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Sonography Principles & Instrumentation A Q&A Review for the ARDMS SPI Exam

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CINDY A. OWEN | JAMES A. ZAGZEBSKI

Ultrasound Physics Review

A REVIEW FOR THE ARDMS SPI EXAM

2019

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Preface

THIS MOCK EXAM is a question/answer/reference review of ultrasound physics for ARDMS candidates who plan to take the Sonography Principles and Instrumentation (SPI) examination for one or more ARDMS credentials. It is designed as an adjunct to your regular study and as a method to help you determine your strengths and weaknesses so that you can study more effectively. *Ultrasound Physics Review* covers everything on the current ARDMS SPI exam content outline and in fact follows that outline, which you will find in Part 8 of this book.

Facts about this new SPI Edition of *Ultrasound Physics Review*:

- It precisely covers and follows the current ARDMS exam outline.
- It focuses exclusively on the SPI exam to ensure thorough coverage of even the smallest subtopic on the exam. (For the ARDMS specialty exams in Vascular Technology, Abdomen, Ob/Gyn, Breast, Adult Echocardiography, and Fetal Echocardiography, see our exam-specific reviews and mock exams at www.DaviesPublishing.com.)
- Topics are covered to the same extent as on the exam itself. Subject headings include the approximate percentage of the exam that a particular topic represents so you know the relative importance of each topic and can study more effectively.
- *Ultrasound Physics Review* contains 600 questions, many of which are image-based or otherwise illustrated.
- Explanations are clear and conveniently referenced for fact-checking or further study.
- Each section is keyed to the ARDMS exam outline so that you always know where you are, what you are studying, and how it applies to your preparation.
- The ARDMS exam outline and contact information for the ARDMS appears in Part 8 at the end of the book.

Ultrasound Physics Review effectively simulates the content and the experience of taking the exam. Current ARDMS standards call for approximately 120 multiple-choice questions to be answered during a two-hour period. That is, you will have an average time of 1 minute to answer each question. Timing your practice sessions according to the number of questions you need to finish will help you prepare for the pressure experienced by ARDMS candidates taking the SPI exam. It also helps to ensure that your score accurately reflects your strengths and weaknesses so that you study more efficiently and with greater purpose in the limited time you can devote to preparation. Because the content of this Q&A review is formatted and weighted according to the registry's outline of topics and subtopics, you can readily identify those areas on which you should concentrate.

ARDMS test results are reported as a "scaled" score that ranges from a minimum of 300 to a maximum of 700. A scaled score of 555 is the passing score (the "passpoint" or "cutoff score" for *all* ARDMS examinations. The scaled score is simply a conversion of the number of correct answers that also, in part, takes into account the difficulty of a particular question. Google *Angoff scoring method* if you want to learn more about scaled scoring. Suffice it to say that it helps to ensure the fairness of the exams and that in the case of all ARDMS exams 555 is the minimum passing score.

We include below and strongly recommend that you read *Taking and Passing Your Exam*, by Don Ridgway, RVT, who offers useful tips and practical strategies for taking and passing the ARDMS examinations.

Finally, you have not only our best wishes for success, but also our admiration for taking this big and important step in your career.

Cindy Owen

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Memphis, Tennessee

PART 5

Doppler Instrumentation and Hemodynamics

Ability to acquire color flow image
Ability to acquire a Doppler spectral image
Ability to take measurements from the spectral waveform
Hemodynamics

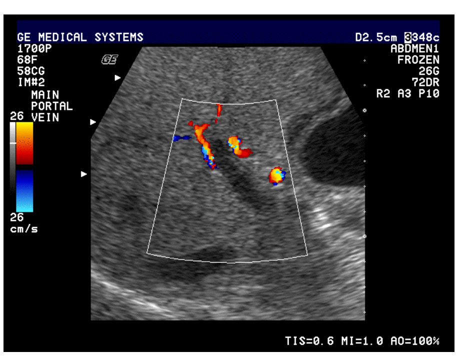
451. What is the maximum velocity limit for a 3 MHz CW Doppler unit operating at depth of 4 cm?

