

**CANADIAN
COLLEGE OF
PHYSICISTS IN
MEDICINE**



**LE COLLÈGE
CANADIEN
DES PHYSICIENS
EN MÉDECINE**

CCPM Membership Examination

Edition 11.1

**MEDICAL PHYSICS QUESTIONS
FOR
MEMBERSHIP EXAMINATION**

Edition 11.1

Canadian College of Physicians in Medicine

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Medical Physics Questions For
Membership Examination
(Edition 11.1)

Questions de Physique Médicale
pour L'Examen d'Admission
(Édition 11.1)

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FOREWORD TO THE ELEVENTH EDITION

This is the eleventh edition of the published question bank for the Canadian College of Physicists in Medicine (CCPM) membership exam. This is an exam to enable the CCPM to certify that those who pass the 4-part written exam and 3-part oral exam are competent in their medical physics subspecialty. Combined with credentialing for the exam, this is an exhaustive process into which a candidate is entering.

All question banks were updated in 2015. The MRI question bank was further updated in 2016. Smaller updates continue to take place each year, so it is important to ensure that the correct question bank is downloaded when exam preparation begins! Much work has been invested in producing a comprehensive set of questions since 1984 thanks to the hard work of Past Chief Examiners: Ervin B. Podgorsak, Terry M. Peters, Gino Fallone, Ting-Yim Lee, Katharina E. Sixel, Michael D.C. Evans, Robert Corns, Boyd McCurdy and Renée Larouche and all those who helped them.

A Preparation Guide now exists and is posted on the CCPM website. The Preparation Guide discusses time management strategies and the typical expected length of hand-written answers.

The College wishes to thank Geneviève Jarry, deputy examiner, as well as the many volunteers that help each year. Candidates preparing for their exam who have comments about the question bank are invited to contact me (chiefexaminer@ccpm.ca).

Best of luck to all of the candidates,

Alasdair Syme
Halifax, NS, Canada
September 28th 2019



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SUGGESTED TEXTS FOR PREPARATION OF THE EXAMINATION.

It must NOT be assumed that questions will be based solely on materials from these texts.

A: Radiation Oncology

1. The physics of radiation therapy: F. M. Kahn; Williams and Williams, Baltimore.
2. Introduction to radiological physics and radiation dosimetry: P.H. Attix; Wiley, New York.
3. The physics of radiology (Fourth Edition.): H.E. Johns and J.R. Cunningham; Charles C. Thomas, Springfield Ill.
4. Modern technology of radiation oncology: J. Van Dyk (Editor); Medical Physics Publishing, Madison Wisconsin.
5. Radiation physics for medical physicists: E.B. Podgorsak; Springer, New York.
6. Radiation oncology physics: a handbook for teachers and students: E.B. Podgorsak (Editor); IAEA, Vienna.
7. Radiobiology for the radiobiologist: E.J. Hall; Lippincott Williams & Wilkins, New York.
8. ICRP publication 103: 2007 recommendations of the international commission on radiological protection, The International Commission on Radiological Protection; New York, 2007
9. NCRP report 147: Structural shielding design for medical x-ray imaging facilities: National Council on Radiation Protection and Measurements; Bethesda MD.
10. NCRP report 151: Structural shielding design and evaluation for megavoltage X- and gamma-ray radiotherapy facilities: National Council on Radiation Protection and Measurements; Bethesda MD.
11. CPQR Technical Quality Control Guidelines. <http://www.cpqr.ca/programs/technical-quality-control/>
12. ICRP publication 112: Preventing Accidental Exposures from New External Beam Radiation Therapy Technologies, The International Commission on Radiological Protection; New York, 2009

