Radiography in the Digital Age

Learning Objectives for Each Chapter

Chapter 1: An Introduction to Radiographic Science

1. List the foundational principles of the scientific method, and how they relate to the standard of practice for radiographers.
2. Describe landmark events in the development of medical radiography, with particular focus on those that brought about reductions in patient exposure.
3. Overview landmark events in the development of modern digital radiographic imaging.
4. Present a scientifically balanced perspective on the hazards of radiation in our environment and workplace.
5. Understand and appreciate the ALARA philosophy in modern radiographic imaging.

Chapter 2: Basic Physics for Radiography

1. List and define each of the three base quantities and the four fundamental forces in physics.
2. State the conversions for basic units between the Systeme International and the traditional British system, and the value of the most used mathematical prefixes for units.
3. List the types of energy and give medically pertinent examples of transducers.
4. Explain the law of conservation of energy, forces, and conserved and non-conserved quantities.
5. Describe how kinetic and potential energy relate to electron positions within the atom.
6. Define the basic states of matter, and how heat causes them to transition from one to another.
7. List and define the three methods of heat transfer, and how each is applied in the x-ray tube.

Chapter 3: Unit Conversions and Help with Math

1. Describe the basic order of operations in math.
2. Appreciate and apply scientific notation.
3. Appreciate and apply dimensional analysis to make difficult unit conversions.
4. Understand calculations for areas and volumes, and how they relate to heating and cooling.
5. Become adept at using the inverse square law and its applications for radiography.
6. Properly construct graphs from data, and correctly interpret various types of graphs.
7. Describe the characteristics of various types of graphs including in particular the x-ray beam spectrum.

Chapter 4: The Atom

1. Define chemical elements, compounds, and mixtures, atoms and molecules.
2. Describe the structure of the atom, its nucleus, electron “shells” and suborbitals.
3. Describe the neutron and how it relates to radioactive decay.
4. Explain the $2N^2$ and octet rules and how they relate to periodicity in the chart of elements.
5. Describe the two major forms of chemical bonding between atoms.
6. Define ionization and how it affects chemical bonds and disease.
7. Interpret nuclear notation for atomic mass and atomic number.
8. Describe the progression of the neutron number as atomic number increases.
9. Define nuclear fission and fusion.
10. Define and give examples of isotopes, radioisotopes, and isomers.
11. Explain the emission of alpha, beta and gamma radiation and their effects on the nucleus.

Chapter 5: Electromagnetic Waves

1. List and define the four common characteristics of all waves. Define transverse and compressional waves.
2. Solve wave formula problems for frequency, wavelength and speed.
3. Solve electromagnetic wave formula problems for frequency and wavelength.
4. Combining the Planck formula and the wave formula, solve for minimum x-ray wavelength and for kVp.
5. Explain how electromagnetic waves are created, and their magnetic and electric components.
6. List the eight types of radiation comprising the electromagnetic spectrum, landmark energies and wavelengths, and the energy and wavelength ranges for diagnostic x-rays.
7. Overview the use of waves in MRI and sonography, and for lasers.
8. Discriminate between the characteristics and behavior of light waves and x-rays.
9. Describe how the differential absorption of x-rays results in radiopaque and radiolucent portions within a radiographic image.
10. Overview the dual nature of subatomic particles and waves, and how their quantum characteristics can best be visualized in the x-ray beam.

Chapter 6: Magnetism and Electrostatics

1. Define the magnetic moment of particles, the magnetic dipole of atoms, and magnetic domains in materials.
2. List and describe the four types of materials according to their magnetic properties.
3. Define magnetic permeability and retentivity.
4. Describe the effects of different materials on magnetic lines of force.
5. Solve simple Gauss’ law formula problems for the effects of pole strength and distance.
6. State the five laws of electrostatics.
7. Explain why only negative charges move in a solid, and why they distribute themselves evenly only on its surface.
8. Describe the effects of charge and distance on electrical force.
9. Define the three methods of electrification.
10. Define potential difference and electromotive force.
11. Solve for charge distribution when objects of varying charge come into contact.
12. Explain polarization and grounding.
13. Describe how the pocket dosimeter uses the principles of the electroscope to detect and measure radiation.

Chapter 7: Electrodynamics

1. Define electrical current and its units, and solve for total mAs and coulombs of charge spent.
2. Define and give examples of electrical conductors, dielectrics, and semiconductors.
3. List the three components of every electrical circuit.
4. List the three changes in a conductor that affect its electrical resistance.
5. Describe the two basic types of circuits.
6. Define the three characteristics of electricity and their units.
7. Solve simple Ohm’s law problems for current, voltage and resistance.
8. Define electrical power and its conservation law.
9. Solve simple power law problems for power, current, voltage and resistance.
10. Draw the wave forms for AC and DC electricity, and explain their shape.
11. Distinguish between the effects of electrical current and actual electron movement.
12. Define electrical frequency.
13. Describe electromagnetic induction, and how it applies to both generators and motors.
14. Explain how an induction motor, such as the one in the x-ray tube, works without magnets.
15. Define step-up, step-down, and auto- transformers.
16. Solve transformer law problems for voltage and amperage.

