

	GD	ZC	JA/NY	NY	NM	JA	JD	Unassigned
1. Structure of the Atom		X						
1.1. Composition	X	X						
1.1.1. Electrons	X	X						
1.1.2. Nucleus	X	X						
1.2. Electronic Structure	X	X						
1.2.1. Electron Orbits	X	X						
1.2.2. Orbital Nomenclature	X	X						
1.2.3. Binding Energy	X	X						
1.2.4. Electron Transitions	X	X						
1.2.5. Characteristic Radiation	X	X						
1.2.6. Auger Electrons		X						
1.3. Nuclear Structure		X						
1.3.1. Composition		X						
1.3.2. Nuclear Force		X						
1.3.3. Mass Defect		X						
1.3.4. Binding Energy		X						
1.3.5. Fission		X						
1.3.6. Fusion		X						
1.3.7. Nuclear Instability - Overview		X						
1.3.7.1. Beta (negative electron) Decay		X						
1.3.7.2. Positron (positive electron) Decay		X						
1.3.7.3. Electron Capture		X						
1.3.7.4. Isomeric Transition		X						
1.3.8. Classification of Nuclides		X						
2. Electromagnetic (EM) Radiation	X	X						
2.1. Wave - Particle Duality	X	X						
2.1.1. Wave Characteristics	X	X						
2.1.2. Particle Characteristics	X	X						
2.2. Electromagnetic Spectrum	X	X						
2.2.1. Ionizing		X						
2.2.2. Non-ionizing		X						
3. Particulate Radiation		X						
3.1. Light Particles		X						
3.2. Heavy-charged Particles		X						
3.3. Uncharged Particles		X						
4. Interaction of Radiation with Matter		X						
4.1. Charged Particle Interactions		X						
4.1.1. Ionization/Excitation		X						
4.1.2. Bremsstrahlung	X	X						
4.1.3. Secondary Ionization		X						
4.1.3.1. Specific Ionization		X						
4.1.3.2. Linear Energy Transfer (LET)		X						
4.1.4. Positron Annihilation		X						
4.2. Neutron Interactions		X						
4.3. Photon Interactions		X						
4.3.1. Coherent Scattering		X						
4.3.2. Compton Scattering		X						
4.3.3. The Photoelectric Effect		X						
4.3.4. Pair Production		X						
4.3.5. Interactions in Tissues		X						
4.3.6. Contrast Media		X						
4.4. Photon Attenuation	X	X						
4.4.1. Linear Attenuation Coefficient	X	X						
4.4.2. Mass Attenuation Coefficient	X	X						
4.4.3. Attenuation Equation	X	X						
4.4.4. Poly-energetic X-Ray Beams	X	X						
4.4.5. Half -value Layer (HVL)	X	X						
4.4.5.1. Effective Energy		X						
4.4.5.2. Beam Hardening	X	X						
4.4.5.3. Geometry		X						
4.4.6. Mass Energy Absorption Coefficient		X						
5. Radiation Units		X						
5.1. System of Units		X						
5.1.1. SI		X						
5.1.2. Classical	X	X						

6.1.1.2.	Influence of Electron Energy	X							
6.1.1.3.	Influence of Target Material	X							
6.1.1.4.	Influence of Filtration	X							
6.1.2.	Characteristic Radiation	X							
6.1.2.1.	Importance in Imaging	X							
6.1.2.2.	Influence of Target Material	X							
6.1.2.3.	Influence of Filtration	X							
6.2.	X Ray Tube	X							
6.2.1.	Cathode	X							
6.2.1.1.	Filament	X							
6.2.1.2.	Focusing Cup	X							
6.2.1.3.	Biasing	X							
6.2.1.4.	Filament and Tube Current	X							
6.2.1.5.	Focal Spot Blooming	X							
6.2.1.6.	Space Charge	X							
6.2.2.	Anode	X							
6.2.2.1.	Composition	X							
6.2.2.2.	Configuration	X							
6.2.2.3.	High Speed Rotating Anode	X							
6.2.2.4.	Line Focus Principle	X							
6.2.2.5.	Focal Spot	X							
6.2.2.6.	Heel Effect	X							
6.2.2.7.	Off-Focus Radiation	X							
6.2.2.8.	Overheating	X							
6.2.3.	Application-Specific Tubes								
6.2.3.1.	Mammography						X		
6.2.3.2.	Straton								X
6.3.	Generators								
6.3.1.	Single-Phase	X							
6.3.2.	Three-Phase	X							
6.3.3.	High-Frequency	X							
6.3.4.	Technique Factors	X							
6.3.4.1.	kVp	X							
6.3.4.2.	mA	X							
6.3.4.3.	Time	X							
6.3.4.4.	Automatic Exposure Control (AEC)	X							
6.3.4.5.	Technique Charts	X							
6.4.	X-ray Beam	X							
6.4.1.	Beam Filtration	X							
6.4.1.1.	Inherent	X							
6.4.1.2.	Added (Al, Cu, Mo, Rh, other)	X							
6.4.1.3.	Minimum HVL	X							
6.4.1.4.	Shaped Filters	X							
6.4.2.	Spectrum	X							
6.4.3.	Collimators	X							
6.4.3.1.	Field Size Limitation	X							
6.4.3.2.	Light/X-Ray Alignment	X							
6.4.3.3.	Effect on Image Quality	X							
6.4.3.4.	Importance to Safety	X							
6.4.4.	Geometry	X							
6.4.4.1.	Source-to-Image Receptor Distance (SID)	X							
6.4.4.2.	Magnification	X							
