BioE 1330 - Exam 1 10/9/2018
Answer Sheet - Correct answer is A for all questions

1. The sagittal plane

A. is perpendicular to the coronal plane.

B. is parallel to the top of the head.

C. represents a projection through the side of the body.

D. is parallel to the front of the body.

E. is used only in projection radiography.

Explanation: The sagittal plane is parallel to the side of the body and is perpendicular to the other two planes (coronal and axial). It may be used in any 3D tomographic imaging modality, but not in projection radiography).
[*imaging0003.mcq*]

2. The following is <u>not</u> true about the impulse function, $\delta(x)$.

A. It cannot be integrated.

B. It is also known as the Dirac function.

C. $\delta(0) = \infty$.

D. It has an area of 1.

E. It is infinitely narrow.

Explanation: The impulse (delta, or Dirac) function is infinitely narrow, infinitely tall, with an area of 1.
[*imaging0004.mcq*]

3. Given the following Contingency Table,

		disease	
		+	-
test	+	a	b
	-	c	d

consider a disease with a prevalence of $\frac{1}{1000}$. A test for the disease has 100% sensitivity and 95% specificity. Of the patients with a positive test result, what percentage can be expected to *not* have the disease? (Approximate and select the correct range.)

A. 80-100%.

B. 60-80%.

C. 40-60%.

D. 20-40%.

E. 0-20%.

Explanation: $a = .001$, c $= 0$, $b \approx .05$, $\frac{b}{a+b} \approx 98\%$ will not have the disease.
[*imaging0506.mcq*]

4. The following is true of the Gaussian function, generally of the form $\frac{1}{\sigma\sqrt{2\pi}}e^{\frac{-(x-\mu)^2}{2\sigma^2}}$ *except*

A. It represents a cosine in the real domain and a sine in the imaginary domain.

B. Multiplication with another Gaussian having the same mean μ yields a Gaussian with the same mean.

C. Convolution with another Gaussian always yields a Gaussian whose standard deviation σ is at least as large as the larger of the two constituent's σ.

D. When $\mu = 0$, the Gaussian is an even function.

E. It approaches an impulse function when σ approaches 0.

Explanation: The complex exponential, not the Gaussian, represents the cosine in the real domain and a sine in the imaginary domain
[*imaging0006.mcq*]

5. The following is true of convolution, *except*

A. Convolution with a Gaussian applied to any function $f(x)$ yields the same function $f(x)$.

B. It can be used on signals in both the temporal and spatial domains.

C. It exhibits the property of commutativity.

D. It exhibits the property of associativity.

E. Convolution in the temporal (or spatial) domain is equivalent to multiplication in the frequency domain.

Explanation: Convolution with an impulse function (not a Gaussian) applied to any function $f(x)$ yields the same function $f(x)$.
[*imaging0007.mcq*]

6. The following statements about the sinc function

$sinc(x) = \frac{sin(\pi x)}{\pi x}$

are true *except*

A. The sinc is not defined at $x = 0$.

B. A sinc can be viewed as a sum of sinusoids in a band of contiguous frequencies that are in phase at the origin and go out of phase as one moves away from the origin.

C. The sinc function in the spatial domain corresponds to a rect function in the frequency domain.

D. The sinc function in the frequency domain corresponds to a rect function in the spatial domain.

E. The sinc function is even.

Explanation: $sinc(0) = 1$. This can be proven by using l'Hopital's rule: the limit of the quotient equals the quotient of the derivatives. The derivatives of the numerator and denominator both equal π at $x = 0$, so their ratio is 1.
[*imaging0507.mcq*]

7. The following is true of the 2D complex exponential function, $e^{j2\pi(u_0x+v_0y)}$, *except*

A. It has an imaginary component, making it incapable of being used in the construction of real images.

B. Complex conjugate pairs of these complex exponentials form real sinusoidal variations at particular orientations and frequency in space.