Chapter 8: X-Ray Machine Circuits and Generators

1. Sketch the basic layout of an x-ray machine circuit, showing in proper order the three main transformers, rectifier bridge, mA control, kVp meter and mA meter.
2. Describe the waveform and voltage changes between each major component of the circuit.
3. Explain how a modern solid-state diode prevents electricity from flowing “backward” on its way to the x-ray tube.
4. In the filament circuit, explain how high amperage is produced, how it results in thermionic emission at the filament of the x-ray tube, and when it occurs.
5. Explain why the mA and kVp meters are connected where they are in the circuit, and why they are connected in different manners.
6. Describe higher-power generators increase both the quantity and the quality of electrical current.
7. Give the percentage ripple and average kV as a percentage of the kVp for each type of generator.
8. Solve for the power rating in kilowatts for single-phase and 3-phase x-ray generators.
9. List the three general types of exposure timers.
10. Explain the principle on which an AEC is able to automatically terminate the exposure.
11. State the functional steps for the AEC circuit to work, and what the thyratron is.
12. Explain why the AEC cannot compensate for any changes in grid or image receptor.

Chapter 9: The X-Ray Tube

1. List the three essential conditions for the production of x-rays, and how each is met.
2. Explain why the creation of a space charge around the filament through the process of thermionic emission makes the x-ray tube more efficient.
3. Describe the materials and construction of the cathode.
4. Describe two ways a repulsive charge on the focusing cup can be used.
5. Distinguish between the purpose of the filament current and the high-voltage current.
6. Explain why the x-ray tube has 3 wires connected to one end and only one on the other end.
7. Describe the materials and construction of the anode.
8. For the target surface, the anode disc, and the anode stem, state whether its electrical conductivity is high or low, and whether its heat conductivity is high or low.
9. Explain the purpose of spinning the anode at high speed.
10. Describe how the copper cylinder of the anode shaft acts as the rotor of the induction motor.
11. Explain the effects of the mA station, the filament selected, and focal spot blooming on heat dissipation and image quality.
12. Describe the function of the glass envelope of the x-ray tube.
13. List the causes of x-ray tube failure, both for the filament and for the anode.
14. Calculate the heat unit load for single-phase and 3-phase x-ray machines.
15. Properly interpret x-ray tube rating charts and cooling charts.
16. List ways of extending x-ray tube life.

Chapter 10: X-Ray Production

1. Describe the tremendous kinetic energies and speeds of the electron stream in the x-ray tube.
2. Describe the Bremsstrahlung interaction, its effect on the x-ray beam spectrum, and its impact upon the image.
3. Describe the Characteristic interaction, its effect on the x-ray beam spectrum, and its impact upon the image.
4. Given the binding energies of various atomic “shells,” calculate the energy of characteristic x-rays resulting from different exchanges of electrons between them.
5. Sketch an accurate representation of the x-ray beam spectrum including both bremsstrahlung and typical characteristic x-rays.
6. Describe the poor efficiency of x-ray production.
7. Describe the effects of target material, mAs, filtration and kVp and the type of generator used upon the x-ray beam spectrum.

Chapter 11: Creation of the Radiographic Image

1. Define the parts of the x-ray beam.
2. List and give examples of the six general types of radiographic variables affecting the image.
3. Describe the photoelectric effect, its occurrence, and its impact upon the “latent” image carried by the remnant x-ray beam.
4. Describe the Compton effect, its occurrence, and its impact upon the “latent” image carried by the remnant x-ray beam.
5. Given the energy of an incoming x-ray photon and the binding energy of an electron shell, calculate the kinetic energy of the ejected electron and energy of any scattered x-ray for the photoelectric and Compton interactions.
6. Quantify the typical energy of a scattered x-ray photon as a function of its angle of deflection.
7. State the implications for the angle of scatter deflection and energy both for exposure at the image receptor and for backscatter exposure to personnel.
8. Describe the results of characteristic interactions within the patient.
9. Explain the exponential attenuation of the x-ray beam through thicknesses of tissue.
10. Apply the “4-centimeter” rule.
11. Explain the necessity of subject contrast in the remnant beam signal, and the role of differential absorption in producing it.
12. Describe how very thin layers of detective material at the image receptor can absorb x-rays effectively to produce an image.

Chapter 12: Production of Subject Contrast

1. Define subject contrast and quantify how it is altered by changes in tissue that result in different ratios of interactions.
2. Give a clear mathematical approach for measuring subject contrast.
3. Quantify the effects of tissue thickness, physical tissue density, and tissue atomic number on the production of subject contrast in the remnant beam signal.
4. Specify the effects of scatter radiation on subject contrast in the remnant beam signal.
5. Describe the effect of increasing kVp upon the predominance of Compton and photoelectric interactions, and the resulting impact on the image.
6. Describe the effect of increasing the atomic number of tissue or contrast agents upon the predominance of Compton and photoelectric interactions, and the resulting impact on the image.
7. Distinguish between the production of Compton interactions and the amount of scatter radiation reaching the image receptor, and why kVp is a relatively minor influence on subject contrast when compared with field size and part thickness.