7.	Basic Imaging Science and Technology								
7.1.	Basic Statistics					X			
7.1.1.	Systematic and Random Error					X			
7.1.2.	Precision and Accuracy					X			
7.1.3.	Statistical Distributions					X			
7.1.4.	Mean, Median and Mode					X			
7.1.5.	Variance					X			
7.1.6.	Confidence Intervals					X			
7.1.7.	Propagation of Error					X			
7.1.8.	Statistical Process Control								X
7.2.	Image Properties								
7.2.1.	Image Representations								
7.2.1.1.	Spatial	X	X	X					
7.2.1.2.	Frequency		X	X					

7.2.8.4.	Bit-depth	X	X						
7.3.	Generic Image Processing								
7.3.1.	Pre-processing								
7.3.1.1.	Non-Uniformity Correction		X	X					
7.3.1.2.	Defect Corrections	X							
7.3.2.	Segmentation								
7.3.2.1.	Collimation	X							
7.3.2.2.	Value of Interest								X
7.3.3.	Grayscale Processing	X							
7.3.3.1.	Window/Level	X							
7.3.3.2.	Characteristic Curves	X							
7.3.3.3.	Look-Up Tables	X							
7.3.4.	Frequency Processing								
7.3.4.1.	Edge Enhancement					X			
7.3.4.2.	Noise Reduction		X			X			
7.3.4.3.	Equalization					X			
7.3.5.	Reconstruction		X						
7.3.5.1.	Simple Back-Projection		X						
7.3.5.2.	Filtered Back-Projection		X						
7.3.5.3.	Iterative Reconstruction Methods		X						
7.3.5.4.	Sinogram		X						
7.3.6.	Three-dimensional		X						
7.3.6.1.	Multi-Planar Reconstruction		X						
7.3.6.2.	Maximum-Intensity Projection		X	X	X				
7.3.6.3.	Volume Rendering/Surface Shading		X						
7.3.6.4.	Quantitative Assessments		X						
7.3.7.	Image Fusion/Registration		X						
7.3.8.	Computer-Aided Detection (CAD) and Diagnosis	X							
7.4.	Display								
7.4.1.	Display Technologies								
7.4.1.1.	Hard-Copy Printers								X
7.4.1.2.	Film	X							
7.4.1.3.	CRT	X							
7.4.1.4.	Liquid Crystal Display (LCD)								X
7.4.1.5.	Other Displays (e.g., plasma, projection, etc.)								X
7.4.2.	Display Settings								
7.4.2.1.	Film Quality Control	X							
7.4.2.2.	Luminance				X				
7.4.2.3.	Matrix Size	X							
7.4.2.4.	Grayscale Display Function Calibration								X
7.4.2.5.	Display Quality Control								X
7.4.3.	Viewing Conditions								
7.4.3.1.	Viewing Distance, Image and Pixel Size								X
7.4.3.2.	Workstation Adjustments								X
7.4.3.3.	Adaptation/Masking	X						X	
7.4.3.4.	Ambient Lighting/ Illuminance	X						X	
7.5.	Perception								
7.5.1.	Human Vision					X			
7.5.1.1.	Visual Acuity					X			
7.5.1.2.	Contrast Sensitivity					X			
7.5.1.3.	Astigmatism					X			
7.5.1.4.	Conspicuity					X			
7.5.2.	Metrics of Observer Performance								
7.5.2.1.	Predictive Values					X			
7.5.2.2.	Sensitivity, Specificity and Accuracy				X				
7.5.2.3.	Contrast-Detail	X							
7.5.2.4.	ROC Curve				X				
7.5.3.	Perceptual Influence of Technology (e.g., CAD)								X
7.6.	Informatics								
7.6.1.	Basic Computer Terminology								X
7.6.2.	Integrating Healthcare Enterprise (IHE)								
7.6.2.1.	PACS	X							
7.6.2.2.	RIS/HIS	X							
7.6.2.3.	EMR (Electronic Medical Record)								X
7.6.2.4.	Health Level 7 (HL7)	X							
7.6.2.5.	DICOM	X							

7.6.8.2.	Firewalls								X
7.6.8.3.	Biometrics								X
7.6.8.4.	Health Insurance Portability and Accountability Act (HIPAA)								X
8.	Radiation Biology								
8.1.	Principles					X			
8.1.1.	Linear Energy Transfer					X			
8.1.2.	Relative Biological Effectiveness					X			
8.1.3.	Weighting Factors								X
8.2.	Molecular Effects of Radiation					X			
8.2.1.	Direct Effects					X			
8.2.2.	Indirect Effects					X			
8.2.3.	Effects of Radiation on DNA					X			
8.3.	Cellular Effects of Radiation					X			
8.3.1.	Law of Bergonié and Tribondeau								X
8.3.2.	Radiosensitivity of Different Cell Types					X			
8.3.3.	Cell Cycle Radiosensitivity					X			
8.3.4.	Cell Damage					X			
8.3.4.1.	Division Delay					X			
8.3.4.2.	Mitotic Death					X			
8.3.4.3.	Apoptosis					X			
8.3.5.	Cell Survival Curves					X			
8.3.6.	Repair					X			
8.4.	System Effects of Radiation					X			
8.4.1.	Tissues					X			
8.4.2.	Organs					X			
8.4.3.	Whole Body					X			
8.4.4.	Population					X			
8.5.	Deterministic (Non-Stochastic) Effects					X			
8.5.1.	Radiation Syndromes					X			
8.5.1.1.	Hematopoietic					X			
