BioE 1330 - Exam 3 12/6/2018
Answer Sheet - Correct answer is A for all questions

1. A coronal slice

A. is parallel to the front of the body.

B. is parallel to the top of the head.

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

D. divides the body into two roughly symmetrical halves.

E. can be at any orientation relative to the patient.

Explanation: The coronal plane parallel to the front of the body, like the corona behind the Christ figure's head in many medieval paintings.
[*imaging0059.mcq*]

2. The following are true about complex exponentials (expressions of the form $e^{j\theta}$) *except*

A. They cannot represent a purely real number.

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

C. The represent a complex number on the unit circle in the complex plain centered on the origin.

D. They are central to Euler's identity.

E. They are used to represent sinusoids in a format that is amenable to algebraic manipulation.

Explanation: e^{j0} is a real number.
[*imaging0064.mcq*]

3. 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*]

4. Bremsstrahlung describes a process in which

A. an electron beam is used to create high energy photons.

B. high energy photons are used to create photoelectrons.

C. high energy photons interact with outer shell electrons.

D. energy is released through nuclear decay.

E. electrons created in the x-ray tube interact directly with atoms in the patient.

Explanation: Electrons are accelerated in the x-ray tube to hit a target in the tube, creating x-ray photons that interact with atoms in the patient.
[*imaging0093.mcq*]

5. The following are true of Filtered Back Projection *except*

A. It is used to maximize resolution in Planar Radiography.

B. It constitutes a process for creating a tomographic image from a series of projections.

C. It is based on the inverse Radon transform and the fact that the Fourier transform of a projection through a 2D image is a line through the origin of the 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: Planar Radiography does not rely on Filtered Back Projection.
[*imaging0096.mcq*]

6. Which one of the following statements is *false*?

A. Compton scattering, which changes the path of photons in the body rendering them useless in image formation, is particularly a problem at low x-ray energies.

B. The probability of the photoelectric effect increases non-linearly with increasing effective atomic number of the material through which the radiation passes.

C. Ionization is the ejection of an orbiting electron from an atom; ionizing radiation has sufficient energy to produce ionization.

D. A "K-edge" occurs in the energy spectrum of photons at the binding energies of inner shell electrons, because above these energies many electrons become available and the probability of the photoelectric effect rises sharply.

E. The electron beam in an x-ray tube transfers energy to the target via collisional transfer (generating heat) and radiative transfer (generating characteristic radiation and bremsstrahlung radiation).

Explanation: Compton scattering is particularly a problem at *high* x-ray energies.
[*imaging0102.mcq*]

7. Which of the following statements about the generation of x-rays is *false*?

A. The majority of energy produced within an x-ray tube is in the form of high-energy (x-ray) photons.

B. Lower frequency x-rays, which are not as useful for imaging purposes due to their poor penetration, are filtered out by metal in the tube itself.

C. In an x-ray tube, electric fields are used to accelerate electrons from the cathode to the anode, where x-rays are produced upon collision with the dense metal anode.

D. The target anode may spin to avoid heat buildup due to a tightly focused electron beam required for a high resolution x-ray image.

E. X-rays were first discovered in 1895, by a German physicist, Wilhelm Roentgen.

Explanation: The majority of energy produced within an x-ray tube is in the form of heat. The other statements are all true.
[*imaging0247.mcq*]

8. Decreasing the accelerating voltage (kVp) in the X-ray tube would cause all of the following *except*

A. Keep the energy of the average photons the same but reduce the number of photons.

B. Reduced number of high-energy photons.

C. Decrease the radiation dose to the patient.

D. Decreased energy of the highest energy photons in the X-ray the beam.

E. Make characteristic radiation lines disappear as the accelerating voltage fell below the energy of the particular characteristic radiation line.

