BioE 1330 - Review Chapters 12 and 13 (MRI) 1/17/2011

Instructions: On the Answer Sheet, enter your 2-digit ID number (with a leading 0 if needed) in the boxes of the ID section. *Fill in the corresponding numbered circles.* Answer each of the numbered questions by filling in the corresponding circles in the numbered question section. Print your name in the space at the bottom of the answer sheet. Sign here stating that you have neither given nor received help.

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

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

B. $M_z(t) = 0$

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

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

E. $M_z(t) = M_0$

2. An RF excitation of 2×10^{-6} Tesla = 0.2 gauss is applied to a sample of protons (γ =42.58 MHz/Tesla) over 3 ms, what is the angle in radians that M is tipped?

A. $\alpha = \pi/2$

B. $\alpha = (42.58)(2 \times 10^{-6})(3 \times 10^{-3})$

C. $\alpha = (42.58)(0.2)(3 \times 10^{-3})$

D. Cannot be determined.

E. $\alpha = 2\pi(42.58)(2 \times 10^{-6})(3 \times 10^{-3})$

3. What is the bandwidth (kHz) of the RF waveform needed to select a slice that is 2 mm thick, given $G_z = 1$ guass/mm and $\gamma = 4.258$ kHz/guass.

A. 4.258 kHz

B. Not enough information given

C. 85.16 kHz

D. 42.58 kHz

E. 8.516 kHz

4. For T_2 -weighted contrast images (maximizing differences in transverse relaxation times) the following is true:

A. T_E should be extremely long.

B. T_E should be in the middle of the range for T_2 values.

C. Echoes should not be used.

D. T_E should be as short as possible.

E. Any T_E duration can be used so long as T_R is short.

5. BOLD fMRI utilizes the following principle:

A. None of the choices.

B. $T2^*$ is decreased by the presence of oxygenated hemoglobin.

C. All of the choices.

D. Water diffuses more quickly along axons.

E. Neuronal activity results in increased blood flow.

6. A large magnetic field $\mathbf{B}_0$ in the z direction is applied to a sample in a clinical MRI scanner. Which of the following is *false* when the x-gradient field is applied?

A. At points with different x-coordinates, the total magnetic field has different magnitudes.

B. The gradient field rotates the orientation of the magnetic field towards the x direction.

C. The gradient field is much smaller in magnitude than $\mathbf{B}_0$.

D. All of the other statements are true

E. $\mathbf{B}_0$ is made extremely uniform so that as much of any non-uniformity as possible is due to the gradient field and not to inhomogeneity in $\mathbf{B}_0$.

7. Which one of the following statements is *false* about MRI?

A. The RF coils or resonators receive the MR signals, and may be large (e.g., a body coil) or small (e.g., a surface coil).

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

C. Although hydrogen accounts for almost all clinical MRI imaging, protons in any atom can be used to image with MRI.

D. The Larmor frequency of hydrogen, which relates the rate of precession of the magnetization vector of a sample to the local magnetic field, varies slightly for different chemical environments such as fat and water, accounting for the *chemcial shift artifact*.

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

8. How does slice selection in MRI take place?

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

B. via manipulation of the magnetic attenuation factor of the tissues

C. via application of a linear magnetic gradient, which limits interaction of the RF to hydrogen with appropriate Larmor frequencies.

D. via external placement of ferromagnetic guides, usually along the z-direction, to direct the detection circuitry

E. via phase encoding to shift the phase such that only hydrogen within the slice is energized

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

A. 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.

B. In T_2-weighted images, fluid appears very bright, because transverse magnetization de-phases relatively slowly in free water.

C. T_E and T_R are among the parameters that are set in order to obtain T_1- and T_2-weighted images.

D. 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.

E. All are true.

10. Which of the following statements about transverse relaxation is *false*?

A. The measured relaxation time T_2^* is longer than the tissue-dependent time constant T_2, because it also contains a term due to field inhomogeneity, $T_2{}'$.

B. Transverse relaxation time T_2 tends to be much shorter than longitudinal relaxation time T_1.

C. The use of a 180° (π) pulse cancels de-phasing due to field inhomogeneity.

D. Transverse relaxation is due to the transfer of magnetization from the transverse (x-y) plane to the longitudinal (z) direction.