C. It forms an orthogonal basis set from which any image can be constructed.

D. It represents a cosine in the real domain and a sine in the imaginary domain.

E. It is a periodic function.

Explanation: The complex exponential does have an imaginary component, but complex conjugate pairs are added together to cancel that component.
[*imaging0008.mcq*]

8. The following are true about the Modulation Function $m_f = \frac{f_{max}-f_{min}}{f_{max}+f_{min}}$ of $f(x, y)$, *except*

A. It equals $\frac{1}{2}$ when there is no contrast in the image.

B. It is always in the range $0 \leq m_f \leq 1$.

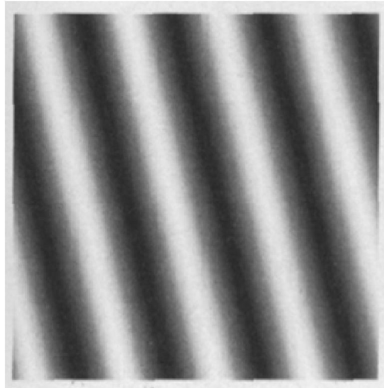
C. It is a measure of the contrast in an image.

D. For a sinusoidal variation in intensity, it represents the amplitude of the sinusoid over its average value.

E. It equals 1 only when$f_{min} = 0$.

Explanation: It equals 0 when there is no contrast in the image.
[*imaging0011.mcq*]

9. Given the image below, from lecture, in which intensity encodes real amplitude of a signal between 1 (white) and -1 (black), which of the following statements is *false*?



$u_0 = 4, v_0 = 1$

A. The image depicts a function displayed in the frequency domain.

B. The frequency of the signal is $\sqrt{4^2 + 1^2}$.

C. A change in phase would cause the pattern to move in the direction along the vector (4,1).

D. The signal consists of a pair of complex exponentials as a function of location that are complex conjugates of each other.

E. Any image may be constructed from a (possibly infinite) set of such signals, with varying amplitudes, frequencies, phases, and directions.

Explanation: The image depicts a function displayed in the *spatial* domain.
[*imaging0508.mcq*]

10. Determine which of the following signals are separable.

I rect(x,y)
II sinc(x, y)
III $\delta(x, y)$

A. I, II, and III

B. II

C. I and II

D. I and III

E. I

Explanation: All are separable.
[*imaging0016.mcq*]

11. A particular image consists of a sinusoidal variation in intensity along the x axis at a certain spatial frequency. Which of the following properties of that sinusoid may be changed by passing the image through a linear shift invariant system?

I - Amplitude.
II - Frequency.
III - Phase.

A. I and III.

B. I and II.

C. II and III.

D. I, II, and III.

E. I.

Explanation: For a linear shift invariant system, only the amplitude and phase of the sinusoid may change. The frequency must remain the same. Thus multiplication by the Fourier transform of the impulse response can define what the system does at each frequency independently.
[*imaging0066.mcq*]

12. The following are all true about the Fourier transform applied to images, *except*

A. A given image has a single Fourier transform, but a given Fourier transform may result from a number of different images.

B. The Modulation Transfer Function (MTF) of a linear shift invariant system is the Fourier transform of its impulse response (or Point Spread Function), normalized to the Fourier transform at the origin of the frequency domain.

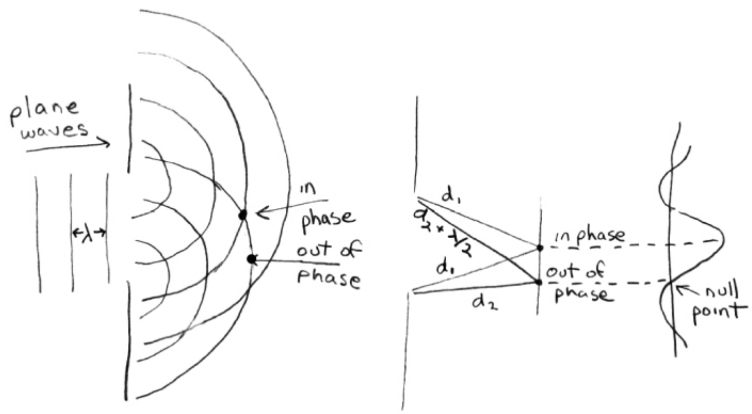
C. Rotating an image results in rotating its Fourier transform.

D. Blurring an image results in reducing the amplitude of the higher spatial frequencies in the image's Fourier transform, found further from the center of the transform than the lower spatial frequencies.