8.5.1.2.	Gastrointestinal					X			
8.5.1.3.	Cerebrovascular					X			
8.5.1.4.	Sequence of Events					X			
8.5.1.5.	LD 50/60					X			
8.5.1.6.	Monitoring and Treatment					X			
8.5.2.	Other Effects					X			
8.5.2.1.	Erythema					X			
8.5.2.2.	Epilation					X			
8.5.2.3.	Cataracts					X			
8.5.2.4.	Sterility					X			
8.6.	Probabilistic (Stochastic) Radiation Effects					X			
8.6.1.	Radiation Epidemiology - Case Studies					X			
8.6.1.1.	Atomic Bomb Survivors					X			
8.6.1.2.	Ankylosing Spondylitis					X			
8.6.1.3.	Epilation for Tinea Capita					X			
8.6.1.4.	Thorotrast					X			
8.6.1.5.	TB Sanatoria					X			
8.6.1.6.	Postpartum Mastitis					X			
8.6.1.7.	Uranium Miners					X			
8.6.1.8.	Marshall Island Residents								X
8.6.1.9.	Radium Dial Painters					X			
8.6.1.10.	Early Radiologists					X			
8.6.2.	Carcinogenesis					X			
8.6.2.1.	Radiation-Induced Cancers					X			
8.6.2.1.1.	Leukemia					X			
8.6.2.1.2.	Solid Tumors					X			
8.6.2.2.	Spontaneous Rate					X			
8.6.2.3.	Latency					X			
8.6.3.	Mutagenesis					X			
8.6.3.1.	Baseline Mutation Rate					X			
8.6.3.2.	Doubling Dose					X			
8.6.4.	Teratogenesis					X			
8.6.4.1.	Developmental Effects					X			
8.6.4.2.	Childhood Leukemia					X			
8.6.4.3.	Gestational Sensitivity					X			
8.7.	Radiation Risk					X			

10.1.	Radiography Concepts	X							
10.1.1.	Geometry	X							
10.1.1.1.	Source-to-Image Receptor Distance/Source-to-Object Dist	X							
10.1.1.2.	Magnification	X							
10.1.1.3.	Inverse Square Law	X							
10.1.2.	Radiographic Contrast	X							
10.1.2.1.	Subject	X							
10.1.2.2.	Object	X							
10.1.2.3.	Detector	X							
10.1.3.	Scatter and Scatter Reduction	X							
10.1.3.1.	Scatter-to-Primary Ratio	X			X				
10.1.3.2.	Scatter Fraction	X							
10.1.3.3.	Collimation	X		X					
10.1.3.4.	Anti-Scatter Grids	X							
10.1.3.5.	Air Gap	X							
10.1.4.	Artifacts and Image Degradation	X							
10.1.4.1.	Geometrical Distortion	X							
10.1.4.2.	Focal Spot Blur/Penumbra	X							
10.1.4.3.	Grid Artifacts/Cutoff	X							
10.1.4.4.	Motion	X							
10.1.4.5.	Superimposition	X							
10.2.	Radiographic Detectors								
10.2.1.	Screen/Film	X							
10.2.1.1.	Phosphors	X							
10.2.1.2.	Film	X							
10.2.1.3.	Screen/Film Systems	X							
10.2.1.4.	Latent Image Formation	X							
10.2.1.5.	Chemical Processing	X							
10.2.1.6.	Characteristic Curve	X							
10.2.1.7.	Spatial and Contrast Resolution	X							
10.2.1.8.	Artifacts								X
10.2.2.	Computed Radiography (CR)	X							
10.2.2.1.	Storage Phosphors	X							
10.2.2.2.	Latent Image Formation	X							
10.2.2.3.	Image Digitization	X							
10.2.2.4.	Preprocessing (e.g., gain and bad-pixel correction)								X
10.2.2.5.	Imaging Characteristics	X							
10.2.2.6.	Artifacts	X							
10.2.3.	Direct Digital Radiography (DR)	X							
10.2.3.1.	Semiconductor and Thin-Film Transistor	X							
10.2.3.2.	Image Formation and Readout	X							
10.2.3.3.	Pre-processing (e.g., gain and bad-pixel correction)	X							
10.2.3.4.	Imaging Characteristics	X							
10.2.3.5.	Artifacts	X							
10.2.4.	Indirect DR	X							
10.2.4.1.	Phosphor, Photo Diodes and Thin Film Transistor	X							
10.2.4.2.	Image Formation and Readout	X							
10.2.4.3.	Preprocessing (e.g., gain and bad-pixel correction)	X							
10.2.4.4.	Imaging Characteristics	X							
10.2.4.5.	Artifacts	X							
11.	General Radiography								
11.1.	System Components	X							
11.1.1.	Tube	X							
11.1.2.	Filtration	X							
11.1.3.	Collimation	X							
11.1.4.	AEC	X							
11.1.5.	Grids and Bucky Factors	X							
11.1.6.	Compensation Filters	X							
11.2.	Geometrical Requirements	X							
11.2.1.	Focal Spot Size	X							
11.2.2.	Collimation	X							
11.2.3.	Heel Effect	X							
11.3.	Acquisition Systems	X							
11.3.1.	Screen/Film	X							
11.3.2.	Digital	X							
11.3.3.	Dual-Energv	X							

13.7.6.	Road Mapping	X							
13.8.	Application Requirements	X							
13.8.1.	Contrast Imaging (e.g., Iodine, barium)	X							
13.8.2.	Cine	X							
13.8.3.	C-Arms	X							
13.9.	Clinical Applications								
13.9.1.	Conventional Fluoroscopy (e.g., GI, GU)	X							
13.9.2.	Interventional	X							