Explanation: Decreasing the kVp of the X-ray machine would reduce the average energy of the photons. Answer A describes what happens when the tube current is reduced.
[*imaging0254.mcq*]

9. The following are true about positron emitters, *except*

A. They tend to be isotopes with too many neutrons.

B. They include atoms found in normal organic molecules.

C. Their decay leads to the creation of two 511 keV gamma photons.

D. Their decay leads to the creation of antimatter.

E. They are particularly useful in imaging brain function.

Explanation: They have too few neutrons, and so "want" to turn a proton into a neutron but giving off a positron.
[*imaging0051.mcq*]

10. *Unlike* in x-ray based imaging modalities, in nuclear medicine

A. orienting the patient with the desired organ near the detector reduces total attenuation in the intervening tissue.

B. to get more signal we can increase dose.

C. we can increase detector efficiency by making it thicker, but this reduces resolution.

D. high energy photons are used to image.

E. tomographic slices may be reconstructed.

Explanation: Since the gamma photons in nuclear medicine originate within the body, the amount of attenuation depends on the distance between the organ and the detector.
[*imaging0052.mcq*]

11. Metastable technetium, or Tc-99m, has some desirable properties for a radiotracer, including which of the following?

I. Its decay yields beta particles which are harmless.
II. Its decay yields high-energy photons with known energy, allowing for specific detection.
III. It is distributed in the body in a physiologically meaningful way, yielding useful diagnostic information.

A. II and III

B. I, II, and III

C. I and II

D. I and III

E. III only

Explanation: Tc-99m exhibits isomeric transition, which does not involve emission of a beta particle. Beta is too destructive for medical imaging. The other statements are true.
[*imaging0118.mcq*]

12. Which of the following statements is *false* about Anger cameras?

A. Multiple photomultiplier tubes, one for each pixel in the image, are arranged in a grid behind a large crystal.

B. Lead septa are required to generate a projection image

C. Each gamma particle produces a scintillation consisting of many light photons.

D. The contribution from Compton scattering to the image is reduced by analyzing the pulse height of the combined responses of the photomultiplier tubes to each detected gamma particle.

E. Gating acquisition to the electrocardiogram reduces motion artifact from cardiac motion.

Explanation: Multiple photomultiplier tubes are indeed used, but not one for each pixel. Rather, they act in concert to determine the actual location of the gamma particle with a spatial resolution greater than that of the tubes.
[*imaging0264.mcq*]

13. Which of the following is (are) *true* about *mass defect*?

I. It is the difference between the sum of the masses of the isolated protons, neutrons, and electrons of an atom and the actual mass of the atom.
II. It is translated via $E = mc^2$ into the binding energy holding the atom together, which may also be expressed in MeV.
III. It is expressed in unified atomic mass units (u), where 12 u = the mass of Carbon-12

A. I, II, and III.

B. I and II.

C. I and III.

D. II and III.

E. Only I.

Explanation: All are true.
[*imaging0268.mcq*]

14. The following are true about the waves used in clinical ultrasound imaging, *except*

A. Their absorption coefficient in biological tissue is largely independent of wavelength.

B. Velocity in soft tissue (not air or bone) is fairly constant at around 1540 meters/second ($< \pm 10\%$).

C. They are primarily compression rather than shear waves.

D. Distance to a target is determined by time of flight.

E. They are used primarily to detect changes in acoustic impedance.

Explanation: Absorption in biological tissue is roughly proportional to frequency and thus inversely proportional to wavelength, given that velocity (in soft tissue) is fairly constant at around 1540 meters/second.
[*imaging0125.mcq*]

15. Which of the following statements is *false* about resolution in ultrasound?

A. Lateral resolution generally increases (gets better) with increasing range.

B. Resolution increases (gets better) with increasing frequency.

C. Resolution is manifested by a "resolution cell" within which many actual reflectors create a total reflection of variable brightness, accounting for speckle.

D. Resolution in the range direction generally stays constant with increasing range.

E. Resolution in the range direction is limited by the duration of the envelope of the transmitted pulse.

Explanation: Lateral resolution generally *decreases* (gets worse) with increasing range.
[*imaging0129.mcq*]

16. Huygen's principle is best stated as

A. A wavefront may be interpreted as a collection of the centers of spherically propagating waves that interfere with each other.

B. The amplitude of a spherically propagating wave must be equal in all directions.

C. A spherical wave can propagate in an outward or inward direction

D. Interference patterns are best approximated by assuming a constant speed of wave propagation throughout the space.

E. The imaginary component of a complex exponential is not linear.

Explanation: B, D, and E are not true. C is true, but not Huygen's principle, which generally assume outward propagation.
[*imaging0347.mcq*]

17. The following are true about *speckle* ultrasound imaging, *except* (or all are true)

A. It results from multiple Doppler shifts from individual targets (such as red blood cells) moving in different directions.

