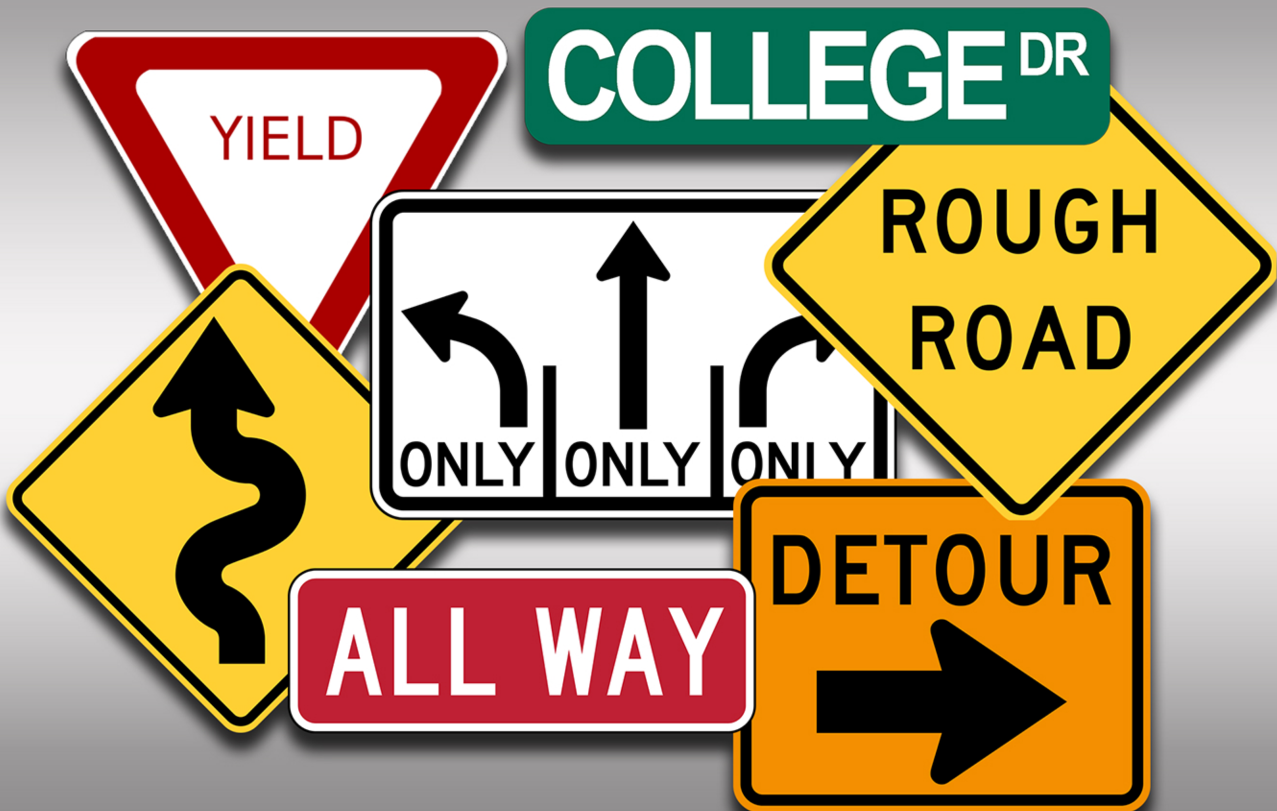
Improving Student Retention in Photonics Technician Education



OP-TEC
National Center for Optics and Photonics Education

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Daniel Hull

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PREFACE

Photonics is a cutting-edge technology that embraces emerging applications such as advanced manufacturing, aerospace, defense, diagnostics and other biomedical equipment, lighting, digital equipment and devices, energy sources and conservation, virtual and augmented reality, and environmental monitoring. Photonics technicians engage in creative, rewarding careers that can lead to professional advancements and leadership opportunities.

Photonics is uniquely interesting, but it can be challenging for technician students to complete a two-year associate degree program that requires understanding and using significant math and physics principles, as well as electronics, controls, and materials sciences. Excellent photonics technicians are hands-on learners who can understand all these principles and technologies if they are presented in the context of how they are used—and if they are willing to face the challenges, study and work hard.

Some photonics students are not prepared; others lack motivation, and still others lack confidence that they can complete this program of study. Dropout rates among photonics students can be high, but the experiences of seasoned photonics faculty members have proven that retention can be greatly improved through the use and adaptation of proven strategies. This monograph collects these successful strategies and offers them to other faculty members so that they may greatly increase their students' completion rates.

Dan Hull, 2017

BACKGROUND

Increasing the capacity of U.S colleges to produce an adequate supply of photonics technicians is a goal that has not yet been realized. U.S. employers need more than eight hundred new technicians each year, and our colleges are producing about four hundred technicians per year.[1] Three strategies to address this goal are:

- Increase the number of two-year colleges teaching photonics systems technicians (PSTs). Currently thirty-seven colleges have photonics programs and about twenty more are considering or planning new programs. Two colleges are closing programs due to low enrollments. "More new programs" is a *long-range plan*, because it takes a college three to four years from the outset of planning to realize significant numbers of completers.
- Increase the enrollment of PST students in existing programs. Efforts to provide focused student recruiters are resulting in significant enrollment growth.[2] OP-TEC has created student recruitment materials and helped fifteen colleges successfully develop focused recruitment efforts for high school students, adults, women, minorities, and returning veterans.

  OP-TEC's current initiative to "Use Current Students as Student Recruiters" has been implemented in six community and technical colleges. More colleges will replicate this model in fall 2017. This strategy will enable colleges with limited or no recruitment budgets to have dedicated recruiters.[2]
- Retain established enrollments by reducing attrition due to student dropouts. This strategy could double the number of completers in many college programs. This monograph identifies the causes of dropouts, documents successful practices that a few colleges have developed, and presents coherent strategies and useful tools that other colleges can adapt and use to retain more students.

