Biology - Health Sciences Program
Assessment Report
2015-2016

I. Introduction

The Biology - Health Sciences program offered on the Klamath Falls campus serves all OIT students wishing to major in a course of study that prepares for entry into professional programs in medicine, dentistry, pharmacy, veterinary medicine, physical therapy, physician assistant, optometry, and related health fields.

Biology - Health Sciences was originally called Health Sciences but renamed in 2012-2013. The Health Sciences program was implemented in 1996. It is a popular program with an enrollment of approximately 150 students. The number of students graduating from the Biology - Health Sciences was 15 in 2012-2013, 17 in 2013-2014, 27 in 2014-2015, and 20 in 2015-2016.

The number of students graduating in past years when the program was called Health Sciences was 8 (1999-2000), 2 (2000-2001), 9 (2001-2002), 10 (2002-2003), 10 (2003-2004), 11 (2004-2005), 7 (2005-2006), 1 (2006-2007), 3 (2007-2008), 2 (2008-2009), 2 (2009-2010), 1 (2010-2011), 6 (2011-2012), 1 (2012-2013), and 0 (2013-2014).

The Biology program was implemented in 2006-2007 and removed from the catalog in 2012-2013. The number of students graduating in past years were 10 (2006-2007), 8 (2007-2008), 18 (2008-2009), 14 (2009-2010), 12 (2010-2011), 13 (2011-2012), 2 (2012-2013), 5 (2013-2014), 2 (2014-2015), and 1 (2015-2016).

We have limited information regarding employment rates and salaries, as most students go on to graduate school and are not employed for two to four years while working on their graduate degrees. Many take a year off while applying to graduate schools, making follow up more difficult, and generally only a low percentage of students complete the exiting senior surveys.

II. Program Purpose, Objectives and Student Learning Outcomes

The purpose, goals, and objectives of the Biological - Health Sciences program were discussed by the program faculty during fall convocation (September 2015). Everyone was satisfied with the current stated purpose, but some minor changes were made to the list of objectives. A possible new Program Student Learning Outcome (PSLO) – communication, team building, and professionalism was also discussed, and will receive further discussion during the coming year.

Biology - Health Sciences Program Purpose

The Bachelor of Science program in Biological - Health Sciences prepares undergraduate students for professional and graduate schools in the medical sciences (medicine, dentistry, pharmacy, veterinary sciences, physical therapy, physician assistant, etc.).

Biology - Health Sciences Program Objectives

- **Old bullet point one**: Provide an integrated foundation of knowledge in biological disciplines that includes genetics, pathophysiology, neurobiology, microbiology, immunology, cellular and molecular biology, physiological, developmental, and evolutionary principles.
- **New bullet point one**: Provide an integrated foundation of knowledge in biological disciplines that includes morphological, cellular, molecular, physiological, developmental, and evolutionary principles
- **Old bullet point two**: Present information on the life sciences that utilize the scientific method and emphasize skills in analysis, evaluation, and critical thinking.

- **New bullet point two**: Train students to utilize the scientific method and develop skills in analysis, evaluation, and critical thinking. (as well as communication, team-building, and professionalism – may be added following more discussion).
- **Old bullet point three**: Prepare students for entrance into graduate schools and professional health schools, including preparation for national admissions examinations such as the Graduate Record Examination (GRE), Medical College Admission Test (MCAT), Dental School Admissions Test (DAT), and similar examinations, or provide students with practical skills that can qualify them for entry level positions in biology and health-related occupations.
- **New bullet point three**: Prepare students for entrance into graduate schools and professional health schools, including preparation for national admissions examinations such as the Graduate Record Examination (GRE), Medical College Admission Test (MCAT), Dental School Admissions Test (DAT), and similar examinations, or qualify them for entry level positions in biology and health-related occupations.

Biology - Health Sciences Program Student Learning Outcomes (PSLOs)

1. Students will demonstrate scientific knowledge and skills in scientific reasoning.
2. Students will be able to apply scientific principles to biology based problems.
3. Students will be able to effectively find and use resources from the literature.
4. Students will demonstrate effective oral, written and visual communication.
5. Students will demonstrate mathematical knowledge and skills in the biological and health sciences.

Some discussion regarding these PSLOs occurred during the convocation program meeting (September 2015):

- The program faculty considered dropping PSLO #4 as it is now one of the ESLOs.
- The program faculty considered adding a new PSLO in team-building, but decided not to, as this is also an ESLO.
- The program faculty considered adding a PSLO regarding expectations for professionalism.
  - It was decided that the program needed to further discuss and define its expectations for professionalism before adding this as a new PSLO.