Chapter 13: Qualities of the Radiographic Image

1. List and define the three visibility components of every image.
2. Describe the effects on details for both excessive contrast and insufficient contrast.
3. List and define the three recognizability or geometrical components of every image.
4. Define and describe the cause of geometrical penumbra.
5. Identify the best level of brightness (density) for a radiograph, and why sufficient penetration of the x-ray beam is critical to achieve it, especially when contrast agents are used.
6. Define radiographic contrast and gray scale, and how they interrelate.
7. Demonstrate that brightness and contrast are independent of each other as image qualities.
8. Define radiographic noise and give examples.
9. State the two ways that the signal-to-noise ratio (SNR) can be improved.
10. Define artifacts and give examples.
11. Calculate radiographic penumbra or unsharpness for variable distances and focal spots.
12. Calculate the relative sharpness for different distances.
13. Distinguish between poor contrast and poor sharpness.
14. Distinguish between the effects of blur and magnification on a penumbra diagram.
15. Calculate the magnification factor for variable distances.
16. Define and quantify shape distortion, as distinct from magnification.
17. Define overall image resolution, and list its two primary components.

Chapter 14: Milliampere-Seconds (mAs)

1. Describe what mAs controls in the x-ray beam, and distinguish between the proper units for x-ray beam intensity and electrical current intensity.
2. Describe why mAs is considered the primary control for exposure.
3. Calculate the total mAs for various combinations of mA and exposure time, and vice versa.
4. Develop the ability to do simple mAs calculations mentally.
5. Explain the root causes of quantum mottle or scintillation, and how to correct it.
6. List those image qualities which are not directly affected by mAs.
7. Accurately explain the relationship between exposure time and motion unsharpness.

Chapter 15: Kilvoltage-Peak (kVp)

1. Describe what kVp controls in the x-ray beam, and distinguish between the proper units for x-ray beam penetration and electrical force.
2. Describe the relationship between increasing beam penetration and subject contrast in the remnant beam signal.
3. Define the minimum kVp for a body part, and what determines it.
4. Explain why increases in x-ray intensity (mAs) cannot compensate for insufficient penetration (kVp).
5. Distinguish between the effects of increased kVp on x-ray tube output and on the remnant x-ray beam reaching the image receptor.
6. Accurately calculate proper mAs compensations for various kVp changes using the 15% rule.
7. Define optimum kVp for digital imaging, and how it differs from minimum kVp.
8. Describe how the 15% rule can be used to advantage in lowering patient exposure.
9. Rank kVp against body part thickness and field size as a contributor to scatter radiation.
10. Explain why much higher kVp's can be used with digital imaging than used to be used for film radiography.
11. List those image qualities which are not directly affected by kVp.

Chapter 16: Generators and Filtration

1. Explain the effects of higher power generators upon effective mA and effective kV.
2. State the appropriate reductions in radiographic technique for higher power generators.
3. List the image qualities that are affected by generator power, and those not affected.
4. State the minimum filtration requirement for x-ray machines operating above 70 kVp.
5. Describe the purpose of protective filtration, and what limits the amount used.
6. List the two types of protective filtration and give examples.
7. Define half-value layer (HVL) and how it is measured.
8. List the three determining factors for x-ray beam penetration and “hardening of the beam.”
9. Describe the purpose of compensating filters and where they might still be of value with digital procedures.

Chapter 17: Field Size Limitation

1. State the major guidelines for determining proper field size.
2. Quantify how effective field size limitation can be in reducing organ dose.
3. Define off-focus radiation and which collimating devices are most effective at reducing it.
4. Describe the history and proper use of positive beam limitation (PBL).
5. State the risks associated with over-collimation, and the guideline to avoid clipping anatomy.
6. Explain how a larger field size contributes to scatter production, and why subject contrast is reduced.
7. Explain how a larger field size contributes to overall exposure level at the IR.
8. List those image qualities that are not affected by field size.
9. For various distances and apertures, calculate the resulting field size, and vice versa.

Chapter 18: Patient Condition, Pathology, and Contrast Agents

1. Describe the proper locations and methods for measuring body part thicknesses.
2. Explain why radiographic technique can be approached in a systematic and scientific way.
3. State the average thicknesses for the adult torso in AP and lateral projection.
4. Use the 4-centimeter rule to derive appropriate techniques for variable part thicknesses.
5. State the rule for minimum change of exposure factors.
6. Describe each of the five types of body habitus and the associated adjustments for technique.
7. Describe the influence of age and anthropological factors on radiographic technique.
8. List the five general types of materials that are radiographically demonstrable, in order from most radiolucent to most radiopaque.
9. Describe the impact of the molecular (average) atomic number and physical density of body tissues upon subject contrast in the image.
10. Describe the impact of the molecular (average) atomic number and physical density of contrast agents upon
subject contrast in the image.