E. Transverse relaxation is modeled as an exponential decay.

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

A. It causes $\mathbf{B}_0$ to spin in the transverse plane generating an RF signal.

B. It is modeled as a phasor spinning in the complex plane.

C. It occurs in the transverse plane.

D. All are true.

E. It turns the path along which the RF field generates a tip angle α from a spiral into a simple rotation.

12. Which of the following statements about Diffusion Tensor Imaging (DTI) with MRI is (are) *true*?

I - Water diffuses more quickly along white matter tracts, and DTI measures this diffusion, as well as its direction.
II - It uses a pair of strong gradient pulses, the first to de-phase the spins, and the second to re-phase the spins. If no net movement occurs, these cancel. If movement (diffusion) occurs they do not cancel.
III - Neuronal activity causes greater diffusion of the water within the axons and can thus be detected.

A. I and III

B. II and III

C. only I.

D. I, II, and III

E. I and II

13. Which of the following statements about Magnetic Resonance Spectroscopy (MRS) with MRI is (are) *true*?

I - It displays the proton spectrum for a region of the MRI scan, allowing differentiation of hydrogen atoms by their local biochemical environment.
II - It essentially makes use of the Chemical Shift Artifact, which normally is considered a problem in MRI.
III - Its resolution is much lower (worse) than regular anatomical MRI.

A. only I.

B. I and II

C. II and III

D. I, II, and III

E. I and III

14. 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 - Saturating the magnetization in a slice, so that only fresh blood entering from outside the slice gives off signal; this requires no contrast agent.
III - Detecting the Doppler shift in the RF signal given off by blood that is moving; this requires no contrast agent.

A. II and III

B. I and III

C. only I.

D. I and II

E. I, II, and III

15. The following are true about Phase Encoding *except* (or all are true).

A. Phase encoding permits selective activation of a particular slice in the patient by restricting interaction between the RF field and the Larmor frequency of particular protons.

B. All are true.

C. It is generally used to establish coordinates in the third dimension (y), after slice selection and frequency encoding have established coordinates in the other two dimensions (z and x, respectively).

D. It typically results in a rectilinear traversal of k-space, permitting direct application of the inverse Fourier transform.

E. It is accomplished by activating a phase-encode gradient for a certain amount of time to add a "twist" proportional to distance along the phase-encode dimension. A series of these are collected each with a different amount of phase-encode gradient.

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

A. 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.

B. All are true.

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

D. They cause those magnetization vectors that have precessed faster and gotten ahead to move to the "back of the pack" where they will eventually catch up with the others to form an echo.

E. They do not cancel all differences between protons, and some dephasing still occurs due to tissue-dependent spin-spin relaxation.

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

A. It decreases with increasing magnetic field.

B. It is dependent on magnetic field but independent of the particular substance (for example, ^{1}H vs. ^{13}C)

C. It is the frequency of precession of the magnetization vector, which is related to the local magnetic field by the gyromagnetic ratio.

D. It is the so-called "frequency of love" of popular lore.

E. None is true.

18. The Bloch Equations, which describe the time course of the magnetization vector $\mathbf{M}(t)$,

$$\frac{d\mathbf{M}(t)}{dt} = \gamma \mathbf{M}(t) \times \mathbf{B}(t) - \mathrm{R}\{\mathbf{M}(t) - \mathbf{M}_0\}$$

where $\mathbf{B}(t) = \mathbf{B}_0 + \mathbf{B}_1(t)$ is composed of the static and RF fields, and where the matrix R is

$$\begin{pmatrix} \frac{1}{T_2} & 0 & 0 \\ 0 & \frac{1}{T_2} & 0 \\ 0 & 0 & \frac{1}{T_1} \end{pmatrix}$$

define the behavior of which of the following?

I - Tipping the longitudinal magnetization into the transverse plane.
II - Longitudinal relaxation.
III - Transverse relaxation.

A. only I.

B. II and III

C. I and II

D. I and III

E. I, II, and III

19. The following are (is) true about Proton Density weighted images:

I - A long T_R is used to allow tissues to be at equilibrium (largest possible longitudinal magnetization vector available to flip).
II - A long T_E is used to avoid signal loss due to dephasing.
III - Proton Density weighted images offer the highest signal-to-noise.

