Use of hybrid online course for retraining employed technicians

John Souders
OP-TEC

Greg Kepner
Indian Hills Community College

ABSTRACT

The National Center for Optics and Photonics Education (OP-TEC) is dedicated to meeting the U.S.'s demand for photonics technicians. A key to meeting this demand is assisting two-year colleges in providing flexible and effective means for preparing these technicians. To this end, OP-TEC has developed a hybrid online course that can be used for multiple purposes, including faculty development, student enrichment, and employee retraining. The online delivery mode and multipurpose capability of this course provide two-year colleges an educational delivery platform that can reach well beyond their local service areas and provide undergraduate students and already employed technicians an opportunity to engage in this technical area. This paper will focus on the use of this course as a tool for retraining technicians who are already employed ("incumbent workers") by photonics and photonics-related companies. It will explain why these workers are important to meeting the technician demand of U.S photonics employers, present the structure of the course and its components, and describe a recent implementation of the course by Indian Hills Community College, Ottumwa, Iowa, in retraining employees at Mound Laser and Photonics Center in Miamisburg, Ohio.

KEYWORDS: Lasers, optics, photonics, fiber optics, OP-TEC, Indian Hills Community College, online hybrid, Blackboard

1. DEMAND EXCEEDS SUPPLY

The main source for providing skilled technicians for U.S. photonics companies is the community and technical college system. However, although several community and technical colleges have excellent photonics programs, the total output of program completers is far below employer demand, according to two studies conducted by OP-TEC.

1.1 Supply

The purpose of the first study was to determine the capacity of U.S. colleges to produce photonics technicians.[1] To collect this information, the study used both Internet searches and telephone surveys. The Internet searches identified postsecondary institutions in the U.S. that offer photonics instruction (from single courses to full programs) that can contribute to the training and education of photonics technicians. The telephone surveys confirmed that the identified colleges still offer this instruction and determined the number of students enrolled and the number of program completers. All the institutions that contributed to the final results of the survey indicated that they have active photonics instructional offerings (at least one course in photonics, optics, and/or laser technology) and that their former students are employed in the optics/photonics industry as a result of their participation in that instruction. The results of the survey indicated that 600–700 students are enrolled in programs that are capable of leading to technician-level employment in the photonics industry. However, only 250–300 are completing their programs each year and are available to fill industry positions.

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1.2 Demand

To determine the demand side, OP-TEC commissioned the University of North Texas (UNT) Survey Research Center to canvass industrial companies around the U.S. that perform R&D with optics, lasers, and photonics technology or are original equipment manufacturers for photonics R&D companies to determine how many photonics technicians they currently have in their employment, the additional number they will need in 2009, and the number they will need in the next five years. Using both the Laurins Publishing Company Photonics Directory (2008) and OP-TEC databases, the researchers identified a total of 3989 U.S. photonics companies. The researchers contacted over 600 companies and generated a representative sample of 300 that employed photonics technicians. Besides employment data, the survey collected information on the educational levels of employed photonics technicians, the employers' preferences with respect to the levels of education those technicians should have, and the types of jobs photonics employers are seeking to fill. After a statistical analysis of this sample-based survey, a final report was issued.[2] In summary, the report stated that over 19,000 photonics technicians are currently employed in the U.S., that over 2100 additional photonics technicians will be needed next year, and that approximately 5900 will be needed over the next five years (2010–2014).

When the supply and demand results are compared, it is clear that for the U.S. to meet its demand for these workers, community and technical colleges must substantially increase the numbers of their graduates and program completers. For example, let's assume that in 2010 U.S colleges can add 300 new technicians to the pool of photonics workers. This will fall far short of the 2100 workers needed. Helping to close the gap between supply and demand is one of OP-TEC's primary challenges. To meet this challenge it must empower colleges to increase enrollments in their existing photonics and photonics-related programs and to implement new programs.

Although these two options—implementing new programs and enhancing existing programs—are viable, experience has shown that colleges are not amenable to making quick changes. Changes at the program level require gaining local and state approvals, purchasing laboratory equipment, establishing advisory committees, and performing many other preliminary tasks—a process that can take years. So OP-TEC sought a quicker way to meet the high demand for photonics technicians. One option was to provide specialized training for incumbent workers in photonics-enabled technologies such as manufacturing, biomedicine, and telecommunication. The training would enhance those technicians' ability to maintain and troubleshoot the systems with which they work.