A. 40 cm/s
B. 200 cm/s
C. 2.5 m/s
D. 4 m/s
E. None of the above

452. You will see aliasing of the Doppler spectrum occurs whenever the frequency shift exceeds:

A. Twice the pulse repetition frequency
B. Three times the pulse repetition frequency
C. One-third the pulse repetition frequency
D. One-half the pulse repetition frequency
E. One-fourth the pulse repetition frequency

453. You obtained this color Doppler image during a hepatic sonogram. There is no color signal detected within the portal vein. What can you do to improve sensitivity to slow flow? *See also Color Plate 1.*



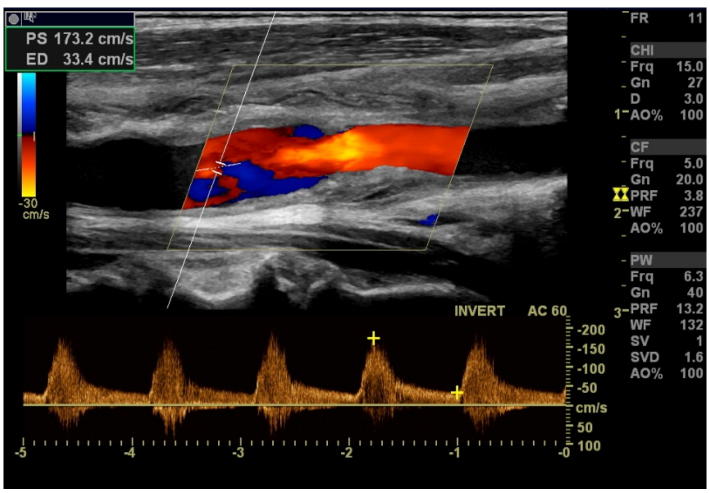
A. Increase wall filter

B. Decrease packet size
C. Decrease color gain
D. Decrease pulse repetition frequency
E. Change color map

454. The packet size in color Doppler refers to the number of:

A. Pulses per second
B. Sample volumes per scan line
C. Scan lines per unit area
D. Pulse/listen cycles per acoustic scan line
E. Pulses required to create one frame

455. Which of the following is present in this Doppler spectral waveform? *See also Color Plate 2.*

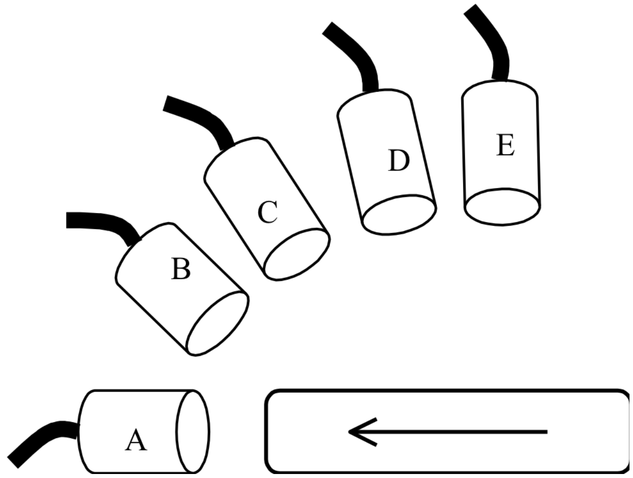


A. Spectral broadening
B. Narrow velocity range
C. Aliasing
D. Mirror imaging
E. Range ambiguity

456. While performing a Doppler study, the measurement of the Doppler angle of incidence was underestimated. What error will result from this mistake?

A. The frequency shift will be underestimated.
B. No Doppler frequency shift will be detected.
C. Mirror imaging of the Doppler spectrum will occur.
D. The velocity estimation will be inaccurate.
E. Aliasing of the Doppler spectrum will occur.

The next 3 questions refer to the following illustration in which five transducers are imaging a vessel at different incident angles. The arrow indicates the direction of blood flow.



457. Which transducer will detect the largest Doppler frequency shift?

A.
B.
C.
D.
E.

458. Which transducer would not detect a Doppler frequency shift?

A.
B.
C.
D.
E.

459. Which transducer would demonstrate a waveform ABOVE the zero baseline?

A.
B.
C.
D.
E. All except for E

460. A commonly used process for determining direction in a Doppler instrument is:

A. Zero-crossing detection
B. Autocorrelation
C. Phase quadrature detection

D. Range gating
E. Spectral analysis

461. What method is used to steer the color beam with a linear array transducer?

A. Mechanical
B. Electronic time delays
C. Electronic voltage variation
D. Apodization
E. The color beam cannot be steered with a linear array transducer.