B: Diagnostic Radiology

1. Physics of radiology (2nd Ed.): A. Wolbarst, Medical Physics Publishing, Madison, WI; 2005
2. Review of Radiological Physics (3rd Ed.): W. Huda, R.M. Slone; Lippincott Williams & Wilkins; 2010
3. Essential Physics of Medical Imaging (2nd Ed.): J.T. Bushberg, J.A. Seibert, E.M. Leidholdt, J.M. Boone; Lippincott Williams & Wilkins; (2001)
4. Medical Imaging Signals and Systems: J.L. Prince, J. Links; 2005
5. Medical Imaging Physics (4th Ed.): W.R. Hendee, E.R. Ritenour; Wiley-Liss; 2002
6. Computed Tomography: Fundamentals, System Technology, Image Quality, Applications (2nd Ed.): W.A. Kalender; Wiley-VCH; 2006
7. Ultrasound Physics and Instrumentation (4th Ed): W.R. Hedrick, D.L. Hykes, D.E. Starchman; Mosby; 2004
8. Guidelines for the safe use of diagnostic ultrasound equipment. Prepared by the Safety Group of the British Medical Ultrasound Society Ultrasound 2010; 18: 52–59.
9. Medical electrical equipment – Characteristics of digital X-ray imaging devices – Part 1: Determination of the detective quantum efficiency. International Standard IEC 62220-1



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C: Nuclear Medicine

1. Physics in nuclear medicine (3rd Ed): S.R. Cherry, J.A. Sorenson and M.E. Phelps; W.B. Saunders, Philadelphia; 2003
2. Nuclear medicine physics: L.E. Williams (Ed); CRC Press, Boca Raton.
3. The physics of radiology (4th Ed.): H.E. Johns and J.R. Cunningham; Charles C. Thomas, Springfield Ill.
4. Introductory physics of nuclear medicine, R. Chandra; Lea & Febiger, Philadelphia.
5. Radiation detection and measurement, G. F. Knoll; John Wiley and Sons, Third Edition, 2000.
6. Basic science of nuclear medicine, R.P. Parker, P.H.S. Smith, D.M. Taylor; Churchill Livingstone, New York.

D: Magnetic Resonance

1. Nuclear magnetic resonance imaging in medicine and biology: P.G. Morris; Oxford University Press, Oxford.
2. Magnetic resonance imaging: physical principles and sequence design, R.W. Brown, YN Cheng, E.M. Haacke M.R. Thompson, and R. Venkatesan, A. John Wiley & Sons, 2014.
3. In vivo NMR Spectroscopy: principles and techniques, R. A. de Graaf, John Wiley and Sons, 2007.
4. Questions and answers in magnetic resonance imaging, Second Edition, A.D. Elster and J. H. Burdette, Mosby, 2001.
5. Handbook of MRI pulse sequences, M. A. Bernstein, K. F. King, and X. J. Zhou, Elsevier Academic Press, 2004.
6. MRI: Basic Principles and Applications (4th Ed.); M.A. Brown, R.C. Semelka; Wiley-Blackwell; 2010
7. Principles of Magnetic Resonance Imaging: A Signal Processing Perspective, Z.P. Liang and P.C. Lauterbur, Wiley-IEEE, 1999

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Suggested Texts

Parts III and IV Questions:

Section A: Radiation Oncology Specialty

Section B: Diagnostic Radiology Specialty

Section C: Nuclear Medicine Specialty

Section D: Magnetic Resonance Specialty



Section B: Diagnostic Radiology Specialty

You will be required to answer **FIVE** questions from Part III and **FIVE** questions from Part IV. Total time to complete these questions is 2.5 hours. Each question is worth an equal percentage, totaling to 100% for each Part.