11. Describe the effects of patient cooperation and stage of respiration on chest radiographs.
12. Define radiographically additive and destructive diseases.
13. For the most common additive and destructive diseases, describe the appropriate types of adjustments in radiographic technique.
14. State the technique guidelines for post-mortem radiography.
15. State the technique guidelines for soft-tissue radiography.
16. State the technique guidelines for cast and splint radiography.

Chapter 19: Scattered Radiation and Grids

1. Prioritize the causes of scatter radiation by their degree of influence.
2. Understand the nominal role of high kVp levels in image degradation, especially for digitally-processed images.
3. Distinguish between the visibility effects of scatter radiation and the geometrical effects of blur, and that they are not directly related to each other.
4. Describe the geometry of how grids eliminate scatter radiation from the remnant beam.
5. Define grid ratio, describe how it improves subject contrast in the remnant beam, and why it is the only reliable method of indicating the effectiveness of a grid.
6. Calculate the grid ratio from grid dimensions.
7. Define grid frequency and lead content, and explain why they are not reliable ways of indicating grid effectiveness.
8. Describe the role of grids for digital imaging.
9. Prioritize part thickness, field size and set kVp in determining grid use and appropriate grid ratio.
10. Define the bucky factor and selectivity of a grid.
11. State technique compensations for landmark grid ratios and from tabletop to bucky.
12. List those image qualities not affected by grids.
14. State the cut-off effects of distances outside the grid radius for focused and parallel grids.
15. State the cut-off effects of off-centering or off-angling the x-ray beam and grid crosswise to the grid strips.
16. Describe grid line patterns and the directions one can off-center or angle the x-ray beam without causing cut-off effects.

Chapter 20: The Anode Bevel and Focal Spot

1. Describe how the line-focus principle is used to allow for high image sharpness while providing for adequate heat dispersion at the anode surface.
2. State how the line-focus principle causes the image to be sharper at one end of the field than the other.
3. Describe the cause of the anode heel effect, and the factors that make it worse.
4. For different body parts of variable thickness, state the best end of the x-ray table to position the patient’s head end, in order to minimize the anode heel effect.
5. Quantify the relationship between focal spot size and image penumbra.
6. Explain why geometrical penumbra occurs.
7. Explain how the umbra portion of the image can be made to completely disappear.
8. Describe why magnification is not affected by the focal spot size.
9. Describe why the focal spot is uniquely considered as the controlling factor for sharpness.

Chapter 21: Source-to-Image Receptor Distance (SID)

1. Describe both the preferred methods and back-up methods for measuring or estimating SID.
2. Explain the effect of SID on image penumbra, and on image sharpness.
3. Explain the effect of SID on image magnification.
4. Describe procedures where the intentional use of short SID can be beneficial for diagnosis.
5. Explain why the inverse square law applies to changes in the SID.
6. Explain why any change greater than 10% in the SID should be compensated for with technique, especially for digital images.
7. State the radiographic formula for the inverse square law.
8. Calculate exposure changes using the inverse square law.
9. State the formula for the square law.
10. Calculate various technique adjustments using the square law.
11. State the rules of thumb for landmark SID changes, especially between 40" (100 cm) and 72" (180 cm).
12. List those image qualities not directly affected by SID.

Chapter 22: OID and Distance Ratios

1. Describe the effect of OID upon subject contrast in the remnant x-ray beam.
2. Explain how OID affects overall exposure level at the image receptor.
3. Describe how OID impacts the spread of penumbra and image sharpness.
4. Describe the influence of OID on image magnification.
5. Describe how the intentional use of long OID can be beneficial for some procedures.
6. Calculate the magnification for various distance combinations using the SID/SOD ratio.
7. Calculate the relative sharpness for various distance combinations using the SOD/OID ratio.
8. Explain why distance ratios, rather than any single distance, must be used to accurately describe their effects on penumbra, sharpness and magnification.

Chapter 23: Alignment and Motion

1. Explain why off-centering of the beam causes the same types of effects as off-angling.
2. Describe how the shape and size of the object affect the degree of distortion that occurs.
3. Describe the extremes of distortion caused by placing the CR perpendicular to either the IR or the object when the object is tilted in relation to the IR.
4. Apply Ceiszynski’s law of isometry in minimizing distortion for a tilted object.
5. Explain why thick objects will always undergo elongation distortion with an angled beam.
6. Give examples of how beam divergence can be taken advantage of to better demonstrate the anatomy for some procedures and situations.
7. Quantify the degrees of beam divergence per inch or cm away from the CR for standard SIDs.
8. Describe how the beam divergence rule can be used to determine the angle for an L5/S1 “spot” projection from observation of the routine lateral L-spine view.
9. Explain how shorter SID becomes a contributing factor for distortion once it is already occurring due to misalignment.
10. State the rule for compensating tabletop-tube distance according to degrees of angulation, in order to maintain exposure level at the IR.
11. List those image qualities not affected by the SID.
12. State the four geometrical objectives of radiographic positioning.
13. Describe why a minimum of two projections must be taken as a general rule for diagnosis.
14. List the three means of controlling the effects of motion.
15. List the types of motion, both for the patient and for equipment.
16. Describe the effect of motion on penumbra and image sharpness.
17. Describe the effects of moderate and extreme motion on image contrast.
18. Define false images, and distinguish between the effects of motion and true distortion.

