RADIOLOGY PHYSICS CORE – Final Exam

31st Aug, 2015, 7AM to 9 AM (2 hours), Proctored.

Please use attached answer sheet to answer questions, and send it to

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80 Raphex Diagnostic Questions, Pg. 2 to 22.

Non-programmable calculators may be used.

Choose the most complete and appropriate answer to each question.

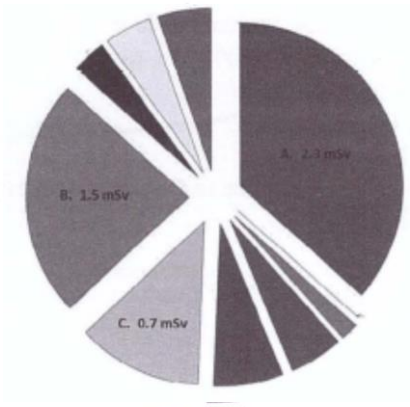
1. Which of the following radioisotopes emits particles having the highest probability of producing a bremsstrahlung interaction?
   A. Y-90
   B. Tc-99m
   C. F-18
   D. Ra-223

2. When traversing matter, x-ray photons interact in four major ways. The most prevalent type of interaction in human soft tissue for 100 kV x-rays is:
   A. photoelectric effect
   B. Compton scattering
   C. pair production
   D. annihilation

3. In the United States, diagnostic reference levels (DRL) are:
   A. a maximum allowable dose for CT imaging protocols (i.e., 75 mGy for adult head)
   B. set at approximately the 75th percentile of measured patient or phantom data
   C. set at the median (50th percentile) of the study dose distribution
   D. dependent upon image quality

4. In fluoroscopically guided interventional (FGI) procedures, air kerma at the reference point ($K_{a,r}$):
   A. includes the effect of backscatter radiation
   B. is the total number of photons emitted by the x-ray tube during an FGI procedure
   C. is an estimate of dose or air kerma from the x-ray tube (excluding backscatter from the patient) where the x-ray beam enters the patient
   D. has a median value of 15 Gy for FGI procedures

5. In 2006, the NCRP estimated an average resident of the United States received an annual effective dose of 6.2 millisieverts (mSv). The chart below describes the three principle contributors. In order of *DESCENDING* contribution, A, B, and C represent:



   A. CT imaging; nuclear medicine imaging; radon and thoron
   B. CT imaging; radon and thoron; nuclear medicine imaging
   C. nuclear medicine imaging; radon and thoron; CT imaging
   D. radon and thoron; CT imaging; nuclear medicine imaging

6. Which of the following statements concerning absorbed dose in bone is *FALSE*?
   A. expresses mean radiation energy deposited per unit bone mass
   B. is directly measured with an ionization chamber
   C. is related to radiation-induced biological effects
   D. is reported in units of Gray (Gy)

7. In fluoroscopically guided interventional procedures (FGI), the peak skin dose:
   A. does not include contribution of scattered radiation
   B. is the total amount of energy imparted to the patient's skin during the procedure
   C. is the highest dose to any portion of the patient's skin during the procedure
   D. is reported in units of $mGy \cdot cm^2$

8. In order to take advantage of the heel effect in posterior-anterior chest radiography, the x-ray tube should be oriented in the following way:
   A. cathode toward the head, anode toward the feet
   B. cathode-anode axis perpendicular to the head-to-foot axis
   C. anode toward the head, cathode toward the feet
   D. cathode-anode orientation has no clinical implication on heel effect

9. Which of the following components is *NOT* part of the material that would make up the fixed (non-removable from the beam path) filtration of a special procedures fluoroscopy unit?
   A. the plastic window of the x-ray tube housing
   B. the copper filter(s) used to harden the beam during special procedures
   C. the insulating oil in the x-ray tube housing
   D. the aluminum filter which guarantees minimum required HVL

10. The major difference between an x-ray tube used for general projection imaging and one used in a multi-slice helical CT scanner is:
   A. The CT tube can be operated at much higher kV
   B. The general-purpose tube has higher anode rotation speed
   C. The CT tube is much smaller in size so that it will fit into the CT gantry
   D. The CT tube has much higher heat capacity

11. A cobalt-57 sample containing 3.7×10^3 Bq of activity is assayed in a sodium iodide well counter, yielding a net count rate of 199,800 cpm. The approximate efficiency of the detector is:
   A. 0.3
   B. 0.5
   C. 0.7
   D. 0.9

12. Which of the following types of ionizing radiation has the highest relative biological effectiveness?
   A. cobalt-60 gamma rays
   B. diagnostic x-rays
   C. iodine-131 beta particles
   D. alpha particles