B. It arises due to multiple scatterers within a single resolution cell.

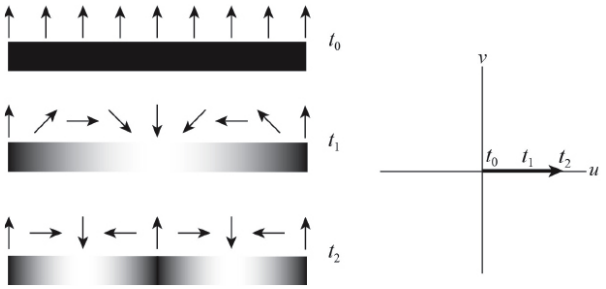
C. It results in a pseudorandom pattern of intensity variation.

D. It moves with tissue and can be used to track that motion.

E. All are true.

Explanation: Answer A is false. This describes continuous wave (CW) Doppler used to hear a fetal heart.
[*imaging0461.mcq*]

18. The figures below shows a fundamental concept in MR imaging. The figure on the left shows the magnetization in the transverse plane, $\mathbf{M}_{x',y'}$ (in the rotating frame of reference), as a function of location along the x-axis, at 3 successive points in time during the application of a gradient G_x. The following statements are true *except* (or all are true)



A. All are true.

B. The figure on the left shows the spatial frequency of the relative phases of $\mathbf{M}_{x',y'}$ increasing in time.

C. The figure on the right shows the location in k space indicating higher spatial frequency at successive times.

D. If all of k space can be traversed, then the MR image can be reconstructed by taking an inverse 2D Fourier transform (some additional filtering may be required depending on how k space is traversed).

E. The v axis of k space, although representing the imaginary coefficient of a complex number, represents spatial frequency along a real dimension in space, namely y.

Explanation: All are true.
[*imaging0527.mcq*]

19. Which of the following statements about the rotating frame of reference in MRI is *false* (or all are true)?

A. It rotates so that the imaginary axis of the transverse plane is always kept aligned with the real axis, negating the effect of T2* relaxation.

B. It causes de-phasing due to T2 relaxation to appear as separation around a stationary vector in the transverse plane.

C. All are true.

D. It spins at the Larmor frequency for B_0, such that changes in B_0 generated by the gradient fields cause the moments to spin either forwards or backwards relative to the rotating frame.

E. It turns the path along which the RF field (B_1) generates a tip angle α from a spiral into a simple rotation from the longitudinal axis to the transverse plane.

Explanation: Answer A is nonsense.
[*imaging0528.mcq*]

20. A sample is in equilibrium, and a $\pi/2$ pulse is applied. What is the longitudinal magnetization of the sample, as developed in the text?

A. $M_z(t) = M_0(1 - e^{-t/T_1})$

B. $M_z(t) = M_0(1 - e^{-t/T_2})$

C. $M_z(t) = M_0(e^{-t/T_1})$

D. $M_z(t) = 0$

E. $M_z(t) = M_0$

Explanation: The longitudinal magnetization rebuilds from 0 approaching M_0 as a first order exponential with time constant T_1. Since it is a $\pi/2$ pulse, there is initially no longitudinal magnetization (it has all be tipped into the transverse plane).

Alternate acceptable answer: D

Errata: Answer D is correct if only t=0 is considered.
[*imaging0136.mcq*]

21. Which of the following statements about MRI contrast mechanisms is *false* (or all are true)?

A. T_1 and T_2 are among the parameters that are set in order to measure tissue characteristics T_R and T_E.

B. All are true.

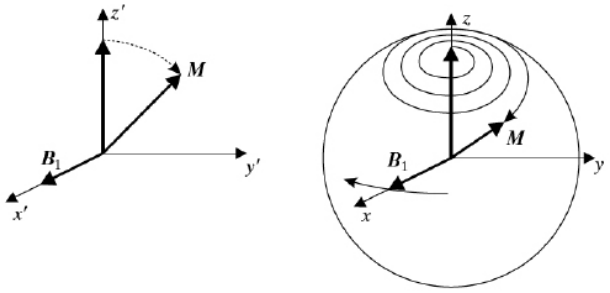
C. In proton density-weighted images, signals must be acquired quickly after the RF pulse, before the signal has a chance to decay from T_2 effects, and the image intensity is roughly proportional to the number of hydrogen nuclei in the sample.