Chapter 24: Analyzing the Radiographic Image

1. List all of the variables affecting exposure level at the image receptor.
2. List all of the variables affecting subject contrast at the image receptor.
3. List all of the variables affecting image noise.
4. List all of the variables affecting sharpness of recorded detail.
5. List all of the variables affecting magnification.
6. List all of the variables affecting shape distortion.
7. Describe the production of absorption penumbra.
8. Interprete exposure trace diagrams.
9. Describe how object shape affects the degree of absorption penumbra.
10. Explain how absorption penumbra and geometrical penumbra combine to form the total
11. Define spatial resolution and the unit for spatial frequency.
12. Calculate the smallest object size that can be resolved at a given spatial frequency.
13. Define contrast resolution and modulation transfer function (MTF).
14. Describe how, as image details become smaller and smaller, the effects of penumbra eventually affect contrast resolution on a microscopic scale.
15. Describe the limiting factors for image resolution with modern digital equipment.

Chapter 25: Simplifying and Standardizing Technique

1. List the three general areas of standardization within a medical imaging department.
2. Describe the advantages and disadvantages of the variable-kVp and fixed-kVp approaches to radiographic technique.
3. Using the base-50 method, apply the variable-kVp approach to developing techniques.
4. List the objectives and advantages of the proportional anatomy approach to technique.
5. List those procedures in the major proportional anatomy groupings which share equivalent overall techniques.
6. Give landmark examples of proportional anatomy derivations from one body part to another.
7. Describe essential considerations for torso shape in adjusting technique.
8. Explain the advantages, proper development, and proper use of technique charts.
9. Describe the basic steps in developing a technique chart “from scratch.”

Chapter 26: Using Automatic Exposure Controls (AEC)

1. List those technique factors, which must still be “manually” set by the radiographer even when the AEC is engaged.
2. Describe the limitations imposed by the minimum response time of the AEC circuit, and how technique can be compensated to correct for them.
3. State the general formula for appropriate back-up mAs or time, and why it is so important.
4. Explain why back-up times pre-set by the manufacturer must be checked and often overridden.
5. Describe typical formats for the intensity (density) control.
6. Describe the proper use of the intensity (density) control setting.
7. Explain five limitations for using the AEC, situations for which “manual” technique may be more appropriate.
8. Describe the major factors that determine the proper AEC detector cell configuration for a particular projection.
9. List AEC detector cell configurations in order, from the least resulting exposure to the most.
10. List the common causes of overexposure using AEC.
11. List the common causes of underexposure using AEC.
12. List essential components for an AEC technique chart.
13. Describe the limitations of programmed exposure controls.

Chapter 27: Computer Basics

1. Overview how computer hardware and software interact to perform tasks at high speed.
2. List the types of computers and terminals, and how they relate to radiography.
3. Overview the history and development of computers and micro-circuitry.
4. Describe how peripherals integrate with the central processing unit.
5. Describe the types of storage and main components in the CPU.
6. Describe the types of storage and major components of a typical PC.
7. Distinguish between the various characteristics of modern digital memory.
8. Analyze the differences between analog and digital data and how they relate to radiographic images.
9. Understand the basic aspects of binary code and ASCII code.
10. Overview the general types of software and levels of machine language.
11. Define the four levels of data processing.
12. Overview the hardware components and compatibility of digital communications systems.

Chapter 28: Creating the Digital Image
1. Describe the aspects of a digital image matrix and how it impacts image resolution.
2. Relate pixel size to the displayed field of view and matrix size.
3. Define the three steps in digitizing any analog image.
4. Explain the relationships between bit depth, dynamic range and image gray scale in providing image resolution.
5. Describe the nature of voxels for CT, CR and DR imaging and how the x-ray attenuation coefficient for each is translated into the gray levels of pixels.
6. Describe the development and limitations of contrast resolution and spatial resolution for digitized radiographic images.
7. Explain how the selection of specific procedural algorithms impacts the displayed image.
8. Fully define window level and window width and how they translate into displayed image brightness and gray scale.
9. Describe the components and function of the PACS, RIS and HIS and the DICOM standard.
10. Define the types, characteristics and proper use of workstations and display stations.
11. Overview how lasers work, and their four types of applications in the medical imaging department.