E. The Fourier transform of the projection of an image onto its x axis is the u axis of the Fourier transform of the original image.

Explanation: Applying the Fourier transform to an image results (under ideal conditions) in no loss of information, and applying the inverse transform recreates the original image completely. It is thus a one-to-one mapping.
[*imaging0067.mcq*]

13. Which of the following statements is *false* about the sketch below?



A. It shows how light bends around the edge of the aperture by refraction, due to differences in the speed of light in different media.

B. It shows the effects of plane waves at a certain wavelength passing through an apperture.

C. It illustrates the concept that each point of an advancing wave front is in fact the center of a fresh disturbance.

D. It shows constructive and destructive interference as a result of differences in distance across the aperture to a given point in space, leading to the creation of standing waves.

E. It depicts Huygen's principle.

Explanation: This is not refraction, but rather diffraction. There is no change in the speed of light required.
[*imaging0509.mcq*]

14. The following are all true about frequencies above half the sampling frequency, *except*

A. Their artifacts are generally avoided by removal in the discrete domain after sampling, rather than by filtering in the continuous domain before sampling.

B. They may be mistakenly interpreted as lower frequencies.

C. In images, they may appear as Moire patterns, or "beat frequencies".

D. The underlying discrete phasors may be viewed as a series of "snapshots" in which the phasors move further than 180 degrees between samples.

E. In the frequency domain, they may result in bleeding into the neighboring Nyquist Sampling Period.

Explanation: Once a frequency above half the sampling frequency is sampled, it is indistinguishable from the alias frequency. Filtering must be used to remove it in the continuous domain before sampling.
[*imaging0068.mcq*]

15. Given $\mathcal{F}[f(x,y)] = F(u,v)$ and $\mathcal{F}[g(x,y)] = G(u,v)$, find $\mathcal{F}[f(x,y) * g(x,y)]$

A. $F(u,v)G(u,v)$

B. $F(u,v) * G(u,v)$

C. $F(u,v) + G(u,v)$

D. $\frac{1}{|ab|}F(\frac{u}{a}, \frac{v}{b}) * \frac{1}{|ab|}G(\frac{u}{a}, \frac{v}{b})$

E. $F(u,v)G(u,v)e^{j2\pi(ux_0+vy_0)}$

Explanation: Convolution in the space domain is multiplication in the frequency domain.
[*imaging0074.mcq*]

16. Given the signal $f(x,y) = x + y$: evaluate $\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)\delta(x-1, y-2)dxdy$

A. 3

B. $3\delta(x-1, y-2)$

C. $f(x-1, y-2)$

D. $f(x,y)$

E. $f(x+1, y+2)$

Explanation: The double integral performs "sifting" on $f(x,y)$ at location $(1,2)$.
[*imaging0073.mcq*]

17. The Greek letter ψ is written in English as

A. psi

B. eta

C. phi

D. zeta

E. chi

Explanation: ψ is sometimes used by psychologists and psychiatrists as shorthand to denote a psychiatric comment in the patient's records.
[*imaging0086.mcq*]

18. The following are true about complex exponentials of the form $re^{j\theta}$ *except*

A. θ represents temporal or spatial frequency.

B. They can operate on the 2D domain (x,y) by, for example, having $\theta = ux + vy$.

C. They can represent any complex number.

D. They are central to Euler's identity.

E. They are used to represent real sinusoids in a format that is amenable to algebraic manipulation, in which case a pair of complex conjugates must always be used.

Explanation: θ represents phase, not frequency.
[*imaging0222.mcq*]

19. Which of the following statements about the point spread function (PSF) is *false*?

A. It is always circularly symmetric (rotationally invariant).

B. Resolution is limited by the PSF of a system.

C. It is sometimes characterized by the full width half maximum (FWHM), which for a Gaussian PSF is proportional to the standard deviation.

D. It fully defines a linear shift-invariant system.

E. If a group of systems are connected in series, the PSF of the group is determined by convolving the PSFs of the individual systems, and cannot be narrower than any of the constituent PSFs.