III. Three Year Cycle for Assessment for Student Learning Outcomes

The Natural Sciences faculty agreed to designate five program student learning outcomes (PSLOs) with one or two to be assessed each year in a rotating three-year cycle, as shown in Table 1 below.

Program Student Learning Outcomes	**2007-2008**	**2008-2009**	**2009-2010**	**2010-2011**	**2011-2012**	**2012-2013**	**2013-2014**	**2014-2015**	**2015-2016**
Assessment Coordinator	Powers	Powers	Sale	Li	Li	Clark	Clark	O'Shaughnessy	O'Shaughnessy
1. Students will demonstrate scientific knowledge and skills in scientific reasoning.	✓	✓		✓			✓		
2. Students will be able to apply scientific principles to biology based problems.			✓			✓			✓
3. Students will be able to effectively find and use			✓			✓			✓

resources from the literature.									
4. Students will demonstrate effective oral, written and visual communication.				✓			✓		
5. Students will demonstrate mathematical knowledge and skills in the biological sciences.	✓	✓			✓			✓	

Table 1. Biology - Health Sciences Program Assessment Cycle.

IV. Summary of 2015–2016 Assessment Activities

The faculty of the Biology – Health Sciences program conducted the following assessments during the 2015-2016 academic year as indicated in Table 2.

Program Student Learning Outcome	**Fall**	**Winter**	**Spring**
PSLO 2 Students will be able to apply scientific principles to biology based problems.		✓ CHE 222 lab	✓ PHY 223 lab
PSLO 3 Students will be able to effectively find and use resources from the literature.		✓ BIO 409	

Table 2. Biology – Health Sciences Program Assessment Activities for Academic Year 2015-2016.

These PSLOs are mapped to the curriculum as shown in appendix A.

PSLO #2: Students will be able to apply scientific principles to biology (or chemistry or physics) based problems.

This PSLO is mapped to the curriculum as shown in appendix A1.

Direct Assessment #1

Seventeen Biology-Health Sciences seniors were assessed winter term of 2016 (201502). These students were enrolled in Elvira Schechtel & Ken Usher's CHE 222 General Chemistry II Lab, a required course.

Assessment criteria:

1. Collect and precisely record data using appropriate units.
2. Analyze data to determine its relationship to principles and evaluate the data for errors.

Assignment used for criteria #1:

This assessment was based on a laboratory experiment and a quiz question in CHE 222 lab related to vapor pressures. Students needed to measure and record quantitative data, graph the data, and do a calculation using data provided to illustrate a chemical principle.

The seventeen students assessed comprised all of the Biology-Health Sciences students who were enrolled in CHE 222 in Winter 2016. These students were at the freshman and sophomore levels, and had all taken MATH 111 as a pre-requisite before this course.

Assessment Rubric:

For "**Collect and precisely record data using appropriate units**" the following rubric was used:
1-student collected no data, or the data collected could not answer the question being asked
2-student collected incomplete or significantly inaccurate data, or used inappropriate units
3-student collected data correctly, but did not state what units were used
4- student collected data correctly, with correct units

Goal:

The desired performance standard was that 75% of students would score 3 or 4 (proficient or highly proficient) on both criteria in the PSLO.

Results:

All seventeen of the students were able to accurately collect data; 100% of the group scored "4" on this part. This part of the assessment was based on a single experiment where each student pair collected temperature and volume data to analyze. This was good, but not surprising, since the task was straightforwardly prescribed for them by the lab handout, the students were able to get immediate feedback from lab partners and the instructor about whether they were doing it right, and because students get lots of practice collecting and recording data in labs of this course (and in CHE 221 which precedes it).

Recommendations related to this criterion:

- Overall, data collection skill is a strength that we would like to retain.
- It might be worthwhile in the future to make more (labs (for assessment and/or learning) where students "take the next step" by choosing more independently for themselves, what data they should collect and how.