A. I, II, and III

B. I and II

C. II and III

D. I and III

E. only I.

20. Which of the following statements about MR and CT is false?

A. MRI is more expensive than CT.

B. MRI is better for imaging bones, while CT is better for imaging soft tissues.

C. MRI does not expose the patient to ionizing radiation, while CT does.

D. MR images can be acquired in any plane, while CT images are typically acquired only in the axial plane.

E. MRI can be used to determine function as well as anatomy, while CT is generally limited to anatomy only.

21. How does slice selection in MRI take place?

A. via phase encoding

B. via external placement of ferromagnetic guides to direct the detection circuitry

C. via elimination of the magnetic field everywhere except the slice of interest

D. via measurement of the magnetic attenuation factor of the tissues

E. via application of a linear magnetic gradient, generally along the z-direction

22. Which of the following statements about MRI contrast mechanisms is *false*?

A. 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.

B. In proton density-weighted images, the image intensity is roughly proportional to the number of hydrogen nuclei in the sample.

C. In proton density-weighted images, images must be acquired quickly before the signal has a chance to decay from T_2 effects.

D. In T_2-weighted images, fluid appears very bright, and intermediate echo times (T_E) are utilized to maximally differentiate between the T_2 of different tissues.

E. T_1 and T_2 are parameters that are set in the computer in order to obtain T_1- and T_2-weighted images.

23. 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 applied?

I - The magnetic field is still oriented in z direction.
II - The strength of the field is not uniform.
III - At points with different x-coordinates, the magnetic field has different strengths.

A. I and III

B. I and II

C. None.

D. I, II, and III

E. II and III

24. Which one of the following statements is TRUE?

A. All of them

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

C. MR data are scans of Fourier space; MR image reconstruction is based on the inverse 2D Fourier transform and represents the distribution of effective spin density.

D. The RF coils or resonators receive the MR signals, and may be large (e.g., a body coil) or small (e.g., a surface coil).

E. Manipulation of the gradient coils produces frequency or phase encoding of location.

25. Which of the following is *false* about the Larmor frequency (or all are true)?

A. All are true.

B. It permits the differentiation of received RF signals by the application of a gradient in the magnetic field during data acquisition.

C. It is the frequency of precession of the magnetization vector, which is related to the local magnetic field by the gyromagnetic ratio.

D. It is dependent on the particular element involved (for example, ^{1}H vs. ^{13}C)

E. It permits the selection of a particular slice by the application of a gradient in the magnetic field during the RF pulse.

26. The Bloch Equations, which describe the time course of the magnetization vector $\mathbf{M}(t)$,

$$\frac{d\mathbf{M}(t)}{dt} = \gamma \mathbf{M}(t) \times \mathbf{B}(t) - \mathrm{R}\{\mathbf{M}(t) - \mathbf{M}_0\}$$

where $\mathbf{B}(t) = \mathbf{B}_0 + \mathbf{B}_1(t)$ is composed of the static and RF fields, and where the matrix R is

$$\begin{pmatrix} \frac{1}{T_2} & 0 & 0 \\ 0 & \frac{1}{T_2} & 0 \\ 0 & 0 & \frac{1}{T_1} \end{pmatrix}$$

define the behavior of which of the following?

I - Tipping the longitudinal magnetization into the transverse plane by means of an RF pulse.
II - Longitudinal and Transverse relaxation with corresponding relaxation times of T_1 and T_2.
III - Precession of the magnetization in the transverse plane due to B_0.

A. II and III

B. I and III

C. I, II, and III

D. I and II

E. only I.

27. Which of the following is *false* about tipping the magnetization vector with an RF field (or all are true)?

A. It only occurs to the extent that the Larmor frequency corresponding to the local magnetic field is contained within the spectrum of the RF pulse.

B. The resulting tip angle is proportional to the RF field strength and the duration of the RF pulse.

C. It amounts to precession around the RF magnetic field, which can be viewed as tipping within a rotating frame of reference.

D. An $\pi/2$ RF pulse transfers the longitudinal magnetization into the transverse plane, where it begins to precess, producing a detectable signal at the Larmor frequency.

E. All are true.

28. Which of the following statements about MRI contrast mechanisms is *false*, or all are true?

A. All are true.

B. In proton density-weighted images, the image intensity is roughly proportional to the number of protons in any chemical element within the sample.

C. In proton density-weighted images, images are acquired with a long T_R and a short T_E.

D. 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.

E. In T_2-weighted images, fluid appears very bright, and an intermediate T_E is utilized to maximally differentiate between the T_2 of different tissues.