Technical education requires the understanding and application of applied math and science, including the ability to use mathematical and scientific concepts and tools to solve problems, perform precise measurements, and successfully perform hands-on tasks in the operation, trouble-shooting, and maintenance of sophisticated equipment, components, and devices. Observing, creating, and manipulating system components, lasers, and optical phenomena are interesting experiences for many students who choose to enter photonics programs of study, but to fully understand and effectively use photonics equipment, most students discover that they must work hard, acquire the required knowledge and skills in math and science, study intently, and consistently improve their work habits and quality. Most hands-on or "applied learners" were not the most accomplished students when math and science concepts were introduced in secondary school. Consequently many of them did not like or understand abstract math or science, performed poorly on tests, and gained little or no confidence that they could master these topics when they finally learned how they would be used.

Younger students may need to improve their study habits and work ethics. Older students may need to gain confidence in their ability to learn and apply math and science to the challenges—and rewards—of technology.

A poll of faculty from well-established photonics programs at seven OP-TEC Partner Colleges revealed that, for most of them, initial dropout rates for first-year students exceeded

50 percent. These are not unexpected attrition levels. According to the National Student Clearinghouse, of the 857,607 first-time students who enrolled in two-year public institutions in fall 2007, only 26.5 percent completed degrees or certificates from their starting institution within six years.[3] ACT trend data and other studies confirm that four-year and two-year graduation rates over the last thirty years have remained relatively flat; as a nation, we have failed to "move the needle in the right direction." [4,5,6]

Some of the causes of high attrition among photonics technician students are:

- Inadequate screening and counseling of student applicants.
- Inappropriate testing and academic remediation of incoming students.
- Lack of student commitment; immature students.
- Failure to remain motivated due to lack of exposure to photonics applications during the first two semesters.
- Lack of a "support group" of fellow students to provide teamwork, technical engagement, and mentoring.
- Low mathematics course placement, resulting in extensive math remediation.

Most of the successful, experienced faculty members at these seven colleges have discovered strategies and improved practices that have reduced their student attrition to less than 10 percent. Preparation for producing this monograph required surveying these experienced faculty to learn critical best practices in student retention. These faculty memebers reviewed the initial draft of this monograph, and I made changes based on their feedback to ensure the accuracy and validity of the proposed strategies.

The Culture of Two-Year College Admission Practices

A very important benefit of our country's support for its population is the opportunity for all citizens to have access to quality higher education. This practice is mainly attributed to the open enrollment policies of our two-year colleges. Generally, any U.S. citizen who wants to pursue coursework or a degree beyond the high school level may apply—and be accepted—at a local community or technical college, where tuition costs are more affordable than at other colleges and universities.

However, this practice has required that two-year colleges accept students without regard to their interests, abilities, and academic accomplishments. Frequently, students accepted into technical programs require testing and extensive remedial coursework. Studies have shown that many of these students drop out of the program (or the college) very early in their first year.

Degree and certificate completion at two-year colleges is sobering. Of the 857,607 first time students who enrolled at two-year public institutions in fall 2007, only 26.5 per cent completed degrees or certificates from their starting institution within six years.[3]

College faculty members have access to information on all students who have enrolled in their program of study. A recommended action for photonics faculty is to review information about all students who have enrolled in their program and take the following actions:

- Review entrance and placement exams to determine whether the students are suitable for entrance to the program.
- Determine the remedial courses that are required of the students. Are they necessary and sufficient to prepare these students for the math, science, and technical courses they will be taking?
- Contact the students who have enrolled in photonics programs and provide them with information about the field, the courses, expected job opportunities, and the importance of adequate preparation.
- Urge these students to apply sufficient time and effort to examine their possible learning deficiencies, explore remedial assistance and resources, and dedicate themselves to successful accomplishment of the required coursework.
- Offer potential students a math refresher course that they can take before taking placement exams.

Critical Issues and Suggested Strategies Regarding Photonics Student Retention[7]

Academic Failure

All colleges surveyed indicated that the greatest cause of dropouts during the first year is the inability to understand and apply math and science concepts that are used in optics, electronics, and lasers.

- Evaluation, Counseling and Remediation

  All entering students should be tested, evaluated, and counseled regarding their proficiencies in math and science. The most prevalent deficiency is in math.

  Frequently students' deficiencies require remediation before they can enroll in photonics or electronics courses. If remediation courses are required for one or two semesters, students must receive experiences in photonics that will help them remain interested in and committed to the program.

  Photonics faculty members have expressed concern that many faculty members in their colleges' math departments teach remedial math courses in the abstract manner in which they were taught in high school, which is relatively ineffective for the applied learners in these courses. If math remediation courses are taught by math faculty members, they should include interesting, "photonics-related" concepts that students can understand and use to solve problems.

- Mathematics for Photonic Technician Education

  Eleven math concepts are required to understand the technology and solve problems in the introductory photonics course, *Fundamentals of Light and Lasers.*

  1. Scientific Notation
  2. Unit Conversion

3. Introductory Algebra
4. Powers and Roots
5. Ratio and Proportion
6. Exponents and Logarithms
7. Graphing in Rectangular Coordinates
8. Geometry
9. Angle measures in Two and Three Dimensions
10. Trigonometry
11. Special Graphs

OP-TEC has developed a text, *Mathematics for Photonics Education,* that contains modules for each of these topics. Each module reviews the concept and presents math solutions to photonics problems. A diagnostic test (provided in Appendix A) can be used by faculty members to measure their new students' understanding of each concept and ability to apply it to solve problems. Faculty members frequently administer this test to new students to identify their ability to understand and apply each concept. Students are advised of apparent deficiencies in their understanding of any of the concepts and are encouraged or assigned to study specific modules. Video tutorials of each math concept are also available for student viewing. These video tutorials are also embedded in the eTextbook version of *Fundamentals of Light and Lasers* so that students can access them when the math topic is required. A similar text, *Essential Mathematics for Engineering Technicians,* is also available; this text contains the eleven math concepts listed above plus several additional modules to support students who are enrolled in introductory electronics courses. Photonics faculty members who have used these math tutorials have reduced student attrition due to math from over 50 percent to less than 10 percent.