D. T_R is the time between RF excitations and T_E is the time between an excitation and the formation of an echo; T_R is generally greater than T_E.

E. In T_1-weighted images, differences in rate of reformation of the longitudinal component of magnetization are emphasized, as compared with T_2-weighted images, in which differences in the de-phasing rates of the transverse magnetization are differentiated.

Explanation: MRI involves the measurement of the inherent tissue characteristics, T_1 and T_2 . The parameters that are set for each image include T_R, T_E and the tip angle α
[*imaging0358.mcq*]

22. The figure below shows a fundamental concept in MR imaging. Regarding this concept, the following statements are true *except* (or all are true)



A. All are true.

B. B_1 is the magnetic field created by the RF coils to tip the longitudinal magnetization into the transverse plane.

C. The figure on the right is in the stationary coordinate system (x, y, z), whereas the figure on the left is in the rotating frame of reference (x', y', z').

D. After the application of B_1, the angle between the z' axis and the vector **M** is known as the "tip angle".

E. B_1 rotates around the z axis at the Larmor frequency corresponding to B_0, so that it is always orthogonal to the (y', z') plane.

Explanation:
[*imaging0485.mcq*]

23. Which of the following is *false* about the physics of Magnetic Resonance?

A. Starting at equilibrium in a static magnetic field $\boldsymbol{B}_0$ along the z-axis, a 45° pulse will tip the magnetization vector M into such a state that there is no longitudinal magnetization immediately after the pulse.

B. Starting at equilibrium in a static magnetic field $\boldsymbol{B}_0$ along the z-axis, a 180° pulse rotates vector M to the negative z-axis.

C. If at $t = 0$ the magnetization vector $\boldsymbol{M}(t)$ is oriented at an angle $\alpha \neq 0°$ and $\alpha \neq 180°$ relative to the z-axis, a static magnetic field $\boldsymbol{B}_0$ along the z-axis will cause a precession of vector $\boldsymbol{M}(t)$ around $\boldsymbol{B}_0$.

D. Nuclei with odd atomic number or odd mass number are capable of having a non-zero angular momentum.

E. The Bloch equation puts together both the *forced* and *relaxation* behavior of a magnetic spin system into a single differential equation.

Explanation: Only a 90° pulse will accomplish this.
[*imaging0448.mcq*]

24. A uniform magnetic field $\mathbf{B}_0$ in z direction is applied to a sample. Which of the following is TRUE when a x-gradient is also applied?

I - The magnetic field is tipped slightly from the z direction to the x direction.
II - The strength of the field is no longer uniform.
III - At points with different x-coordinates, the Larmor frequency is different because of the x-gradient.

A. II and III

B. I and II

C. I and III

D. I, II, and III

E. II

Explanation: The gradient is in the scalar strength, not the direction of the magnetic field.
[*imaging0301.mcq*]

25. The following are true about Spin Echoes *except* (or all are true).

A. They reverse the dephasing so that T_2 has no effect on the intensity of the recovered echo.

B. They are accomplished using a 180° (π) RF pulse, which flips each magnetization vector to the other side of the transverse plane.

C. They cause those magnetization vectors that have precessed faster and gotten ahead to move to the "back of the pack" where they will still be precessing faster .

D. They are used to cancel the effect of field inhomogeneity, which causes some protons to have different Larmor frequencies than others due to their location in the magnet.

E. All are true.

Explanation: Spin echoes flip the magnetization vectors over so that the leading ones are now behind and will catch up. They cancel the effects of field inhomogeneity, which accounts for $T_2{}^*$, leaving the desired tissue-dependent T_2 due to spin-spin relaxation.
[*imaging0302.mcq*]

26. Which of the following are legitimate methods of accomplishing Magnetic Resonance Angiography (MRA), to image blood flow?

I - Introduction of a contrast agent (gadolinium) into the vasculature to reduce the T1 or T2 relaxation time of protons located nearby.
II - Detecting of blood flow using Doppler shift in the Larmor frequency.
III - Saturating the magnetization in a slice, so that only fresh blood entering from outside the slice gives off signal; this requires no contrast agent.