Explanation: The PSF does not have to be circularly symmetric, although for many systems it is assumed to be.
[*imaging0228.mcq*]

20. The following are true about Receiver Operator Characteristic (ROC) curves *except* (or all are true):

A. They express the precision of a test but not the accuracy.

B. They represent a plot of sensitivity vs. (1-specificity) over a range of thresholds.

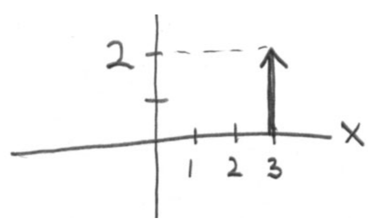
C. The plot always proceeds from (0,0) and ends at (1,1).

D. A test that produces random results has an area under the curve of 1/2.

E. All are true.

Explanation: The ROC is an expression of the accuracy of a test, because it is assumed that the ground truth (i.e., whether the disease is present) is knowable.
[*imaging0389.mcq*]

21. Assuming $g(x) = f(x) * h(x)$, for the $h(x)$ shown below, which of the following is true?



A. $g(x) = 2f(x-3)$.

B. $g(x) = 2f(x+3)$

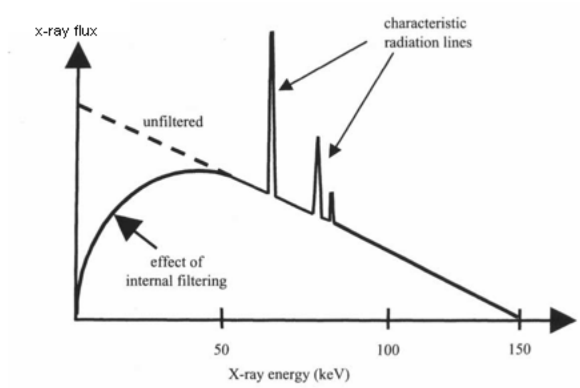
C. $g(x) = 3 - f(2x)$

D. $g(x) = 6f(x)$

E. None of the other answers is correct

Explanation: Convolution with the displaced and scaled impulse function results in an equally displaced and scaled output.
[*imaging0464.mcq*]

22. Which of the following statements about the graph below is false?,



A. The graph depicts the generation of x-rays within the patient due to high-energy electrons.

B. Characteristic radiation lines occur at particular energies corresponding to the difference between two electron shells in a given atom.

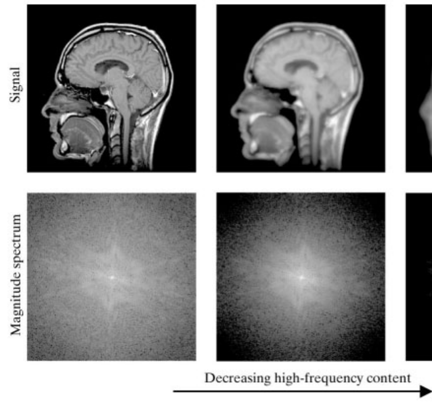
C. The spectrum content is the result of bremsstrahlung as well as characteristic radiation.

D. Decreasing the tube current would result in lowering the height of the graph evenly across energy.

E. The intersection of the graph with the x-axis occurs at the tube voltage.

Explanation: The graph depicts the creation of x-rays within the *x-ray tube* due to high-energy electrons.
[*imaging0510.mcq*]

23. Given the images below and their corresponding Fourier transforms, showing an original scan followed by convolution with 2 Gaussians, which of the following statements is *false* (or all are true)?



A. All are true.

B. The Fourier transforms (from left to right) show decreasing magnitudes in the high frequencies, which are furthest from the center of each transform as shown.