- The math modules in *Mathematics for Photonics Education* are effectively used in three ways:
  - As support for remedial math courses taught by the math faculty.
  - As a text for a special course taught by the photonics faculty.
  - As diagnostic testing and assignments given by members of the photonics faculty who are integrating the math material into their introductory photonics courses.
- In many colleges, math tutors are available for students requiring this assistance. Some colleges have used second-year photonics students to mentor first-year students in the math skills required for photonics education.
- Some entering students are not committed to applying the necessary effort to understand this math and are likely to lose interest and drop out quickly. Where possible, these students need to be identified and encouraged not to study photonics technology.

Loss of Interest

Many colleges do not offer photonics courses to first-year students. Their course assignments are primarily general studies, remedial courses, and preparatory courses in science and electronics. This practice can lead these students to lose interest in photonics and either change majors or drop out of college.

Two strategies are being used to deal with this issue:

- Provide a one-credit *Introduction to Photonics* course for first-semester photonics students, as well as students in other technical majors and students who have not declared a major. No prerequisites would be required for this course.
- Integrate first-year photonics students into a social network with second-year photonics students.

The following two sections describe these strategies.

One-Credit, No-Prerequisites Course, Primarily for First-Semester Photonics Students

Purpose

- Introduce photonics; orient, interest, and encourage new students.
- Expose students to interesting aspects of photonics labs and equipment.
- Integrate students into social networks.
- Identify students' academic and personal needs; direct or provide assistance.
- Show the relevance of technical, math, science, and general studies courses to the field of photonics.

Content (topics)

- Introduce new students to the field of photonics.
  - ➢ Spectrum of light, from UV thru IR (electro-magnetic spectrum)
  - ➢ Key elements
    - ✓ Light sources (lasers, LEDs, blackbody radiators, solar, etc.)
    - ✓ Passive devices (lenses, prisms, filters, polarizers)
    - ✓ Detectors (eye, electro-optical sensors, electroluminescence film, etc.)
    - ✓ Absorption and scattering of light.
  - ➢ Familiarize students with photonics labs and equipment and lab safety.
    - ✓ Introduce the labs and discuss appropriate lab practices, such as handling of equipment and optical components.
    - ✓ Measure basic characteristics of optical components and laser safety goggles.
    - ✓ Measure basic characteristics of optical components and laser safety goggles.
    - ✓ Operate a simple, low-power laser to observe collimation, reflection, and refraction.
    - ✓ Create an optical axis and perform simple optical alignments.

        - ✓ Experience other interesting optical devices and phenomena.
    - ➢ Show applications of lasers
        - ✓ Use videos.
        - ✓ Schedule employer presentations.
        - ✓ Describe possible jobs and advancement potential for photonics technicians.
- Prepare students for advanced photonics courses by introducing:
    - ➢ Electrical and electronic equipment and devices used in photonics.
    - ➢ Math used in photonics.
    - ➢ Science used in photonics.
    - ➢ Lab notebooks and reports.
    - ➢ Where to get help if needed.
- Connect new students with related social and technical organizations at the college.

This course may also be useful for students with undeclared majors.

Appendix B provides a detailed description of this course.

A Social Network Connecting First-Year Students, Faculty Members and Second-Year Students

New students need to feel that they are a part of the photonics community at their college. If first-year students are not in photonics classes, they may have little or no opportunity to interact with department faculty members or other students, which could cause them to lose interest in the program.

- Photonics faculty members have access to information about first-year students who have committed to the photonics major. The photonics faculty should meet with and counsel these entering students. In addition, if these students are required to take a one-credit *Introduction to Photonics* course in their first semester, they will not only learn about the technology, but also become connected with the photonics community of students and faculty. In colleges that do not offer a first-semester course, some faculty members meet with students in other courses to orient the students and connect them into a social network.
- Faculty members at many colleges have learned the value of hosting a photonics club for first- and second-year students. Such clubs feature a variety of beneficial activities:
    - ➢ Guest speakers (especially former students) who describe various types of technician jobs and photonics applications.
    - ➢ Field trips to photonics companies.
    - ➢ Group projects, such as student recruiting assignments, design and construction of demonstration equipment, and fundraising to pay for second-year students to attend national photonics professional society meetings where they can meet photonics employers and review equipment exhibits.

- Opportunities for social and technical collaboration with faculty members and other students.
- Opportunities for students to study together and engage in technical discussions.
- Opportunities for second-year photonics students to mentor or tutor first-year students.

Useful resources for creating student interest in photonics are listed in Appendix C.

Perception that Rewarding Jobs for Photonics Technicians are Not Available in the Geographical Area Where the Student Wants to Live

- Students need to identify the types of photonics applications they are interesting in pursuing for careers.
- They also need to be aware of geographical locations where there are desirable jobs available and consider whether they are willing to relocate after graduation.
- Some colleges in remote areas inform entering students that they will need to relocate to work on a particular photonics application.