13.9.3.	DSA	X							
13.9.4.	Bi-Plane	X							
13.9.5.	Cardiac	X							
13.9.6.	Pediatric								X
13.10.	Dose and Dosimetry	X							
13.10.1.	FDA and State (where applicable) Dose Rate Limits	X							
13.10.2.	Dose-Area-Product (DAP) Meters	X							
13.10.3.	Entrance Skin Exposure	X							
13.10.4.	Patient Dose for Various Acquisition Modes	X							
13.10.5.	Patient Size	X							
13.10.6.	Operator and Staff Dose	X							
13.10.7.	Operator, Staff and Caregiver Shielding and Protection Con	X							
13.10.8.	Technique Optimization	X							
13.11.	Image Quality	X							
13.11.1.	Low-Contrast Resolution	X							
13.11.2.	High-Contrast Resolution	X							
13.11.3.	Temporal Resolution	X							
13.12.	Regulations	X							
13.12.1.	Five-Minute Timer	X							
13.12.2.	Minimum Source to Patient Distance	X							
13.12.3.	Sentinel Event	X							
13.13.	Technical Assessment and Equipment Purchase Recommendations								X
13.14.	QC Tests and Frequencies	X							
13.15.	Guidelines								X
14.	Computed Tomography (CT)		X						
14.1.	System Components		X						
14.1.1.	System Geometry		X						
14.1.2.	Tube		X						
14.1.3.	Bow-Tie Filters		X						
14.1.4.	Added Filtration		X						
14.1.5.	Collimation		X						
14.1.6.	Data Acquisition System		X						
14.1.7.	Detector Types and Arrays		X						
14.2.	System Types		X						
14.2.1.	Third Generation		X						
14.2.2.	Electron-Beam		X						
14.2.3.	Dual Source		X						
14.2.4.	Cone-Beam		X						
14.3.	Image Acquisition Parameters		X						
14.3.1.	kVp		X						
14.3.2.	mAs/effective mAs		X						
14.3.3.	Pitch (Collimator)		X						
14.3.4.	Slice Thickness and Sensitivity Profile		X						
14.3.5.	Detector Binning		X						
14.4.	Image formation		X						
14.4.1.	Filtered Projection		X						
14.4.2.	Back-Projection		X						
14.4.3.	Convolution Algorithms (Filters)		X						
14.4.4.	Helical Reconstruction		X						
14.4.5.	Linear Attenuation Coefficient		X						
14.4.6.	Hounsfield Unit Definition		X						
14.4.7.	Typical CT Numbers		X						
14.5.	Modes of operation		X						
14.5.1.	Axial and Helical Modes		X						
14.5.2.	Fixed and Variable mA		X						
14.5.3.	CT Fluoroscopy		X						
14.5.4.	Localizer Image (Scout)		X						
14.5.5.	Contrast CT		X						

14.8.3.	Thoracic		X						
14.8.4.	Angiography		X						
14.8.5.	Cardiac		X						
14.8.6.	Abdomen		X						
14.8.7.	Virtual Colonoscopy		X						
14.8.8.	CT Fluoroscopy		X						
14.8.9.	Whole-Body		X						
14.8.10.	Pediatric		X						
14.9.	Dose and Dosimetry		X						
14.9.1.	CT Dose Index (CTDI, etc.)		X						
14.9.2.	Multiple Scan Average Dose (MSAD)		X						
14.9.3.	Dose Length Product (DLP)		X						
14.9.4.	Dose Profile		X						
14.9.5.	Effective Dose		X						
14.9.6.	Phantom Measurement Methods		X						
14.9.7.	Dose for Different Application Protocols		X						
14.9.8.	Technique Optimization		X						
14.10.	Technical Assessment and Equipment Purchase Recommendations								X
14.11.	QC Tests and Frequencies		X						
14.12.	Guidelines								X
15.	Ultrasound								
15.1.	Sound Wave Propagation	X							
15.1.1.	Definition of Sound and Ultrasound	X							
15.1.2.	Longitudinal Waves	X							
15.1.3.	Transverse Waves	X							
15.2.	Sound Wave Properties	X							
15.2.1.	Wavelength, Frequency, Period and Velocity	X							
15.2.2.	Density and Pressure Changes in Materials	X							
15.2.3.	Particle Motion and Particle Velocity	X							
15.2.4.	Compressibility and Bulk Modulus	X							
15.2.5.	Dependence of Sound Speed on Medium and Properties	X							
15.3.	Power and Intensity	X							
15.3.1.	Decibel Scale	X							
15.3.2.	Relationship between Intensity and Pressure	X							
15.4.	Interactions of Ultrasound with Matter								
15.4.1.	Acoustic Impedance	X							
15.4.1.1.	Relationship to Density, Speed and Compressibility	X							
15.4.1.2.	Impedance in Tissues	X							
15.4.2.	Attenuation	X							
15.4.2.1.	Causes and Relationship to Sound Properties	X							
15.4.2.2.	Attenuation Coefficient	X							
15.4.2.3.	0.5 dB/cm/MHz for Soft Tissue	X							
15.4.3.	Reflection	X							
15.4.3.1.	Role of Impedance	X							
15.4.3.2.	Normal and Oblique Incidence	X							
15.4.3.3.	Specular Reflection	X							