13. The hematopoietic syndrome is the primary clinical consequence of acute doses:
    A. in the range of 0.5 to 10 Gy
    B. in the range of 20 to 50 Gy
    C. greater than 100 Gy
    D. greater than 200 Gy

14. Epidemiological data from the Chernobyl nuclear accident in 1986 suggest:
    A. No excess cancer risk was associated with the accident.
    B. Neuroblastoma was the most common cancer associated with pediatric exposure to fallout.
    C. Thyroid cancer was the most common cancer associated with pediatric exposure to fallout.
    D. The study population was too small to infer statistically significant conclusions regarding the effect of the accident on cancer incidence.

15. The doubling dose is the dose of radiation expected to double the spontaneous mutation rate. The doubling dose to human populations is approximately:
    A. 0.1 Gy
    B. 1 Gy
    C. 10 Gy
    D. 100 Gy

16. Analysis of existing epidemiological studies of irradiated populations derives an approximate risk of _____ increase in fatal cancer following a whole body dose of 1 Sv.
    A. 0.1%
    B. 0.5%
    C. 1%
    D. 5%

17. Repair of which of the following types of DNA damage is closely associated with cell survival after exposure to ionizing radiation?
    A. single base damage
    B. single strand damage
    C. double-stranded breaks
    D. pyrimidine dimers

18. Based on estimates from the International Commission on Radiation Protection, for a nuclear accident where two million people are exposed to an average dose of 3 mSv, the number of excess cancer deaths would be:
    A. 5
    B. 30
    C. 150
    D. 300

19. What is an estimate of the probability of a live birth without malformation or without childhood cancer if the conceptus receives 5 mGy?
    A. 10%
    B. 25%
    C. 50%
    D. 75%
    E. 95%

20. For a fetal dose of 100 mGy, what stage of embryonic development is most likely to result in gross malformation?
    A. preimplantation
    B. early organogenesis
    C. late organogenesis
    D. early embryonic development
    E. late fetal period

21. Genetic effects of radiation have been seen in the following groups:
    A. atomic bomb survivors
    B. patients with high numbers of CT scans
    C. radiation therapy patients
    D. radon-exposed miners
    E. none of the above

22. All of the following studies have shown evidence of increased risk of radiation-induced cancers *EXCEPT*:
    A. diagnostic bone scans
    B. atomic bomb survivors
    C. chest fluoroscopy for tuberculosis
    D. radium dial painters

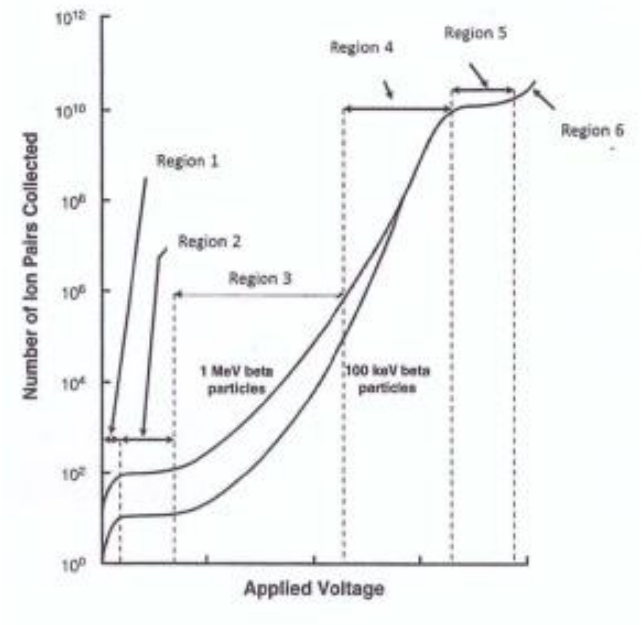
23. For radiation biology studies, LD_{50} is the radiation dose that kills _____.
    A. 50% of exposed cells
    B. 50 exposed cells
    C. All exposed cells within 50 days
    D. 10–50 of exposed cells

24. A pregnant diagnostic radiology imaging technologist declares her pregnancy to the radiation safety officer. For the entire gestation period, the allowable dose equivalent to the embryo-fetus is:
    A. 0.5 mSv
    B. 5 mSv
    C. 50 mSv
    D. 500 mSv

25. A nurse stands at a distance of 1 meter from a patient undergoing an interventional procedure. The entrance skin dose rate for the patient is 20 mGy/minute. With NO shielding in place, the scatter radiation level where the nurse is standing is approximately:

A. 0.002 mGy/minute
B. 0.02 mGy/minute
C. 0.2 mGy/minute
D. 2 mGy/minute

The figure below represents a characteristic curve for gas detectors. Use the graph to answer questions D50 and D51.