Chapter 29: Digital Image Processing

1. Define preprocessing and postprocessing.
2. Describe six types of corrections made to the acquired image to establish field uniformity.
3. Define partitioned pattern recognition and exposure field recognition.
4. Explain the construction of the image histogram and the characteristics of three general types of histograms.
5. Describe how pixel values in the image are re-mapped to rescale both brightness and contrast and correct for scatter radiation.
6. Define gradient processing and describe how LUTs are used to customize image brightness and gray scale according to the anatomical procedure.
7. Define data clipping, dynamic range compression and tissue equalization.
8. Define spatial domain and frequency domain processing of image detail.
9. Explain how an image can be represented in the form of wavelengths and frequencies.
10. Describe point processing and kernels, and how they are used to enhance image detail.
11. For the electronically-displayed image, define the relationships between object size, frequency, and image sharpness.
12. Define Fourier transformation, high-pass filtering, and low-pass filtering.
13. Describe the steps in unsharp mask filtering.
14. Define pyramidal decomposition and the steps of multiscale processing.
15. Define the parameters of frequency processing and how they are used to enhance detail and reduce noise in the image.
16. Describe the necessity for additional gradation processing before image display.
17. Overview processing suites used by manufacturers.
18. Describe operator adjustments to the image, including windowing, edge enhancement, smoothing and tomographic artifact suppression.
19. Explain how dual-energy subtraction works and the different approaches to achieving it.

Chapter 30: Postprocessing Operations in Practice

1. Overview the typical menu screen functions for operator adjustments to the image.
2. Define speed class and how it is best used to minimize patient exposure.
3. List the three rules for proper use of the exposure indicator.
4. Describe the general approaches to formulating the exposure indicator and their accuracy.
5. Define the three general types of scales used for exposure indicators, (logarithmic, proportional, and inversely proportional), and overview how they are used by different manufacturers.
6. List recommendations for more accurate and more pertinent exposure indicators.
7. State the typical parameters for acceptable exposure based on different types of indicators.
8. List typical causes of exposure indicator error.
9. Explain the proper use and limitations of alternative procedural algorithms in manipulating the image.
10. Describe the proper use of windowing, edge enhancement and smoothing in manipulating the image.
11. Define various features for adjusting the image, (dark masking, image reversal, resizing, image stitching, etc.)
12. Clearly define the seven criteria for digital radiography image quality.

Chapter 31: Capturing the Digital Image: DR and CR

1. Compare the practical advantages and disadvantages of DR versus CR.
2. Describe the development of DR and miniaturized detector elements (dexels).
3. Describe the components, function, detective quantum efficiency, and fill-factor of dexels.
4. Describe the components of an active matrix array (AMA) and their functions.
5. Distinguish between the function, advantages and disadvantages of direct-conversion versus indirect-conversion DR systems.
6. Explain the function of the CR cassette and phosphor plate in capturing the image.
7. Explain the functions of the CR reader/processor as it samples and processes the image.
8. Describe the limitations of CR and its sensitivity to “pre-fogging” of the phosphor plate.
9. State the formula relating pixel pitch to spatial resolution and define the Nyquist frequency.
10. Compare the absorption efficiency, conversion efficiency, and emission efficiency of CR, indirect-conversion DR. and direct-conversion DR systems.
11. Explain the impact of the K-edge effect on detector efficiency.
12. Define detective quantum efficiency and how it impacts the image.
13. Describe the causes and appearance of common digital image and printer artifacts.

Chapter 32: Computer Radiography (CR) Applications

1. Describe the effects of centering of the anatomy, alignment of multiple fields on the IR, and overcollimation on processing errors in CR.
2. State important considerations for horizontal projections and bilateral views to avoid CR processing errors.
3. Describe the retention of the image on CR phosphor plates and its implications for practice.
4. Appreciate differences in image qualities between CR manufacturers.

Chapter 33: Applying Radiographic Technique to Digital Imaging

1. Describe the impact of centering on mottle in DR images.
2. Explain the rationale for allowing much higher kVp levels in digital imaging than were used in conventional film-based radiography, and why a 15% “across-the-board” increase in kVp is recommended.
3. Define the continuing role of “manual” technique skills and proportional anatomy in the age of digital imaging.
4. Describe the exposure latitude for digital images, what factors set its upper and lower limits, how it has impacted patient exposure and what we as a profession should do about it.
5. Describe the proper use of AEC for digital imaging and preventing mottle in AEC images.
6. Explain the importance of sufficient penetration and a high signal-to-noise ratio (SNR) for digital imaging.
7. Explain the effects and ranges of underexposure and overexposure for both mAs and kVp in digital imaging.
8. Dispel common myths about technique settings for digital imaging.
9. Clearly describe the resilience of digital imaging to scatter radiation caused during exposure.
10. Explain the possible effects of scatter radiation on the digital process and the continuing need for grids.

Chapter 34: Display Systems and Electronic Images

1. Describe the basic components and operation of a TV camera tube.
2. Describe the function and advantages of a charge-coupled device (CCD) and sequels.
3. Explain how a CRT reconstructs an electronic image on a fluorescent phosphor screen.
4. Describe the spatial and contrast resolution, dynamic range and signal-to-noise ratio for CRTs.
5. Define light polarization and how it is used in a liquid-crystal diodes (LCDs) to produce an image.
6. Explain how the pixels of an LCD are constructed and controlled.
7. Describe the light sources for passive-matrix and active-matrix LCDs.
8. Describe the resolution, advantages and disadvantages of LCDs.
9. Describe the nature of pixels and subpixels in display monitors, their dynamic range and options for resolution.