29. 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 III

C. I, II, and III

D. I and II

E. II

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

A. 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.

B. 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 .

C. All are true.

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

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

31. Which of the following statements about fMRI is (are) *true*?

I - It displays the neuronal activity by using differences in the magnetic susceptibility of oxygenated and deoxygenated hemoglobin.
II - It depends on changes in blood flow in areas of neuronal activity.
III - Its resolution is much lower (worse) than regular anatomical MRI.

A. only I.

B. I and II

C. I and III

D. II and III

E. I, II, and III

32. 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 - Saturating the magnetization in a slice, so that only fresh blood entering from outside the slice gives off signal; this requires no contrast agent.
III - Detecting the diffusion of blood with Diffusion Tensor Imaging.

A. I and III

B. only I.

C. II and III

D. I and II

E. I, II, and III

33. Which of the following statements about Diffusion Tensor Imaging (DTI) with MRI is (are) *true*?

I - Water diffuses more quickly along white matter tracts, and DTI can measure the amount of this diffusion but not its direction.
II - It uses a pair of strong gradient pulses, the first to de-phase the spins, and the second to re-phase the spins. If no net movement occurs, these cancel. If movement (diffusion) occurs they do not cancel.
III - It is used to establish neuroanatomy but not neuronal activity.

A. I, II, and III

B. only II.

C. II and III

D. I and II

E. I and III

34. Which of the following statements about Short Tau Inversion Recovery (STIR) and Fluid Attenuation Inversion Recovery (FLAIR) is *false*, or all are true?

A. STIR is used to suppress fat, for example, to see tumors in the breast.

B. FLAIR is used to suppress watery fluids such as cerebral spinal fluid (CSF), for example, to visualize high-intensity objects in the ventricles.

C. All are true.

D. Both use π RF pulses and then wait for an appropriate amount of time before applying a $\pi/2$ RF pulse, when a particular tissue type has recovered just enough of its longitudinal magnetization to have reached a "null" point.

E. Both are based on the interaction between Gadolinium and the tissue to nullify certain tissue types..

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BioE 1330 - Review Chapters 12 and 13 (MRI) 1/17/2011
Answer Sheet - Correct answer is A for all questions

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

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
[*imaging0136.mcq*]

2. An RF excitation of 2×10^{-6} Tesla = 0.2 gauss is applied to a sample of protons (γ =42.58 MHz/Tesla) over 3 ms, what is the angle in radians that M is tipped?

A. $\alpha = 2\pi(42.58)(2 \times 10^{-6})(3 \times 10^{-3})$
B. $\alpha = (42.58)(0.2)(3 \times 10^{-3})$
C. $\alpha = (42.58)(2 \times 10^{-6})(3 \times 10^{-3})$
D. $\alpha = \pi/2$
E. Cannot be determined.

Explanation: The gyromagnetic ratio γ is in units of MHz/Tesla, and determines the Larmor frequency given the strength of the magnetic field, in this case, provided by the RF excitation in the rotating frame of reference.
[*imaging0137.mcq*]

3. What is the bandwidth (kHz) of the RF waveform needed to select a slice that is 2 mm thick, given $G_z = 1$ guass/mm and $\gamma = 4.258$ kHz/guass.

A. 8.516 kHz
B. 4.258 kHz
C. 42.58 kHz
D. 85.16 kHz
E. Not enough information given

Explanation: The gyromagnetic ratio γ is in units of kHz/Tesla, and determines the Larmor frequency given the strength of the magnetic field, in this case, provided by the RF excitation in the rotating frame of reference. The bandwidth is proportional to the change in magnetic field, which is proportional to the gradient. $2mm \times 1guass/mm \times 4.258kHz/guass = 8.516kHz$.
[*imaging0138.mcq*]

4. For T_2 -weighted contrast images (maximizing differences in transverse relaxation times) the following is true:

A. T_E should be in the middle of the range for T_2 values.

B. T_E should be as short as possible.

C. Any T_E duration can be used so long as T_R is short.

D. T_E should be extremely long.

E. Echoes should not be used.

Explanation: To differentiate tissues by their transverse relaxation time T_2, an echo time T_E is chosen in the middle of the range of the T_E values for the various tissues, so that the echo strength will depend maximally upon T_E.
[*imaging0139.mcq*]

