CHRIST CHURCH GRAMMAR SCHOOL

YEAR 12 PHYSICS
MOCK EXAMINATION 2008

Stick Label Here

A		
B		
C		
Total		/ 200 = %

TIME ALLOWED FOR THIS PAPER

Reading time before commencing work: Ten minutes
Working time for paper: Three hours

MATERIALS REQUIRED FOR THIS PAPER

Pens, pencils, eraser or correction fluid, ruler, highlighter and a calculator satisfying the conditions set by the Curriculum Council.

INSTRUCTIONS TO CANDIDATES.

This exam consists of three sections. The *Physics: Formulae, Constants and Data Sheet* is provided separately.

Write your answers in the space provided and explain or justify all your answers where appropriate.

Marks will be awarded for clear working even if an incorrect answer is obtained. If you cannot do a section and the answer is needed for a subsequent part assume a value and show all working.

Marks will be deducted for absent or incorrect units.

Answers to numerical questions should be given to the correct number of significant figures [usually three]. Estimations should be given to the appropriate accuracy.

SECTION A: Short Answer Section: [60 marks]
This section contains fifteen [15] questions of **equal value** and is worth 30%.

SECTION B: Longer Questions and Problems: [100 marks]
This contains eight [8] questions **not of equal value** and is worth 50%.

SECTION C: Comprehension and Interpretation Section: [40 marks]
This section contains two [2] questions of **equal value** and is worth 20%.

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SECTION A

1. In 1976 the Who set a record for the loudest concert; the sound level 46.0 m in front of the speaker systems was 120 dB. What is the ratio of the intensity of the band at that spot to the intensity of a jackhammer operating at 92.0 dB?

[4]

2. You find that the belt drive connecting a powerful electric motor to an air conditioning unit is broken and the motor is running freely. Should this be a cause of concern for you? Explain your reasoning.

[4]

3. The 80.0 kg pilot of a jet fighter makes an emergency **vertical** turn to avoid an approaching missile, subjecting himself to a centripetal acceleration of 10.0g while flying at 450 ms^{-1} (supersonic!).

(a) What is the radius of his turn?

[1]

(b) Determine the reaction force the pilot feels at the top of the turn – assume he is upside down at this point in the turn.

[3]

4. The ‘lead’ in lead pencils is a graphite composition with a Young’s Modulus of about 1.00×10^9 Pa. Calculate the change in the length of the lead in an automatic pencil (e.g. a Pacer) if you tap it straight into the pencil with a force of 4.00 N. The lead is 0.50 mm in diameter and 60.0 mm long.

[4]

5. An 800 W (output power) microwave oven has an operating frequency of 2450 MHz. If a bowl of porridge takes 3.00 minutes to cook in this microwave determine the number of microwave photons absorbed by the porridge.

[4]

6. If you stretch a rubber band and pluck it, you hear a ‘musical’ note. How does the frequency of this note change as you stretch the rubber band further?

[4]

7. A Cessna 175 (a type of aircraft) with a wingspan 11.0 m of flies South across the city of Perth at a speed of 150 kmh^{-1}. Determine the EMF induced between the wingtips of the airplane and which wing is at the higher potential.
The Earth's magnetic field in Perth is 5.80×10^{-5} T at 66.0° to the horizontal.

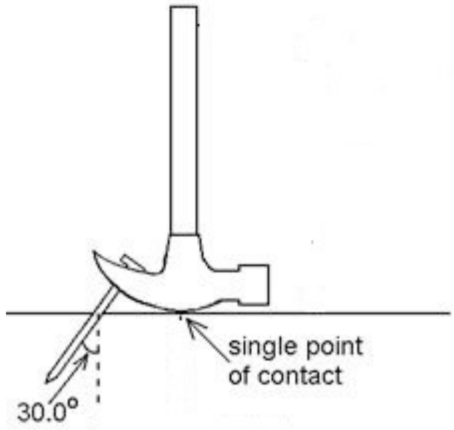
[4]

8. A girl is sitting on a horse on a merry-go-round at the Royal Show. Whilst on the ride, she feels as if she is being 'thrown to the outside' of the ride. Is the girl experiencing a real force? Explain your reasoning.

[4]

9. A man wishes to use a claw hammer (see the diagram below) to pull a nail out of a board. **Estimate** the minimum force that must be exerted by the man to remove the nail from the board (assume a force of 500 N is required to remove the nail from the board).

[4]

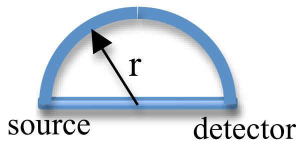


10. What minimum accelerating voltage in an x-ray tube will produce 0.02 nm wavelength radiation, such as might be useful for x-ray crystallography?