Personal Problems

- Some students lack the self-discipline to attend class regularly, complete homework assignments, or study sufficiently to learn the material. Students need to develop good work and study habits very early in their first semester.
- Some students feel that they don't "fit in" with the photonics community. Women and other underrepresented populations may feel that they don't fit in with other students on the program.
- Work requirements (to support their living and college expenses) leave some student with little time to attend classes and labs and to complete homework assignments.
- Family responsibilities or activities that consume a great deal of students' time may require that they attend college for three or four years before completing.
- Some students have unmet financial needs. Many colleges have funds available for student financial support. Students need to be made aware of these opportunities.

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APPENDIX A

Entering Student Assessment for Mathematics for Photonics Education

The following problems require the mathematics skills that are expected of photonics technicians. Your performance on this assessment is an indication of your prior experience and the degree of mastery you have obtained in those skill areas.

Record your answer to each problem on the answer sheet provided.

(Problems 1 – 2) Choose the letter that best describes the relationships between the numbers in the boxes.

1.

A	B
0.357×10^5	357×10^1

a. A > B

b. A < B

c. A = B

d. There is no way to tell.

2.

A	B
250×10^{-3}	2.5×10^{-1}

a. A > B

b. A < B

c. A = B

d. There is no way to tell.

3. The boxed number below shows a certain display on a scientific calculator.

4.752 02

The value of the displayed number is between which of the following pairs of numbers?

a. 0.04 and 0.05

b. 0.4 and 0.5

c. 4 and 5

d. 40 and 50

e. 400 and 500

4. The product of $(2 \times 10^3)(4 \times 10^{-2})$ is
   a. -80
   b. -8
   c. 8
   d. 80

5. What is the value of the ratio $\frac{2 \times 10^{-3}}{0.5 \times 10^4}$?
   a. 4×10^{-7}
   b. 4×10^{-1}
   c. 1×10^{1}
   d. 2×10^{7}

6. If a box is described as having 48 cubic inches, the description represents the
   a. distance around the top of the box.
   b. length of an edge of the box.
   c. surface area of the box.
   d. volume of the box.

7. Convert 350 cm to meters.
   a. 0.35 m
   b. 3.5 m
   c. 35 m
   d. 117 m
   e. 3500 m

8. How many hours are equal to 150 minutes?
   a. 1½ hours
   b. 2¼ hours
   c. 2½ hours
   d. 2¾ hours
   e. 3¼ hours

9. Which of the conversions given below will change 55 miles/hour to units of feet per second? (Note: 5280 feet= 1 mile.)

   a. $\frac{55 \text{ mi}}{1 \text{ h}}$ x $\frac{5280 \text{ ft}}{1 \text{ s}}$

   b. $\frac{55 \text{ mi}}{1 \text{ h}}$ x $\frac{1 \text{ h}}{3600 \text{ s}}$ x $\frac{1 \text{ mi}}{5280 \text{ ft}}$

   c. $\frac{55 \text{ mi}}{1 \text{ h}}$ x $\frac{5280 \text{ ft}}{1 \text{ mi}}$

   d. $\frac{55 \text{ mi}}{1 \text{ h}}$ x $\frac{1 \text{ h}}{3600 \text{ s}}$ x $\frac{5280 \text{ ft}}{1 \text{ mi}}$

10. A 45,000-liter water tank is to be filled at the rate of 220 liters per minute. Estimate, to the nearest half hour, how long it will take to fill the tank.

   a. 2½ hours

   b. 3 hours

   c. 3½ hours

   d. 4 hours

11. Simplify: $3^3 + 4(8 - 5) \div 6 =$

   a. 6.5

   b. 11

   c. 27.5

   d. 29

   e. 34.16

12. If $x = -4$, the value of $-4x$ is

   a. -16

   b. -8

   c. 8

   d. 16

13. Solve for x. $7 = 4 - 0.5x$

   a. -6

   b. -1.5

   c. 2

   d. 5.5

   e. 22

14. Solve for x. $2x + 7 = 4x - 3$
  a. 1
  b. 2
  c. 4
  d. 5
  e. 10

15. If d = 110 and a = 20 in the formula $d = \frac{a}{2}(2t - 1)$, t =
  a. $\frac{15}{22}$
  b. $\frac{15}{8}$
  c. 5
  d. $\frac{111}{20}$
  e. 6

16. Solve for x. $\frac{1}{5} = \frac{1}{15} + \frac{1}{x}$
  a. -10
  b. -5
  c. 7.5
  d. 12.5

17. Simplify: $\sqrt{16} + 3^2$
  a. 10
  b. 13
  c. 19
  d. 22

18. How many whole numbers are between $\sqrt{15}$ and $\sqrt{63}$?
  a. Three
  b. Four
  c. Five
  d. Six
  e. Seven

19. Solve for x: $x^3 = 27$

a. 0

b. 3

c. 9

d. 27

20. Joe is adding a square room to the back of his house. He wants the floor to have an area of 825 square feet. To the nearest foot, how long will each side of the floor be?

a. 22 ft

b. 25 ft

c. 29 ft

d. 83 ft

21. A group of 1200 adults is made up of vegetarians and nonvegetarians. Of the total, 300 are vegetarians. What is the ratio of nonvegetarians to vegetarians in the group?

a. 1 to 3

b. 1 to 4

c. 3 to 1

d. 4 to 1

e. 4 to 3

22. 15% of 60 =

a. 9

b. 15

c. 18

d. 60

23. If $\frac{2}{25} = \frac{n}{500}$, n =

a. 10

b. 20

c. 30

d. 40

e. 50

24. A map has a scale of 1 inch : 10 miles. Erika wants to know the distance from her house to the stadium. On the map, the stadium is 3lf2 inches away. How far is it in miles from her house to the stadium?