5. BOLD fMRI utilizes the following principle:

A. Neuronal activity results in increased blood flow.

B. $T2^*$ is decreased by the presence of oxygenated hemoglobin.

C. Water diffuses more quickly along axons.

D. All of the choices.

E. None of the choices.

Explanation: Blood Oxygen Level Dependent (BOLD) Functional MRI (fMRI) shows neuronal activity by its increase in blood flow, which results in increased oxygenated hemoglobin because of increased blood flow. Oxygenated hemoglobin has a *longer* $T2^*$ and thus a stronger signal. The fact that water diffuses more quickly along axons is used in Diffusion Tensor Imaging (DTI).
[*imaging0140.mcq*]

6. A large magnetic field $\mathbf{B}_0$ in the z direction is applied to a sample in a clinical MRI scanner. Which of the following is *false* when the x-gradient field is applied?

A. The gradient field rotates the orientation of the magnetic field towards the x direction.

B. The gradient field is much smaller in magnitude than $\mathbf{B}_0$.

C. $\mathbf{B}_0$ is made extremely uniform so that as much of any non-uniformity as possible is due to the gradient field and not to inhomogeneity in $\mathbf{B}_0$.

D. At points with different x-coordinates, the total magnetic field has different magnitudes.

E. All of the other statements are true

Explanation: The gradient field produces a variation is in the scalar strength, not the direction, of the overall magnetic field.
[*imaging0141.mcq*]

7. Which one of the following statements is *false* about MRI?

A. Although hydrogen accounts for almost all clinical MRI imaging, protons in any atom can be used to image with MRI.

B. The Larmor frequency of hydrogen, which relates the rate of precession of the magnetization vector of a sample to the local magnetic field, 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 RF coils or resonators receive the MR signals, and may be large (e.g., a body coil) or small (e.g., a surface coil).

Explanation: Only nuclei with odd atomic number or odd mass number can be used in MRI.
[*imaging0142.mcq*]

8. How does slice selection in MRI take place?

A. via application of a linear magnetic gradient, which limits interaction of the RF to hydrogen with appropriate Larmor frequencies.

B. via manipulation of the magnetic attenuation factor of the tissues

C. via external placement of ferromagnetic guides, usually along the z-direction, to direct the detection circuitry

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

E. via phase encoding to shift the phase such that only hydrogen within the slice is energized

Explanation: Slice selection occurs by controlling the strength generally of the z-gradient of the magnetic field and by controlling the frequency of the RF pulses. The other choices do not make any sense or are incorrect.
[*imaging0143.mcq*]

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

A. All are true.

B. T_E and T_R are among the parameters that are set in order to obtain T_1- and T_2-weighted images.

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. In T_2-weighted images, fluid appears very bright, because transverse magnetization de-phases relatively slowly in free water.

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 T_1 and T_2. The parameters that are set for each image include T_R, T_E, and the tip angle α.
[*imaging0144.mcq*]

10. Which of the following statements about transverse relaxation is *false*?

A. Transverse relaxation is due to the transfer of magnetization from the transverse (x-y) plane to the longitudinal (z) direction.

B. The measured relaxation time T_2^* is longer than the tissue-dependent time constant T_2, because it also contains a term due to field inhomogeneity, T_2'.

C. The use of a 180° (π) pulse cancels de-phasing due to field inhomogeneity.

D. Transverse relaxation time T_2 tends to be much shorter than longitudinal relaxation time T_1.

E. Transverse relaxation is modeled as an exponential decay.

Explanation: Transverse relaxation is not due to the transfer of magnetization from the transverse (x-y) plane to the longitudinal (z) direction, which is the slower process governed by T_1. Rather, transverse relaxation is due to de-phasing of the magnetization within the transverse plane.
[*imaging0145.mcq*]

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

A. It causes $\mathbf{B}_0$ to spin in the transverse plane generating an RF signal.

B. All are true.

C. It occurs in the transverse plane.

D. It is modeled as a phasor spinning in the complex plane.

E. It turns the path along which the RF field generates a tip angle α from a spiral into a simple rotation.

Explanation: $\mathbf{B}_0$ is the axis of the rotating frame of reference and does not spin.
[*imaging0146.mcq*]

12. Which of the following statements about Diffusion Tensor Imaging (DTI) with MRI is (are) *true*?

I - Water diffuses more quickly along white matter tracts, and DTI measures this diffusion, as well as its direction.
II - It uses a pair of strong gradient pulses, the first to de-phase the spins, and the second to re-phase the spins. If no net movement occurs, these cancel. If movement (diffusion) occurs they do not cancel.
III - Neuronal activity causes greater diffusion of the water within the axons and can thus be detected.