462. When color Doppler is activated, in order to maintain frame rate, what may be reduced in the underlying B-mode image?

A. The number of focal zones
B. The scan line density
C. The frame averaging
D. A and B
E. B and C

463. What Doppler technique does NOT provide range resolution?

A. Color Doppler
B. Power Doppler
C. Pulsed-wave Doppler
D. Continuous-wave Doppler
E. No Doppler technique can provide range resolution.

464. You have obtained a color Doppler image of the common carotid artery. If the received ultrasound frequency is greater than the transmitted ultrasound frequency, which of the following would be correct?

A. Color encoding red, negative Doppler shift
B. Color encoding blue, negative Doppler shift
C. Color encoding red, positive Doppler shift
D. Color encoding blue, positive Doppler shift
E. No Doppler shift was detected.

465. Aliasing is a potential problem in PW Doppler because of:

A. The use of high pulse repetition frequencies
B. The Doppler signal being sampled rather than recorded continuously.
C. Dynamic focusing
D. The motion of the interface perpendicular to ultrasound wave propagation
E. Perpendicular incidence

466. What does the Doppler signal spectral display depict?

A. Relative signal power at each frequency in the Doppler signal
B. Depth to each vessel
C. Volume flow rate
D. Transmit frequency
E. Acoustic power

467. Increasing the wall filter during Doppler sampling will:

A. Increase visibility of low velocity signals
B. Increase spectral broadening
C. Decrease bandwidth
D. Reduce display of low-frequency shifts
E. Reduce aliasing

468. What would be the most likely result from increasing the transmit frequency of the color Doppler?

A. Improved sensitivity to slow flow
B. Improved penetration for imaging flow in deep tissues
C. Reduced flash artifact obscuring small vessel flow
D. Reduced color Doppler aliasing
E. Improved visibility of complex flow hemodynamics

469. What would be the most likely result from lowering the color threshold?

A. Increased visibility of small vessel flow in a parenchymal organ
B. Decreased flash artifact
C. Increased color writing on the vessel or cardiac wall
D. Increased frame rate
E. Improved color penetration

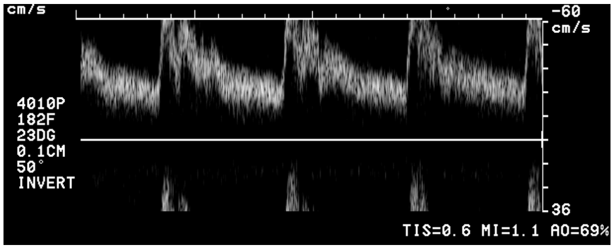
470. What method is most commonly used to perform spectral analysis for pulsed Doppler?

A. Zero-crossing detection
B. Fourier analysis
C. Reynolds number
D. Cross-correlation
E. Autocorrelation

471. During Doppler interrogation of the carotid artery, you detect spectral mirroring. Which of the following is a common cause of this artifact?

A. Doppler angle of interrogation near 90°
B. Doppler angle of interrogation near 0°
C. Wall filter set too high
D. PRF set too low
E. Doppler gain set too low

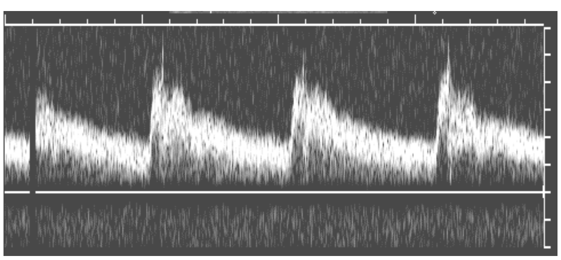
The next 2 questions refer to the following image:



472. This Doppler waveform can be most accurately described as exhibiting:
    A. Aliasing
    B. Spectral broadening
    C. Mirror image
    D. Bidirectional flow
    E. Saturation

