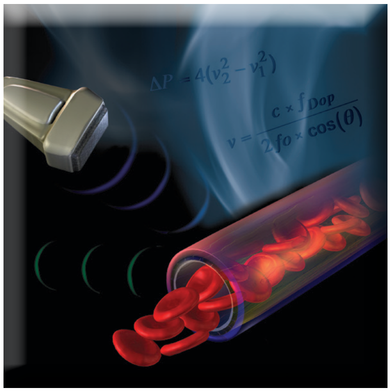
Ultrasound Physics

eCourse

Summary



This online eCourse is designed to cover the content tested on the ARDMS Sonography Principles and Instrumentation (SPI) exam and the Physics portion of the CCI RCS and RVS exams. Concepts covered include ultrasound math principles, waves, attenuation, pulsed wave operation, transducers, system operation, Doppler, artifacts, bioeffects, contrast and harmonics, quality assurance, and hemodynamics. Acclaimed physics author Frank Miele, MSEE, delivers these lectures in an engaging and interactive format, relating ultrasound physics to the clinical aspects of what ultrasound professionals do on a day-to-day basis. A Study Guide provides a structured reference which outlines course text readings, conceptual questions and exercises for each module. The unique Pegasus Direct delivery platform allows the viewer to view modules at your convenience, print notes, and even bookmark topics to create their own focused review session.

Instructor Biography

Frank Miele, MSEE

President, Pegasus Lectures, Inc., Dallas, Texas

Frank graduated cum laude from Dartmouth College with a triple major in physics, mathematics, and engineering. While at Dartmouth, he was a Proctor Scholar and received citations for academic excellence in comparative literature, atomic physics and quantum mechanics, and real analysis. After co-teaching a course in digital electronics at Dartmouth, Frank was a research and design engineer and project leader, designing ultrasound equipment and electronics for more than ten years at Hewlett Packard Company. Frank also served as the chief scientist and Vice President of Research and Development for a small medical company designing non-invasive hemodynamic based measurements. As a designer of ultrasound, he has lectured across the country to sonographers, physicians, engineers and students on myriad topics.

Frank has authored multiple texts on ultrasound physics, produced multiple educational videos, designed exam simulation programs, as well as created the patented analysis algorithm method and apparatus for evaluating educational performance. Frank has recently produced multiple online ultrasound seminars, focusing on making high quality educational programs affordable and accessible to the domestic and international ultrasound community. He is credited with several ultrasound and medical device patents, trade secrets, and publications.

Module Descriptions

Physics Module 1A: Basic Math

Core Concepts: 113 min
Focus Session: 85 min

The math covered in this module is foundational to the physics covered in all of the later modules. With the exception of the CCI basic science exam, which tests basic math concepts directly, the material taught in this module is tested indirectly on exams. For example, as specified by the CCI Science exam content outline, questions are asked which directly related to fractions, reciprocals, conversions, and basic mathematical operations. In comparison, few if any of the other exams specify direct testing of these basic math concepts. Instead, basic math skills are assumed and tested indirectly in the context of solving other problems. Knowledge of basic mathematics facilitates answering physics test questions quickly and efficiently. In addition to the basics of how to deal with fractions, reciprocals, unit conversions, and equation manipulation, you will find significant emphasis placed on understanding the physical relationships between variables as expressed by mathematical equations. By learning the mathematical terminology and understanding the physical relationships between variables in physics equations, your ability to comprehend and answer test questions will significantly improve.

Physics Module 1B: Advanced Math

Core Concepts: 60 min
Focus Session: 45 min

In this module, we discuss the concept and application of logarithms, basic trigonometry, analog to digital conversion, the Nyquist Criterion, and constructive and destructive interference of waves. In comparison to the module covering basic mathematics, more of the content of this module is directly tested on exams. For example, it is possible that you will be asked to convert a ratio of powers into decibels using logarithms and the definition of decibels. As a second example, you may be asked direct questions about analog to digital conversion and binary numbers. Although some of the content of this module might be tested directly, you can expect a fair amount of this information to also be tested in an indirect manner. For example, Doppler questions often require a basic understanding of the cosine from trigonometry to specify angular effects on measurements. The Nyquist criterion will most certainly be tested with respect to aliasing as occurs in spectral and color Doppler. In summary, we will discuss the more advanced math concepts that will significantly improve your ability to appreciate, comprehend, and apply ultrasound physics.