15.4.3.4.	Diffuse Reflection	X							
15.4.3.5.	Reflection Coefficient	X							
15.4.4.	Transmission	X							
15.4.5.	Refraction - Snell's Law	X							
15.4.6.	Scattering	X							
15.4.6.1.	Hyperechoic and Hypoechoic Regions								X
15.4.6.2.	Relationship to Frequency and Scatterer Size	X							
15.4.6.3.	Rayleigh Scattering								X
15.5.	Transducer Components	X							
15.5.1.	Piezoelectric Materials	X							
15.5.1.1.	Composition								X
15.5.1.2.	Piezoelectric Reception and Transmission	X							
15.5.1.3.	Physical and Electrical Properties	X							
15.5.1.4.	Resonance Frequency and Crystal Thickness	X							
15.5.2.	Transducer Construction	X							
15.5.2.1.	Electronics	X							
15.5.2.2.	Matching Layers	X							
15.5.2.3.	C-MUT Transducers	X							
15.6.	Transducer Arrays	X							
15.6.1.	Linear and Curvilinear Arrays	X							

15.10.2.	Timing	X							
15.10.2.1.	Pulse-Repetition Frequency	X							
15.10.2.2.	Pulse-Repetition Period	X							
15.10.3.	Field of View/Maximum Depth	X							
15.10.4.	Frame Rate	X							
15.11.	Image Data Acquisition	X							
15.11.1.	Signal Acquisition	X							
15.11.2.	Pre-amplification and Analog to Digital Conversion	X							
15.11.3.	Time Gain Compensation	X							
15.11.4.	Logarithmic Compression	X							
15.11.5.	Demodulation and Envelope Detection	X							
15.11.6.	Rejection	X							
15.11.7.	Processed Signal	X							
15.12.	Image Processing and Display								
15.12.1.	Display Modes	X							
15.12.1.1.	A-Mode	X							
15.12.1.2.	B-Mode	X							
15.12.1.3.	M-Mode	X							
15.12.2.	Scan Converter								X
15.12.3.	Image Frame Rate Dependencies	X							
15.12.3.1.	Depth Setting	X							
15.12.3.2.	Transmit Focal Zones	X							
15.12.3.3.	Sector Size and Line Density	X							
15.12.4.	Image Display								
15.12.4.1.	Preprocessing and Post-processing	X							
15.12.4.2.	Speckle and Speckle Reduction	X							
15.12.4.3.	Read Zoom and Write Zoom								X
15.12.5.	Distance, Area and Volume Measurements								X
15.12.6.	Compound Imaging								X
15.13.	Ultrasound Contrast Agents								X
15.14.	Harmonic Imaging								X
15.14.1.	Nonlinear Propagation and Origin of Harmonics								X
15.14.2.	Formation of Harmonics in Ultrasound								X
15.14.3.	Features of Harmonic Imaging								X
15.14.3.1.	Resolution Improvements								X
15.14.3.2.	Side-Lobe Interference								X
15.14.3.3.	Artifact Reduction								X
15.14.4.	Discrimination of Fundamental and Harmonic Frequencies								X
15.14.5.	Narrow-Band Harmonic Imaging								X
15.14.6.	Pulse-Inversion Harmonic Imaging								X
15.15.	Special Purpose Transducer Assemblies								X
15.15.1.	Intra-Cavitary Transducers								X
15.15.2.	Catheter-Mounted								X
15.15.2.1.	Rotating Single-Element Transducers								X
15.15.2.2.	Phased Array Transducers								X
15.16.	Three-Dimensional (3D) Imaging								X
15.16.1.	Image Reconstruction								X
15.16.2.	Transducer Registration Methods								X
15.16.2.1.	Free-Form Motion with External Localizers								X
15.16.2.2.	Free-Form Motion without External Localizers								X
15.16.2.3.	Externally Driven Mechanical								X
15.16.2.4.	Mechanical 3-D transducers								X
15.16.2.5.	2-D Arrays								X
15.16.3.	Extended View Imaging								X
15.16.4.	Time-Dependent Imaging (4D)								X
15.17.	Artifacts								X
15.17.1.	Refraction	X							
15.17.2.	Shadowing and Enhancement	X							
15.17.3.	Reverberation	X							
15.17.4.	Speed Displacement	X							
15.17.5.	Comet Tail	X							
15.17.6.	Side and Grating Lobes	X							
15.17.7.	Multipath Reflection and Mirror Image	X							
15.17.8.	Range Ambiguity	X							
15.18.	Doppler Ultrasound								
15.18.1.	Doppler Theory	X							

15.22.2.2.	Pulse Repetition Frequency								X
15.22.2.3.	Transducer Frequency								X
15.22.2.4.	Operation Mode								X
15.22.3.	Intensity Measures of Pulsed Ultrasound								X
15.22.3.1.	Spatial Average/Temporal Average Intensity [I (SATA)]	X							X
15.22.3.2.	Spatial Peak /Temporal Average Intensity [I (SPTA)]	X							X
15.22.3.3.	Spatial Peak/Pulse Average Intensity [I (SPPA)]	X							X
15.22.3.4.	Spatial Peak/Temporal Peak Intensity [I (SPTP)]	X							X