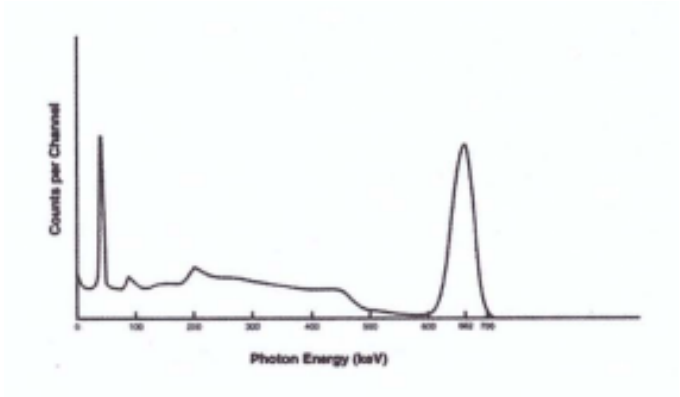
26. A nuclear medicine dose calibrator operates in:

A. region 2
B. region 3
C. region 4
D. region 5

27. A Geiger–Müeller counter operates in:

A. region 2
B. region 3
C. region 4
D. region 5

28. The graph below depicts an energy spectrum for Cesium-137 collected on a sodium iodide detector. The energy resolution of the displayed system is approximately _____ FWHM at the 662 keV photopeak:



A. 0.7%
B. 7%
C. 25%
D. 66%

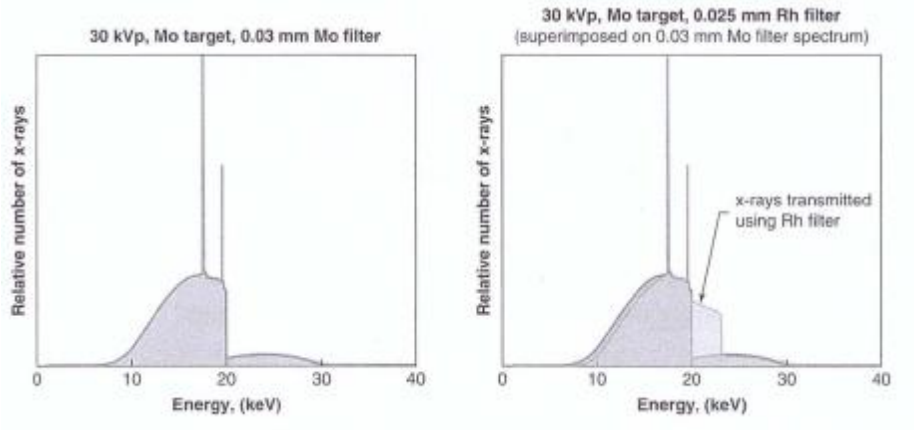
29. Assuming identical acquisition parameters and field dimensions, which of the following statements is *TRUE* for projection radiography of the chest?
A. The effective dose for an AP acquisition is higher than a PA acquisition.
B. The effective dose for a PA acquisition is higher than an AP acquisition.
C. The effective dose for AP and PA acquisitions are the same.
D. Effective dose cannot be calculated for projection radiography of the chest.

30. Nuclear cardiology stress tests using 30 mCi of 99mTc sestamibi will result in approximate effective dose of about:
A. 0.04 mSv
B. 0.4 mSv
C. 4 mSv
D. 40 mSv

31. What limit applies for the general public in corridors or waiting rooms adjacent to an x-ray room?
A. 0.1 mSv/y
B. 1 mSv/y
C. 10 mSv/y
D. 10 mSv/h

32. The radiation dose limit for a patient undergoing a bone scan is:
A. 0.5 mSv
B. 5 mSv
C. 50 mSv
D. not limited

33. **For the two x-ray energy spectra below, which statement is correct regarding their clinical applications?**



A. Both spectra could be used for general radiographic application.
B. The left-hand spectrum would be used for mammography of women with smaller/thinner breasts, while the right-hand spectrum would be used for mammography of women with larger/thicker breasts.
C. The right-hand spectrum would be used for mammography of women with smaller/thinner breasts, while the left-hand spectrum would be used for mammography of women with larger/thicker breasts.
D. Both spectra would be used head CT exclusively.
E. Neither spectrum would be used clinically.