A. I and II

B. II and III

C. I and III

D. I, II, and III

E. only I.

Explanation: Neuronal activity is detected by BOLD, not DTI, and does not cause greater diffusion of water in the axons.
[*imaging0147.mcq*]

13. Which of the following statements about Magnetic Resonance Spectroscopy (MRS) with MRI is (are) *true*?

I - It displays the proton spectrum for a region of the MRI scan, allowing differentiation of hydrogen atoms by their local biochemical environment.
II - It essentially makes use of the Chemical Shift Artifact, which normally is considered a problem in MRI.
III - Its resolution is much lower (worse) than regular anatomical MRI.

A. I, II, and III

B. I and II

C. I and III

D. II and III

E. only I.

Explanation: All are true. Slight differences in the Larmor frequency for hydrogen atoms due to their biochemical environment cause the Chemical Shift Artifact, but may be used to produce useful spectra of regions in the MRI image.
[*imaging0148.mcq*]

14. 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 - Saturating the magnetization in a slice, so that only fresh blood entering from outside the slice gives off signal; this requires no contrast agent.
III - Detecting the Doppler shift in the RF signal given off by blood that is moving; this requires no contrast agent.

A. I and II

B. I, II, and III

C. I and III

D. II and III

E. only I.

Explanation: III is not true. Doppler is used in ultrasound, not in MRI. Electromagnetic induction propagates at the speed of light, not the speed of sound, so any Doppler shift would be negligible.
[*imaging0149.mcq*]

15. The following are true about Phase Encoding *except* (or all are true).

A. Phase encoding permits selective activation of a particular slice in the patient by restricting interaction between the RF field and the Larmor frequency of particular protons.

B. It is generally used to establish coordinates in the third dimension (y), after slice selection and frequency encoding have established coordinates in the other two dimensions (z and x, respectively).

C. It is accomplished by activating a phase-encode gradient for a certain amount of time to add a "twist" proportional to distance along the phase-encode dimension. A series of these are collected each with a different amount of phase-encode gradient.

D. It typically results in a rectilinear traversal of k-space, permitting direct application of the inverse Fourier transform.

E. All are true.

Explanation: Answer A refers to the slice selection gradient, not the phase encoding gradient.
[*imaging0150.mcq*]

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

A. All are true.

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 eventually catch up with the others to form an echo.

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. They do not cancel all differences between protons, and some dephasing still occurs due to tissue-dependent spin-spin relaxation.

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, leaving the desired tissue-dependent spin-spin relaxation.
[*imaging0151.mcq*]

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

A. It is the frequency of precession of the magnetization vector, which is related to the local magnetic field by the gyromagnetic ratio.

B. It is the so-called "frequency of love" of popular lore.

C. It decreases with increasing magnetic field.

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

E. None is true.

Explanation: The Larmor frequency depends both on the local magnetic field (to which it is proportional) and the substance (which determines the proportionality, the gyromagnetic ratio).
[*imaging0152.mcq*]

18. The Bloch Equations, which describe the time course of the magnetization vector $\mathbf{M}(t)$,

$$\frac{d\mathbf{M}(t)}{dt} = \gamma\mathbf{M}(t) \times \mathbf{B}(t) - \mathrm{R}\{\mathbf{M}(t) - \mathbf{M}_0\}$$

where $\mathbf{B}(t) = \mathbf{B}_0 + \mathbf{B}_1(t)$ is composed of the static and RF fields, and where the matrix R is

$$\begin{pmatrix} \frac{1}{T_2} & 0 & 0 \\ 0 & \frac{1}{T_2} & 0 \\ 0 & 0 & \frac{1}{T_1} \end{pmatrix}$$

define the behavior of which of the following?

I - Tipping the longitudinal magnetization into the transverse plane.
II - Longitudinal relaxation.
III - Transverse relaxation.

A. I, II, and III

B. I and II

C. I and III

D. II and III

E. only I.

Explanation: The Bloch equation encapsulates all three processes into a single differential matrix equation.
[*imaging0153.mcq*]

19. The following are (is) true about Proton Density weighted images:

I - A long T_R is used to allow tissues to be at equilibrium (largest possible longitudinal magnetization vector available to flip).
II - A long T_E is used to avoid signal loss due to dephasing.
III - Proton Density weighted images offer the highest signal-to-noise.