15.22.4.	Real-time Acoustical Output Labeling								X
15.22.4.1.	Thermal Index (TI)								X
15.22.4.2.	Mechanical Index (MI)								X
16.	Magnetic Resonance					X			
16.1.	Magnetism and Magnetic Fields					X			
16.1.1.	Magnetic Susceptibility					X			
16.1.2.	Type of Magnetic Materials					X			
16.1.3.	Magnetic Fields (B)					X			
16.1.3.1.	Units for B					X			
16.1.3.2.	Magnetic Dipole					X			
16.1.3.3.	Magnetic Moment					X			
16.1.3.4.	Nuclear Magnetism (protons and biologically relevant nuclei)					X			
16.1.4.	Magnetic Moment Interaction with an External Field (B0)					X			
16.1.4.1.	Alignment (low-energy/high-energy states)					X			
16.1.4.2.	Precession					X			
16.1.4.3.	Larmor Equation					X			
16.1.5.	Net Magnetization Due to B0					X			
16.1.5.1.	Longitudinal Magnetization (Mz)					X			
16.1.5.2.	Transverse Magnetization (Mxy)					X			
16.1.5.3.	Proton Density (Spin-Density)					X			
16.1.5.4.	Field Strength Dependence					X			
16.2.	Nuclear Magnetic Resonance and Excitation					X			
16.2.1.	Radiofrequency (RF) field (B1)					X			
16.2.2.	Flip Angle RF Pulse					X			
16.2.3.	Free-Induction Decay (FID)					X			
16.2.4.	90/1800 RF Pulses					X			
16.3.	Spin Density					X			
16.4.	T2 (Spin-Spin or Transverse) Relaxation					X			
16.4.1.	Intrinsic Spin-Spin Interactions					X			
16.4.2.	Transverse Magnetization Decay					X			
16.4.3.	Typical Tissue T2 Values					X			
16.5.	T2* Relaxation					X			
16.5.1.	Dependence on Field Inhomogeneity					X			
16.5.2.	Susceptibility-Induced Dephasing (e.g., tissue-air interfaces)					X			
16.6.	T1 (Spin-Lattice or Longitudinal) Relaxation					X			
16.6.1.	Spin-Lattice Interactions					X			
16.6.2.	Longitudinal Recovery					X			
16.6.3.	Typical Tissue T1 values					X			
16.6.4.	Field-Strength Dependence					X			
16.7.	Contrast Mechanisms (pulse sequences)					X			
16.7.1.	Spin Echo (SE) Pulse Sequence					X			
16.7.1.1.	Pulse Sequence Basics (Timing Diagrams)					X			
16.7.1.2.	Echo Time (TE)					X			
16.7.1.3.	Repetition Time (TR)					X			
16.7.1.4.	SE Signal Intensity Dependence on TE and TR					X			
16.7.1.5.	SE Contrast (T1, Proton density, T2-weighted)					X			
16.7.2.	Inversion Recovery Pulse Sequence					X			
16.7.2.1.	Inversion Time (TI)					X			
16.7.2.2.	Short-Time (tau) Inversion Recovery (STIR)					X			
16.7.2.3.	Fluid-Attenuated Inversion Recovery (FLAIR)					X			
16.7.3.	Gradient Echo Pulse Sequence					X			
16.7.3.1.	Basic Advantages/Disadvantages Compared to SE Sequence					X			
16.7.3.2.	Gradient-Echo Signal-Intensity and Effect of Flip Angle					X			
16.7.3.3.	RF-Pulse Spoiling					X			
16.7.3.4.	Gradient Echo Contrast (T2*/T1, T2*, and T1 - weighting)					X			
16.8.	MR instrumentation					X			
16.8.1.	Static Magnetic Field (B0) Systems					X			
16.8.2.	Gradient Field Subsystem					X			

16.8.6.5.	Birdcage Coils				X				
16.8.6.6.	Phased-Array Coils				X				
16.8.6.7.	SENSE Coils				X				
16.8.7.	Data acquisition				X				
16.8.7.1.	Analog-to-Digital Converter (ADC) Sampling				X				
16.8.7.2.	Other Data Acquisition Elements								X
16.9.	Image Acquisition				X				
16.9.1.	Slice-Selection Gradient (SSG)				X				
16.9.2.	Phase-Encoding Gradient (PEG)				X				
16.9.3.	Frequency-Encoding Gradient (FEG)				X				
16.10.	Specifications of Pulse Sequences				X				
16.10.1.	Acquisition Time Calculations				X				
16.10.2.	Multi-Slice Acquisition				X				
16.10.3.	Timing Diagrams of Common Pulse Sequences				X				
16.10.3.1.	Spin-Echo/Multi-Echo				X				
16.10.3.2.	Inversion Recovery				X				
16.10.3.3.	Gradient Echo				X				
16.10.3.4.	Multi-Planar				X				
16.10.3.5.	Fast- or Turbo-Spin-Echo (FSE/TSE)				X				
16.10.3.6.	Echo-Planar Imaging (EPI)				X				
16.10.3.7.	Volume Imaging (3D)				X				
16.11.	Two-dimensional Fourier Transform (2DFT) Image Reconstruction				X				
16.11.1.	k-space Description				X				
16.11.2.	Methods of "Filling k-Space"				X				
16.11.2.1.	Rectangular				X				
16.11.2.2.	Spiral				X				
16.11.2.3.	Radial				X				
16.11.2.4.	Fractional (e.g., Propeller, One-Half NEX, etc.)				X				
16.12.	Image Characteristics				X				
16.12.1.	Factors Affecting Spatial Resolution				X				