a. 35 feet

b. 3.5 miles

c. 7 miles

d. 35 miles

e. 70 miles

25. Simplify: log 167

a. 2.22

b. 5.12

c. 7.40

d. 16.70

26. Simplify: ln 7

a. 0.70

b. 0.85

c. 1.95

d. 3.50

27. Solve for x: $y = 10^x$

a. 0

b. 10

c. y

d. log y

e. ln y

28. If $I = I_0 e^{-2a}$, $\ln\frac{I}{I_0} =$

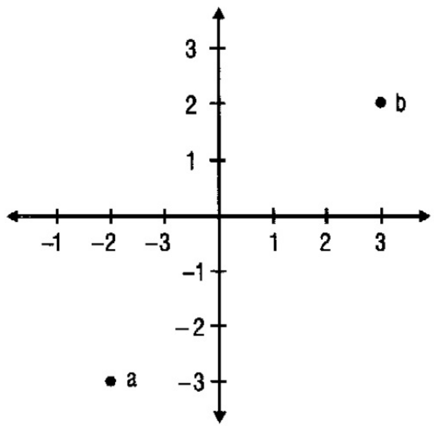
a. 1

b. 0

c. $-2a$

d. e^{-2a}

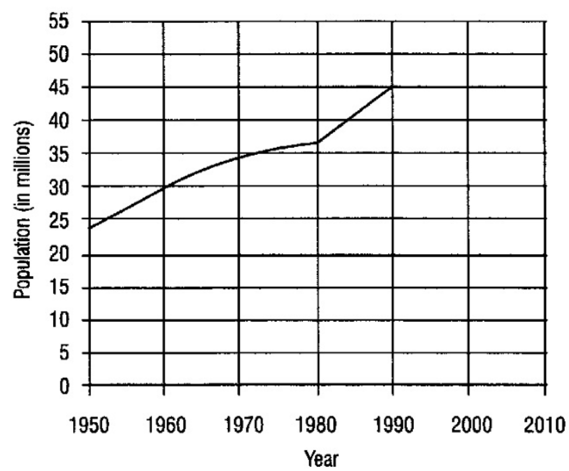
29. Choose the ordered pairs below that correctly identify the points **a** and **b**.



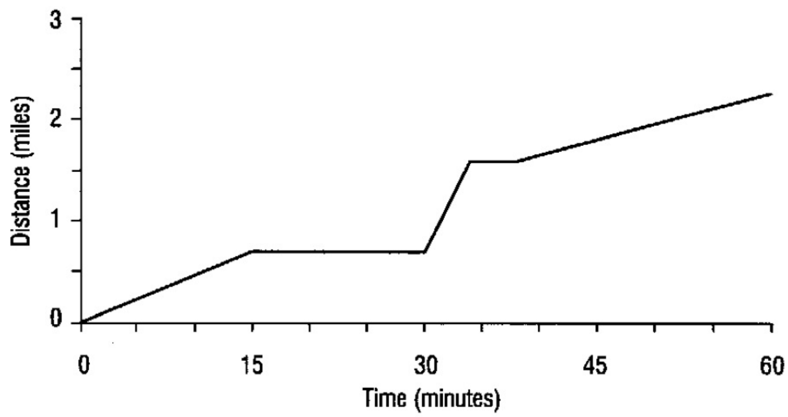
a.	a (3, 2), b (2, 3)
b.	a (2, 3), b (3, 2)
c.	a (–2, –3), b (3, 2)
d.	a (–3, –2), b (2, 3)

30. The graph below is a plot of population versus year. If the population increases by the same rate from the year 1990 to the year 2000 as it did in the years from 1980 to 1990, approximately what is the expected population by the year 2000?

a. 47 million
b. 50 million
c. 53 million
d. 58 million



31. The plot below shows the graph of distance versus time for a man taking a walk through the park along a straight path. In addition to walking, he encounters a friend, is chased by a dog, and takes a rest. Look at the graph and then answer the question about his walk



At the 35-minute mark into his journey, approximately how far had the man traveled?

a. 0 miles

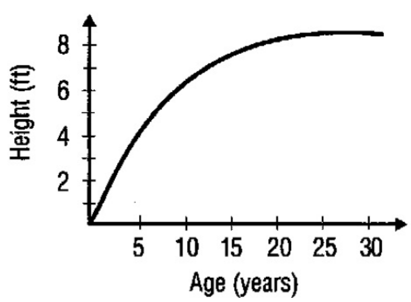
b. 1.2 miles

c. 1.6 miles

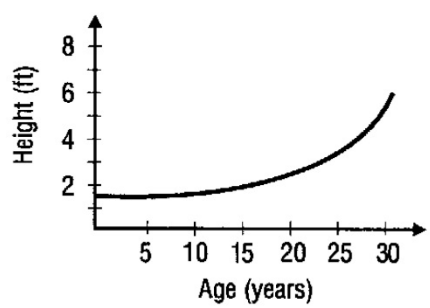
d. 2.1 miles

32. Which of the following is the best representation of the relationship between the height of a typical person and his/her age from birth to 30 years

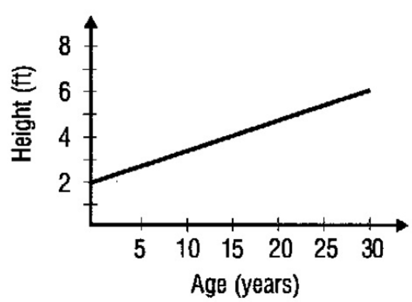
a.