Chapter 35: Mobile Radiography and Tomography
1. Describe technique considerations, geometrical factors, and positioning and alignment considerations unique to mobile x-ray units.
2. Explain the principle of parallactic shift and how it is used to create tomograms.
3. Describe the relationships between tomographic amplitude, blurring effectiveness and focal plane thickness.
4. Describe the importance of movement patterns and orientation in preventing false images.
5. Apply the correct selection of focal depth and focal intervals for tomographic procedures.

Chapter 36: Fluoroscopy and Digital Fluoroscopy

1. Overview the history and development of fluoroscopy, especially in regard to patient exposure.
2. Describe the components of an image intensifier and how they work together to amplify the image.
3. Define the brightness gain and conversion factor for an image intensifier.
4. Explain how multiple field sizes are achieved, their effect on magnification and patient exposure.
5. Describe the two types of signal sensing and four approaches to stabilizing the brightness of the fluoroscopic image.
6. List the requirements for a high-quality automatic brightness stabilization system.
7. Explain the adjustment of proper fluoroscopic techniques.
8. Describe the qualities of the fluoroscopic image and the various forms of distortion that occur.
9. Describe the proper manipulation and positioning of a C-arm fluoroscopy unit.
10. Explain how patient exposure is minimized during fluoroscopy.
11. Describe the advantages and disadvantages of pulsed-progressive mode fluoroscopy, especially in regard to patient exposure.
12. Describe dynamic flat-panel detectors for fluoroscopy, their advantages and disadvantages.
13. Explain the application of temporal and energy subtraction methods to improve the image.

Chapter 37: Quality Control

1. Define quality assurance and quality control as they relate to radiography, and list the components of a comprehensive quality control program.
2. List the methods and parameters for testing the exposure timer, mA linearity, exposure reproducibility, half-value layer, kVp calibration, collimator and distance controls, focal spot size and condition for radiographic units.
3. List the methods and parameters for testing the AEC, tomography units, and fluoroscopy units.
4. List the methods and parameters unique to testing digital image acquisition systems.
5. Describe the methods and parameters for testing electronic image display systems, including luminance, illuminance, contrast, ambient lighting and reflectance, noise and resolution.
6. Explain the function of photometers and densitometers.
7. Explain the nature, prevention and correction of dead and stuck pixels for LCD monitors.
8. Describe viewing angle dependence for LCDs.
9. Describe tests unique to both LCDs and CRTs, and for a viewbox illuminator.
10. Describe the relevance and issues of repeat analysis in the age of digital imaging.

Chapter 38: Radiation Perspectives

1. Provide a balanced perspective on the radiation risk levels and standards of practice for the working radiographer.
2. Provide a balanced perspective on environmental radiation and its associated levels of risk.
3. Develop a scientifically-based frame of reference to compare the risks of radiography for patients to other common health risks.
4. Describe the sources of natural background radiation, man-made radiation, and their associated levels of risk.
5. State the proportional contribution of each source of radiation to our total annual exposure.
6. List the types of radiation and, for each, their associated levels of penetration, biological harm, mass and charge.
7. Explain why each of these types of radiation causes greater or lesser biological harm.
8. Define half-life, and calculate the levels of radioactivity associated with different half-lives and elapsed times.
9. Explain the relationship between the level of radioactivity and the half-life in determining risk.
Chapter 39: Radiation Units and Measurement

1. Define the conventional units of measurement for radiation and how they are derived.
2. Explain dose-area product (DAP) and its importance for understanding biological harm.
3. List the Systeme International units for radiation and their conversion factors from the conventional units.
4. Calculate dose-area products and conversions between conventional and SI units.
5. List the dose-limiting organs of the body and how they are used to determine total effective dose equivalents.
6. Describe the historical evolution of dose equivalent limits (DELS) and its implications.
7. Define and calculate cumulative lifetime limits, prospective limits, and retrospective limits for different workplace scenarios, and state in each case which limit supersedes the others.
8. State by memory landmark occupational and public whole-body dose equivalent limits (DELS).
9. State by memory landmark parital-body DELs for different organs.
10. Define genetically significant dose, state the current estimate and percentage contributions by radiographic examination.
11. Describe the modes of operation and appropriate units for radiation detection instruments.
12. Define the sensitivity, accuracy, resolving time and range for radiation detection instruments, and how these apply to radiographic equipment.
13. Describe the four generic types of radiation detection instruments, how each works, and the advantages and disadvantages of each.
14. Describe the four types of gas-filled radiation detectors, how each works, and the advantages and disadvantages of each.
15. Describe the advantages and disadvantages of three different types of devices for personal radiation monitoring.
16. Explain the voltage-dependence of each of the four types of gas-filled detectors and how it affects calibration, accuracy, and validity of measurements taken.