34. Identify the image below.

A. gamma camera contrast phantom
B. CT contrast and spatial resolution phantom
C. ACR mammography accreditation phantom
D. PET contrast and resolution phantom

35. Diagnostic interpretation of digital mammograms should be performed on display monitors that:
    A. have a contrast ratio of at least 10:1
    B. have a minimum of 5 megapixels
    C. have a luminance of at least 40 cd/mm^2
    D. are approved by the AAPM and ACR for mammography

36. Mammography digital tomosynthesis:
    A. employs a moving x-ray tube and moving image receptor
    B. provides a series of thin slices with about the same total dose as a conventional mammogram
    C. employs standard CT x-ray detectors
    D. most commonly uses a projection angle of 180 degrees

37. The FDA requires that all fluoroscopes sold in the United States after May 2006 have the following radiation monitoring technologies:
    A. effective dose indicator
    B. focal spot-to-skin indicator
    C. peak skin dose indicator
    D. total air kerma at the reference point indicator

38. An interventional system performs fluoroscopy at 15 fps, DSA at 7.5 fps, and cine at 10 fps. Rank the patient entrance dose rates (mGy/min) in ascending order for a 20 cm thick patient:
    A. fluoro, DSA, cine
    B. fluoro, cine, DSA
    C. DSA, fluoro, cine
    D. DSA, cine, fluoro
    E. cine, fluoro, DSA
    F. cine, DSA, fluoro

39. A "radiation-conscious" radiologist is considering replacing the image intensifier on his one-year-old GI fluoroscope with a flat panel. (The system is in excellent condition.)
   A. Only the fluoroscopic patient dose rate can be expected to decrease by at least 75%.
   B. Only the "spot film" patient dose rate can be expected to decrease by at least 75%.
   C. Both the fluoroscopic and "spot film" patient dose rates can be expected to decrease by at least 75%.
   D. Neither the fluoroscopic nor the "spot film" patient dose rates can be expected to decrease by at least 75%.

40. The x-ray-sensitive layer in a flat-panel fluoroscopic detector is mainly:
   A. AgBr
   B. CsI
   C. NaI
   D. ZnCdS

41. For an image intensifier-based system, the limiting spatial resolution of a neurointerventional examination is *NOT* influenced by the:
   A. active field size of the image intensifier
   B. examination magnification factor
   C. radiation dose per frame
   D. x-ray tube focal spot size

42. A major objective in many examinations is optimizing the visibility of iodine-based contrast agents and patient dose. Which of the following measures is most effective:
   A. adding 1.0–10.0 mm Al to the beam while adjusting x-ray factors
   B. adding 0.1–1.0 mm Cu to the beam while adjusting x-ray factors
   C. increasing mAs while reducing kV without changing the x-ray beam filter
   D. increasing kV while reducing mAs without changing the x-ray beam filter

43. In multi-detector helical CT scanning, the detector pitch:
   A. is the table movement (mm) per 360° rotation divided by detector width (mm)
   B. is the table movement (mm) per 360° rotation divided by collimator width at isocenter (mm)
   C. has a typical value between 2.0 and 3.0 for clinical imaging
   D. is associated with partial scanning for values less than 1.0

44. When compared to traditional radiography, CT has:
    A. superior spatial resolution and superior image contrast
    B. inferior spatial resolution and inferior image contrast
    C. superior spatial resolution and inferior image contrast
    D. inferior spatial resolution and superior image contrast

45. The $CTDI_{vol}$:
    A. is equal to the DLP scan length
    B. is measured by placing a dose meter in a phantom, measuring a large series of scans of the phantom, and adding up the dose from all the slices
    C. measures air kerma in a plastic phantom and is reported in units of mGy
    D. is independent of pitch

46. Which of the following statements about the changing of single CT scan parameters without automatic exposure control (AEC) is *TRUE*:
    A. Doubling the pitch will double the $CTDI_{vol}$.
    B. Doubling the pitch will cut the $CTDI_{vol}$ in half.
    C. Doubling the tube rotation time from 0.5 to 1.0 second will cut the $CTDI_{vol}$ in half.
    D. $CTDI_{vol}$ is indirectly proportional to tube current.