Assignment used for criteria #2:

This assessment was based on the laboratory experiment used in criterion #1 and a different question from the same CHE 222 lab quiz. Students needed to do a calculation using data provided. The same students were assessed as in criterion #1

Assessment Rubric:

1. Student solved the problem incorrectly, and either used the wrong formula or the wrong numerical information to begin solving it.
2. student started to use the correct formula and numerical information to solve the problem, but made an error within the calculation
3. student got the right answer and showed his/her work, but did not state what units were used, or used inappropriate units
4. student got the right answer and showed his/her work, with correct/appropriate unit

Goal:

The desired performance standard was that 75% of students would score 3 or 4 (proficient or highly proficient) on BOTH criteria in the PSLO.

Results:

Five students scored (1); one student scored (2), one student scored (3), ten students scored (4).

This result has 11/17 (65%) of the students performing at the desired level (3 or 4) on this criterion, which is lower than we had hoped. This part of the assessment was based on a single quiz question (see last page of this report). We chose to use a quiz question instead of the students' lab reports because the quiz (about the same lab) represents more of an individual effort.

Possible explanations or recommendations related to this lower than expected performance:

- Next time, perhaps we should base the assessment on more than one question, to ensure that it captures more of students' general capability to analyze data, rather than possible idiosyncrasies of one question.
  - Our assessment really did not address "and evaluate data for errors", either.
- This assessment criterion (or at least the way we interpreted it) seems slanted towards analysis of numerical data, but the underlying concepts could be used with more qualitative data.
- Since these students were at a freshman/sophomore level, it would be interesting to see if upper-division students do better at analyzing data later in their college path.

- In this problem, more information was given than students actually needed to solve it, and the most common difficulty for students was in deciding which information was relevant.
    - Giving students more practice at choosing which information is relevant to a scientific principle or problem could be helpful, both in chemistry and in other areas of our program curriculum.
    - Students generally seem to be able to do basic algebra, if they know what numbers to plug in.

PSLO #2: Students will be able to apply scientific principles to biology (or chemistry or physics) based problems.

This PSLO is mapped to the curriculum as shown in appendix A2.

Direct Assessment #2

Nine Biology-Health Sciences juniors were assessed spring term of 2016 (201503). These students were enrolled in Dr. Matt Beekman's PHY 223 General Physics with Calculus III, a required course.

In two sections of PHY 223, there were a total of nine Biology-Health Sciences students. Data were attempted to be collected for all nine students (one student, however, did not turn in either assignment). If a student did not complete the assignment, a zero was assigned. The measurement scale used for the assessment can be found in the table on the next page. Copies of student work can be found in Attachment 3.

Criteria for Assessment:

1. Collect and precisely record data using appropriate units.
2. Analyze data to determine its relationship to principles and evaluate the data for errors.

Assignments used:

The first criterion was assessed using a lab worksheet for an experiment conducted in week 9 of the term. The laboratory worksheet can be found in Appendix B. The data for this assessment were collected from Data Table 1 of the worksheet. Students were expected to report the collected data to the appropriate number of significant figures based on the precision of the measurement device (in this case a spectrometer), as well as report a calculated quantity (in this case, wavelength of light) with the appropriate units and precision (based on the measured data, in this case an angle). It should be noted that the data were typically collected in groups of three or four, but each student recorded the data in their own worksheet.

The second criterion was assessed using a take-home writing assignment that was associated with a graph that produced as part of the lab data analysis from the same Week 9 experiment that the above worksheet was associated with. This writing assignment (Scientific Communication Exercise 3) was the third assignment in a series of three assignments intended to help students develop written communication skills in describing and interpreting experimental data. For context, the entire series of assignments as well as the assignment actually assessed can be found in Appendix C.

Assessment Rubric:

A simple scale of 4 = Exemplary, 3 = Proficient, 2 = Progressing, 1 = Unsatisfactory, 0 = Insufficient was used.

Goal:

75% of students should score at least 3 or 4 on the above scale.

Results:

Performance Criteria	Assessment Method	Measurement Scale	Minimum Acceptable Performance	Results
Collect and precisely record data using appropriate units. (Criterion #1)	Lab Worksheet	4 = Exemplary 3 = Proficient 2 = Progressing 1 = Unsatisfactory 0 = Insufficient	75 % of students should get at least 3 out of 4 correct	11% scored 4 56% scored 3 22% scored 2 0% scored 1 11% scored 0
Analyze data to determine its relationship to principles and evaluate the data for errors. (Criterion #2)	Writing Assignment	4 = Exemplary 3 = Proficient 2 = Progressing 1 = Unsatisfactory 0 = Insufficient	75 % of students should get at least 3 out of 4 correct	22% scored 4 22% scored 3 11% scored 2 0% scored 1 45% scored 0

Discussion:

It is clear from the table that the expectation of minimum acceptable performance for both criteria were not met for this outcome. For the first criterion, only 67% scored a 3 or 4. For the second criterion, only 44% scored a 3 or 4. This may in part be due to the significant number of students that did not complete the assignment and therefore received a zero, however it nevertheless suggests deficiencies in this PSLO.