But why did we choose incumbent workers as our other target? Why not concentrate on producing new technicians? The demand for photonics workers covers a broad spectrum of ability levels. Organizations involved in research, original equipment manufacturers, and field service companies need photonics technicians who have a detailed understanding of lasers and their operations. These technicians typically have AAS degrees in laser electro-optics, photonics, or closely related fields and represent one part of the demand identified in the UNT survey results. Another significant portion of this demand comes from companies that use photonics as an enabler of other technologies. Examples include telecommunication companies that are heavily dependent on lasers and fiber optics; manufacturing companies that use lasers for welding, cutting, and scribing; and medical groups that use lasers and fiber optics for diagnostic and therapeutic procedures. Each of these organizations employs technicians who need an understanding of photonics to fully comprehend the performance of the systems they maintain, calibrate, and/or repair. However, many of these technicians never had the opportunity during their years of formal education to learn about photonics. As a result, their employers feel this deficiency on the shop floor. To remedy this deficiency, companies could hire new technicians with a basic understanding of photonics. However, it is less expensive to provide a means for incumbent technicians to acquire these basic skills. To meet this training need, OP-TEC has created a hybrid online course that enables incumbent workers to develop basic photonics skills and knowledge using a flexible format.

2. HYBRID ONLINE COURSE CONTENT AND STRUCTURE

Technicians working in photonics-enabled fields typically have the basic skills and knowledge that photonics technicians require. They understand the theory and application of AC, DC, and electronic circuits; are well versed in metrology; have a working knowledge of basic scientific principles; and have analytical skills sufficient to solve basic problems that may involve college algebra and trigonometry. These technicians also have honed their problem solving skills and have experience working in teams. What they lack is a basic understanding of photonics and how it enables the processes they are responsible for maintaining.

To meet this need for basic photonics skills and knowledge, OPTEC has devised a course titled *Fundamentals of Light and Lasers* that covers basic concepts related to light, optics, and laser operations. Figure 1 lists the modules that make up the course.

Fundamentals of Light and Lasers
Nature and Properties of Light
Optical Handling and Positioning
Laser Safety
Basic Geometric Optics
Basic Physical Optics
Principles of Lasers

Figure 1 Course Content

This foundational course provides incumbent technicians working in photonics-related fields a broad overview of the scientific and technological concepts required for understanding the basic operational concepts and applications of photonics devices.

As Figure 1 shows, this course covers a progressive sequence of topics that allows students to start with the basic concepts of light; learn about laser and optical lab procedures; become familiar with laser safety issues; understand how light is controlled by lenses, gratings, and other optical devices; and integrate these concepts into a study of laser operation. *Fundamentals of Light and Lasers* provides the basic skills and knowledge needed by technicians in most photonics-enabled industries and thus serves to meet a portion of the demand identified in the UNT report.

2.1 Course Structure

This course is a true online hybrid. It contains all the basic elements that are typically present in online offerings. It is a hybrid in that it requires participants to perform the laboratory exercises “on site” at educational institutions selected by their employers. This requirement was put in place because OP-TEC’s educational philosophy maintains that technicians need more than a conceptual understanding of photonics. They should also have experience in working with photonics laboratory protocols and practicing data acquisition and analysis techniques. Consequently, the hands-on component is considered an essential part of the course.

The length of the course can be adjusted to fit the employer’s need. It can be completed in five eight-hour days or expanded to any reasonable length, though we recommend that the timeframe not exceed one year. If the course extends much beyond a year, it loses its coherence and requires extensive review, which can entail larger time commitments and thus more lost work time.

The online elements of the course are shown in Figure 2 (a screen capture of the course’s homepage).