16.12.1.1.	Field-of-view (FOV)				X				
16.12.1.2.	Pixel Size				X				
16.12.1.3.	Slice Thickness				X				
16.12.1.4.	Image Matrix Size				X				
16.12.2.	Factors Affecting Signal-to-Noise Ratio (SNR)				X				
16.12.2.1.	Voxel Size				X				
16.12.2.2.	Signal Averages				X				
16.12.2.3.	Receiver (Sampling) Bandwidth				X				
16.12.2.4.	Magnetic Field Strength				X				
16.12.2.5.	Slice "Cross-Talk"				X				
16.12.2.6.	Reconstruction Algorithms				X				
16.12.2.7.	RF Coil Quality Factor				X				
16.12.2.8.	Pulse Sequence Specific Effects				X				
16.12.3.	Tradeoffs among Spatial Resolution, SNR, and Acquisition Time				X				
16.12.4.	Factors Affecting Image Contrast				X				
16.12.4.1.	Proton Density, T1, T2				X				
16.12.4.2.	Susceptibility				X				
16.13.	Contrast Agents				X				
16.13.1.	Paramagnetic				X				
16.13.2.	Superparamagnetic				X				
16.13.3.	Susceptibility Agents				X				
16.14.	Saturation				X				
16.14.1.	Spatial				X				
16.14.2.	Chemical (e.g., fat, silicone)				X				
16.15.	Special Acquisition Techniques				X				
16.15.1.	Angiography				X				
16.15.1.1.	Effect of Blood Flow on Signal Intensity				X				
16.15.1.2.	Time-of-Flight (2D/3D) Techniques				X				
16.15.1.3.	Phase-Contrast Techniques				X				
16.15.1.4.	Contrast-Agent Enhanced MRA Techniques				X				
16.15.2.	Diffusion Imaging				X				
16.15.2.1.	Basic Principles				X				
16.15.2.2.	Diffusion-Weighted Imaging (DWI) Techniques				X				
16.15.2.3.	Apparent Diffusion Coefficient (ADC)				X				
16.15.2.4.	Diffusion Tensor Imaging (DTI) Techniques				X				
16.15.3.	Functional MRI (fMRI)				X				

16.16.4.	k-space Errors			X					
16.16.5.	Motion Artifacts			X					
16.16.6.	Chemical Shift Artifacts (Fat/Water)			X					
16.16.7.	Gibbs (Ringing, Truncation) Artifacts			X					
16.16.8.	Aliasing (wraparound)			X					
16.16.9.	Partial-Volume Artifacts			X					
16.16.10.	High Speed Imaging Artifacts (e.g., Echo-Planar Distortion, Ghosting)			X					
16.16.11.	Effect of High Field Strength on Artifacts			X					
16.17.	Image Processing and Display			X					
16.17.1.	Maximum-Intensity Projection (MIP)			X					
16.17.2.	Volume-/Surface-Rendering				X				
16.18.	Safety and Bioeffects			X					
16.18.1.	Static Magnetic Field			X					
16.18.1.1.	Biological Effects			X					
16.18.1.2.	Projectile Hazards			X					
16.18.1.3.	Effects on Implanted Devices			X					
16.18.1.4.	FDA Limits			X					
16.18.2.	RF Field			X					
16.18.2.1.	Biological Effects, Including Tissue Heating			X					
16.18.2.2.	RF Heating of Conductors and Potential Burns			X					
16.18.2.3.	Specific Absorption Rate (SAR)			X					
16.18.2.4.	Problems with High Field Strength Systems			X					
16.18.2.5.	FDA Limits			X					
16.18.3.	Gradient Field			X					
16.18.3.1.	Biological Effects, Including Peripheral Nerve Stimulation			X					
16.18.3.2.	Sound Pressure Level ("Noise") Issues and Limits			X					
16.18.3.3.	FDA Limits			X					
16.18.4.	Contrast Agent Safety Issues			X					
16.18.5.	Screening of Patients and Healthcare Workers			X					
16.18.6.	MR Safety Systems (including superconducting magnet "quench" systems)			X					
16.18.7.	Cryogenic Materials			X					
16.19.	Magnet System Siting			X					
16.19.1.	Basic Facility Design (including "zone" design)			X					
16.19.2.	Magnetic Fringe Field and the 0.5 mT (5G) Line			X					
16.19.3.	Magnetic Field Shielding			X					
16.19.4.	RF Field Shielding			X					
16.19.5.	Effects of MRI on Other Equipment/Objects			X					
16.19.6.	Effects of Equipment/Objects on MRI			X					
16.20.	Technical Assessment and Equipment Purchase Recommendations								X
16.21.	QC tests and frequencies			X					
16.22.	Guidelines								X
17.	Nuclear Medicine			X					
17.1.	Radionuclide Decay			X					
17.1.1.	Radioactivity			X					
17.1.1.1.	Definition			X					
17.1.1.2.	Units			X					
17.1.1.3.	Decay Constant			X					
17.1.1.4.	Decay Equation			X					
17.1.1.5.	Half-Life (Physical, Biological, and Effective)			X					
17.1.2.	Nuclear Transformation			X					
17.1.2.1.	N/Z Ratio and Nuclear Stability			X					
17.1.2.2.	Beta (negative electron) Decay			X					
17.1.2.3.	Positron (positive electron) Decay			X					
