MRI – Lesson Outline

Syllabus References

9.6.4.2.5 – Define precessing and relate the frequency of the precessing to the composition of the nuclei and the strength of the applied external magnetic field
9.6.4.2.6 - Discuss the effect of subjecting precessing nuclei to pulses of radio waves
9.6.4.3.3 - Gather and process secondary information to identify the function of the electromagnet, radio frequency oscillator, radio receiver and computer in the MRI equipment

Resources

Video: MRI Introduction
http://www.hscphysics.edu.au/resource/MRIintro.flv

Video: MRI Theory
http://www.hscphysics.edu.au/resource/MRITheory.flv

Video: MRI Images
http://www.hscphysics.edu.au/resource/MRIImages.flv

Pre-video Activities

Activity: Pre-video quiz
Split students into groups of three. Students complete the pre-video quiz in these groups.

View Video

Video: MRI Introduction
http://www.hscphysics.edu.au/resource/MRIintro.flv

Activities

Students resume their groups. Hand out butcher's paper and a marker to each group. Students brainstorm the following questions:
What is magnetic resonance imaging?
Predict the applications of MRI. How would these compare to other diagnostic imagine techniques?
When a patient receives an MRI scan, particles in their body creates a magnetic field. What is the origin of this magnetic field?

View Video

Video: MRI Theory
http://www.hscphysics.edu.au/resource/MRITheory.flv

Activities

Activity: Cloze passage I
Students work in their previous groups to complete the cloze passage. When finished, hand each group some butcher's paper and a marker.

Each group answers one of the following questions:

1. Identify the property of the hydrogen nucleus that makes it useful in magnetic resonance imaging.
2. State the functions of the superconducting magnet assembly and the radio frequency (RF) coil in the MRI system.
3. Explain the difference between a T1-weighted image and a T2-weighted image. Would there be differences between tissues containing hydrogen bound water molecules and tissues containing other molecules?

Representatives present the group's responses to the rest of the class. Encourage class discussion and questioning.

View Video

Video: MRI Images
http://www.hscphysics.edu.au/resource/MRIImages.flv

Activities

Activity: Cloze passage II
Students work in their previous groups to complete the cloze passage. When finished, hand each group some butcher's paper and a marker.

Each group answers one of the following questions:

1. A patient enters a hospital after hitting his head while playing football. He is diagnosed with a fractured skull but has other symptoms that may indicate he is suffering from brain damage. Why would you use an MRI scan to confirm this diagnosis?
2. Explain why MRI scans can be used to detect:
– cancerous tissues
– identify areas of high blood flow
– distinguish between grey and white matter in the brain
3. List the advantages of using MRI scans. When would an MRI scan be an inappropriate diagnostic tool?

Representatives present the group's responses to the rest of the class. Encourage class discussion and questioning.

Activity: Concepts in MRI quiz
Students complete quiz individually.

MRI – Pre-video Quiz

Q1. What does the term MRI stand for?

A. Medium Resolution Instrument
B. Magnetic Research Instrumentation
C. Magnetic Resonance Imaging
D. Medium Resonance Imaging

Q2. MRI does not use contrasts or dyes.

True
False

Q3. MRI systems use ionising radiation.

True
False

Q4. Cancerous tissue can be detected with MRI.

True
False

Q5. MRI can reproduce 3D images.

True
False

Q6. Which type of magnet is most commonly used in MRI scanners?

A. Permanent magnet
B. Superconducting magnet
C. Resistive magnet
D. Rare-earth magnetic

Q7. Which of the following are involved in MRI?

I Optics
II Magnetism
III Quantum Mechanics

A. I and II
B. II and III
C. I and III
D. I, II, and III

Q8. Which atoms or molecules are responsible for the production of MRI images?

A. Hydrogen atoms
B. Protein molecules
C. Carbon atoms
D. Mineral Molecules

MRI – Concepts

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Q3. Which type of magnet is most commonly used in MRI scanners?

