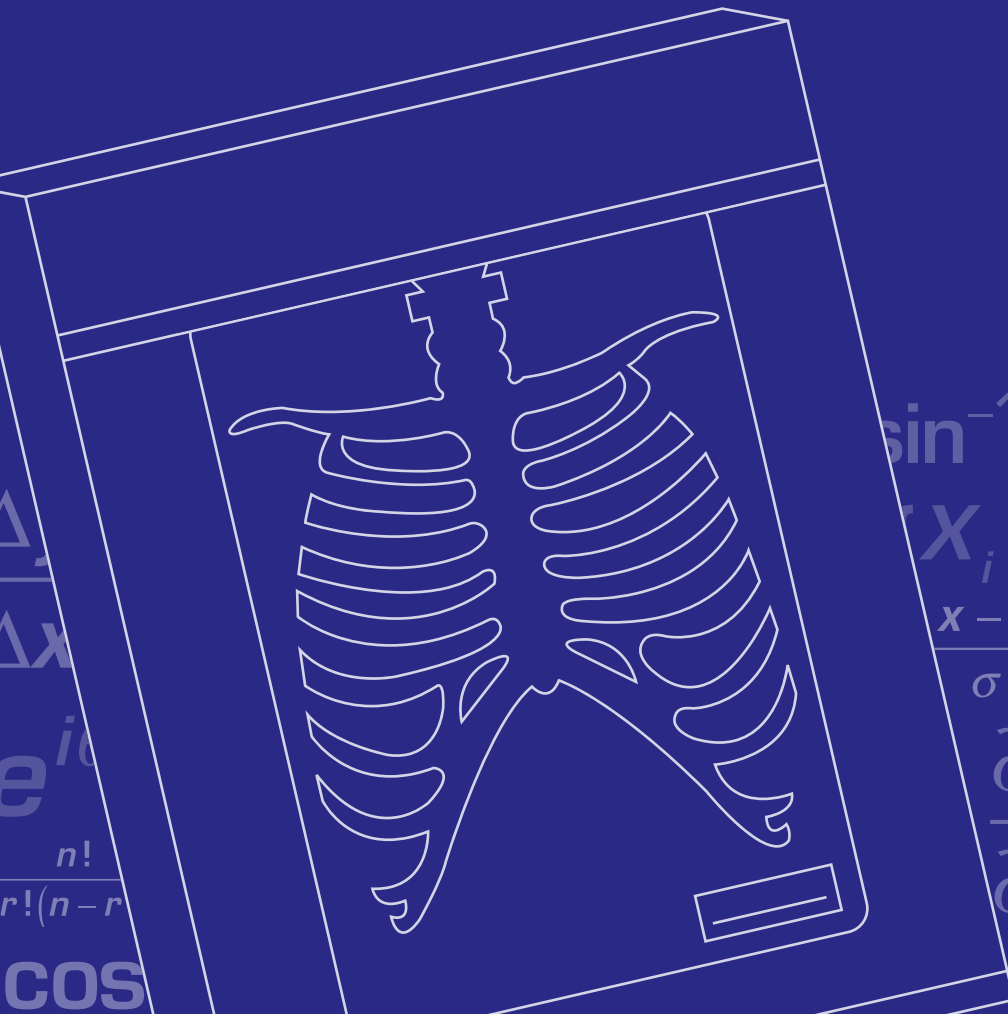


mathematics at work

Health Care



$$\sin^{-1} \theta$$

$$\sum (X_i - \bar{X})^2$$

$$\frac{x - \mu}{\sigma} \delta x \rightarrow 0 \sum_{i=1}^n$$

$$\frac{\partial^2 \Omega}{\partial u^2}$$

$$\sum_{i=1}^n$$

$$\sqrt{a^2 + b^2}$$

$$\Delta$$
$$\Delta x$$
$$e^{i\theta}$$
$$n!$$
$$r!(n-r)$$
$$\cos$$



Mathematics in the Health Care Sector

The health care industry is one of the fastest-growing sectors of our economy, and all signs point to this trend continuing as advances in health care provide new and improved processes for diagnosing and treating illness and disease. Technological advances in health care have led to the creation of new careers — as well as major growth in existing health care occupations — many of which require strong mathematics skills to support technology-based diagnoses and treatment. Understanding how high-tech equipment works and how it can best be used to treat patients requires that health care workers have a solid foundation in the underlying mathematical and scientific principles at work.