A. I and III

B. I and II

C. I, II, and III

D. II and III

E. only I.

Explanation: II is false, a *short* T_E is used to avoid signal loss due to dephasing.
[*imaging0154.mcq*]

20. Which of the following statements about MR and CT is false?

A. MRI is better for imaging bones, while CT is better for imaging soft tissues.

B. MR images can be acquired in any plane, while CT images are typically acquired only in the axial plane.

C. MRI is more expensive than CT.

D. MRI does not expose the patient to ionizing radiation, while CT does.

E. MRI can be used to determine function as well as anatomy, while CT is generally limited to anatomy only.

Explanation: As Dr. Branstetter mentioned, MRI is ideal for imaging soft tissues, while CT is optimal for tissues with high attenuation coefficients, like bone. The other statements are all true.
[*imaging0184.mcq*]

21. How does slice selection in MRI take place?

A. via application of a linear magnetic gradient, generally along the z-direction

B. via measurement of the magnetic attenuation factor of the tissues

C. via external placement of ferromagnetic guides to direct the detection circuitry

D. via elimination of the magnetic field everywhere except the slice of interest

E. via phase encoding

Explanation: Slice selection occurs by controlling the strength generally of the z-gradient of the magnetic field and by controlling the frequency of the RF pulses. The other choices do not make any sense or are incorrect.
[*imaging0185.mcq*]

22. Which of the following statements about MRI contrast mechanisms is *false*?

A. T_1 and T_2 are parameters that are set in the computer in order to obtain T_1- and T_2-weighted images.

B. In proton density-weighted images, images must be acquired quickly before the signal has a chance to decay from T_2 effects.

C. In proton density-weighted images, the image intensity is roughly proportional to the number of hydrogen nuclei in the sample.

D. In T_2-weighted images, fluid appears very bright, and intermediate echo times (T_E) are utilized to maximally differentiate between the T_2 of different tissues.

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: T_1 and T_2 are not parameters to be set during image acquisition. Rather, they are characteristics of tissues being imaged. MRI involves the measurement of T_1 and T_2. The parameters that are set for each image include T_R, T_E, and the tip angle α.
[*imaging0192.mcq*]

23. 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 applied?

I - The magnetic field is still oriented in z direction.
II - The strength of the field is not uniform.
III - At points with different x-coordinates, the magnetic field has different strengths.

A. I, II, and III

B. I and II

C. I and III

D. II and III

E. None.

Explanation: The gradient is in the scalar strength, not the direction of the magnetic field.
[*imaging0216.mcq*]

24. Which one of the following statements is TRUE?

A. All of them

B. MR data are scans of Fourier space; MR image reconstruction is based on the inverse 2D Fourier transform and represents the distribution of effective spin density.

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

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

E. The RF coils or resonators receive the MR signals, and may be large (e.g., a body coil) or small (e.g., a surface coil).

Explanation: See the text book for explanation.
[*imaging0218.mcq*]

25. Which of the following is *false* about the Larmor frequency (or all are true)?

A. All are true.

B. It permits the selection of a particular slice by the application of a gradient in the magnetic field during the RF pulse.

C. It permits the differentiation of received RF signals by the application of a gradient in the magnetic field during data acquisition.

D. It is dependent on the particular element involved (for example, ^{1}H vs. ^{13}C)

E. It is the frequency of precession of the magnetization vector, which is related to the local magnetic field by the gyromagnetic ratio.

Explanation: The Larmor frequency depends both on the local magnetic field (to which it is proportional) and the substance (which determines the proportionality, the gyromagnetic ratio).
[*imaging0296.mcq*]

26. The Bloch Equations, which describe the time course of the magnetization vector $\mathbf{M}(t)$,

$$\frac{d\mathbf{M}(t)}{dt} = \gamma \mathbf{M}(t) \times \mathbf{B}(t) - \mathrm{R}\{\mathbf{M}(t) - \mathbf{M}_0\}$$

where $\mathbf{B}(t) = \mathbf{B}_0 + \mathbf{B}_1(t)$ is composed of the static and RF fields, and where the matrix R is

$$\begin{pmatrix} \frac{1}{T_2} & 0 & 0 \\ 0 & \frac{1}{T_2} & 0 \\ 0 & 0 & \frac{1}{T_1} \end{pmatrix}$$

define the behavior of which of the following?