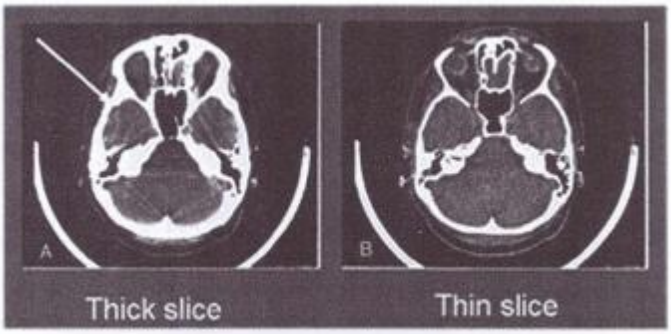
47. In CT, relative to a standard patient size, automatic exposure control (AEC):
    A. tends to decrease $CTDI_{vol}$ in large patients
    B. tends to decrease $CTDI_{vol}$ in small patients
    C. tends to increase $CTDI_{vol}$ in small patients
    D. does not affect $CTDI_{vol}$

48. An increase in which of the following variable parameters of a CT acquisition will *NOT* result in an increase in patient dose?
    A. kV
    B. mA
    C. noise index
    D. tube rotation time

49. For a CT image, as the pixel size decreases, the signal-to-noise ratio (SNR):
   A. decreases
   B. increases
   C. remains the same

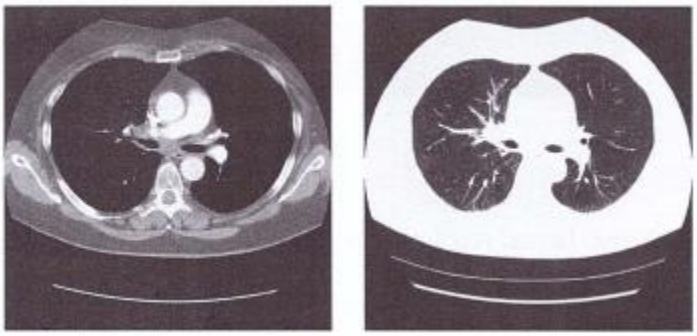
50. For a CT image, as the x-rays per projection increase, the signal-to-noise ratio (SNR):
   A. decreases
   B. increases
   C. remains the same

51. The bone thickening seen in the axial CT image on the left below is due to:



   A. beam hardening
   B. susceptibility artifact
   C. partial volume artifact
   D. aliasing

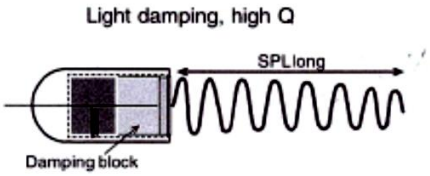
52. The two CT scans of the thorax shown below are from the same location in the patient. What is the difference between the two images?



   A. The image on the left is displayed with a higher-level setting.
   B. The image on the left is displayed with a wider window setting.
   C. The image on the left was obtained with a lower kV.
   D. The image on the left was obtained with higher mAs.

Use the graphic below to answer questions D84 through D86.

53. The Q factor for the transducer below is:



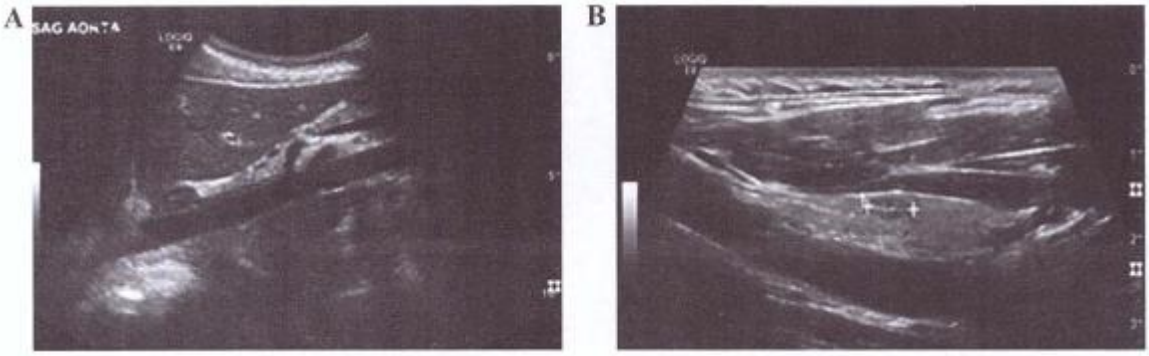
A. low
B. high
C. cannot be determined
D. medium

54. The frequency spectrum bandwidth for the transducer is:
A. low
B. high
C. broad
D. narrow

55. If the spatial pulse length (SPL) shown in the image is 3.0 mm, the axial resolution for the transducer is:
A. 6.0 mm
B. 3.0 mm
C. .5 mm
D. 1.0 mm