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B. Superconducting magnet
C. Resistive magnet
D. Rare-earth magnetic

Q5. Which of the following are involved in MRI?

I Dyes
II Gamma Radiation
III Radioactive Isotopes

A. I only
B. I, II, and III
C. II and III
D. None of the Above

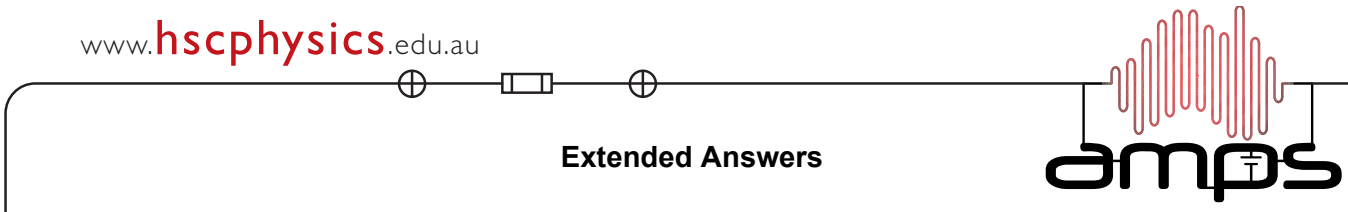
Q6. MRI is possible because hydrogen atoms precess in the presence of a magnetic field. What is precession?

A. The decay of heavy elements into lighter and more stable elements
B. The spin of a proton due to the Earth's magnetic field
C. The absorption or release of photons by electrons in the electron cloud
D. The wobble of a spinning body where its rotation axis sweeps out a cone

Q7. What are the relaxation times in MRI?

I T1 Spin-lattice that happens as the nuclei transfer energy quanta to the nearby molecular lattice
II T2 Spin-spin that happens as nuclei transfer energy quanta between each other
III T3 Lattice-lattice that happens as lattices transfer energy between each other

A. I and III
B. II and III
C. I and II
D. I, II, and III



Q8. Describe how the nuclei of certain atoms and molecules behave as small magnets.

Q9. Explain how the behaviour of nuclei with a net spin, particularly hydrogen, is related to the magnetic field they produce.

Q10. Describe the changes that occur in the orientation of the spin axis of nuclei before and after the application of a strong magnetic field.

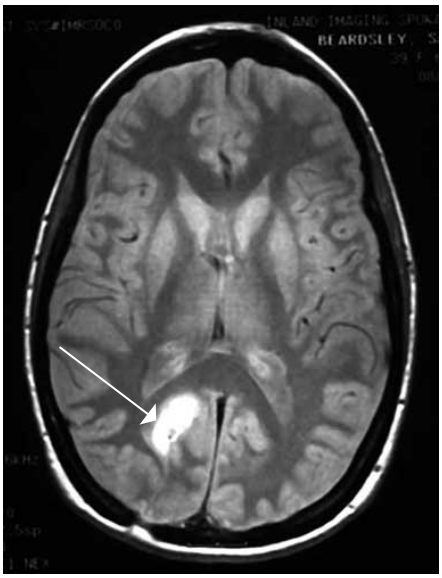
Q11. Define precession and the Larmor frequency.

Q12. How is the frequency of the precessing nuclei affected by the composition of the nuclei and the strength of the applied external magnetic field?

Q13. Discuss what happens to the precessing nuclei when they are subjected to pulses of radio waves.

Q14. The arrow indicates an abnormality that has been detected in one hemisphere of the brain.

MRI Brain Scan



Identify the advantages of MRI in detecting the abnormality.

Q15. Explain how MRI scans can be used to detect cancerous tissues.

MRI – Cloze Passage I

The human body is around 63 percent _____ atoms. A _____ atom is composed of 1 proton and 1 electron. The proton has a positive charge and it spins on its axis, making it similar to a tiny loop of _____. This in turn produces a _____ along the proton's spin axis so the proton is like a little bar magnet.