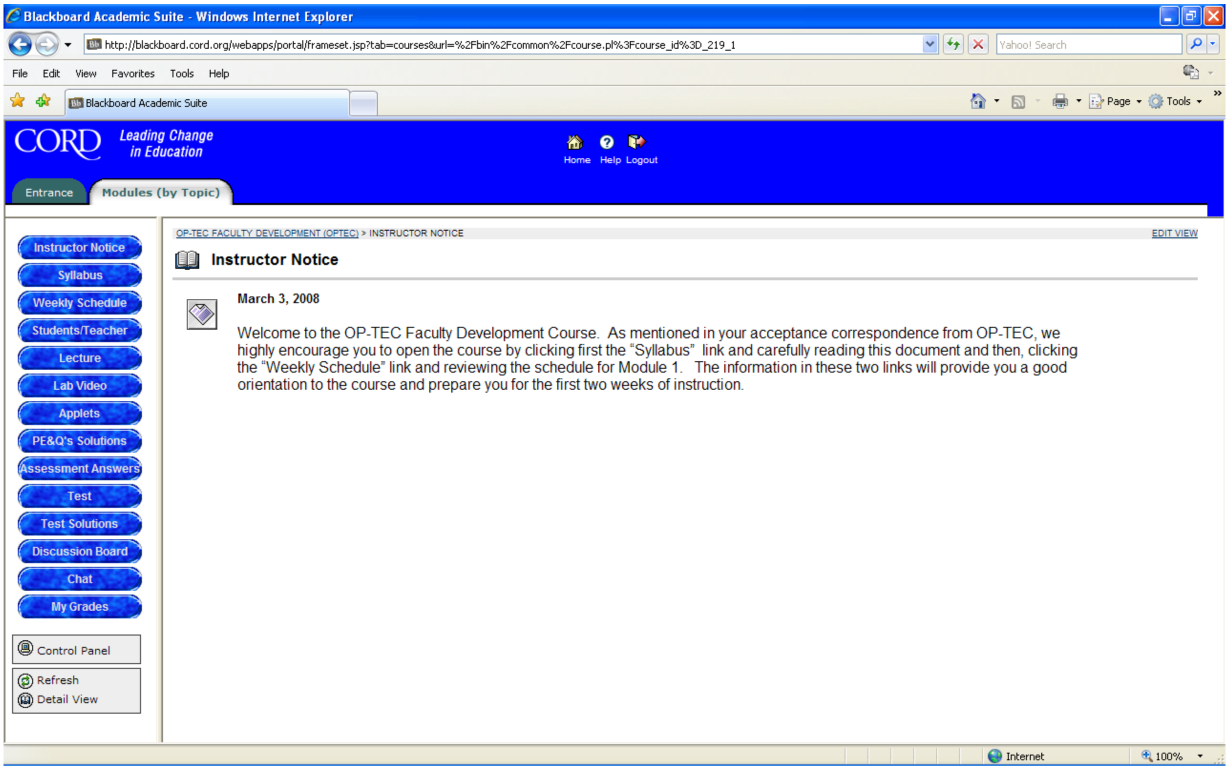

Fig 2 Online Elements of OP-TEC's *Fundamentals of Light and Lasers*

The buttons along in the left-hand column provide the following links:

Instructor Notice: This link takes students to a page where the instructor posts notices that are time sensitive or important in administering the course. This screen automatically opens when students log on to the course.

Syllabus: This link takes students to the course syllabus, which provides key information relating to the course.

Weekly Schedule: This link allows students to view assignments for a given week.

Students and Teachers: This link accesses the bios of the course instructor(s) and bios submitted by students.

Lecture: This link opens a video that provides background materials and an overview of the laboratory that can be accessed through the *Lab Video* link.

Lab Video: This link accesses a video that shows a course laboratory being conducted. The video emphasizes the equipment used, safety issues, required data, and data acquisition techniques. Students are asked to keep laboratory notebooks to record this information. (The notebooks are useful to the students during their on-campus laboratory capstone experience.) Through this link, students can also access data tables that present "live" data taken during the laboratory. Using these data, students perform specified calculations that verify equations or explain concepts investigated in the laboratory.

Applets: This link accesses other links that allow students to view the applets referenced in the *Fundamentals of Light and Lasers* text. These applets supplement instruction presented in the text.

PE&Q Solutions: This link accesses solutions to the assigned problems, exercises, and questions (PE&Q) compiled from the text. Course instructors can close student access to the *PE&Q Solutions,* requiring that the students solve the problems on their own, either independently or in groups. The answers are provided as a means for students to check the accuracy of their work. Once students have had time to work independently on the assigned PE&Q's, the instructor will grant then access to the solutions.

Assessment Answers: This link provides answers to assigned PE&Q's. These answers are always available to the students.

Test: This link allows students to access graded tests. Instructors set the dates that students can access the tests.

Test Solutions: This link provides a means for students to review the solutions to graded tests. Instructors set the dates that students can access the solutions.