17.1.2.4.	Electron Capture			X					
17.1.2.5.	Isomeric Transition			X					
17.1.2.6.	Alpha Decay			X					
17.1.2.7.	Internal Conversion			X					
17.1.3.	Radioactive Equilibrium			X					
17.1.3.1.	Transient			X					
17.1.3.2.	Secular			X					
17.1.4.	Nuclear Fission			X					
17.1.5.	Nuclear Fusion			X					
17.2.	Radioisotope Production			X					
17.2.1.	Accelerator/Cyclotron			X					
17.2.2.	Reactor			X					
17.2.2.1.	Fission Products			X					

17.3.2.4.	Thyroid Probe		X						
17.3.2.5.	Well Counter		X						
17.3.2.6.	Survey Meter		X						
17.3.2.7.	Quality Control		X						
17.3.3.	Semi-Conductor Detectors		X						
17.3.3.1.	Mechanisms of Operation		X						
17.3.3.2.	Applications and Limitations		X						
17.3.3.3.	Pulse-height Spectroscopy		X						
17.3.4.	Thermoluminescent Dosimeters (TLDs)		X						
17.3.4.1.	Mechanisms of Operation		X						
17.3.4.2.	Applications and Limitations		X						
17.3.5.	Optically-Stimulated Luminescent (OSL) Dosimeters		X						
17.3.5.1.	Mechanisms of Operation		X						
17.3.5.2.	Applications and Limitations		X						
17.4.	Scintillation Camera		X						
17.4.1.	Clinical Purpose		X						
17.4.2.	Camera Design		X						
17.4.2.1.	Crystal Parameters		X						
17.4.2.2.	Spatial Localization		X						
17.4.2.3.	Energy Discrimination		X						
17.4.3.	Collimators		X						
17.4.3.1.	Parallel Hole		X						
17.4.3.2.	Pinhole		X						
17.4.3.3.	Sensitivity		X						
17.4.3.4.	Resolution		X						
17.4.4.	Image Acquisition		X						
17.4.4.1.	Static		X						
17.4.4.2.	Dynamic		X						
17.4.4.3.	Gated		X						
17.4.4.4.	List-Mode		X						
17.4.5.	Image Processing		X						
17.4.5.1.	Subtraction		X						
17.4.5.2.	ROI		X						
17.4.5.3.	Time-Activity Curves		X						
17.4.5.4.	Spatial Filtering		X						
17.4.5.5.	Temporal Filtering		X						
17.4.6.	Measures of Performance		X						
17.4.6.1.	Uniformity		X						
17.4.6.2.	Spatial Resolution		X						
17.4.6.3.	Energy Resolution		X						
17.4.6.4.	Spatial Linearity		X						
17.4.6.5.	Sensitivity		X						
17.4.6.6.	Count-rate Performance		X						
17.4.6.7.	Patient Parameters		X						
17.4.7.	Artifacts		X						
17.4.7.1.	Damaged or Broken Crystal		X						
17.4.7.2.	Non-Uniformity		X						
17.4.7.3.	Bad Photo Tube		X						
17.4.7.4.	Improper Energy Peaking		X						
17.4.7.5.	Mechanical Separation of Coupling Elements		X						
17.4.7.6.	Damaged Collimators		X						
17.4.7.7.	Motion		X						
17.4.8.	Clinical Examples								
17.4.8.1.	Thyroid								X
17.4.8.2.	Bone								X
17.4.8.3.	Renal								X
17.4.8.4.	Liver/Spleen								X
17.4.8.5.	Cardiac (Ejection Fraction, Myocardial Perfusion)								X
17.4.8.6.	Ventilation Perfusion (VO)								X
17.4.8.7.	Multi-Energy Imaging		X						
17.4.8.8.	Tumor Imaging								X
17.4.9.	Procedure Types (Alternate to Above)								X
17.4.9.1.	Adult								X
17.4.9.2.	Pediatric								X
17.4.9.3.	Infant								X
17.4.9.4.	Pregnant								X

17.5.9.5.	Motion		X						
17.5.10.	Clinical Examples		X						
17.6.	Positron Emission Tomography (PET)		X						
17.6.1.	Clinical Purpose		X						
17.6.2.	Mechanisms of Operation		X						
17.6.3.	Detector		X						
17.6.3.1.	Type		X						
17.6.3.2.	Configuration		X						
17.6.4.	Coincidence Detection		X						
17.6.5.	Time-of-Flight		X						
17.6.6.	Attenuation Correction		X						
17.6.7.	Standardized Uptake Value (SUV)		X						
17.6.8.	2D vs. 3D Operation		X						
17.6.9.	Count Rate / Administered Dose Considerations		X						
17.6.10.	Image Reconstruction		X						
17.6.11.	Sensitivity and Resolution		X						
17.6.12.	Technical Assessment and Equipment Purchase Recommendations		X						
17.6.13.	Quality Control		X						
17.6.14.	Artifacts		X						
17.6.14.1.	Attenuation Correction		X						
17.6.14.2.	Motion		X						
17.6.15.	Clinical Examples		X						
17.7.	Combined Modalities		X						
17.7.1.	SPECT/CT		X						
17.7.1.1.	Mechanisms of Operation		X						
17.7.1.2.	Clinical Applications		X						
17.7.1.3.	Quality Control		X						
17.7.1.4.	Artifacts		X						
17.7.2.	PET/CT		X						
17.7.2.1.	Mechanisms of Operation		X						
17.7.2.2.	Clinical Applications		X						
17.7.2.3.	Quality Control		X						
17.7.2.4.	Artifacts		X						