III. DIAGNOSTIC RADIOLOGY SPECIALTY

1. Define or explain:
 - a) photoelectron
 - b) Auger effect
 - c) internal conversion
 - d) annihilation quantum
 - e) characteristic radiation
 - f) electron-hole pair
 - g) recoil electron
 - h) absorption edge
2. List three ways in which x-rays in the diagnostic energy range interact with matter and discuss their dependence on photon energy and atomic number.
3. Plot the mass attenuation coefficients for tissue, bone and lead in the diagnostic energy range and discuss the key characteristics of these curves.
4. What is the relationship between the linear attenuation coefficient, mass attenuation coefficient and mass energy absorption coefficient? Plot these three coefficients for air in the diagnostic energy range.
5. Derive an expression for converting exposure to absorbed dose (f -factor). Describe the f -factor energy dependence for bone, soft tissue and fat in the diagnostic x-ray energy range.
6. Briefly define or explain:
 - a) Roentgen
 - b) KERMA
 - c) electrode
 - d) W for air
 - e) mass attenuation coefficient
 - f) collection efficiency
 - g) recombination
 - h) electronic equilibrium
7. Sketch and explain the functioning of the following:
 - a) a free air ionization chamber;
 - b) a typical thimble ionization chamber;
 - c) a typical saturation curve for an ionization chamber.
8. Describe quantitatively how the output ($\mu\text{Gy} / \text{mAs}$) of a diagnostic x-ray system varies with x-ray tube parameters (kVp, anode material and tube filtration). Discuss the different kVp ranges, anodes and filters employed in diagnostic radiology.
9. Estimate the energy imparted to a 23 cm thick patient for an AP abdominal radiograph obtained using a computed radiography cassette of size of $25 \times 30 \text{ cm}^2$. Estimate the effective dose for this patient.



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10. Describe the spectrum obtained using a tungsten target x-ray tube operated at a 100 kVp tube potential. Describe how the spectrum is altered by the following changes:
- tube potential is lowered to 60 kV,
 - mAs is doubled,
 - 0.5 mm Cu filtration is added.
11. Briefly define or explain:
- | | |
|------------------------|----------------------------|
| a) inherent filtration | e) beam hardening |
| b) added filtration | f) homogeneity coefficient |
| c) compound filter | g) effective energy |
| d) K-edge filter | h) broad beam attenuation |
12. Outline an experimental method for the determination of the Half Value Layer of a diagnostic x-ray system. What information does the HVL provide about a diagnostic x-ray system? List typical HVL values for CT (120 kVp), radiography (80 kVp) and mammography (28 kVp).
13. Quantify the patient entrance air kerma for chest x-rays as a function of tube potential (kV) and added filtration and explain any necessary modifications for the selected mAs value.
14. Discuss the characteristics and magnitude of scattered radiation from patients undergoing fluoroscopy.
15. Briefly define or explain:
- | | |
|-------------------------|-------------------------------|
| a) LET | e) radiation weighting factor |
| b) RBE | f) equivalent dose |
| c) latent period | g) effective dose |
| d) deterministic effect | h) GSD |
16. Discuss five methods with the potential to significantly reduce patient doses in diagnostic radiology.



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17. Discuss the potential detrimental effects of ionizing radiation at the exposure levels encountered in diagnostic radiology with respect to:
 - a) genetic effects;
 - b) somatic effects.

18. Describe three common personnel dosimeters and explain how the dose is estimated for each one.

19. Give typical doses to pregnant women from abdominal radiographs and abdominal CT examinations and discuss the corresponding radiation risks to the embryo/fetus.

20. For a typical PA chest examination, give estimates of the following:
 - a) entrance exposure
 - b) entrance skin dose
 - c) dose to lungs, breast, ovaries and gonads
 - d) integral dose (imparted energy)
 - e) effective dose (E)
 - f) image receptor entrance air kerma.

21. Discuss the merits and limitations of expressing patient doses in terms of:
 - a) entrance skin dose
 - b) integral dose (imparted energy)
 - c) effective dose (E)

22. Discuss the patient doses and potential risks associated with the following diagnostic examinations:
 - a) skull radiographs
 - b) abdominal radiographs
 - c) IVP examinations
 - d) barium meals