Discussion Board: This provides a means for students to interact with each other and their instructors. A discussion board is an asynchronous communication option that students use to exchange information on course-related matters.

Chat: This is another means for students to interact with each other and their instructors. The chat rooms are synchronous and allow students to work together in group activities. The course has at least one instructor-led chat each week for the whole class.

My Grades: This link allows students to view their grades. The link is password protected, thus ensuring confidentiality.

2.2 Laboratory Capstone Experience

As already mentioned, the *Fundamentals of Light and Lasers* course requires students to participate in laboratory activities. The intent of the laboratory capstone experience is to give students the opportunity to conduct the experiments contained in the text. Since all OP-TEC partner colleges have the facilities and equipment necessary to conduct the laboratories, the capstone experience can be scheduled on any of their campuses. However, in case this is inconvenient for the students or employers, OP-TEC has worked with IHCC to develop a mobile laboratory package that can be shipped to wherever the laboratories are to be conducted. The capstone experience lasts two and a half to three days and includes additional hands-on activities that are not contained in the textbook.

2.3 Course Adaptations

The architecture of the course is flexible, which allows it to be adapted for two other applications.

Faculty Development: One key to increasing the flow of students through the pipeline is to increase the number of faculty members who are qualified to teach photonics courses. The *Fundamentals of Light and Lasers* course can be adapted to provide faculty development in photonics. This is typically a twelve-week course with a laboratory capstone experience that includes best practices in teaching photonics.

Dual Credit: Career pathways reach back into high schools. One of their purposes is to enable students to begin exploration of their career options. This course can be adapted as a dual credit offering (students receive both high school and college credit) and become part of the curriculum supporting photonics career pathways. Because of its online format, high schools do not have to find qualified instructors and, because of the capstone experience, do not need to purchase expensive laboratory equipment. Students who take the course are exposed to the technology that underlies photonics and, through the capstone experience, get to visit a college campus and hear about career opportunities. Both these assets have positive impacts on student recruitment and the flow of students through the photonics pipeline.

3. COURSE PRESENTATION: A SUMMARY OF INDIAN HILLS COMMUNITY COLLEGE'S TECHNICIAN TRAINING OFFERING TO MOUND LASER AND PHOTONICS CENTER

3.1 Course Customization

Before OP-TEC's *Fundamentals of Light and Lasers* could be taught at Indian Hills Community College (IHCC), it had to be customized to fit the IHCC online course format. Of the several available online formats, IHCC uses the format known as ANGEL. The OP-TEC course also required minor adjustments in content to make it an acceptable substitute for the IHCC's LEO 101–Photonics Concepts (four semester credit hours). Once these alterations had been completed, the course was entered into the IHCC course schedule to be offered during the twelve-week spring 2009 term.

3.2 MLPC Students

Mound Laser and Photonics Center (MLPC) enrolled eight students in the course. The students were MLPC technicians, engineers, and research scientists with a broad range of credentials, from associate degrees to bachelor's degrees in mechanical engineering, education, material science, and engineering physics. One student held a Ph.D. in physics (see the list below). The students were highly motivated and very interested in learning about lasers and photonics so they would have a better understanding of the photonics equipment they were responsible for working with. Each student had the option of taking the course for college credit (four semester hours) or completing the course as an audit with no grade assigned. All selected the audit option.

3.3 Positions and Education of MLPC Participants

Position	*Education*
Project Manager	Ph.D. in Physics
Research Specialist	Bachelor's in Materials Science and Engineering
Project Engineer	Bachelor's in Mechanical Engineering
Laser Micromachinist	Bachelor's in Engineering Physics
Project Engineer	Bachelor's in Mechanical Engineering
Project Engineer	Bachelor's in Mechanical Engineering
Laser Technician	Bachelor's in Education
Laser Technician	Associate in Physical Chemistry

3.4 Plan for Delivery of the Course

The course delivery plan was to have students participate online in the theory portion of the course with weekly interactions and then to complete the laboratory capstone experience on-site at MLPC near the end of the course. The plan called for the IHCC instructor to travel to MLPC to work with students for one to three days as needed to complete the laboratory exercises. The instructor was tasked with assembling laboratory kits and shipping them to MLPC or taking them with him. OP-TEC provided every student with a copy of the *Fundamentals of Light and Lasers* textbook.