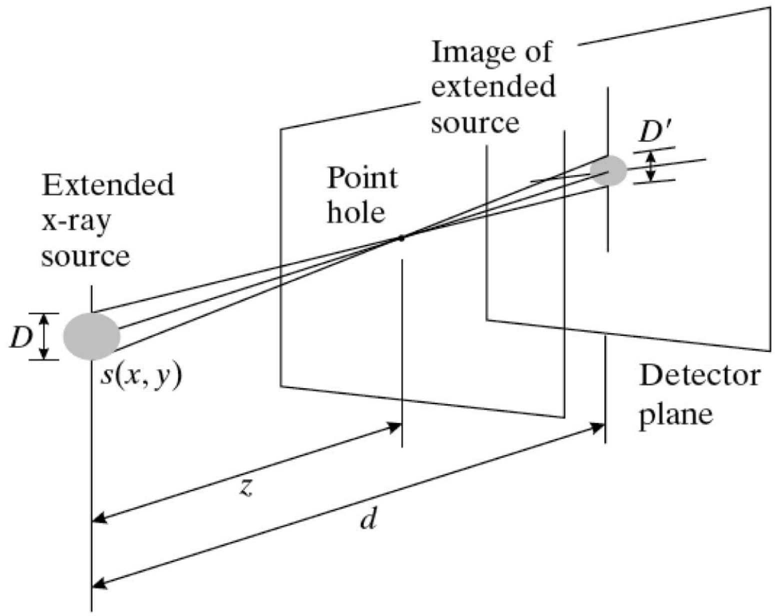
C. For each of the Fourier magnitude transforms, there is a corresponding phase transform that is not shown.

D. A given location in each Fourier transform represents a phasor with a particular horizontal and vertical frequency component.

E. The original image (upper left) is a sagittal slice through a human head.

Explanation:
[*imaging0465.mcq*]

24. In the following figure from the text, which of the following statements is *false*, or all are true?



A. As z approaches 0, the image of $s(x, y)$ through the point hole approaches an impulse function.

B. It illustrates how, for a given value of z, the image represents a convolution of a scaled version of $s(x, y)$ with the transmittivity at each point in the object being imaged.

C. It illustrates how both source magnification and object magnification effect the image.

D. All are true.

E. As z is reduced from d towards 0 the image gets blurrier.

Explanation: As z approaches d, the image of $s(x, y)$ through the point hole approaches an impulse function.
[*imaging0498.mcq*]

25. Which of the following has an energy per photon *less* than infrared?

A. Microwave.

B. X-rays.

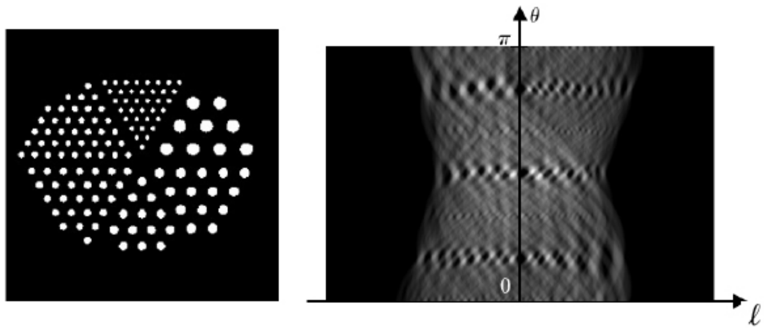
C. Gamma rays.

D. Ultraviolet light.

E. Visible light.

Explanation: Only microwave and radio have longer wavelengths (less energy per photon) than infrared.
[*imaging0471.mcq*]

26. Which of the following statements about the following figures is *false* (or all are true)?



A. All are true.

B. The figure on the right is the Radon transform of the figure on the left.

C. Each horizontal line through the figure on the right shows the projection through the figure on the left at a certain angle.

D. The figure on the right is also called a sinogram, because each point in the figure on the left traces a vertical sinusoid in the figure on the right.

E. The vertical axis in the figure on the right only goes from 0 to π, because the projection at a given angle is the same in either direction.

Explanation: All are true.
[*imaging0511.mcq*]

27. The following are all true about the attenuation coefficient μ as applied to x-rays, *except*

A. Variation in attenuation coefficient μ between tissue types makes it more difficult to create an x-ray image with high contrast.