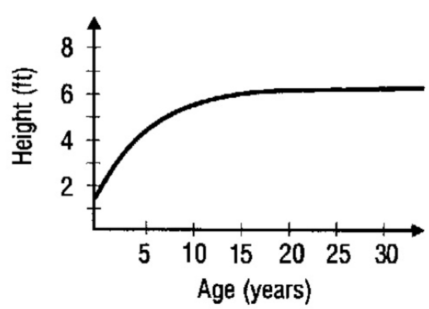
b.



c.



d.



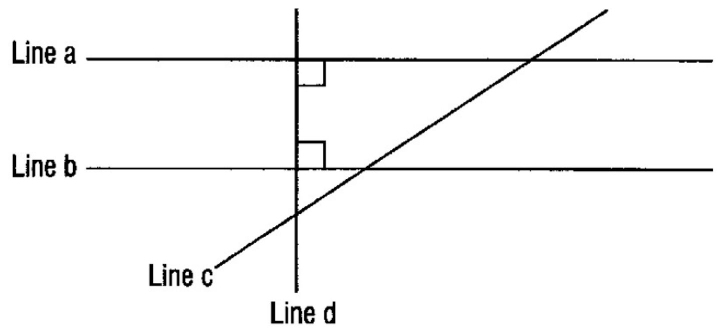
33. Which statement is true?
(Note: ⊥ means perpendicular and ∥ means parallel.)

a. a∥b and c⊥d

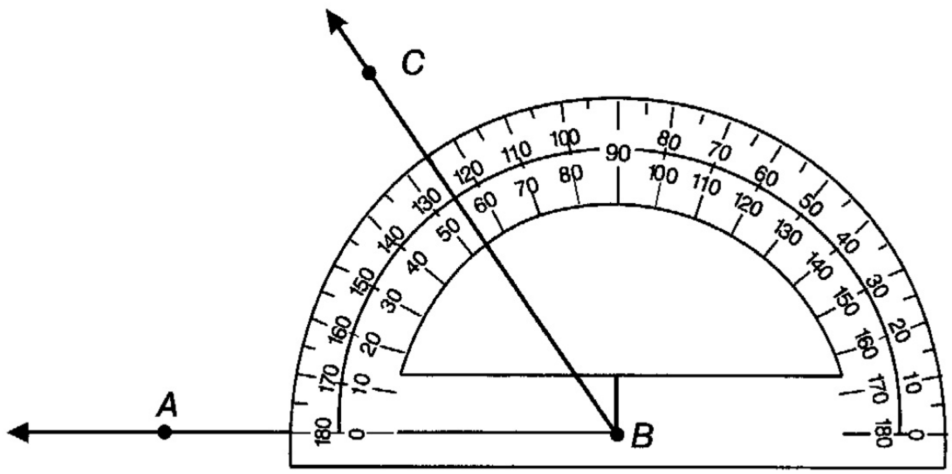
b. a∥b and b⊥d

c. b∥c and c⊥d

d. b∥c and b⊥d



34.



In the figure above, the measure of angle ABC is

a. 55˚

b. 60˚

c. 65˚

d. 125˚

e. 135˚

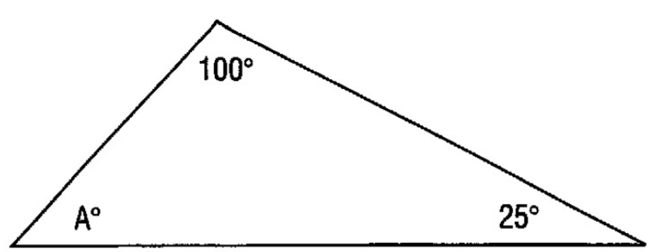
35. Find the angle A algebraically.

a. 0˚

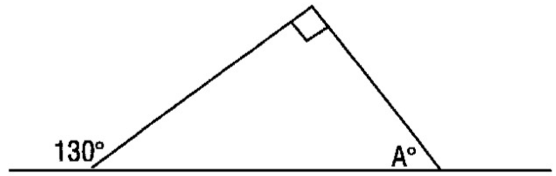
b. 25˚

c. 45˚

d. 55˚



36. Find the angle A algebraically.



a. 40˚

b. 45˚

c. 50˚

d. 130˚

37. What is 45° in radians?

a. 1 radian

b. $\pi/4$ radians

c. $\pi/2$ radians

d. π radians

38. What is $\frac{5\pi}{6}$ in radians in degrees?

a. 30˚

b. 56˚

c. 90˚

d. 150˚

39. A solid angle is measured with what symbol and unit?

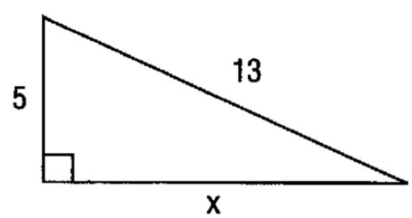
a. Σ, feet

b. π, radians

c. Ω, steradians

d. Φ, degrees

40. Find *x* algebraically.



a. 5

b. 11

c. 12

d. 13

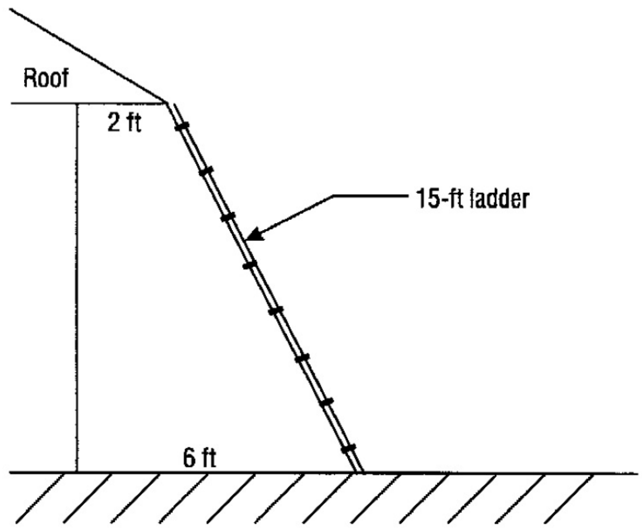
41. A 15-ft ladder leans against the roof edge of a house as shown. The base of the ladder is 6ft from the wall. Assume that the top of the ladder rests perfectly on the roof edge of the house. The roof overhang is 2 ft from the side of the house. How high above the ground is the house at the intersection of the roof edge and the ladder? Round to the nearest tenth of a foot.