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23. Briefly define or explain the following with respect to x-ray tubes:
- | | |
|--------------------------|--------------------|
| (a) thermionic emission | (e) rotating anode |
| (b) space charge effect | (f) blooming |
| (c) focusing cup | (g) filtration |
| (d) line focus principle | (h) beam quality |
24. Draw a schematic diagram of a typical x-ray tube, clearly identifying the component elements. Describe how the heel effect arises, using the diagram to illustrate.
25. Discuss in detail the two types of x-ray production resulting from an electron beam with a given kinetic energy incident on a tungsten target. Describe their relative contributions to the emitted radiation.
26. Discuss heat production and dissipation in x-ray tubes. Sketch typical x-ray tube rating charts and anode heating/cooling curves.
27. Discuss how the radiation output of an x-ray tube varies with applied voltage waveform. Describe the impact of different waveforms on patient dose and image quality.
28. Estimate the radiation doses to key organs (gonads, hands, thyroid, eye lens) and the corresponding effective dose for a radiologist performing percutaneous transluminal coronary angioplasty (PCTA) using fluoroscopic guidance.
29. Discuss the shielding requirements for a fluoroscopic room, giving representative values for all parameters used.
30. Describe the necessary equipment and tests performed to ensure that the shielding in an x-ray room is satisfactory. Describe the information necessary to perform shielding calculations for an x-ray room.
31. Define or explain the following with respect to digital image receptors:
- | | |
|-------------------|--------------------------|
| a) pixel | e) direct detection (DR) |
| b) dark field | f) amorphous silicon |
| c) exposure index | g) dose creep |
| d) scintillator | h) flat field |
32. Describe in detail a quality control program to monitor the performance of a radiology film processor.
33. Compare and contrast the performance of cesium iodide (CsI) and gadolinium oxysulfide (Gd_2O_2S) scintillators used in indirect flat panel detectors.



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34. Describe the regular quality control tests you would perform for a digital radiography system, including their frequency.
35. Quantitatively discuss the resolution properties for the following:
 - a) x-ray focal spot
 - b) direct detection digital radiography
 - c) indirect detection digital radiography
36. Describe how the resolution properties of the x-ray focal spot, direct detection digital radiography, and indirect detection digital radiography are modified when magnification radiography is performed.
37. Discuss the measurement of focal spot sizes using both a pinhole camera and by taking a radiograph of a star pattern. Compare the advantages and limitations of each method.
38. Discuss the variation of the focal spot size with x-ray tube current and x-ray tube potential. Discuss the "NEMA" specifications for focal-spot sizes.
39. Specify and explain the focal spot size requirements for the following examinations:
 - a) fluoroscopy
 - b) chest radiographs
 - c) magnification neuroradiography
 - d) magnification mammography.
 - e) skeletal radiography.
40. Explain the procedure and equipment used for quality control tests of an x-ray generator.
41. With regard to the Deviation Index (DI):
 - a) Explain why it was created;
 - b) How could a facility implement the DI in their clinical practice?
 - c) How is the DI different from the Exposure Indicator?
42. Outline the design of a reject image analysis including the expected number of images in each major reject category.



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43. Discuss the merits and limitations of CR for performing the following clinical examinations:
- portable chest radiographs
 - abdominal radiographs
 - extremity radiography
 - mammography
44. Outline the acceptance tests that should be performed on a newly installed CR system.
45. Describe the unsharp mask image processing technique currently used by most commercial CR systems.
46. Sketch a computed radiography system including the CR reader. Describe the image formation process.
47. Discuss the factors that affect scattered radiation in diagnostic radiology. List four possible methods for scatter reduction.
48. Define or explain the following with respect to anti-scatter grids:
- | | |
|--------------------|------------------------------|
| a) grid ratio | e) parallel grid |
| b) linear grid | f) moving grid |
| c) focused grid | g) Bucky factor |
| d) convergent line | h) primary grid transmission |
49. Discuss contrast reduction and image artifacts caused by scattered radiation and quantify the contrast improvement achieved using anti-scatter grids.
50. Discuss in detail the relationship between grid parameters and patient dose.
51. Describe two practical methods for reducing scatter in diagnostic radiology other than anti-scatter grids. Compare their advantages and limitations with the use of anti-scatter grids.
52. Outline an experimental method to determine the ratio of scatter to primary radiation for a diagnostic x-ray system. Discuss the difference between the scatter fraction and the scatter-to-primary ratio.
53. Sketch a diagram of a dedicated mammographic system and indicate how it differs from a general radiographic unit.