Module 2: Waves

Core Concepts: 129 min
Focus Session: 97 min

In this module, we start building the foundation for understanding what sound wave parameters can be changed to improve clinical information acquired during imaging, as well as building the foundation for understanding the potential risk of causing tissue damage referred to as a bioeffect.

Module 3: Attenuation

Core Concepts: 85 min
Focus Session: 64 min

In this module, we discuss the three primary components of attenuation, which include absorption, reflection, and refraction. Most people find this chapter very interesting since it describes what physically occurs within the patient as imaging takes place. In essence, in this module, we come to better appreciate how the mechanical sound waves physically interact with the various mediums within the human body. Like the content discussed in the Waves module, this module directly affects our understanding of material discussed later such as bioeffects, system operation, and contrast and harmonics.

Module 4: PW

Core Concepts: 105 min
Focus Session: 79 min

This module begins by considering the fundamental limitation of continuous wave transmission - no ability to resolve structures based on depth. In order to create ultrasound images, depth resolution is required. The fact that we must use pulses to achieve depth resolution forces a discussion about a whole new group of timing considerations and issues, referred to as the pulse wave parameters. For example, we must discuss the pulse duration, pulse repetition period, duty factor, and spatial pulse length. This discussion about PW timing and pulse characteristics becomes the foundation for understanding depth resolution, the point at which aliasing occurs, the calculation of the frame time and the frame rate, as well as temporal resolution. Additionally, in this module, we learn how the pulse duration affects the bandwidth and we learn about the benefits of broad band transducers.

Module 5: Transducers

Core Concepts: 122 min
Focus Session: 92 min

We begin by discussing the theory of transducers, the piezoelectric effect, and basic ultrasound transducer design. Once we have developed an understanding of the transducer basics, we discuss the beam characteristics produced by the simplest possible transducer, a simple, single, round crystal. After we have mastered the basic beam characteristics, we then discuss the evolution of transducers from the simple, single, round crystals through 1D arrays to the most modern 2D arrays. In this module, we review the evolution of transducer development in a unique manner. Instead of just listing characteristics of each transducer type, we will focus on the benefits and limitations of each transducer type so that we can understand the motivation for designing each successive generation of transducers. There are two very evident benefits from this approach. First, this approach puts each successive generation of transducer into historical perspective and into context as to why each generation came into existence. Second, this approach teaches transducers from the perspective of the advantages and disadvantages of each transducer type, which happens to form the foundation of many of the exam questions related to transducers.

Module 6: System Operation

Core Concepts: 148 min
Focus Session: 111 min

In this module, we will learn how the system imaging controls affect all of the parameters we have discussed in previous modules. In essence, this chapter unifies the myriad concepts we have discussed up to this point. Within this module we develop and discuss an ultrasound imaging system block diagram so that the various system knobs, buttons, and controls can be understood in the greater context of the interactions that take place within the ultrasound system. In addition to discussing the transmit power, receiver gain, time gain compensation, video compression, and data storage, we discuss some advanced system features such as compound imaging, spatial averaging, multiple transmit foci, and continuous receive focusing.

Module 7A: Doppler System and Spectral Doppler

Core Concepts: 151 min
Focus Session: 114 min

We begin this module by learning basic Doppler theory including deriving the Doppler equation from a discussion of the Doppler Effect. After developing the Doppler equation, we discuss how the Doppler equation is applied in ultrasound. As we developed the ultrasound system block diagram for imaging in the Systems module, we will develop the Doppler system block diagram so that Doppler controls can be understood in the greater context of performing a clinical exam. In this section we will discuss the Doppler controls of transmit, receiver gain, signal detection, the Doppler wall filters, video compression, the PRF, Doppler spectral processing, and the spectral display. After we have completed the block diagram we will then be ready to discuss basic spectral interpretation, angular effects, and the parameters affecting aliasing.

Module 7B: Color Doppler

Core Concepts: 43 min

Focus Session: 32 min

In this module, we discuss the application of the Doppler effect in color Doppler imaging, including color Doppler gain, color wall filters, color persistence, and color priority. As you will see, color Doppler has some characteristics similar to spectral Doppler, some characteristics similar to 2D imaging, and some characteristics that are unique just to color Doppler imaging. Finally, we will concentrate on the ability to distinguish flow direction from a color image, regardless of transducer format, vessel tortuousity, and aliasing.