473. What system control should be adjusted to optimize this waveform?
    A. Wall filter
    B. Packet size
    C. Gain
    D. Pulse repetition frequency
    E. Sample volume size

474. What Doppler control should be adjusted to optimize this Doppler spectral waveform?



    A. Wall filter
    B. Packet size
    C. Gain
    D. Pulse repetition frequency
    E. Baseline

475. The Doppler frequency shift is defined as:
    A. The difference between the Doppler frequency and the imaging frequency
    B. The difference between the transmitted and received frequencies
    C. The time between the transmitted and received pulses
    D. The rate at which the transducer emits pulses

image. They are most easily seen when imaging fluid because of the decreased attenuation and increased visibility of artifacts.

448. A. Dynamic receive focusing.

449. E. Tissue harmonic imaging.

*In **tissue harmonic imaging**, the receiver selectively "listens" to the harmonic frequencies that were generated as the sound traveled through the tissue. The second harmonic is the strongest harmonic produced. This is twice the transmitted frequency.*

450. A. One.

DOPPLER INSTRUMENTATION AND HEMODYNAMICS

451. E. None of the above.

CW (continuous-wave) Doppler does not have an imposed maximum velocity limit like PW (pulsed-wave) Doppler. In fact, CW Doppler may be used in instances where accurate velocities cannot be obtained with PW Doppler.

452. D. One-half the pulse repetition frequency.

***Aliasing** of the Doppler spectrum is an artifact that occurs with PW Doppler when the frequency shift is greater than ½ the Doppler PRF.*

453. D. Decrease pulse repetition frequency.

*When **slow flow** is present, the color Doppler system must be sensitized to detect low-frequency shifts (slow flow produces low-frequency shifts). Setting PRF lower increases sensitivity to low-frequency shifts. At low PRFs there is more time between the pulses, which allows time for the slow moving blood flow to move and be detected by the system. Other methods of improving sensitivity to slow flow include decreasing the wall filter and increasing the Doppler frequency.*

454. D. Pulse/listen cycles per acoustic scan line.

*For color Doppler, each line of sight must be pulsed multiple times. The number of pulses per line is termed **ensemble length**, **packet size**, or **shots per line**. The number of pulses transmitted in one second is the pulse repetition frequency (PRF). How many of those pulses are fired on each scan line is the ensemble length.*

455. A. Spectral broadening.

*The waveform shows fill-in of the spectral window. This loss of the window is indicative of spectral broadening. **Spectral broadening** is associated with turbulent flow.*

456. D. The velocity estimation will be inaccurate.

*The velocity estimation in Doppler ultrasound is based on measurement of the **Doppler angle of incidence**—the angle at which the Doppler beam intersects the blood flow. Because the blood flow is not directly visualized, the Doppler angle-correction cursor is aligned parallel to the walls of the vessel at the point of sampling. If this measurement is underestimated, the velocity of the flow will be underestimated. If this measurement is overestimated, the velocity of flow will be overestimated. Any time the angle-correction cursor is not adjusted parallel to the wall, the velocity estimation is in error.*

457. A.

The transducer labeled A is firing its beam at a 0° angle to flow. For any given velocity of flow, the maximum frequency shift will be obtained at 0°.

458. E.

The transducer labeled E is firing its beam at a 90° angle to flow. The Doppler equation tells us that we cannot detect a frequency shift at an incident angle of 90°.

459. E. All except for E.

460. C. Phase quadrature detection.

461. B. Electronic time delays.

*A **linear array transducer** steers the beam for color Doppler in the same way a phased array transducer steers its beam—electronically. The active elements are fired with very slight time delays, causing the beam to veer off at an angle from the transducer face.*

462. D. A and B.

To maintain an adequate frame rate in color Doppler, the B-mode image is compromised by reducing the number of focal zones to 1 or 2 and by reducing the scan line density, which results in lower lateral resolution.