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54. Indicate the settings or choices of technical parameters in a mammographic unit for the following:
- | | |
|------------------------|-----------------------------------|
| a) tube potential (kV) | e) source to image distance (SID) |
| b) focal spot size | f) breast compression |
| c) anode material | g) film gradient |
| d) filter material | h) HVL |
55. Outline procedures for acceptance testing of a newly installed digital mammography system and give typical values for any measured parameters.
56. Discuss the factors that affect radiation dose in digital mammography and give typical values of the mean glandular dose (MGD) normally encountered on state-of-the-art systems.
57. Discuss the risk-benefit ratio associated with screening mammography.
58. Discuss the variation of subject contrast in mammography with x-ray energy.
59. Outline the technology of the following as applied to mammography:
- | |
|----------------------------------|
| a) photon-counting detectors; |
| b) digital breast tomosynthesis. |
60. Discuss the primary sources of image blur and image noise in digital mammography.
61. Sketch an image intensifier tube and clearly label and discuss its components.
62. Define the following image intensifier parameters, and provide representative values:
- | | |
|----------------------------|----------------------|
| a) brightness gain | d) contrast ratio |
| b) minification gain | e) conversion factor |
| c) electronic or flux gain | f) electronic zoom |
63. Discuss the image quality obtained with image intensifiers with respect to noise, contrast, resolution and image distortion.
64. Estimate the effective dose to a patient undergoing percutaneous transluminal coronary angioplasty (PCTA) with fluoroscopic guidance. State all assumptions made.
65. Sketch a block diagram of a fluoroscopy unit based on an image intensifier and CCD camera system and describe the function of the major components.



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66. Briefly define or explain the following with respect to CCD detectors:
- a) frame rate
 - b) saturation
 - c) flat field correction
 - d) dark noise
 - e) readout noise
 - f) quantum detection efficiency
 - g) temporal lag
 - h) blooming
67. Compare and contrast image quality and dose efficiency of image intensifier systems versus flat panel detector systems when used for fluoroscopy.
68. Describe quality control tests for a flat panel detector fluoroscopy system. Name equipment used for these tests.
69. Discuss patient doses encountered over the range of current fluoroscopy procedures, both diagnostic and therapeutic, and describe methods used to minimize patient doses.
70. With regards to digital subtraction angiography (DSA), answer the following:
- a) Outline the physics of image acquisition;
 - b) Why are patients imaged using DSA?
 - c) List and briefly explain factors which affect patient dose in an interventional procedure using DSA.
71. Describe how the image processing techniques available with current DSA systems are used when performing interventional procedures.
72. Define or explain the following with respect to computed tomography:
- (a) bowtie filter
 - (b) Hounsfield unit
 - (c) axial scan mode
 - (d) helical scan mode
 - (e) flying focal spot
 - (f) third-generation scanner
 - (g) isocenter
 - (h) tube current modulation
73. Sketch and describe the major components of a modern third-generation multislice CT scanner.
74. Qualitatively describe and compare the different approaches to CT image reconstruction available in modern CT scanners.



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75. Discuss the following CT artefacts, including methods implemented to minimize them:
- beam hardening,
 - partial volume effects,
 - streak artifacts, and
 - ring artifacts.
76. Describe the radiation detector arrays in use in current multislice CT scanners, including representative technical specifications and performance criteria.
77. Compare and contrast multislice and cone-beam CT scanners, including advantages and disadvantages and clinical applications.
78. Describe the following dose parameters associated with CT scanners, and give typical values for clinical head and body scans:
- weighted CTDI_w
 - volume CTDI_{VOL}
 - dose-length product
 - Size Specific Dose Estimate (SSDE)
 - effective dose
79. Describe a comprehensive quality assurance program for a CT scanner, including the relative importance and frequency of test procedures.
80. Describe and compare digital breast tomosynthesis to general 2D mammography including detector requirements.