a. 13.7 ft

b. 14.1 ft

c. 14.5 ft

d. 15.0 ft



42. Simplify: $\frac{8\cos 60^\circ}{2}$

a. $\frac{\sqrt{3}}{2}$

b. 2

c. $2\sqrt{2}$

d. $3\sqrt{3}$

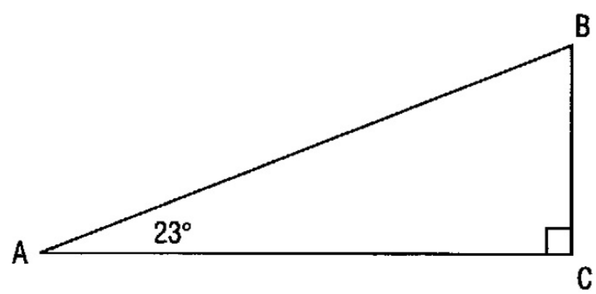
43. In the triangle ABC shown below, AB = 14 feet. What is BC to the nearest hundredth of a foot?

a. 4.78 feet

b. 5.47 feet

c. 12.89 feet

d. 15.21 feet

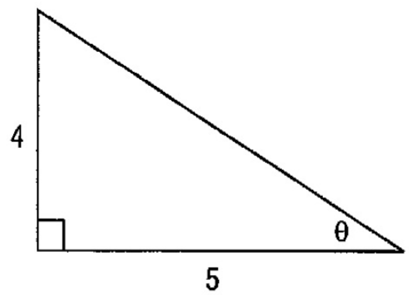


44. In the triangle below, what is θ? 36.9°

a. 38.7°

b. 51.3°

c. 53.1°



45. In the equation $n_1\sin\theta_1 = n_2\sin\theta_2$, n_1=1, n_2=1.5, and θ_1=45°. Find θ_2.

a. 20.8°

b. 28.1°

c. 30.0°

d. 45.0°

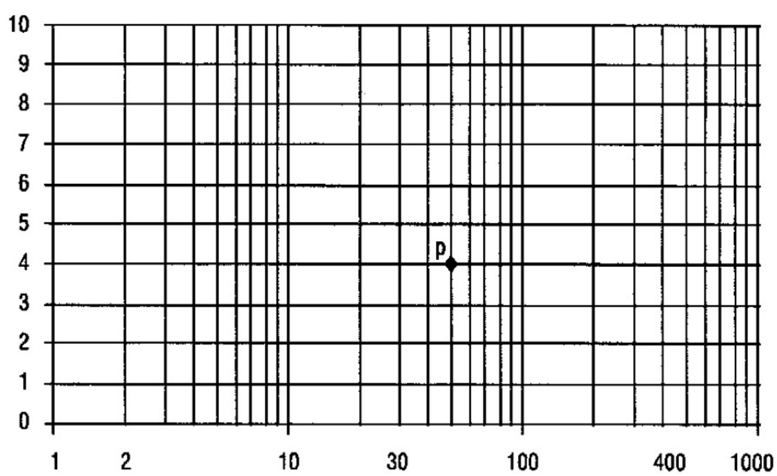
e. 61.9°

46. Select the ordered pair that correctly identifies the point **p** on the semilog plot below. p (5,4)

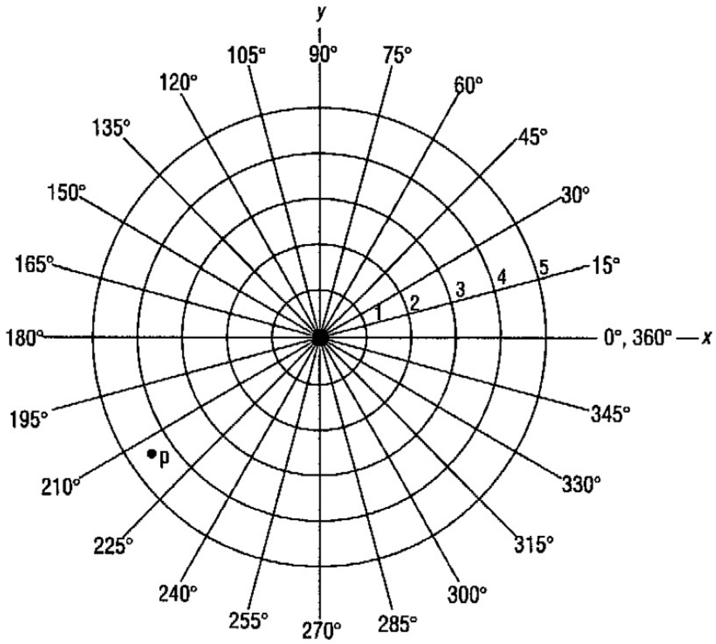
a. p (50,4)

b. p (60,4)

c. p (600,4)



47. Select the ordered pair that correctly identifies the point p on the polar graph below.



a. p (205˚, 4.5)
b. p (215˚, 4.5)
c. p (4.5, 205˚)
d. p (4.5, 215˚)

48. Which of the following are equivalent polar and rectangular coordinate pairs?

a. (14, 300˚) = (7, $-7\sqrt{3}$)
b. (4, 135˚) = ($2\sqrt{2}$, -3)
c. (5, 90˚) = (5,0)
d. (5, 36.9˚) = (-4, -3)

APPENDIX B

One-Credit Photonics Course for First-Semester Students: Introduction to Photonics[8]

Outline of Fifteen Module Lessons and Lab Experiences

Note: Faculty may select as many modules as necessary to create a one- or two-credit course with no prerequisites.