463. D. Continuous-wave Doppler.

***Range resolution** is the ability to determine the depth from which an echo has arrived. For range resolution, the sound must be pulsed so that the echo arrival time from each pulse can be measured. By knowing the* *arrival time of the echo, the distance to the reflector can be determined. This works because we know the speed of sound in tissue and assume it to be constant.*

464. C. Color encoding red, positive Doppler shift.

*When the Doppler ultrasound beam intersects a vessel in which the blood is flowing toward the Doppler beam, the frequency of the reflected signal is higher than that of the transmitted signal. This is termed a **positive frequency shift**. All Doppler systems are set up so that positive Doppler shifts are color-encoded red and negative Doppler shifts are color-encoded blue. The specific color map in use determines the shading of red and blue and the colors in between. An Invert function is available on most systems that allows the user to reverse the color designation.*

465. B. The Doppler signal being sampled rather than recorded continuously.

***Aliasing** occurs because the frequency-shifted signal is not adequately sampled. The sampling rate is set by the system pulse repetition frequency (PRF). If the frequency shift exceeds ½ the PRF, aliasing of the signal will occur.*

466. A. Relative signal power at each frequency in the Doppler signal.

The Doppler signal spectral display depicts the frequency bandwidth and range of amplitudes in the reflected signal. The amplitude or signal power depends on the relative number of red blood cells comprising each component of the frequency-shift spectrum.

467. D. Reduce display of low-frequency shifts.

*The **wall filter** (also known as **high pass filter**) is used to eliminate frequency shifts below a set threshold from the display. If the filter is set at 50 Hz, then any frequency shift of 50 Hz or less will not be displayed. Increasing the wall filter helps to eliminate the high-amplitude, low-frequency shift signals caused by movement of the vessel wall. Nevertheless, it must be kept in mind that low-frequency shifts may also be a result of slow flow. So any time the wall filter is increased, the system is less sensitive to slow flow.*

468. A. Improved sensitivity to slow flow.

Increasing the color Doppler transmit frequency will result in larger frequency shifts from slow flow and thus, improved visibility. It will decrease penetration to flow in vessels deep within the tissues. Changing the ultrasound frequency has a negligible effect on frame rate, flash artifact, or visualization of complex flow hemodynamics. Although one could argue that the increased frequency shifts from slow moving tissue would be more visible with higher frequencies and may result in increased *flash artifact, nevertheless, increased visibility of slow flow is the best answer to this question.*

469. C. Increased color writing on the vessel or cardiac wall.

The threshold controls the brightness of the shade of gray that the color is allowed to overwrite. If the threshold is lowered, it is more likely that the color will overwrite the vessel or cardiac wall. Axial resolution in color Doppler almost always is poorer than that in B-mode.

470. B. Fourier analysis.

471. A. Doppler angle of interrogation near 90°.

At a 90° Doppler angle, flow direction cannot be determined and the waveform will be seen on both sides of the baseline.

472. A. Aliasing.

*With an **aliased signal**, the peak of the waveform is clipped off and appears on the opposite side of the baseline. It starts from the bottom of the image and points up toward the baseline. It does not start from the baseline and point down. That would indicate retrograde flow.*

473. D. Pulse repetition frequency.

*Because **aliasing** occurs when the frequency shift exceeds ½ the PRF, the frequency at which aliasing occurs increases as the PRF increases. Depending on the ultrasound system, the PRF control may be called **Velocity Scale**, **Velocity Range**, **Flow Rate**, or other terms. Whatever it is called, it controls PRF.*

474. C. Gain.

The gain should be reduced. There is noise in the background behind the spectrum and within the spectral window because the gain is set too high. Changing the sample volume would not affect the background noise, nor would changing the wall filter setting.

475. B. The difference between the transmitted and received frequencies.

*The **Doppler effect** causes the transmitted Doppler frequency to be altered when it encounters a moving reflector. The frequency is increased if the reflector is moving toward the beam and decreased if the reflector is moving away from the beam. The difference that occurs between the transmitted frequency and the altered frequency that is reflected back is known as the frequency shift.*

476. B. Increasing Doppler interrogation angle will increase the frequency shift.

*The **Doppler equation** is:*

$\Delta F = 2V\cos\theta F \div C$

where ΔF represents the frequency shift, $\cos\theta$ represents the Doppler angle of incidence, F represents the Doppler frequency, and C represents sound propagation speed. From this equation we can see that the value for the frequency shift will increase if the velocity of the reflector (the red blood cell) increases. Also, if the Doppler frequency increases, the frequency shift will increase. The cosine value of the Doppler angle of incidence is used in the equation. This tells us that the smaller the angle, the larger the frequency shift obtained for any given velocity.