IV. DIAGNOSTIC RADIOLOGY SPECIALTY

1. Briefly define or explain the following with respect to radiation detectors:
 - (a) photo-peak
 - (b) dynode
 - (c) stopping power
 - (d) Compton edge
 - (e) electronic avalanche
 - (f) thermogram
 - (g) quenching
 - (h) paralyzable system
2. Describe the following radiation detectors based on gas ionization and discuss their relative merits in radiation protection:
 - a) ionization chamber
 - b) Geiger-Mueller (G-M) counter
3. Derive expressions for exposure and absorbed dose in air per unit photon fluence in terms of the air mass energy absorption coefficient. Plot the exposure per unit fluence as a function of photon energy in the range from 20 to 150 keV and explain the curve shape in terms of photoelectric and Compton interaction processes.
4. Describe how film and optically stimulated luminescence dosimeters may be used for personnel dosimetry and discuss their relative advantages and limitations.
5. Discuss typical doses to staff working in Radiology and compare these with dose limits for occupationally exposed individuals and members of the public.
6. Briefly define or explain:
 - (a) indirect action
 - (b) non-stochastic
 - (c) directly ionizing
 - (d) chromosome aberration
 - (e) linear quadratic model
 - (f) absolute/relative risk models
7. Discuss why it is difficult to obtain accurate information about the biological effects on humans of low doses (e.g. 10 mGy) of low-LET radiations delivered over extended periods of time.
8. Discuss the radiation risks associated with a typical barium enema study and an interventional cardiac catheterization procedure.
9. Quantitatively discuss sources of natural background radiation (including medical exposure) in North America and estimate their contributions to the genetically significant dose.
10. Compare the diagnostic information obtained, image quality parameters and patient doses of a nuclear medicine brain scan, skull x-ray and head CT examination.



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11. Compare and contrast the benefits and limitations of SPECT myocardial perfusion and CT coronary angiography studies, including artifacts typically encountered.
12. Discuss or define the following as they apply to magnetic resonance:
 - (a) Larmor equation
 - (b) gyromagnetic ratio
 - (c) paramagnetism
 - (d) 90 degree pulse
 - (e) gradient echo
 - (f) magnetization transfer
 - (g) chemical shift
 - (h) susceptibility
13. Discuss the factors that influence the signal to noise ratio in an MR image.
14. Describe, with the aid of sketches, the RF pulses, gradients and signal acquisition of the following imaging techniques:
 - a) Inversion Recovery (IR)
 - b) Spin-Echo (SE)
 - c) Gradient Echo (GE)
15. For spin-echo imaging:
 - a) use graphs to explain how image contrast can be varied by the choice of spin-echo imaging parameters.
 - b) what spin-echo imaging parameters would you use to maximize image contrast between tissues having:
 - i) different T_1
 - ii) different T_2
 - iii) different proton density.
16. Compare the imaging aspects of an MR head scan with a CT scan of the head (including image quality, patient dose, scan time and cost).
17. Define or discuss the following with respect to ultrasound imaging:
 - (a) piezoelectric effect
 - (b) matching layer
 - (c) acoustic impedance
 - (d) scan converter
 - (e) pulse length
 - (f) aliasing
 - (g) reverberation artifact
 - (h) duplex scanning
18. Discuss the structure of an ultrasound transducer array. Describe how images are formed using linear, curved, and phased array transducers.
19. Explain what is meant by **B** and **M** mode ultrasound scans. Explain how the temporal resolution is limited for each technique.