A. I and III

B. I, II, and III

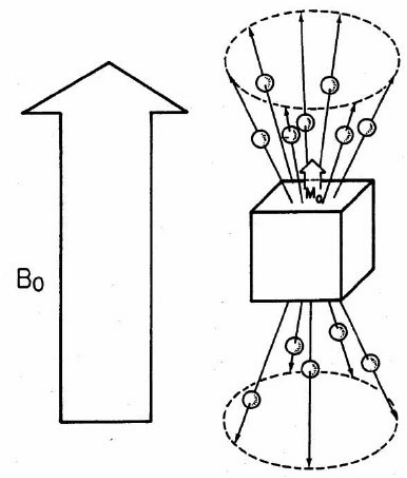
C. I and II

D. II and III

E. only I.

Explanation: III is not true. Doppler shift is used in ultrasound, but not in MRI.
[*imaging0435.mcq*]

27. The figure below shows a fundamental concept in MR imaging. The following statements are true *except* (or all are true).



A. All are true.

B. The net magnetization at rest $\mathbf{M}_0$ within a voxel is aligned with the magnetic field $\mathbf{B}_0$ produced by the superconducting magnet.

C. Quantum mechanics restricts individual protons to one of two states, precessing at a certain angle either with or against $\mathbf{B}_0$.

D. A larger voxel will yield a larger value for $\mathbf{M}_0$.

E. $\mathbf{M}_0$ is also called "longitudinal magnetization", and the time it takes to form is called "T1".

Explanation:
[*imaging0489.mcq*]

28. How does slice selection in MRI take place?

A. via application of a magnetic gradient such that only the slice of interest has Larmor frequencies within the spectrum of the RF pulse.

B. via tipping of the $\mathbf{B}_0$ magnetic field into the plane of the slice of interest

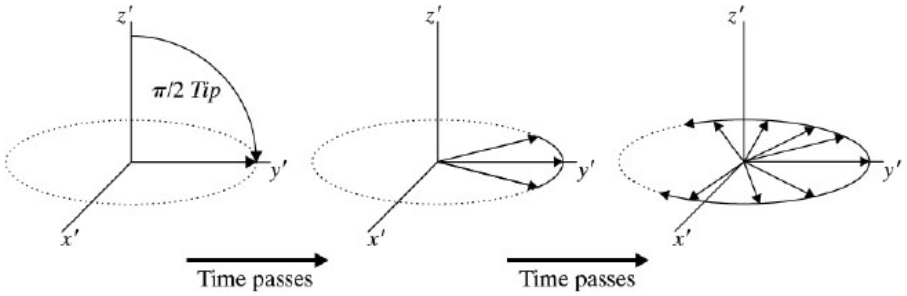
C. via application of the RF pulse only within the slice of interest.

D. via elimination of the $\mathbf{B}_0$ magnetic field everywhere except within the slice of interest

E. via application of a 180° RF pulse

Explanation: Slice selection occurs by controlling the strength generally of the z-gradient of the magnetic field $\mathbf{B}_0$ (but not changing its direction) and by controlling the frequency of the RF pulses. The other choices do not make any sense or are incorrect.
[*imaging0434.mcq*]

29. The figure below shows a fundamental concept in MR imaging. The following statements are true *except* (or all are true).



A. The rate at which the components de-phase is a function solely of the local chemical environment, and is not effected by $\mathbf{B}_0$ field inhomogeneity.

B. $\pi/2$ is the tip angle that yields the greatest signal from the transverse magnetization.

C. The figures are shown in the reference frame (x', y', z'), known as the "rotating frame of reference", such that faster or slower precessing components are seen to move correspondingly forward or backwards relative to a stationary component.

D. T2-weighted images are primarily dependent upon this mechanism to generate contrast between tissues.

E. All are true.

Explanation: The rate at which the components de-phase is a function of the local chemical environment, but is also affected by $\mathbf{B}_0$ field inhomogeneity, which changes the Larmor frequency depending on location.
[*imaging0490.mcq*]

30. Which of the following is *false* about readout gradient (or all are true)?

A. It is applied during the 90° RF pulse.

B. It is applied during the acquisition of the RF signal.

C. It causes the Larmor frequency to vary across the slice, producing a spectrum of frequencies.

D. It permits localization by using the Fourier Transform.

E. All are true.

Explanation: The "write" gradient, not the readout gradient, is applied during the 90 ° RF pulse.
[*imaging0432.mcq*]

31. Which of the following is *false* about k-space (or all are true)?

A. All are true.

B. The term arises from the convention in physics where wave number k represents a spatial frequency.

C. If we can cover all of k-space, we can recover the image of the corresponding slice.

D. It can be covered rectilinearly using phase encoding, in which case an inverse Fourier transform can recover the image.