The two most common deficiencies observed for the first criterion were the inability to correctly report data values to the correct number of significant figures based on the precision of a measurement device and the ability to report a calculated value to the correct number of significant figures based on the precision of the numbers used in the calculation. This suggests that students still need more practice at this stage to develop a habit of mind regarding these attributes.

Regarding the second criterion, the overwhelmingly most common deficiencies were the inability to interpret data in graphical form and communicate conclusions made from that interpretation. This suggests that students need significantly more training in analyzing and interpreting data in graphical form.

In general, it appears that students at this stage have better developed skills related to the first criterion (data collection) that the second (data analysis and interpretation). This is perhaps not too surprising.

PSLO #3: Students will be able to effectively find and use resources from the literature.

This SLO is mapped to the curriculum as shown in appendix A2.

Direct Assessment #1

Seventeen Biology-Health Sciences seniors from two sections of BIO 409 Current Research Topics in Medical Sciences II, were assessed winter term of 2016 (201502). Seven students were in a section of BIO 409 taught by Dr. Hui-Yun Li and ten students were in a section taught by Dr. Ken Usher. BIO 409 is a required course for Biology-Health Sciences majors.

Assessment criteria:

1. Students will be able to identify and locate appropriate sources for reference citation in presentations, papers, and research reports.
2. Students will be able to use library and online technologies to locate and acquire reference materials.
3. Students will be able to recognize different levels of information authority and select reference materials appropriate to intended audience.

Assignment used:

The student prompt for the assignment was: “You will be required to write a 7-10 page research paper on the same topic as your oral presentation. This article should utilize at least six referenced sources, including at least one primary research article, and should describe an area of current research, explain its context and importance, and suggest the possible direction of further developments in the field. It should be written in the third person, and illustrations or figures should only be included if they help explain the topic and are referred to within the text of the paper.”

Assessment Rubric:

A simple scale of 3 = high proficiency, 2 = proficiency, and 1 = no/limited proficiency was used.

Goal:

At least 85% of students should score a 2 or 3.

Results:

Performance Criteria	Assessment Method	Measurement Scale	Minimum Acceptable Performance	Results
1. Search and acquire resources a. Identify and locate appropriate sources 1b. Use library and online technologies to locate references	Research paper	3= high proficiency 2= proficiency 1=no/limited proficiency	85% at 2 or 3	1a. 5 students-2 12 students-3 1b. 16 students-3 1 student-2

2. Utilize data bases a. recognize appropriate data bases and their limitations b. extract information from data bases	Research paper	3= high proficiency 2= proficiency 1=no/limited proficiency	85% at 2 or 3	2a. 17 students-3 2b. 5 students-2 12 students-3
3. Evaluate reference sources a. recognize different levels of information authority b. power of conclusions	Research paper	3= high proficiency 2=proficiency 1=no/limited proficiency	85% at 2 or 3	3a. 6 students-2 11 students-3 3b. 6 students-2 11 students-3

Discussion:

This assessment shows that 100% of students in this course meet our standard of proficiency (2) or high proficiency (3) in every category. They demonstrate very good performance in searching and acquiring resources, utilizing data bases, and evaluating reference sources, while showing satisfactory but somewhat limited proficiency in justifying confidence levels to conclusions stated in reference sources.

Students participating in the assessment are seniors and have taken several courses which contained writing components in course evaluation. Most have taken WRI 227 and WRI 327, as well as courses within their major that require research-based papers and/or presentations. All of the students are equipped with the ability to utilize available database and search literature. However, some students are weak in evaluating the results and conclusions presented in the papers and references. The students have taken courses (*eg*. BIO 209, BIO 341, BIO 342, CHE 450) in their major that require some critical reading of scientific research articles, but the instructors felt that more should be done in this regard. Three possibilities for this include: additional practice of such reading, more explicit instruction of principles for critically reading articles, and deliberate inclusion of instructor-chosen articles that are less strong, so that students can practice recognizing flaws and limitations of conclusions there.