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20. Discuss the most important factors that affect the axial, lateral, and elevation resolution of an ultrasound scanner. How are these controlled on a linear array transducer?
21. For diagnostic ultrasound:
 - a) Explain the terms mechanical index (MI) and thermal index (TI).
 - b) Discuss the hazards associated with mechanical and thermal effects.
 - c) What special safety considerations are required for ultrasound contrast agents?
22. Describe the following Doppler modes:
 - a) Continuous Wave
 - b) Pulsed
 - c) Color
 - d) Power
23. Discuss and show mathematically the relationship between the Point Spread Function (PSF), Line Spread Function (LSF) and Modulation Transfer Function (MTF) of a medical imaging system.
24. Define the Nyquist frequency for a digital imaging system and explain why undersampling causes aliasing. Give representative values of the Nyquist frequency for digital image receptors used in mammography and general radiography.
25. Discuss the MTF of a digital imaging system and how this is affected by the following:
 - a) detector element size
 - b) detector element spacing
 - c) display matrix size
26. Outline a method for determining the presampling MTF of a digital imaging modality (e.g. CR) and plot a representative MTF for the chosen modality.
27. Describe the primary components of noise in the formation of a digital radiographic image, including their relative contributions to overall image noise levels.
28. Define the noise power spectrum (NPS) of a digital radiographic image receptor and explain in detail how it is measured.
29. Discuss how the noise power spectrum (NPS) for an indirect-conversion flat panel detector would change when:
 - a) a thicker scintillator is used
 - b) a scintillator with a higher conversion efficiency is used
 - c) a detector with a higher quantum detection efficiency is used.



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30. Define noise equivalent quanta (NEQ) and describe the factors that influence the NEQ for a digital image.
31. Define detective quantum efficiency (DQE) and describe the factors that influence the DQE for a digital radiographic image receptor.
32. Draw a 2 x 2 matrix of disease (D+ or D-) and a diagnostic test (T+ or T-) for some patient population. Identify true positives, false positives, true negatives and false negatives and define the following terms:
 - a) sensitivity
 - b) specificity
 - c) accuracy
 - d) prevalence of disease
 - e) predictive value of the test
33. Sketch a Receiver Operating Characteristic (ROC) curve and indicate the operating points on the curve corresponding to strict and lax thresholds. Explain the meaning of these thresholds and of the diagonal connecting (0,0) and (1,1) on the ROC plot. Discuss the use of the area under the ROC curve as a measure of the accuracy of a diagnostic test.
34. Describe the procedure used to perform an ROC study to compare the performance of two competing imaging modalities to diagnose a specific clinical problem.
35. Compare and contrast ROC and alternative forced choice (AFC) methods for assessing observer performance in visual signal detection.
36. Describe the Rose criterion for detection of a uniform object in a uniform background, including assumptions used in developing the model and practical limitations.
37. Describe the following three accidental exposures reported in the press. For each event, list at least two strategies that, had they been in place, would have reduced the risk of this type of event.
 - a) CT brain perfusion scans at Los Angeles's Cedars-Sinai Medical Center in 2008-2009;
 - b) Multiple CT scans of the same 3 mm slice at Arcata, California in 2008;
 - c) Trainee touching a radiography camera source at Port Lavaca, Texas in 2011.



- 38.
- a) Describe how a Failure Modes and Effects Analysis could be performed in the radiology setting.
 - b) For each of the following Failure Modes, identify one possible cause and suggest, with reasons, values for Frequency (F), Severity (S) and Detectability (D) parameters
 - (i) incorrect patient for procedure;
 - (ii) incorrect scanning parameters used;
 - (iii) exam on pregnant patient.
 - c) For each case in (b) above, what preventative measures could be employed to decrease D, (i.e. increase the detectability of the error before it reaches the patient)?
39. In relation to Radiology Information Systems (RIS) in running a radiology department, explain the purpose and use of:
- a) firewall,
 - b) checksum,
 - c) IPv6,
 - d) RAID,
 - e) DICOM,
 - f) PACS.
40. With regards to X-ray measurement equipment calibration, explain the following:
- a) Describe the importance of calibration;
 - b) Outline how a calibration is performed and with what frequency;
 - c) What are potential issues that arise if calibration is not performed?
 - d) What is cross-calibration?