B. In reality, μ for a given tissue type is a function of x-ray photon energy E.

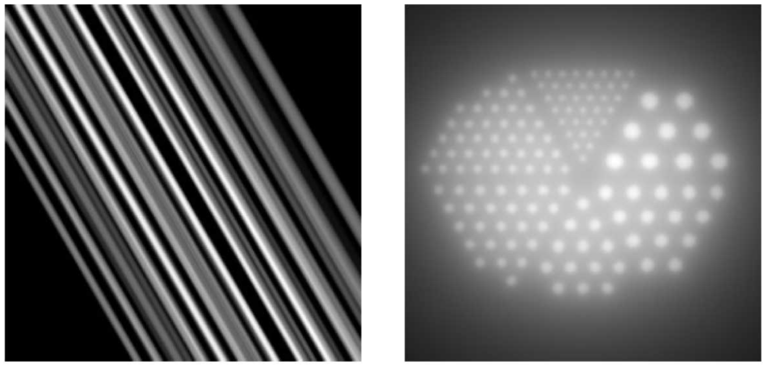
C. To use the Radon transform in CT, we make the assumption that all x-ray photons have an average energy $\overline{E}$, so we can make μ depend solely on location.

D. Assuming a homogeneous slab and a beam of monoenergetic photons perpendicular to the slab, we have a total attenuation of $e^{-\mu \Delta x}$ through a slab Δx thick.

E. Attenuations along the path of the x-ray beam are combined by multiplication, since they each represent a certain percentage (per unit length) of photons removed from the beam.

Explanation: Variation in attenuation coefficient μ between tissue types accounts for the contrast between tissues in an x-ray.
[*imaging0469.mcq*]

28. Which of the following statements about the following figures is *false* (or all are true)?



A. All are true.

B. The figure on the left is the back projection from a particular projection, representing the fact that one projection alone does not include information about where along the projection line the attenuation occurs.

C. The figure on the right is the summation of many back projections.

D. The figure on the right demonstrates a loss of high-frequency information.

E. The figure on the right demonstrates the presence of a DC (average) value that is not in the original image.

Explanation: Both D and E are true, leading to the use of filtering before backprojection.
[*imaging0412.mcq*]

29. Which of the following statements about the following equation is *true* (or none is true)?

$$I(x, y) = \int_0^{E_{\max}} S_0(E')E' \exp\left\{-\int_0^{r(x,y)} \mu(s; E', x, y)ds\right\} dE'$$

where $r(x,y)$ is the length of the path,
$S_0(E)$ is spectrum of the incident x-rays,
s is the distance from the x-ray source along the path
and $I(x,y)$ is the intensity of x-rays remaining.

A. It represents attenuation of a polyenergetic x-ray source by a non-homogeneous structure.

B. It represents attenuation of a monoenergetic x-ray source by a non-homogeneous structure.

C. It represents attenuation of a polyenergetic x-ray source by a homogeneous structure.

D. It represents attenuation of a monoenergetic x-ray source by a homogeneous structure.

E. None of the others is true.

Explanation: The equation includes a double integration, one over the x-ray spectrum and one along the individual paths through a non-homogeneous structure.
[*imaging0411.mcq*]

30. Which one of the following statements is true about projection radiography?

I - Attenuation of x-rays within the body is the primary phenomenon resulting in image contrast.
II - Practical radiography depends upon *fluorescence* to produce light photons from x-ray photons.
III - Collimating grids reduce the number of Compton scattered photons reaching the detector and thus increase image contrast.

A. I, II and III

B. I and III

C. II and III

D. I and II

E. III

Explanation: All are true.
[*imaging0410.mcq*]

31. The following are true about fluoroscopy *except* (or all are true)

A. Because the patient is moving, the dosage from fluoroscopy is generally less than that of the stationary radiograph.

B. The front of the fluoroscope tube uses an input phosphor to convert x-rays to light photons, which hit a photocathode generating electrons within the tube.

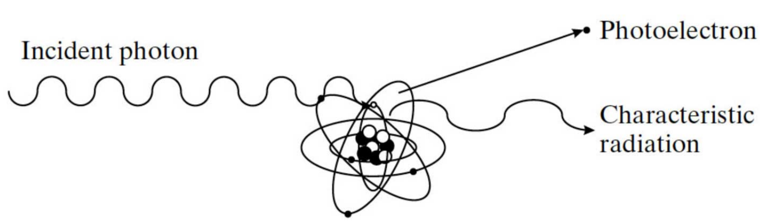
C. Electrons are accelerated by electrostatic lenses and focused at the anode on an output phosphor.