VI. Evidence of Student Learning

PSLO #2: Students will be able to apply scientific principles to biology (or chemistry or physics) based problems.

Criterion #1:

Overall, data collection skill, at least at the lower levels of expectation (CHE 222), is a strength to be maintained. In more complex data collection assignments however, weaknesses begin to show. In particular, using the correct number of significant figures is a skill that needs to be worked on. 100% of lower level students reached the goals of assessment #1, but only 67% in assessment #2.

It is suggested that students need more practice at higher levels of data reporting and more awareness of the importance of correct significant figures.

Another suggestion was to make more labs where students choose what data they should collect and how.

Criterion #2:

This criterion (analyzing data) was more difficult for students, who fell below goal levels in both assessments, 65% reaching goals in assessment #1, and 44% in assessment #2. In assessment #1 the most common difficulty for students was in deciding which information was relevant in cases where they were given more information than was needed. In assessment #2, the overwhelmingly most common difficulties were in interpreting data in graphical form.

Recommendations to improve student success in this area include:

- Basing the assessments on more than one quiz question, to have more confidence in the low number sample.
- Develop an assessment that addresses evaluating data for errors.
- Apply concepts to more qualitative data, not just numerical data.
- More practice in choosing which information is relevant to a scientific principle or problem.
- Significantly more training in analyzing and interpreting data in graphical form.

PSLO #3: Students will be able to effectively find and use resources from the literature.

The assessment showed that 100% of students assessed met the standard for every criterion. The only weakness was a satisfactory but somewhat limited proficiency in evaluating the results and conclusions presented in the papers and references.

The instructors had three recommendations for improving this weakness:

- Additional practice in reading scientific research articles.
- More explicit instruction of principles for critically reading articles.
- Deliberate inclusion of instructor-chosen articles that are less strong, so that students can practice recognizing flaws and limitations of conclusions.

V. Changes Resulting from Assessments

There were no recommendations to make changes from previous assessments.

Appendix A1. Curriculum Map for Biology - Health Sciences

PSLO 2: Apply biological principles to solving biology (or chemistry or physics) problems

Year	Fall	Outcome*	Winter	Outcome*	Spring	Outcome*
F 1						
	BIO 211 Principles of Biology	I	BIO 109 Intro to Medical Sciences		BIO 213 Principles of Biology	I
	MATH 111 College Algebra		BIO 212 Principles of Biology	I	MATH 361 Statistical Methods I	
	WRI 121 English Composition		MATH 112 Trigonometry		Health Biology Elective (lower division)	
	Social Science Elective		WRI 122 English Composition		Humanities Elective	
			Social Science Elective			
S 2						
	BIO 345 Medical Microbiology	I	BIO 209 Current Research Topics in Medical Sciences I		CHE 223 General Chemistry	
	CHE 221 General Chemistry		CHE 222 General Chemistry		WRI 227 Technical Report Writing	
	MATH 251 Differential Calculus		MATH 252 Integral Calculus		Health Biology Elective (upper division)	R
	SPE 111 Fundamental of Speech		SPE 321 Small Group Communication		Humanities Elective	
			‡ Health Biology Elective (upper division)	R		
J 3						
	BIO 331 Human Anatomy & Physiology I	R	BIO 332 Human Anatomy & Physiology II	R	BIO 333 Human Anatomy & Physiology III	R
	CHE 331 Organic Chemistry I		CHE 332 Organic Chemistry II		CHE 333 Organic Chemistry III	R
	PHY 221 General Physics with Calculus		PHY 222 General Physics with Calculus		PHY 223 General Physics with Calculus	
			Humanities Elective		WRI 327 Advanced Technical Writing	
S 4						
I	CHE 450 Biochemistry I	R	BIO 346 Pathophysiology I	E	BIO436 Immunology	E
	Health Biology Elective (upper division)	R	BIO 409 Current Research Topics in Medical Sciences II		Health Biology Elective (upper division)	R
	Social Science Elective		CHE 451 Biochemistry II	R	Health Biology Elective (upper division)	R
	Elective		Social Science Elective		Health Biology Elective (upper division)	R
	Elective				Elective	

* In these columns, the outcome is either introduced (I), reinforced (R), or emphasized (E) in each course. It is left blank if not applicable.

‡ Outcomes applicable to Health Biology Electives (upper division) are: BIO 341 (R), BIO 342 (R), BIO 347 (E), BIO 357 (R), BIO 426 (R), BIO 436 (E), and CHE 452 (R).