Available Health Care Diagnostics Jobs

Within the health care industry, there are a variety of entry-level jobs that pay well and offer opportunities for advancement — jobs for high school graduates with postsecondary training or education but less than a four-year college degree. There is particularly high demand for qualified individuals in the field of medical imaging and diagnostics. Many of the jobs in this area of health care — from radiologic technologists who take

and process X-rays to clinical laboratory technicians who analyze blood and tissue samples — typically require an associate degree or equivalent postsecondary training.

Core Mathematics Knowledge in Today's Health Care Diagnostics Jobs

Developed by secondary, postsecondary, business, industry and government leaders, the national Career Cluster Pathway Plan of Study for *Health Science Diagnostic Services* recommends a set of rigorous mathematics courses for students to take at both the secondary and postsecondary levels in traditional or vocational settings to pursue a career track in health care diagnostics. This Plan of Study shows in detail how the foundation provided by courses such as Algebra I, Geometry, Algebra II, Statistics and Calculus equips high school graduates with the mathematical knowledge and skills needed for success on the job. Until high school graduates understand the advanced mathematical and technological skills used in the health care sector, they will remain unable to meet the demands of this high-growth industry. For more information on the Career Clusters Initiative, see www.careerclusters.org/resources/web/pos.cfm.

Jobs	Median yearly salary	Percentage of total jobs by education/training (ages 25–44)*		Number of total jobs		
		High school	Some college	2006	2016	% change
Radiologic technicians/technologists	\$48,200	7.2%	67.9%	196,200	225,900	15%
Diagnostic medical sonographers	\$57,200	7.2%	67.9%	45,700	54,400	19%
Medical and clinical laboratory technologists	\$49,700	14.2%	35.3%	167,200	188,000	12%
Health care technologists and technicians	\$35,100	20.1%	57.1%	79,300	91,200	15%

*Remaining percentage of workers in occupation have a bachelor's degree or higher

Source: Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Outlook Handbook, 2008–09 Edition*.

Ensuring College and Career Readiness: The American Diploma Project

In 2001, Achieve and several partner organizations launched the American Diploma Project (ADP) to identify a common core of English and mathematics academic knowledge and skills, sometimes referred to as “benchmarks,” that American high school graduates need for success in college and the workforce. These ADP benchmarks, released in the 2004 report *Ready or Not? Creating a High School Diploma That Counts*, are the result of two years of intensive research conducted in colleges and universities as well as workplaces across the country.

The real-world expectations identified by ADP are significantly more rigorous than many current high school graduation standards — which helps explain why many high school graduates arrive at college or the workplace with major gaps in their English or mathematics preparation.

To help pinpoint the academic knowledge and skills required for future employment, ADP commissioned leading economists to examine labor market projections for the most promising occupations — those that pay enough to support a family and provide real potential for career advancement. ADP then surveyed officials from 22 industries, ranging from manufacturing to financial services, about the most useful skills for their employees to bring to the job.

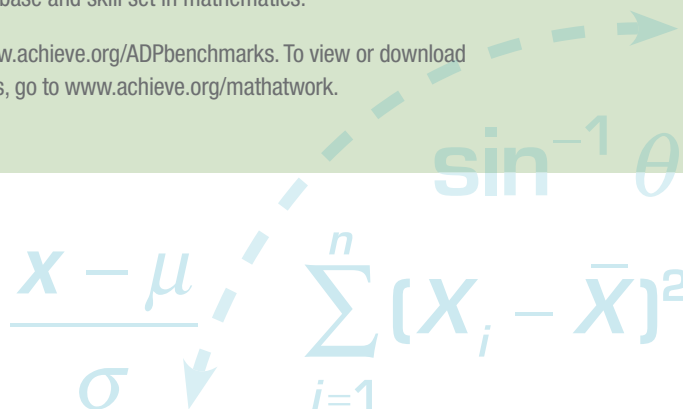
ADP also worked closely with two- and four-year post-secondary faculty from five partner states to determine the prerequisite English and mathematics knowledge and skills required to succeed in entry-level, credit-bearing higher education courses. These conversations revealed an unprecedented convergence of the knowledge and skills employers and postsecondary faculty say are needed for new employees and freshmen beginning credit-bearing coursework to be successful.

“Mathematics at Work” Series

Following up on the work of ADP, Achieve has produced a series of “Mathematics at Work” brochures to examine how higher-level mathematics is used in today’s workplaces. The brochures present case studies drawn from leading industries nationwide to illustrate the advanced mathematics knowledge and skills embedded in jobs that offer opportunities for advancement and are accessible to high school graduates.