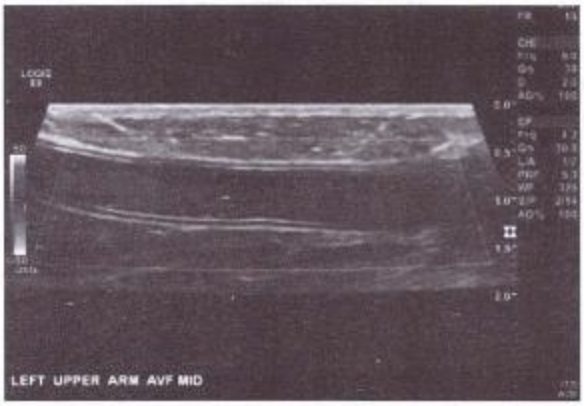
56. In ultrasound imaging, the HVT or half value thickness, in soft tissue is the thickness of tissue necessary to attenuate signal intensity by how many decibels?
A. 0.3
B. 3
C. 30
D. 300

57. Compared to image A (aorta) below, the frequency of the transducer used in image B (thyroid) will be:



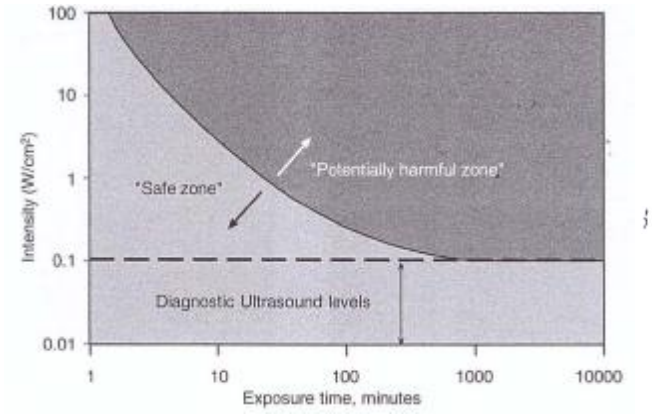
A. higher
B. equal
C. lower
D. unable to determine

58. With respect to the Doppler image shown below, which transducer angle *IDEALLY* should be used to optimize the accuracy of the blood flow measurement?



A. 90°
B. 60°
C. 30°
D. 0°

59. In the diagnostic range (dashed line below), the intensity limit for prolonged use of ultrasound is closest to which of the following (in W/cm)?



A. 0.1 W/cm^2
B. 1 W/cm^2
C. 10 W/cm^2
D. 100 W/cm^2

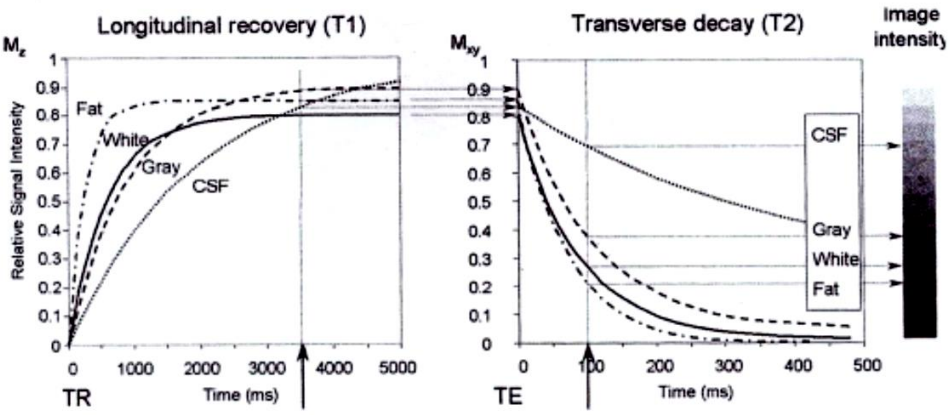
60. A patient previously underwent a brain MRI scan on a 1.5 Tesla scanner. His next brain MRI will take place on a 3 Tesla scanner. Which one of the following statements is *TRUE*?

A. The identical pulse sequence parameters can be safely used on the 3 Tesla scanner.
B. Larger fields of view must be used on 3 Tesla scanners.
C. The pulse sequence parameters may need to be adjusted because of RF heating/SAR limitations.
D. T1 contrast properties will not change because proton T1 values are independent of field strength.

61. A patient previously underwent a brain MRI scan on a 1.5 Tesla scanner. A follow-up brain MRI is scheduled to take place on a 3 Tesla scanner. He has an implanted stent which was labeled by the manufacturer as safe at 1.5T. Which one of the following statements is *TRUE*?