Appendix A2. Curriculum Map for Biology - Health Sciences

PSLO 3: Students will be able to effectively find and use resources from the literature.

Year	Fall	Outcome*	Winter	Outcome*	Spring	Outcome*
F 1						
	BIO 211 Principles of Biology		BIO 109 Intro to Medical Sciences		BIO 213 Principles of Biology	I
	MATH 111 College Algebra		BIO 212 Principles of Biology		MATH 361 Statistical Methods I	
	WRI 121 English Composition		MATH 112 Trigonometry		Health Biology Elective (lower division)	
	Social Science Elective		WRI 122 English Composition		Humanities Elective	
			Social Science Elective			
S 2						
	BIO 345 Medical Microbiology		BIO 209 Current Research Topics in Medical Sciences I	I	CHE 223 General Chemistry	
	CHE 221 General Chemistry		CHE 222 General Chemistry		WRI 227 Technical Report Writing	R
	MATH 251 Differential Calculus		MATH 252 Integral Calculus		Health Biology Elective (upper division)	
	SPE 111 Fundamental of Speech		SPE 321 Small Group Communication		Humanities Elective	
			‡ Health Biology Elective (upper division)	R		
J 3						
	BIO 331 Human Anatomy & Physiology I		BIO 332 Human Anatomy & Physiology II		BIO 333 Human Anatomy & Physiology III	
	CHE 331 Organic Chemistry I		CHE 332 Organic Chemistry II		CHE 333 Organic Chemistry III	
	PHY 221 General Physics with Calculus		PHY 222 General Physics with Calculus		PHY 223 General Physics with Calculus	
			Humanities Elective		WRI 327 Advanced Technical Writing	R
S 4						
	CHE 450 Biochemistry I	R	BIO 346 Pathophysiology I		Health Biology Elective (upper division)	R
	Health Biology Elective (upper division)	R	BIO 409 Current Research Topics in Medical Sciences II	E	Health Biology Elective (upper division)	R
	Social Science Elective		CHE 451 Biochemistry II	R	Health Biology Elective (upper division)	R
	Elective		Social Science Elective		Elective	
	Elective					

* In these columns, the outcome is either introduced (I), reinforced (R), or emphasized (E) in each course. It is left blank if not applicable.

‡ Outcomes applicable to Health Biology Electives (upper division) are: BIO 341 (E), BIO 342 (R), BIO 436 (R), and CHE 452 (R).

Appendix B: Laboratory Worksheet for PSLO #2, Direct Assessment #2, first criterion

Grating Spectrometer
PHY 223 Lab 8
Oregon Institute of Technology
NOTE: Retain any graphs and analysis done on the computer until the end of lab, and discuss your analysis with your instructor before obtaining the sign-off.

I. Overview

Diffraction gratings are used in a wide variety of applications in optical systems. They are especially useful in applications requiring the spatial separation of light of different wavelengths. For example, spectrophotometers use diffraction gratings to "pick out" the wavelength of interest from a multi-wavelength light source, in order to measure a sample's absorbance at that particular wavelength. The functionality of a diffraction grating depends on two properties of light: diffraction and interference. When a coherent light wave of wavelength λ passes through two slits in a barrier, separated by a distance *d*, the two waves can interfere with each other either constructively or destructively on the other side of the barrier at a location away from the slits. The type of interference that occurs is determined by the **path length difference** for the two waves exiting the two slits. You can find the derivation of the condition for constructive interference in your text, which yields the following equation:

$m\lambda = d\sin\theta,\ m = \pm\ 0,1,2,3,\cdots$ (1)

The integer m is called the **order** of the maximum. The angle θ specifies the direction in which the constructive interference occurs, measured relative to the perpendicular line that bisects the two slits (the midpoint of the slits). If a screen was placed some distance away from the slits, one would observe bright maxima, or **fringes**, in the directions given by Eq. (1) where constructive interference is occurring. If instead of just two slits we have a **grating** comprised of many slits all separated by the same distance d, it turns out that the positions of the intensity maxima resulting from constructive interference of the many waves leaving the slits are still given by Eq. (1). Also, the more slits we have in our **diffraction grating**, the sharper the maxima will be, i.e. the width of the fringes become smaller so that they can be better resolved (separated). For a fixed d, we can also see from Eq. (1) that different wavelengths of light will diffract in different directions. That is one of the very useful properties of a diffraction grating: if light containing several different wavelengths comes in from a single direction, monochromatic light is sent off in different directions, similar to a prism. The wavelength of light that is of interest can then be isolated and used.