Week 1: Spectrum of Light [Classroom]

- Discuss ultraviolet (UV) through infrared (IR) (electromagnetic spectrum).
- Show and discuss different types of light sources (lasers, LEDs, blackbody radiators, etc.).
- Show and discuss passive devices (lenses, prisms, filters, etc.).
- Show and discuss optical detectors.
- Demonstrate and discuss absorption and scattering of light.

Week 2: Labs and Safety, Spectrum of Light Hands-On Lab.

- Discuss basic lab procedure and safety.
- Discuss and show laser safety goggles and their optical density.
- Discuss real-world applications: polarized sunglasses, passenger mirrors on cars, etc.
- Use a laser pointer or other low-power laser to observe collimation, reflection, and refraction.

Week 3: Technical Societies and Social Networks [Classroom]

- Introduce students to SPIE, OSA, LIA, and other technical societies.
- Show resources available from the society websites.
- Discuss the benefits of LinkedIn for networking and job searching.
- Invite members of local society chapters to speak, if available.

Week 4: Visible Light Spectrum Hands-OnLab.

- Use a spectrometer with different light sources (fluorescent, incandescent, etc.)
- Use a diffraction grating with a white-light source to view the color spectrum.
- Use a diffraction grating with a single-color source.

Week 5: Applications and Careers I [Classroom]

- Videos, employer presentations, or guest speaker(s) to discuss photonics careers
- Jobs and advancement potential

- Recent program graduates are ideal as speakers.

Week 6: Math Used in Photonics [Classroom]

- Discuss mathematics required in photonics.
- Use images and diagrams of total internal reflection (TIR) and other phenomena to demonstrate applications that require math problem solving.
- Demonstrate math videos and point students to available math resources.

Week 7: Math Used in Photonics Hands-On Lab.

- Use a laser pointer or other low-power laser to observe collimation, reflection, and refraction.
- Experience lab activities with lenses, mirrors, and prisms.
- Perform calculations based on measurements taken in the lab.

Week 8: Electrical Equipment and Computers [Classroom]

- Introduce students to some of the more complex tools and equipment used in the workplace.
- Discuss computer usage and types of programs used.
- Discuss the types of tools used at the workplace where an industry tour will take place

Week 9: Industry Tour [Off-Campus]

- Observe work environment.
- Experience hands-on applications.
- Show use of lab notebook, if possible.
- If possible, have program graduates who work at the site give the tour and show the students their workstation.

Week 10: Lab Notebooks, Reports, and Writing [Classroom]

- Show an example of a laboratory notebook. Discuss critical elements of entries.
- Discuss the importance of keeping an accurate log of work and data.
- Have students suggest scenarios that require a well-kept notebook.
- Show an example of a lab report.
- Have students practice writing a report.

Week 11: Beam Divergence and Collimation Hands-On Lab.

- Measure the divergence of a beam.
- Use lenses as a collimator and measure the changed divergence.
- Perform small calculations using divergence equations.

Week 12: Applications and Careers II [Classroom]

- Assign students to view and report on videos of recent graduates.
- Schedule employer presentations or guest speaker(s) to discuss photonics careers.
- Discuss possible jobs and advancement potential.
- Invite recent program graduates as speakers.

Week 13: Detectors and Filters Hands-On Lab.

- Discuss some of the different types of detectors.
- Show students how to use detectors to adjust and measure laser output.
- Use a filter to block some of the power from the laser, and discuss what type of light the filter blocked.
- Use detectors to record power readings.

Week 14: Fibers and TIR [Classroom]

- Discuss optical fibers and demonstrate how they work.
- Show videos on telecommunications and other uses of optical fibers.

Week 15: Fibers and TIR Hands-On Lab.

- Send light through fibers, rods, and other mediums (like a stream of water).
- Measure the "power in" and "power out" of a fiber.
- Discuss power loss within fibers and ways to reduce the loss.

APPENDIX C

Resources

- Photonics Technician Career Videos
  Students searching for careers need to understand what kinds of things they may be doing once they are in the workforce. Students also gain motivation and focus when they can identify with a role model and understand why they have to learn certain areas of mathematics, science, and technology. These videos give students a look at a variety of employees and jobs.
  - http://www.op-tec.org/resources/videos
- Photonics Alumni Council for Technicians
  In 2009, OP-TEC created the Photonics Alumni Council for Technicians (PACT). The PACT is an organization of distinguished graduates who have received education and training in lasers, electro-optics, optics and/or photonics applications from two- and four-year technical colleges. More than fifty alumni are featured on OP-TEC's website, and their one-page biographies showcase photonics students' diversity of backgrounds.
  - http://www.op-tec.org/alumni/photonics-alumni-council-for-technicians
- What is Photonics? Video Series
  Many students have never heard the term "photonics" and don't know what it means. These videos explain the basic elements of photonics, why photonics is important, and some of the many fields that use photonics.
  - http://www.op-tec.org/what-is-photonics
- Essential Mathematics for Engineering Technicians Video Series
  Mathematics can be a hurdle for students. OP-TEC has created a series of videos that explain some basic mathematical concepts that technicians encounter, such as scientific notation, angle measures in degrees and radians, order of operations, and more. There are also several videos that explore the uses of math in technological fields.
  - https://vimeo.com/channels/optecmathforengineering
  - http://optecvideo.opteccrm.org/