A. If the implant was safe at 1.5T, then it is non-ferrous and is safe at 3.0 Tesla.
B. The MRI personnel should scan the patient with a hand-held metal detector, and if the stent is not detected, it is safe for the patient to be scanned at 3.0 Tesla.
C. The MRI personnel should only image the patient at 3.0 Tesla if the patient's physician verbally states that it is safe.
D. The MRI personnel should only scan the patient at 3.0 Tesla if they are able to find documentation of the implanted stent's safety at 3.0 Tesla.

62. The relative signal intensity for a spin-echo image is shown with TR and TE as indicated in the graph below. The image contrast obtained will be:



A. T1 weighted
B. T2 weighted
C. proton density
D. T1T2 weighted

63. Parallel imaging techniques such as SMASH, SENSE, and GRAPPA employ a multi-coil receiver array. Which of the following statements is FALSE?

A. Using multiple receiver coils requires a longer TR.
B. Prior knowledge of the parallel coil geometry permits a reduction in the number of phase encode steps needed.
C. Parallel imaging usually requires a calibration scan.
D. Parallel imagine permits shorter effective TE values in fast spin-echo sequences.

64. Which of the following techniques are used to reduce respiratory motion artifacts in MRI?

A. diffusion weighting
B. cardiac gating
C. inversion recovery
D. navigator echo

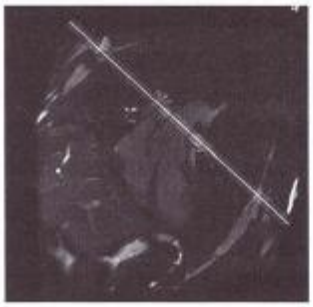
65. The image below is a proton-density-weighted image of the knee. Which MRI parameter combination will generate a proton-density-weighted spin-echo image?

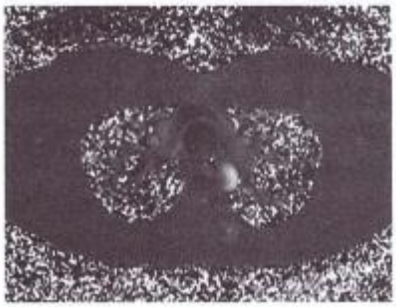
A. long TE, long TR
B. short TE, long TR
C. short TE, short TR
D. long TE, short TR

66. A single-slice spin-echo MR image is acquired using the following parameters: FOV = 360 mm, matrix = 256 × 256 voxels, number of acquisitions = 2. Which parameter combination would result in increased SNR assuming all other parameters are kept constant?

A. FOV = 320 mm, matrix = 256 × 256, acquisitions = 2
B. FOV = 180 mm, matrix = 256 × 256, acquisitions = 4
C. FOV = 360 mm, matrix = 256 × 256, acquisitions = 1
D. FOV = 360 mm, matrix = 256 × 128, acquisitions = 4

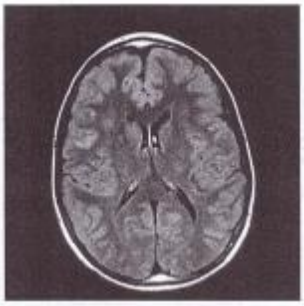
67. The image below left is a cardiac sagittal image used to plan an oblique slice perpendicular to the aorta to generate the image on the right. What kind of MRI image is shown on the right?





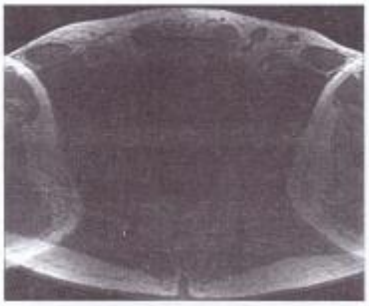
A. perfusion MRI image of heart
B. T2* mapped vardiac image
C. T1 weighted vardiac image
D. phase contrast image

68. On images with a fluid attenuated inversion recovery (FLAIR) sequence as shown in figure below, typical values for TI/TE/TR on a 1.5 Tesla scanner might be:



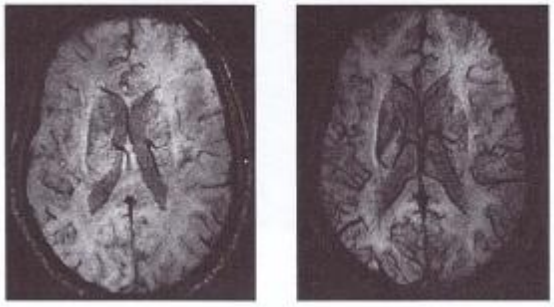
A. 150 / 80 / 3000 ms
B. 150 / 20 / 500 ms
C. 1000 / 80 / 10,000 ms
D. 2200 / 20 / 500 ms
E. 2200 / 125 / 10,000 ms