3.5 Course Delivery

The course began on Monday, February 23, 2009, with a GoToMeeting.com activity arranged through OP-TEC. (GoToMeeting.com is an online meeting service that allows computer screen sharing along with live, interactive audio and video delivery to all participating locations.) The participating MLPC employees (students), Dr. John Souders of OP-TEC, and Bill Gray and Greg Kepner of IHCC all participated in the kick-off activity. Instructor Bill Gray used a webcam while introducing himself and discussing the course content and online delivery system. Bill explained how the online course worked and gave instructions on how to access the course content and submit assignments. Students were able to ask questions as Bill demonstrated the features of the online course system. With all questions answered and the demonstration complete, the students were ready to begin the course.

The course was composed of eleven lessons or units of instruction. Each lesson was composed of pre-quiz focus questions, mini-lectures, discussion forums, assignments, quizzes, and a unit exam. Each lesson was open and available to students online for a period of one week. All of the students' written work was submitted online through the course system. Multiple-choice or true-false quizzes and exams were automatically graded by the system and feedback was automatically provided online to the students. Short-answer questions and other essay-type answers were graded manually by the instructor, who provided feedback online.

The students read the textbook and worked through the online course content weekly. Students whose schedules allowed met for one hour each week during work time to discuss the course content and how it related to their work at MLPC. All of the student-instructor communication about course content took place online. Group questions and comments were emailed to the instructor through the online course feature. The instructor responded to each inquiry or comment as needed.

Students read the applicable textbook chapters weekly and then typically spent two to three hours online completing the questions, assignments, quizzes, and exams. Online PowerPoint slideshows with video voiceovers covered the course content for each lesson. Occasional technical difficulties in synchronizing the video and voice occurred, but this problem has been corrected.

3.6 Laboratory Kits

For the lab kits, instructor Bill Gray selected components and equipment that would be mobile and fit easily into 6" x 17" x 23" plastic storage containers. Each kit included an optical breadboard, a diode laser, four lenses, four mounted mirrors, translation stages, a variety of optical mounting hardware, a diffraction grating, colored filters, slit apertures, concave mirrors, convex mirrors, a power meter, an LED flashlight, a protractor, a tape measure, a ruler, paper, and a pencil. Relatively inexpensive equipment was selected from a variety of vendors that could be transported easily and could be effectively and conveniently used in most classrooms or laboratories. (A list of laboratory equipment is provided as an appendix.) The *Fundamentals of Light and Lasers* text sometimes calls for very precise measurements that require more sophisticated equipment, but IHCC's kits were adequate to accomplish the main laboratory objectives.

3.7 Capstone Laboratory Activity

The IHCC instructor traveled to MLPC on the weekend of May 1–2, 2009, and brought the laboratory kits with him. The students were well prepared to perform the laboratory exercises. Each student had read through the laboratory exercises in advance and had a good understanding of their goals and objectives. Working in pairs, the students began setting up laboratory equipment early on Friday morning. Because the students had excellent and diverse educational backgrounds plus relevant work experience, they were able to work through the laboratory exercises very efficiently and had completed their work by late Friday afternoon. The instructor worked with the students to ensure that the labs were correctly set up and that the appropriate techniques and safety precautions were followed. He answered questions and discussed laboratory data after the laboratory activities were completed. Due to the advanced student preparation and the efficiency of the students' work on the laboratory exercises, the second day of the laboratory was not needed.

3.8 Student Feedback

The overall student response for the class was very positive. Students felt that they had learned valuable and practical skills and knowledge and that their time was well spent. Considering the excellent educational backgrounds and industry experience of the students, this was good news. In an e-mail to the IHCC instructor, MLPC R&D Research Specialist Sarah Bertke wrote, "Before we started, we thought we knew everything there was to know about lasers but we were wrong. We are very happy with what we learned in your class."

Ms. Bertke also had this to say:

> Several months ago there were a few samples at MLPC that we noticed exhibited diffraction-grating-like characteristics after we scanned a laser across their surfaces. When you move the sample around, the light would reflect in different colors depending on the angle at which you looked at the surface. We had since set these samples aside.
>
> When Bill came to our company in May with the LEO 101 lab kits, we were performing Lab1-5B, and one of our employees remembered our samples with the mysterious diffraction characteristics and brought one of the samples down to the conference room where we were performing the lab. We shined one of the lasers in Bill's lab kits onto our sample and sure enough, a diffraction pattern appeared on the wall. So, we repeated Lab 1-5B with our sample, except instead of calculating the laser's wavelength (which we already knew), we used the same equation to instead calculate the diffraction grating spacing, "a," of our sample. We intend to repeat this procedure on our other samples with this characteristic to see if we can find any patterns between the spacings, "a," and the laser parameters which were used to create them.
>
> It was so poetic that a professor of a lasers course showed us, employees at a lasers company, how to use this laser-induced phenomenon to solve a dilemma that was caused by other lasers. You learn something new every day!