The series underscores the value of a rigorous high school curriculum in mathematics. All high school graduates — regardless of whether they enroll in college, join the workforce or enter the military — benefit from acquiring a comprehensive knowledge base and skill set in mathematics.

To view or download the ADP benchmarks, go to www.achieve.org/ADPbenchmarks. To view or download a PDF of additional “Mathematics at Work” brochures, go to www.achieve.org/mathatwork.



Career Preparation for Radiographers

All radiographers — or radiologic technologists — have some form of postsecondary training, typically provided by a two-year college or teaching hospital, before entering the field of diagnostic medicine. The standard curriculum in those programs stresses radiographic procedures, medical imaging, anatomy and physiology, and applied physics. Beyond knowing how to take X-rays and other images, radiographers are expected to know how radiation works, the potential negative impact of radiation on patients and bystanders, and the radiographer's crucial role as a team member working with physicians and other medical professionals to provide health care to patients. It is common for these two-year programs, which culminate in certification and/or an associate degree, to require at least college-level algebra or its equivalent.

The American Society of Radiologic Technologists (ASRT) is a membership organization that seeks to foster the professional growth of radiologic technologists. ASRT has been developing and publishing radiography curricula for more than 50 years and offers 10 specific curricula for various professions within this field. For more information on ASRT and its curricula, see www.asrt.org/Content/educators/_educatorsstudents.aspx.

Two other major organizations in this field — the American Registry of Radiologic Technologists (ARRT), which offers voluntary certification; and the Joint Review Committee on Education in Radiologic Technology (JRCERT), which accredits most formal training programs for the field — also support the ASRT curriculum. The objectives for ARRT's voluntary certification exam are well aligned with ASRT's recommended content, and JRCERT urges radiography programs to include the core content in their instruction. JRCERT also considers the alignment of curriculum when evaluating programs to determine whether to approve them and offer them accreditation.

Embedded within ASRT's recommended curriculum are many specific mathematical concepts covering many of the core concepts found in the ADP benchmarks, including:

- Basic Principles of Computed Tomography (e.g., algorithms, ratios, proportions, error in measurement, scale factor)
- Pharmacology and Drug Administration (e.g., ratio and proportion, measurement, exponential decay models)
- Radiation Biology (e.g., interpreting graphs, functions, measurement, probability)
- Radiation Production and Characteristics (e.g., trigonometric functions, scattering theory, direct and inverse variation, periodic functions)
- Radiation Protection (e.g., interpreting graphs, linear and quadratic variation)
- Digital Image Acquisition and Display (e.g., measurement, data acquisition and display, histograms)
- Image Analysis (e.g., data interpretation, problem solving, algorithms)
- Film-Screen Image Acquisition and Processing (e.g., ratios, proportionality, scale factors, graphic representation of functions)

The work of ASRT, ARRT and JRCERT demonstrates that there is a common core of expectations among the radiologic technology community, one that is rooted in a practical and theoretical understanding of mathematics and physics. Although ASRT has revised its curriculum a number of times in the past half-century, understanding the mathematics and science of radiology has remained at the center of its preparatory materials for all future radiographers.