69. Which of the following is true about the MRI artifact below?



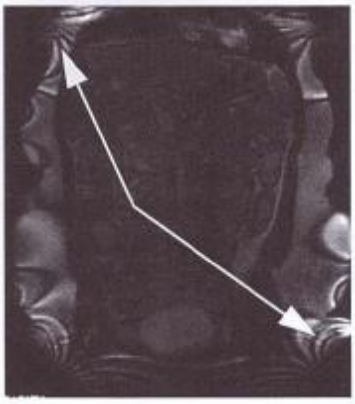
A. The artifact can be reduced by increasing slice thickness.
B. The artifact is caused due to susceptibility effects.
C. The artifact is caused due to T1 effects.
D. The artifact occurs in the phase-encode direction.
E. The artifact is reduced by decreasing TE.

70. The image on the left below is a 3D gradient echo image which utilizes only magnitude data to produce contrast. The image on right is from the same scan, but it uses both magnitude and phase information to produce image contrast, which enhances microbleeds and venous architecture. What is the technique called?



A. phase contrast imaging
B. perfusion weighted imaging
C. susceptibility weighted imaging
D. diffusion weighted imaging
E. MR relaxometry

71. What is the prominent artifact around the image boundary shown by the arrows?



A. ghosting
B. fat water shift
C. moiré fringe
D. DC offset artifact
E. eddy currents

72. MR dynamic Gd-enhanced 3D T1 gradient echo as shown below is performed routinely for the detection of breast malignancy. Which of the following is true?

A. All lesions that enhance are probably malignant.
B. All lesions that enhance quickly are more likely malignant.
C. All lesions that enhance slowly are more likely malignant.
D. The measurement of T1 allows for determination of benign or malignant.
E. The measurement of T2 allows for determination of benign or malignant.

73. The beta-ray emitted by yttrium-90, used in the form of microspheres for radioembolic therapy of liver tumors, has a maximum energy of 2.3 MeV. The average energy of the yttrium-90 beta-ray is therefore approximately:

A. 0.23 MeV
B. 0.47 MeV
C. 0.77 MeV
D. 1.15 MeV

74. Iodine-131 (physical half-life, Tp = 8.04 days) is eliminated from the body of a post-thyroidectomy thyroid cancer patient with a biological half-time, Tp, of 2.0 days. What is the effective half-time, Te, of iodine-131 in this patient?

A. 0.8 days
B. 1.6 days
C. 3.2 days
D. 4.8 days

75. For which of the following radioactive shipments would the following DOT label be appropriate?

A. Metastron™ (89Sr strontium chloride)
B. A Mo99-Tc99m generator
C. 131-Iodide thyroid cancer treatment dose
D. a multi-patient vial of 18F-FDG
E. a 68Ge-68Ga cylindrical phantom for PET QC and calibration

76. For a hypothetical 5 × 5 gamma camera flood image with the following numbers of counts in each pixel, the integral uniformity (IU) is:

1000	1010	870	920	990
1060	940	940	1020	1030
890	1090	1120	1100	950
1010	880	920	1110	1120
880	990	1040	1040	1140

A. 1%
B. 3%
C. 7%
D. 10%
E. 13%

77. For an intrinsic gamma camera uniformity measurement ("daily flood"), which of the following is true?
    A. Use a Co-57 sheet source with collimators on.
    B. Use a Co-57 sheet source with the collimator removed.
    C. Use a Tc-99m point source in a syringe at a distance more than 3× the diameter (or largest dimension) of the detector with the collimator on.
    D. Use a Tc-99m point source in a syringe at a distance more than 3× the diameter (or largest dimension) of the detector with the collimator removed.
    E. Use a four-quadrant bar phantom.

78. For a controlled (or restricted) area, such as a radiopharmacy in a nuclear medicine department, radiation surveys (i.e., measurement of the ambient exposure rates) must be performed:
    A. daily
    B. weekly
    C. monthly
    D. yearly
    E. at the discretion of the licensee

79. The exposure rate measured at 1 m from the surface of a package containing radioactivity is 0.006 R/hr. The transport index (TI) of this package is therefore:
    A. 0
    B. 1
    C. 3
    D. 6
    E. 10

80. Mammography is the technique of choice for detecting non-palpable breast cancers. However, the risk of carcinogenesis in screening mammography is a concern. Mammography Quality Standards Act (MQSA) requires monitoring the dose annually for a typical patient. What is the legally required dose index in mammography dose monitoring?
    A. committed dose
    B. peak skin dose
    C. deep dose
    D. average glandular dose
    E. dose area product