Diffraction gratings can also be used to measure the wavelength of light passing through it. In this lab we will use the diffraction grating for this purpose. The light waves emitted from excited helium gas have very well-defined wavelengths. We will measure the wavelengths of the light emitted from the helium source, and compare our experimental values to the known values for this spectrum. We will also use the same data we collect to experimentally determine the line spacing in our diffraction grating.
Your instructor will help you to become familiar with the spectrometer and its operation, including how to focus the telescope and how to operate the collimator. 2

II. Measuring the Wavelength of Light by Diffraction

Once your spectrometer is focused, turn on the helium source and align the telescope so that it is directly across from the collimator slit. Rotate the table so that the angular position of the telescope is zero when directly across from the collimator slit, and lock the table in place. Place the diffraction grating in the center of the table such that the incident light is perpendicular to the surface of the grating.

Look at the light exiting the other side of the diffraction grating with your eye (without the telescope). You should be able to see a series or different colored lines of light. These are the diffraction maxima that we will be using in our data collection.

We will use only the $m=1$ diffraction orders to determine the wavelengths of light. Starting from $\theta=0°$, measure the angular position of the each line of light that is visible using the crosshairs in your telescopes. Since the diffraction grating will diffract the different wavelengths both left and right of $0°$ by the same angle θ, measure from both sides to check that the angles agree with each other in order to confirm the grating is correctly aligned. Record the positions in Data Table 1. Once you have confirmed that the angular positions of the intensity maxima are the same in both directions, calculate the wavelength of light for each line using one set of angles and record it in the table. Include your estimated uncertainties for all values, and include sample calculations for one of the lines (wavelengths) in the space provided on the next page.

On the diffraction grating, the manufacturer has stated the number of lines (equivalent to "slits") per mm. Determine the line spacing for the grating (d):

Data Table 1	□ 1 (deg) to left	□ 2 (deg) to right	□ (nm)
Color			
Red			
Red			
Yellow			
Green			
Aqua			
Blue			
Violet			

Appendix C: Series of Scientific Communication Exercises
Take-home writing assignments used in PSLO #2, Direct Assessment #2, second criterion

PHY 223 – Scientific Communication Exercise 1

Due in lab Week 3

Write a paragraph for each of the following. Try to simultaneously be as detailed as possible and as concise as possible. Try to help the reader extract as much information from the graph as possible and lead them to your conclusion in the fewest number of words.

1. **Describe.** What data does your graph show? Explain what is plotted in the graph for the reader. Include how it was generated – explain what each of the quantities relates to in the experiment that was performed.
2. **Interpret.** Can any quantitative relationship be deduced between the two quantities plotted, based on the graph? Does that mathematical relationship correspond to any physical model? If so, what is the model? What can be concluded from the graph? What can be learned?

Please print out your two paragraph writing assignment and bring to your lab section Week 3.

PHY 223 – Scientific Communication Exercise 1
"Expert" Example – Do not read this until you have turned in your paragraphs

Please type your responses to the questions on the next page, print them out, and bring to lab during Week 4 (due in lab, Week 4).

Figure 1. Weight attached to the end of a vertical spring plotted as a function of the resulting displacement of the spring away from equilibrium.

The spring constant of the spring was determined by measuring the displacement of the vertical spring from equilibrium upon attaching different masses m to the end of the spring. Figure 1 shows the weight $F_g = mg$ of the masses attached to the end of a vertical spring versus the resulting displacement of the spring away from equilibrium. In this experiment, the equilibrium position $x = 0$ corresponds to no mass attached.

As illustrated in the figure, the displacement increased monotonically with the weight attached. A relatively good fit to the data was achieved using a linear trend line of the form $y = mx$. Since the mass is in static equilibrium, the weight is equal in magnitude to the force applied by the spring. The data in Figure 1 suggest that the measured displacement and magnitude of applied force are proportional to each other, in good agreement with Hooke's law, $F_x = -kx$. The slope of the trend line therefore represents the spring constant, k, which we determined from our fit to be $k = 9.6$ N/m.

Comparison Questions:

1. How does the "expert" introduce and describe the data? Did you do similar things in your description? What might you differently if you did this again?
2. How does the "expert" explain how the data were interpreted and what was learned from the data? Did you do similar things in your description? What might you differently if you did this again?