Perfect Exposure: X-Rays and the Role of Mathematics

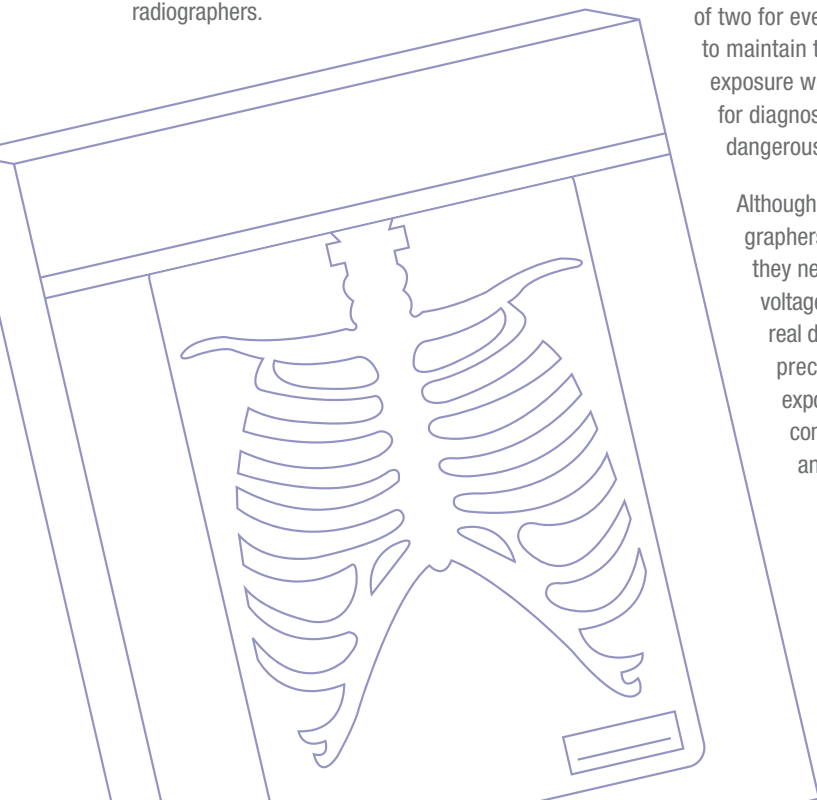
Radiographers are present at just about every level of our health care system. Responsible for taking X-rays in a variety of settings — including emergency rooms, surgery wards, imaging labs and even outpatient clinics — radiographers employ the art and science of medical imaging to improve the lives of others. Radiographers — or radiologic technologists — provide doctors and patients with the necessary information about patients' injuries or illnesses required to make sound decisions about treatment options. Radiographers must have excellent communication skills; extensive knowledge of biology, chemistry and physics; and a firm foundation in mathematics — all to ensure that their patients receive the very best care. From speaking to patients to operating multimillion-dollar equipment, these skills are embedded in the daily tasks of radiographers.

Taking an X-Ray

Algebra, Number Sense and Functions

One of the most important mathematical applications used by radiographers each day is determining the proper exposure time to create the resulting X-ray image. There are a number of factors that need to be taken into consideration when preparing to take an X-ray. At a minimum, the radiographer must know the size of the patient, the thickness of the area being X-rayed, any disease that might distort the image and the power of the machine being used. After measuring the section to be X-rayed, radiographers set controls on the machine to produce radiographs of the appropriate density, detail and contrast. The standard formula is that the total amount of X-rays must increase by a factor of two for every five centimeters of body thickness to maintain the right contrast. Although too little exposure will result in an image not bright enough for diagnosis, too much exposure is potentially dangerous for the patient.

Although one might think it is possible for radiographers to simply memorize the adjustments they need to make to the exposure time and voltage based on the variable factors, there are real dangers to relying on memory. Calculating precisely the right amount and length of exposure — and being well versed in their conceptual underpinnings — is key for safe and successful X-rays to be produced.



$$[X_i - \bar{X}]^2$$

$$e^{i\theta}$$

Digitizing Medical Imaging

Geometry and Spatial Relations

Recent advances in digital diagnostic technology have made it possible for radiographers to take clearer and cleaner images that are three-dimensional (3-D). Computed tomography — known as CT imaging — uses specialized X-ray equipment to produce multiple exposures. The resulting images are then assembled by computers into 3-D cross-sections of a person's anatomy.

CT imaging requires radiographers to use a host of mathematical and computer-based skills, including geometry and spatial relations to isolate the area of interest and create the targeted 3-D images. To use the machines successfully, radiographers must understand the mathematics underlying the data storage techniques as well as the mathematics behind the processing steps for CT data.

Processing and Analyzing an Image

Measurement, Inverse Laws and Problem Solving

Even if radiographers position patients correctly and use the appropriate amount of exposure, there is no guarantee that the result will be a high-quality image. Preparing and processing an image requires patience, a steady hand, and a strong head for mathematics and physics. Radiographers often need to perform calculations to determine image magnification to bring an image up to scale. They also may be required to apply conversion factors for changes to such variables as distance from

the image receptors to bring the image into focus. Finally, radiographers sometimes use X-ray beam filters and need to be able to quantify the impact of filtration on the intensity and quality of the resulting images, as well as on patient exposure.

Once the images are processed, radiographers' next responsibility is to work closely with radiologists — doctors specializing in radiology — to analyze them. It is a radiographer's job to ensure that a radiologist does not misread an X-ray due to an image's lack of clarity or its failure to sufficiently isolate the injury or illness. Radiographers must evaluate the images for adequate density and brightness, contrast, spatial resolution, and acceptable limits of distortion to make sure that the radiologist is able to make a truly informed judgment. This phase of the radiographer's work requires advanced problem solving and data interpretation skills.