D. Fluoroscopy permits rapidly moving X-ray images.

E. All are true

Explanation: Because of the duration of the scan, fluoroscopy entails relatively high doses of radiation to the patient, and may even pose a risk to the clinician using it to guide procedures in real time.
[*imaging0512.mcq*]

32. The following figure from the text represents which of the following?



A. Photoelectric effect.

B. Compton scatter.

C. Collision transfer.

D. Bremsstrahlung radiation.

E. None of the others.

Explanation: Answers C and D involve bombardment by electrons, not photons. Answer B produces a scattered "Compton" photon.
[*imaging0409.mcq*]

33. Which of the following statements about the Projection Slice Theorem is *false* (or all are true)?

A. It applies only to projections onto the x or y axes.

B. It states that the 1-D Fourier transform of the projection through a 2-D image is a line through the origin of the 2-D Fourier transform of that image orthogonal to the direction of the projection.

C. All are true.

D. It relies on the fact that rotating a 2-D image corresponds to rotating its 2-D Fourier transform.

E. It allows us to perform image reconstruction using filtered backprojection in the frequency domain.

Explanation: Because of answer D, answer A is false. Projections in any direction result in what is stated in answer B.
[*imaging0408.mcq*]

34. The following are all true about tomographic images, *except*

A. Examples of tomographic image modalities includes fluoroscopy and CT.

B. They can be coronal, sagittal, or axial.

C. Each pixel represents a localized sample in space.

D. They are called 'tomographic' because *tomos* is Greek for 'slice'.

E. 2D tomographic images may be subsets of 3D tomographic images.

Explanation: Fluoroscopy is a projection imaging modality.
[*imaging0388.mcq*]

35. Given that relativistic mass $m = \frac{m_0}{\sqrt{1-v^2/c^2}}$, where m_0 is the resting mass, v is the velocity, and c is the speed of light, the following are true about relativistic and Newtonian physics *except*, or all are true.

A. All are true.

B. Relativistic mass equals Newtonian mass when velocity equals 0.

C. Relativistic mass approaches infinity as velocity approaches the speed of light.

D. Kinetic energy in the Newtonian system, $\frac{1}{2}mv^2$, can be derived from $E = mc^2$ when $v << c$.

E. It is impossible to accelerate a particle with mass past the speed of light because the relativistic mass approaches infinity.

Explanation: All are true.
[*imaging0513.mcq*]

36. The following are true of Filtered Back Projection *except* (or all are true)

A. All are true

B. The Back Projection part is simply the concept that each projection predicts the presence of contributions somewhere along each line of projection, and that these will tend to add up over different projections where the actual contributions are.

C. Its application is based on the inverse Radon transform and the fact that the 1D Fourier transform of a projection through a 2D image is a line through the origin of the 2D Fourier transform of that image.

D. Filtering is used to boost high frequencies, in effect, to fill in under-sampled areas in the Fourier transform of the tomographic image.

E. It can be accomplished either by multiplication in the frequency domain or convolution in the spatial domain.

Explanation: All are true
[*imaging0336.mcq*]

37. Which of the following is (are) true? In the atom, the binding energy for an electron

I - is specific to a given element, shell, and quantum state.
II - generally increases with increasing shell number.
III - generally decreases with lower atomic number.

A. I and III

B. II and III

C. I and II

D. I, II, and III

E. I

Explanation: Binding energy generally *decreases* with increasing shell number (further from the nucleus) because it takes less energy to remove them from the atom.
[*imaging0334.mcq*]

38. The following are true about CT numbers (Hounsfield units) *except*

A. They permit interpretation of tissue attenuation at a single location in the patient from a single planar X-ray scan (projection radiograph).

B. They are used to compensate for the fact that the effective energy $\bar{E}$ of the X-ray photons varies from scanner to scanner.

C. They are based on measured values for the linear attenuation coefficient for water.

D. They yield standard values for tissue types such as -1000 HU for air, 0 HU for water, 3000 for bone, etc., that vary by only about ± 2 HU between scans and across scanners.

E. They account for the fact that CT, compared to most other imaging modalities, is very quantitative in the physical meaning of pixel intensity.

Explanation: Local tissue attenuation cannot be retrieved from a single projection radiograph, since each pixel in the image represent the total attenuation along a projected line through the patient.
[*imaging0327.mcq*]