PHY 223 – Scientific Communication Exercise 1-C (2nd Attempt)
Due in lab Week 5

Rewrite your one paragraph for each of the following. Try to simultaneously be as detailed as possible and as concise as possible. Try to help the reader extract as much information from the graph as possible and lead them to your conclusion in the fewest number of words.

1. **Describe.** What data does your graph show? Explain what is plotted in the graph for the reader. Include how it was generated – explain what each of the quantities relates to in the experiment that was performed.
2. **Interpret.** Can any quantitative relationship be deduced between the two quantities plotted, based on the graph? Does that mathematical relationship correspond to any physical model? If so, what is the model? What can be concluded from the graph? What can be learned?

Please print out your two paragraph writing assignment and bring to your lab section Week 5.

PHY 223 – Scientific Communication Exercise 2-A
Due in lab Week 7

Write a paragraph for each of the following. Try to simultaneously be as detailed as possible and as concise as possible. Try to help the reader extract as much information from the graph as possible and lead them to your conclusion in the fewest number of words.

1. **Describe.** What data does your graph show? Explain what is plotted in the graph for the reader. Include how it was generated – explain how each of the quantities relates to in the experiment that was performed.
2. **Interpret.** Can any quantitative relationship be deduced between the two quantities plotted, based on the graph? Does that mathematical relationship correspond to any physical model? If so, what is the model? What can be concluded from the graph? What can be learned?

Please print out your two paragraph writing assignment and bring to your lab section Week 7.

PHY 223 – Scientific Communication Exercise 2-B

"Expert" Example – Do not read this until you have turned in your paragraphs
Please type your responses to the questions on the next page, print them out, and bring to lab during Week 8 (due in lab, Week 8).

Figure 1. Experimentally measured intensity as a function of distance (log-log scale) from an incandescent light bulb. The solid line is the calculated dependence of intensity on distance predicted by the point source model.

Figure 1 shows the experimentally measured light intensity I as a function of distance r from the incandescent light bulb. The error bars indicate the estimated uncertainty in the measured distance and intensity. Also shown (solid curve) is the calculated intensity as a function of distance predicted from the point source model,

$I =$
P_S
$4\pi r^2$ (1)

where P_S is the power emitted by the light bulb. Since the power P_S is not known and not easy to measure, the intensity was calculated at each r based on the measured intensity I_0 at the farthest measured distance r_0. Assuming a constant power for the light bulb, the ratio of I to I_0 is

I
I_0
$=$
P_S
$4\pi r^2$
P_S

$$4\pi r_0^2 = \frac{r_0^2}{r^2} \quad (2)$$

Thus I can be predicted for any other r once I_0 and r_0 are defined. Since the intensity varied over two orders of magnitude, the data are plotted on a log-log scale.

Since the intensity decreases with the inverse square of the distance in the point source model, the curve calculated by Eq. 2 appears linear with a slope of – 2 when plotted on a log-log scale. Examining Figure 2, it is apparent that the experimental data agree very well with the point source until the distance from the light bulb is 0.1 m, at which point the intensity changes with distance less rapidly than predicted by the point source model. We conclude that, for distances greater than 0.1 m, the light bulb studied in our experiment appears to be very well modeled as a point source. However, for distances closer than 0.1 m the point source model does not successfully predict the dependence of intensity on distance. This may suggest that the extended size of the light bulb filament becomes important at smaller distances.

Comparison Questions:

1. How does the “expert” introduce and describe the data? Did you do similar things in your description? What might you differently if you did this again?
2. How does the “expert” explain how the data were interpreted and what was learned from the data? Did you do similar things in your description? What might you differently if you did this again?

PHY 223 – Scientific Communication Exercise 2-C

Due in lab Week 9

Rewrite your one paragraph for each of the following. Try to simultaneously be as detailed as possible and as concise as possible. Try to help the reader extract as much information from the graph as possible and lead them to your conclusion in the fewest number of words.

1. **Describe.** What data does your graph show? Explain what is plotted in the graph for the reader. Include how it was generated – explain what each of the quantities relates to in the experiment that was performed.
2. **Interpret.** Can any quantitative relationship be deduced between the two quantities plotted, based on the graph? Does that mathematical relationship correspond to any physical model? If so, what is the model? What can be concluded from the graph? What can be learned?

Please print out your two paragraph writing assignment and bring to your lab section Week 9.