477. C. Sampling frequency needed for detecting the Doppler signal unambiguously.

478. D. Amplitude.

*The **z-axis** on the Doppler spectrum is represented by the brightness of the dot. The brighter the dot, the greater the amplitude of the reflected signal. The factor affecting the amplitude is the relative number of RBCs reflecting that particular frequency shift. So by noting the brightness of a specific point on the spectral waveform we can get an idea about how much of the flow is moving at any given velocity at a particular point in time.*

479. D. Increase the pulse repetition frequency.

Decreasing the angle of incidence would cause a larger frequency shift for any given velocity and increase the odds of aliasing. The high pass filter has no effect on aliasing. To reduce aliasing, the zero baseline should be lowered instead of raised. Increasing the PRF raises the Nyquist limit and will help reduce aliasing (unwrap the waveform). Increasing the Doppler frequency will result in a larger frequency shift for any given velocity and increase the chances of aliasing.

480. C. Decrease the color box width.

The wider the color box, the more lines of sight that must be fired to create one frame. So decreasing the width of the box will improve the frame rate. Increasing the packet size will increase the frame rate. Decreasing the pulse repetition frequency may or may not affect the frame rate, but is more likely to decrease it rather than increase it. Increasing the scan line density will decrease the frame rate. Adjusting the wall filter will not affect the frame rate.

481. E. 3 kHz.

Ultrasound Physics Review: SPI Edition

Looking for guidance and a clear understanding of the principles and facts on which you will be tested? Here is the new SPI edition of the single bestselling mock exam devoted to the ARDMS exam in ultrasound physics. Written by an internationally renowned sonographer who not only loves ultrasound physics but delights in—and excels at—explaining it to others, *Ultrasound Physics Review* hones your test-taking skills, measures your progress as you study, and reveals your strengths and weaknesses topic by topic. Contains 600 complex registry-style questions that cover and follow the new ARDMS Sonography Principles and Instrumentation (SPI) outline, 65 image-based questions, and simple, clear explanations with current references for further study. Coverage includes patient care, safety, and communication, physical principles, ultrasound transducers, pulse-echo instrumentation, Doppler instrumentation and hemodynamics, and quality assurance/quality control of equipment—all in the same proportion as in the exam itself. Especially effective in combination with the Davies specialty exam reviews in Vascular, Abdomen, Ob/Gyn, Adult Echo, Fetal Echo, and Breast. Why are our mock exams so popular and effective? Because they contain the same kinds of thought-provoking questions you will find on the exam! 12 hours' SDMS-approved CME. Davies catalog #11030.

About the authors . . .

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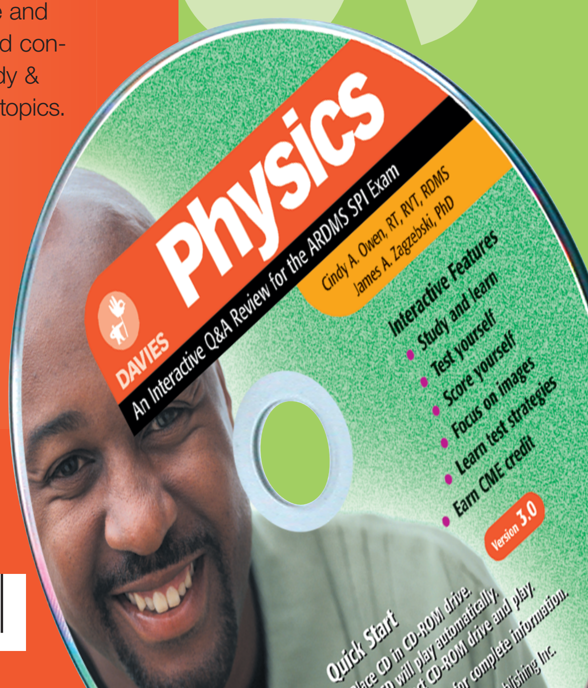

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