Adding It All Up

It is estimated that there are approximately 2 billion radiographs taken around the world each year, including chest X-rays, mammograms, dental X-rays, CT scans and so on. Radiography is a critical diagnostic tool for identifying and treating illness and injury. Without skilled radiographers on the job to take clear images and protect patients from the dangers of overexposure, the number of misdiagnosed and untreated Americans would undoubtedly rise. A future as a radiographer is just one example of a promising career path in health care that requires a firm grounding in mathematics and science.

$$\frac{n!}{(n-r)!}$$

$$\sum_{i=1}^n X_i^2$$

u^2 $\lim_{\delta x \rightarrow 0}$

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Mathematics + Communications = Success

From calculating the correct exposure time to understanding the basic properties of radiation, radiographers apply mathematics on the job every day. They employ trigonometric functions, direct and inverse variation, and exponential decay models to analyze the consequences of radiation, and they rely on their knowledge of geometry and spatial relations to properly orient patients for their X-rays and 3-D CT images. For example, correctly positioning a patient's arms, legs, head and torso can mean the difference between a crisp, informative image and one that provides little insight. After ensuring minimal distortion and correct spatial resolution, radiographers must manage a host of complex variables that affect contrast and brightness and the level and length of exposure. Selecting the appropriate dosage requires radiographers to take careful measurements and perform additional calculations based on multiple variables. The work requires advanced problem-solving skills, as well as a facility with number sense to perform image magnification and bring the image into proper focus. When armed with a deep understanding of the principles and consequences of too much radiation, radiographers are able to communicate with precision the potential benefits and dangers of radiation to their patients.

But understanding the mathematical principles at work in radiography is only part of the story. Technologists work as part of a team of health care professionals committed to the well-being of their patients, and they therefore have to possess equally strong teamwork and communication

skills to diagnose and treat patients successfully. They are called on regularly to communicate with patients from a wide variety of backgrounds — many of whom may be injured or anxious. They are required to take a complete patient history so that they can identify any potential illnesses or prescriptions that may lead to an adverse reaction or misdiagnosis. At the same time, the technologists need to correspond with hospital personnel as they carry out orders, communicate results, and handle a range of administration functions for billing or insurance purposes.

“ *Understanding mathematics is critical to my ability to do my job and achieve accurate results for my patients.* **”**

Rebecca Delabra, Radiographer
Internist Associates of Iowa

The host of skills that radiographers need to treat patients — such as mathematical and spatial reasoning, effective communication, and problem solving — underscores the importance of rigorous preparation in mathematics. Hospitals and doctors today are actively seeking out radiographers who not only can handle the increasingly complex mathematical calculations required to effectively use the latest equipment but also are articulate co-workers who can collaborate on complex cases and studies.

“ *The vocabulary of today's medical imaging and radiation therapy technologists includes terms such as algorithms, lookup tables, data compression, multiplanar reconstruction, bit depth, window and leveling. Students who seek careers in the radiologic sciences will be best prepared if they have a strong academic preparation in math and science.* **”**

Kevin Powers, Ed.S., R.T., Director of Education
American Society of Radiologic Technologists

$\cos^{-1} \theta$
 $\sqrt{a^2 + b^2}$
 $(X_i - \bar{X})^2 e^{i\theta}$

The graphic features a dashed grey arc with an arrowhead pointing left at the top. Below the arc, the mathematical expressions are displayed in a light grey font.

About Achieve

Achieve, Inc., created by the nation's governors and business leaders, is a bipartisan, non-profit organization that helps states raise academic standards, improve assessments and strengthen accountability to prepare all young people for postsecondary education, careers and citizenship.

About the American Diploma Project (ADP) Network

In 2005, Achieve launched the ADP Network — a collaboration of states working together to improve their academic standards and provide all students with a high school education that meets the needs of today's workplaces and universities. The ADP Network members — responsible for educating 80 percent of all our nation's public high school students — are committed to taking four college and career readiness action steps:

1. Align high school standards with the demands of college and careers.
2. Require all students to complete a college- and career-ready curriculum to earn a high school diploma.
3. Build college- and career-ready measures into statewide high school assessment systems.
4. Hold high schools and postsecondary institutions accountable for student success.

The world has changed, and high schools must change with it. The ADP Network is leading the charge in ensuring that all high school students graduate with a degree that works.

Visit our Web site for more information about the ADP Network and the ADP benchmarks (www.achieve.org/ADPBenchmarks) and to view additional "Mathematics at Work" brochures (www.achieve.org/mathatwork).

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