Chapter 40: Radiation Biology: Cellular Effects

1. Review the basic tissues of the human body, cell structure and metabolism.
2. Explain the roles of DNA and RNA in protein synthesis, and the three levels of genetic information transfer.
3. Describe the structure of DNA and chromosomes at different stages in cell’s life cycle.
4. Describe in detail each stage in the life cycle of the cell, and at which stages the cell is most sensitive to radiation exposure.
5. Distinguish between the stages of mitosis and those of meiosis in cell reproduction.
6. Explain the two major propositions of the Law of Bergonie and Tribondeau.
7. Prioritize different types of cells according their sensitivity to radiation exposure.
8. Correctly interpret various radiation response curves, and survival curves, from graphs.
9. State the main propositions of the target theory for radiation damage to cells.
10. Describe the radiolysis of water and how it contributes to indirect damage mechanisms.
11. Explain how radiation can damage the cell membrane and its consequences.
12. Describe the specific types of structural changes that occur to the DNA molecule from radio-ionization, and their implications for mutations, repair, and disease.
13. Define and calculate linear energy transfer (LET) for different radiations.
14. Define and calculate relative biological effectiveness (RBE) for different radiations.
15. Describe the impact of dose rate, protraction, and fractionation on the effectiveness of a radiation exposure.
16. Describe the influence of oxygen enhancement ratio (OER), age and gender on the effectiveness of radiation exposure.
17. Relate LET, RBE, direct effect, indirect effect, single-strand breaks, double-strand breaks, point mutations, frameshift mutations, oxygen enhancement and reparability to the penetration of a particular type of radiation.

Chapter 41: Radiation Biology: Organism Effects

1. Describe the roles, advantages and disadvantages of epidemiology, extrapolation and direct experimentation in measuring radiation risk.
2. Define absolute risk, relative risk, and excess risk for radiation exposure.
3. Distinguish between stochastic effects of radiation and deterministic effects.
4. List and describe various early effects of radiation.
5. Define common expressions of *lethal dose*, such as $LD_{50,30}$.
6. List and describe the stages of acute radiation syndrome and define the *N-V-D* syndrome.
7. For each type of acute radiation syndrome (ARS), state the mean survival time, the predominant cause of death, and the relationship between these two.
8. State by memory the *threshold dose* for each type of ARS.
9. Define erythema and epilation.
10. List and describe various late effects of radiation.
11. State for each period of human embryo and fetal development the expected *teratogenic* effects of radiation exposure.
12. Describe the *mutagenic* effects of radiation.
13. Quantify the life-span shortening effects of radiation.
15. Elaborate on the carcinogenic effects of radiation, especially in regard to leukemia.
16. Describe the different carcinogenic risks of recreational and occupational exposure to radiation, including UV.
17. Describe the typical dose levels, risks and benefits of modern mammography, and the generally accepted guidelines for when mammograms should be performed.

Chapter 42: Radiation Protection: Procedures and Policies

1. State typical *distributed skin exposures* for landmark radiographic procedures, and equivalent comparative risks.
2. Describe typical gonadal exposure levels for landmark radiographic procedures.
3. List methods of optimizing radiographic technique in order to minimize patient exposure.
4. Relate the roles of digital processing speed class and quality control programs to minimizing patient exposure.
5. Describe the types and methods of shielding appropriate for use on patients.
6. Describe those policies and practices which are appropriate for minimizing radiation exposure to the pregnant patient.
7. State guidelines for equipment monitoring related to patient exposure levels.
8. Explain the issues of fluoroscope technology and use, especially in relation to *high-level* or *pulse-controlled* equipment, that relate to minimizing patient exposure.
9. List those procedures identified by the *Safe Medical Devices Act of 1990* as high risk procedures, and state the five recommendations made for addressing these risks.
10. Provide perspective on controversy over patient exposure levels for CT exams, especially for young patients.
11. Describe the elements of a good personnel monitoring program, and the minimum information that should be provided on occupational radiation reports.
12. List the three cardinal principles for occupational radiation protection, and the effectiveness of each on exposure level.
13. Correctly interpret *isorexposure* curves.
14. Describe the effectiveness of lead aprons, and guidelines for their use by personnel.
15. Define *tenth-value layer*.
16. State the requirements for radiographic equipment shielding.
17. Explain the philosophy and recommendations for holding of patients during an exposure.
18. Describe appropriate policies for limiting personnel exposure, especially in regard to pregnant working radiographers.
19. State general guidelines for equipment, which minimize exposure to personnel.
20. Describe the factors and formula for the adequacy of structural barriers to radiation.
21. State the thickness requirements for *primary* and *secondary* barriers, and which applies to the control booth.
22. Define the types of radiation control areas, and the posted warnings required for each.
23. List the main advisory and regulatory agencies for radiation control and the primary focus of each.
24. Distinguish between legal requirements and the *standard of practice* in keeping all radiation exposures *ALARA*.
25. Define the role of the radiographer in being of professional service to other medical personnel and the public, as it relates to understanding and minimizing radiation exposure.