E. It can be covered in a polar fashion by using a series of read gradients with different x and y components, in which case filtered back projection is required to "fill in" the high frequencies.

Explanation: All are true.
[*imaging0369.mcq*]

32. The equation

$\frac{d\mathbf{M}(t)}{dt} = \gamma \mathbf{M}(t) \times \mathbf{B}(t)$

predicts which of the following phenomena?

A. Precession.

B. Relaxation according to T1.

C. Formation of longitudinal magnetization.

D. Temperature dependance of MR signal strength.

E. None of the others is correct.

Explanation: Precession results from a force orthogonal to both **M** and **B**, provided the angle between them is not zero.
[*imaging0492.mcq*]

33. Which of the following is true about the Larmor frequency (or none is true)?

A. It is dependent both on the local magnetic field (to which it is proportional) as well as the particular atomic number, atomic mass, and chemical environment of the atom (which determine the proportionality, the gyromagnetic ratio).

B. It is dependent only on the atomic number and mass of the particular element but not on the chemical environment that atom.

C. It decreases with increasing magnetic field.

D. It is dependent on magnetic field but independent of the particular atomic number and atomic mass (for example, ^{1}H vs. ^{13}C)

E. None is true.

Explanation: B is wrong because of chemical shift. The whole use of NMR in chemistry depends upon this variation with chemical environment.
[*imaging0362.mcq*]

34. Which one of the following statements is true? The two medical imaging techniques, CT (Computed Tomography) and MRI (Magnetic Resonance Imaging), are complimentary because

A. CT differentiates tissue by attenuation of photons whereas MRI differentiates tissue by the amounts of transverse magnetization.

B. CT differentiates soft tissue whereas MRI does not.

C. None of the other statements is true.

D. MRI is a tomographic modality whereas CT is not.

E. CT involves risk from ionizing radiation, whereas MRI is completely safe for all patients.

Explanation: MRI is not completely safe for patients with pacemakers, embedded metal, etc.
[*imaging0493.mcq*]

35. Which one of the following statements is *false* about MRI (or all are true)?

A. All are true.

B. The Larmor frequency of hydrogen varies slightly for different chemical environments such as fat and water, accounting for the *chemcial shift artifact*.

C. The observed signal in MRI is an RF signal produced by the rapidly rotating transverse magnetization.

D. Manipulation of the gradient coils can produce frequency or phase encoding of location.

E. The protons in hydrogen accounts for almost all clinical MRI imaging.

Explanation: All are true.
[*imaging0360.mcq*]

36. The following are true about *mathematical morphology*, *except*

A. It operates only on binary images, consisting of 1's and 0's.

B. It is based on two fundamental operations, *erosion* and *dilation*.

C. It includes two secondary operations, *opening* and *closing*.

D. Its operations depend upon the definiton of a *structuring element*, whose shape can vary depending on the desired effect.

E. It is particularly useful for eliminating small objects and filling in holes in objects.

Explanation: It can operate either on binary or grayscale images.
[*imaging0524.mcq*]

37. The following are true about *quaternions*, *except* (or all are true)

A. All are true.

B. They are the 3D equivalent of phasors in 2D.

C. They consist of one real and 3 mutually orthogonal imaginary axes.

D. They are used to represent orientation in 3D.

E. They can be multiplied by each other, effecting rotation from any of the x, y, or z axes to any of the other axes.

Explanation: All are true.
[*imaging0525.mcq*]

38. The following are true about *lenses* in optical imaging, *except*

A. Although a prism is capable of breaking white light into its constituent colors through the phenomenon of *dispersion*, lenses do not exhibit this phenomenon, and focus all colors identically.

B. They create standing waves according to Huygen's principle.

C. They slow down the speed of light along a particular ray, introducing a delay proportional to the thickness of the glass along that particular ray.

D. When looking through a concave lens, a virtual image may be observed, from which photons appear to be emanating.

E. The resolution of what can be seen through a lens is limited by the wave nature of light.

Explanation: Lenses *do* exhibit dispersion, which is one the optical aberrations that all lenses suffer from.
[*imaging0526.mcq*]