I - Tipping the longitudinal magnetization into the transverse plane by means of an RF pulse.
II - Longitudinal and Transverse relaxation with corresponding relaxation times of T_1 and T_2.
III - Precession of the magnetization in the transverse plane due to B_0.

A. I, II, and III

B. I and II

C. I and III

D. II and III

E. only I.

Explanation: The Bloch equation encapsulates all three processes into a single differential matrix equation. You can tell precession in B_0 (as well as tipping with the RF pulse, which is precession in B_1) is covered by the inclusion of the cross product.
[*imaging0297.mcq*]

27. Which of the following is *false* about tipping the magnetization vector with an RF field (or all are true)?

A. All are true.

B. It only occurs to the extent that the Larmor frequency corresponding to the local magnetic field is contained within the spectrum of the RF pulse.

C. It amounts to precession around the RF magnetic field, which can be viewed as tipping within a rotating frame of reference.

D. The resulting tip angle is proportional to the RF field strength and the duration of the RF pulse.

E. An $\pi/2$ RF pulse transfers the longitudinal magnetization into the transverse plane, where it begins to precess, producing a detectable signal at the Larmor frequency.

Explanation: All are true.
[*imaging0298.mcq*]

28. Which of the following statements about MRI contrast mechanisms is *false*, or all are true?

A. In proton density-weighted images, the image intensity is roughly proportional to the number of protons in any chemical element within the sample.

B. In proton density-weighted images, images are acquired with a long T_R and a short T_E.

C. All are true.

D. In T_2-weighted images, fluid appears very bright, and an intermediate T_E is utilized to maximally differentiate between the T_2 of different tissues.

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: Only protons in hydrogen are imaged, mainly those within fat and water.
[*imaging0300.mcq*]

29. 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*]

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

A. They reverse the dephasing so that T_2 has no effect whatsoever 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*]

31. Which of the following statements about fMRI is (are) *true*?

I - It displays the neuronal activity by using differences in the magnetic susceptibility of oxygenated and deoxygenated hemoglobin.
II - It depends on changes in blood flow in areas of neuronal activity.
III - Its resolution is much lower (worse) than regular anatomical MRI.

A. I, II, and III

B. I and II

C. I and III

D. II and III

E. only I.

Explanation: Neuronal activity leads to a local increase in blood flow and therefore increased oxygenated hemoglobin.
[*imaging0303.mcq*]

32. 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 - Saturating the magnetization in a slice, so that only fresh blood entering from outside the slice gives off signal; this requires no contrast agent.
III - Detecting the diffusion of blood with Diffusion Tensor Imaging.

A. I and II

B. I, II, and III

C. I and III

D. II and III

E. only I.

Explanation: III is not true. Diffusion is much slower than blood flow.
[*imaging0304.mcq*]

33. Which of the following statements about Diffusion Tensor Imaging (DTI) with MRI is (are) *true*?

I - Water diffuses more quickly along white matter tracts, and DTI can measure the amount of this diffusion but not its direction.
II - It uses a pair of strong gradient pulses, the first to de-phase the spins, and the second to re-phase the spins. If no net movement occurs, these cancel. If movement (diffusion) occurs they do not cancel.
III - It is used to establish neuroanatomy but not neuronal activity.

A. II and III

B. I and II

C. I and III

D. I, II, and III

E. only II.

Explanation: DTI can measure the amount as well as the direction of the diffusion. It does not measure neuronal activity, which is primarily done with fMRI.
[*imaging0299.mcq*]

34. Which of the following statements about Short Tau Inversion Recovery (STIR) and Fluid Attenuation Inversion Recovery (FLAIR) is *false*, or all are true?

A. Both are based on the interaction between Gadolinium and the tissue to nullify certain tissue types..

B. FLAIR is used to suppress watery fluids such as cerebral spinal fluid (CSF), for example, to visualize high-intensity objects in the ventricles.

C. STIR is used to suppress fat, for example, to see tumors in the breast.

D. Both use π RF pulses and then wait for an appropriate amount of time before applying a $\pi/2$ RF pulse, when a particular tissue type has recovered just enough of its longitudinal magnetization to have reached a "null" point.

E. All are true.

Explanation: Gadolinium is not required.
[*imaging0295.mcq*]