4. FUTURE PLANS

Based on the success of this pilot course offering and the need for incumbent worker training in the photonics industry, IHCC plans to continue to offer LEO 101 Photonics Concepts online. IHCC will also continue to utilize OP-TEC's *Fundamentals of Light and Lasers* textbook in the course.

OP-TEC will continue to expand the use of this course in training incumbent workers and will make the course available to any educational institution that has the faculty and laboratory equipment necessary to deliver it. OP-TEC will also work with educational institutions in helping them train faculty, identify equipment, build advisory boards, develop curriculum, and supply instructional materials. This course is one of several means OP-TEC uses to accomplish its mission of increasing the supply of well-educated photonics technicians by building and strengthening the capacity and quality of photonics education in U.S. two-year colleges. To learn of other means OP-TEC uses in accomplishing this mission, visit www.op-tec.org.

REFERENCES

[1] Hull and Gutzwiller, Two-year College Enrollment and Completion Rates: An Estimation of Workforce Supply for Technicians in Optics, Photonics, and Laser Technology, OP-TEC Working Paper Series, Working Paper #5, 2008

[2] Hull, Ruggiere, Illich, Photonics Technician Employment in the United States: An Industry Survey of Current and Future Demand in 2009 for Education and Training Programs, OP-TEC Monograph, 2009

APPENDIX: EQUIPMENT PROVIDED IN LABORATORY KITS

QTY	PART#	ITEM	VENDOR
1	MB1218	Base Plate	Thorlabs
1	17474 TL	Laser Pointer/LED light	Marlin P. Jones & Associates
1	VC-3	V-clamp mount for laser	Thorlabs
2	m33-501	1" mounted first surface mirrors	Edmund Optics
3	m58-961	1.5" posts	Edmund Optics
3	M58-977	1.5" post holders	Edmund Optics
1	M54-038	Power Meter	Edmund Optics
1	W96212	1" diam negative meniscus lens, -55mm f	Anchor Optics
1	W20919	1" diam plano concave lens, -93mm f	Anchor Optics
1	W74570	1" diam plano convex lens, 24mm f	Anchor Optics
1	W74259	1" diampositive meniscus lens, 201mm f	Anchor Optics
3	LMR1	1" fixed lens mount	Thorlabs
3	BA2	Mounting Base	Thorlabs
2	AX73961	1" round glass polarizers	Anchor Optics
2	DH1	Dual Filter Holder	Thorlabs
1	33-0190	Additive/Subtractive filter set 6 filters	Arbor Scientific
1	33-0175	Primary/Secondary Color sheets	Arbor Scientific
1	LED-100	X-LIGHT	Educational Innovations
1	01_3900	Metric ruler	Arbor Scientific
1	P2-7145	2" diam, Concave/convex mirrors 6 mirrors	Arbor Scientific
1	LMR2	2" optic mount	Thorlabs
1	W30759	2" X 2", Diffused glass plate	Anchor Optics
1	P2-7680	Light source, multi colored flash light	Arbor Scientific
1	33-0980	Diffraction grating	Arbor Scientific
2	Jul-51	Microscope slides	Arbor Scientific
2	W27453	1" square mirror	Anchor Optics
1	3120406	Spectroscope, pkg. of 6	Edmund Scientifics
1	P2-9420	Phosphor glow paper	Arbor Scientific
1	P2-7060	Night Spectra Quest	Arbor Scientific
1	34410	Heat Filter	American Science & Surplus
1	2610	Ground Glass, Rectangular	American Science & Surplus
1	W99415	Fresnel lens	Anchor Optics
1	17346 TL	Ultra-violet LED flashlight	Marlin P. Jones
1	UV-750	Ultraviolet Beads	Educational Innovations
1	3030979	Equilateral Glass Prism	Edmund Scientifics
1	3081424	Rainbow window holographic prism	Edmund Scientifics
1		Candle	Walmart