The hydrogen protons in your body have their spins _____ oriented. All of the spins cancel each other out. That is why you do not behave like a magnet. In MRI, the body is exposed to a _____ magnetic field. This causes the _____ axis of the protons to align either parallel or _____ to the field lines.

The proton alignment is such that while spinning the protons actually _____ as well. This is just like a spinning top tracing out a cone shape. This movement is called _____.

The _____ of precession depends on the nucleus that's spinning – in this case, a hydrogen proton, and the strength of the magnetic field. The frequency of precession is directly proportional to the _____ field – the stronger the field, the faster the frequency of precession. This is expressed in what is called the _____. The frequency of precession is equal to a constant times the magnetic field. For hydrogen, the constant is about 42.6 Mhz/T meaning that in a 1 Tesla magnetic field, the hydrogen atoms rotate on their axis 42.6 million times per _____.

A pulse of energy from the _____ frequency region of the electromagnetic spectrum is then used. The RF pulse _____ the protons so that they no longer precess around the field lines – instead they precess _____ to the field lines. The radio frequency pulse also causes the protons to spin in synchronization with each other. This is important because it means the little magnetic fields of each proton add up to produce a net transverse magnetic field that can be detected by the _____.

The precessing transverse magnetic field creates a _____ magnetic field that induces a small AC emf in the detector coils. The strength of the induced emf depends on the strength of the _____ magnetic field and hence on the number of nuclei contributing to the signal.

After the stimulating Radio Frequency pulse stops, the nuclei start to _____. As they do so they cause the net transverse magnetic field to weaken. This means that the amplitude of the signal detected gradually _____.

There are several ways in which images are generated. Firstly we have images with _____ relaxation time, called proton-density images. Then there are two relaxation processes and the time taken for each is important. Spin-lattice or longitudinal relaxation, T1, happens as the excited nuclei gradually realign with the magnetic field lines. T1 relaxation times are about _____ second for tissue. Spin-spin or transverse relaxation, T2, happens as excited nuclei undergo _____ with each other and therefore stop spinning in _____. The relaxation times are about 100ms.

Word List:

Collisions

Synchronisation

Magnetic

Spin

One

Frequency

Excites

Radio

Coils

Changing

Hydrogen

Decreases

Relax

Rotate

Hydrogen

Magnetic field

Precession

No

Larmor equation

Transverse

Second

Strong

Perpendicular

Electrical current

Randomly

Anti-parallel

MRI – Cloze Passage II

Cancerous tissues are areas of rapidly growing and dividing _____. This increased cellular activity is accompanied by increased _____ flow to the tissue and therefore increased _____ content in the cells. As a result a T2 weighted image will show cancerous tissue as an unusually _____ area.

Image contrasts are used to produce the different types of images. On a T1 weighted image, white matter appears _____ and grey matter appears grey. For example, in the normal brain, T1-weighting causes the nerve connections of _____ to appear white, and the congregations of neurons of _____ to appear grey, while cerebrospinal fluid appears _____. While on a T2-weighted image, the contrasts are reversed, white matter appears dark and grey matter appears grey. Proton-density weighted imaging provides little _____ in normal subjects but shows significant contrast with _____ tissue.

A contrast agent is often used. Water can be taken _____, for imaging the stomach and small bowel. Most commonly, a paramagnetic contrast agent is given. Gadolinium-enhanced tissues and fluids appear extremely _____ on T1-weighted images providing high sensitivity for detection of _____ and permits assessment of stroke.

_____ has many advantages over other _____ imaging techniques. MRI systems do not use _____, and therefore have a very low incidence of side effects. Another major advantage of MRI is its ability to image in any _____. MRI gives high resolution images with excellent _____ tissue contrast. However, it is an _____ procedure and unsafe for people with pacemakers. It is also a challenge for claustrophobic people.

Word list:

Plane	White Matter
MRI	Cells
Soft	Blood
Diseased	Bright
Orally	Water
Bright	Dark
Expensive	White
Tumors	Grey Matter
Ionising Radiation	Cerebrospinal Fluid
Contrast	Diagnostic