.00	Fall 2014
MUS*135 A Indiv Instruc Cello I	A	1.00	Fall 2014
MUS*154 A Piano Class I	A	1.00	Fall 2014
PSY*111 M Introduction to Psychology	A	4.00	Fall 2014
MTH*252 A Multivarbl Calc/Analyt Geomet	A	4.00	Spring 2014
MUS*010 A Recital Attendance	S	0.00	Spring 2014
MUS*106 A Saxophone Ensemble	A	1.00	Spring 2014
MUS*132 B Indiv Instr Saxophone I	A-	2.00	Spring 2014
PHY*222 A University Physics II	A-	4.00	Spring 2014
THE*101 A Intro to Theatre	A	4.00	Spring 2014
THE*125 B Acting for Non-Majors	A	4.00	Spring 2014

ECF*111 A Paths Inquiry Arts & Sciences	A-	4.00	Winter 2014
CSC*130 D Computer Science I	B	4.00	Fall 2013
ELN*101 SB Elon 101	S	1.00	Fall 2013
ENG*250 C Interpretations of Literature	A	4.00	Fall 2013
GST*110 DA The Global Experience	A	4.00	Fall 2013
MUS*106 A Saxophone Ensemble	A	1.00	Fall 2013
MUS*132 A Indiv Instr Saxophone I	A	1.00	Fall 2013
PHY*221 A University Physics I	A-	4.00	Fall 2013
MTH*151 Calculus I		4.00	Transfer Work
MTH*251 Calculus II		4.00	Transfer Work
SCI*1XX SCI Elective Course		4.00	Transfer Work
SPN*050 SPN 222 Placement		0.00	
ENG*110 Writing, Argument and Inquiry		4.00	Transfer Work
HST*121 US History Through 1865		4.00	Transfer Work
MTH*112 General Statistics		4.00	Transfer Work

Total Earned Credits	142.00
Total Grade Points	453.60
Cumulative GPA	3.877

OK