Module 8: Artifacts

Core Concepts: 53 min

Focus Session: 40 min

In the previous modules, we have discussed much of the physics as it relates to the production of artifacts. In this chapter, we formalize the physics concepts through examples and our discussion of the underlying principles. In essence, artifacts are generated whenever an assumption of ultrasound is violated. In this module, we discuss the imaging artifacts of limited detail resolution, reverberation, grating lobes, refraction, shadowing, enhancement, multi-path, and mirroring. Once the imaging artifacts have been reviewed, we discuss Doppler artifacts such as aliasing, wall filter saturation, spectral broadening, and blooming or blossoming.

Module 9: Bioeffects

Core Concepts: 39 min

Focus Session: 29 min

Although ultrasound is considered to be a very safe modality, there is a small potential risk of doing damage to tissues, referred to as bioeffects. Because of this risk, practitioners must make prudent use of ultrasound. Obviously, in order to be prudent when applying ultrasound, an understanding must be developed of the mechanism by which bioeffects occur, as well as the parameters which most directly impact the likelihood of bioeffects. The foundation for bioeffects was already laid in many of the previous modules. In this module, we integrate these previously reviewed concepts together to formalize our understanding of the two primary bioeffect risks, mechanical bioeffects, related to cavitation, and thermal bioeffects, related to temperature increase. Additionally, in this module we review some of the AIUM statements as regard the safety of ultrasound and the risk of bioeffects.

Module 10: Contrast and Harmonics

Core Concepts: 29 min

Focus Session: 22 min

The introduction of contrast imaging and harmonic imaging has revolutionized ultrasound. Interestingly, to some extent, harmonic imaging was born out of a desire to overcome a basic limitation which occurred with contrast imaging. As a result of this limitation, harmonic contrast was created. We will discuss the mechanism and limitations of harmonic contrast, tissue perfusion and harmonic imaging of tissue. The use of harmonics, also referred to as native, tissue, or second harmonic imaging, has dramatically impacted the ultrasound world. In this module, we learn the relative amplitudes of normal blood, blood with a contrast agent, harmonic signals from blood, harmonic contrast blood signals, and harmonic signals from tissue. We then discuss how harmonics are generated from tissue without the use of a contrast agent, the non-linear aspects of harmonic signal generation, the benefits of harmonic imaging, and the limitations of harmonic imaging, as well as approaches to overcome these limitations.

Module 11: Quality Assurance

Core Concepts: 60 min

Focus Session: 45 min

The first topic discussed in this module is Doppler system testing. Doppler system testing is performed so as to insure against transducer damage or transducer or system degradation over time. In order to perform Doppler testing, specialized testing equipment has been developed including Doppler flow phantoms, string phantoms, and vibrating plate phantoms. We will then discuss image performance testing. As with Doppler, many different imaging phantoms have been designed to test imaging performance including the parameters of detail resolution, contrast resolution, sensitivity, image distortion, and measurement accuracy. In the third part of this module, we learn about statistical test validation. In this section, we learn the statistical parameters used to compare various aspects of a clinical test we want to validate against a gold standard test. This statistical information will also prove very useful for labs undergoing laboratory accreditation.

Module 12: Fluid Dynamics and Hemodynamics

Core Concepts: 136 min

Focus Session: 102 min

The laws that govern fluid dynamics generally seem outside the intuitive grasp of many people. In this module we begin with a simple analogy which puts the complex content of this often intimidating topic in terms of an analogy to which everyone can relate. From this analogy, not only are general fluid dynamic principles appreciated, but also the foundation of the fluid dynamic equations are derived. Further use of analogies and thought experiments will then allow us to derive all of the equations needed, including the resistance equation, the simplified law of hemodynamics, the continuity equation, Poiseuille's Law, and the Bernoulli equation. Once the equations are derived, we develop a conceptual appreciation of the equations through direct application in various clinical situations. Finally, we will learn how to relate the Doppler spectral characteristics with the hemodynamic concepts just learned.

OPTIONAL:

Module 13: Test Taking Strategies

Core Concepts: 78 min

Focus Session: 59 min

The ability to perform well on a multiple choice test is a skill that requires both forethought and practice. In this module, some very unique techniques are taught which will significantly change your test taking approach, as well as improve your test taking abilities. Within this module we will discuss concepts which include how best to read a test question, how to approach answering a test question, types of questions, distracter types, dealing with questions of inversion, logic and reasoning skills, and intelligent use of scrap paper. Additionally, specific test questions are given which allow for direct application of these concepts.

Ultrasound Physics eCourse Totals:

Core Concepts: 22.5 hours
Focus Sessions: 17 hours

For more information:

info@pegasuslectures.com
972.564.3056