[4]

11. A sound wave of 40.0 cm wavelength enters the tube shown in the diagram below at the source end. What must be the smallest radius '**r**' such that a **minimum** will be heard at the detector end if sound waves travel through both the curved and the straight part of the pipe.

[4]



12. A Physics student claims that if a permanent magnet is dropped down a vertical copper pipe, it will eventually reach a terminal velocity, even if there is no air resistance. Is the student's claim correct? Explain your reasoning.

[4]

13. Determine the acceleration **due to the Earth** on the surface of the moon.

[4]

14. A ladder leans against a frictionless wall, but is prevented from falling because of the friction between it and the ground. If the base of the ladder is shifted towards the wall, determine the effect this will have on the on magnitude of the static friction force required from the ground. Explain your reasoning with the aid of a diagram/diagrams.

[4]

15. A cyclotron is operated at a frequency of 12.0 MHz and has a radius of 53.0 cm. Determine the magnitude of the magnetic field required for deuterons to be accelerated in the cyclotron.
[A deuteron is an isotope of hydrogen; $m_{deuteron} = 3.34 \times 10^{-27}$ kg]
[4]

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SECTION B

Name: ________________________________

1. One of the 63.5 cm long strings of an ordinary acoustic guitar is tuned to produce the note B_3 (frequency 245 Hz) when vibrating in its fundamental mode.

   (a) Determine the speed of transverse waves on this string.

   [3]

   (b) The velocity of a wave on a string is proportional to the square root of the tension of the string (ie $\sqrt{T}$). If the tension of the string is increased by 1.00%, show that the new velocity of the wave is 313 ms^{-1}.

   [4]

   (c) Determine the new frequency of the wave on the string.

   [2]

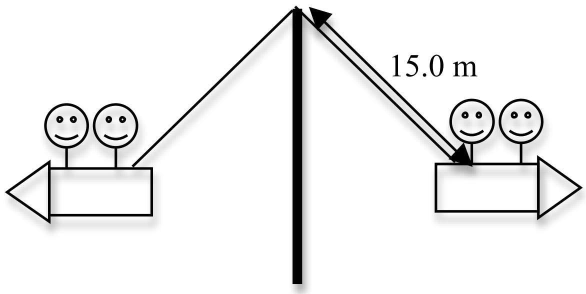
(d) Determine the frequency and wavelength of the **sound** waves produced by the guitar with the tightened string.

[3]

(e) The strings of a guitar are very narrow and only displace a small amount of air - this means they cannot produce a loud sound by themselves. To overcome this an acoustic guitar makes use of a sound box. Explain how the sound box of an acoustic guitar increases the amplitude of the sound produced.

[3]

2. A ride at the Royal Show consists of rocket shaped cars attached to **mild steel** rods. When the ride is operating the 'rockets' move in a horizontal circle and 'lift up' in the air. Each rod has a length of 15.0 m and a cross sectional area of 8.00 cm^2. Each car plus two passengers have a total weight of 1.90×10^3 N.



(a) How much is each rod stretched when the ride is at rest?

[3]

(b) When the ride is operating the maximum angle between the vertical support and the rods is 30.0°. Determine the tension in the rods when the ride is operating.

[3]

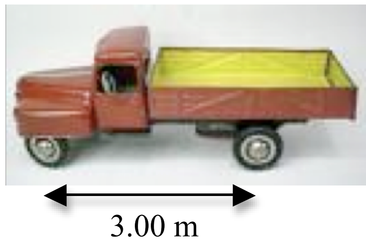
(c) Determine the maximum force the rods can sustain without breaking.

[2]

(d) Determine the maximum speed of the ride (ie the speed at which there is risk of the rods breaking).

[4]

3. A truck has a wheelbase of 3.00 m.
Usually, 1.08×10^4 N rests on the front wheels and 8.82×10^3 N on the rear wheels when the truck is parked on a level road.



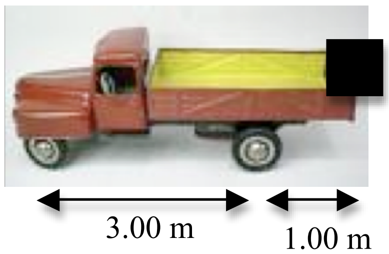
(a) Determine the total weight of the car.

[1]

(b) Using the sum of moments, determine the location of the centre of gravity of the car.

[4]

(c) If a box weighing 3.60×10^3 N is now placed at the rear of the truck, with its centre of gravity 1.00 m **behind** the rear wheel, determine, the weight that now rests on the front wheels and the weight that rests on the back wheels.



[5]

4 (a) Which of the two objects below is likely to be the more stable? Explain your reasoning with the aid of diagrams.

[4]

(b) When a runner turns a corner he or she will instinctively 'lean into' the corner. Explain, with the aid of diagrams, why this is so.

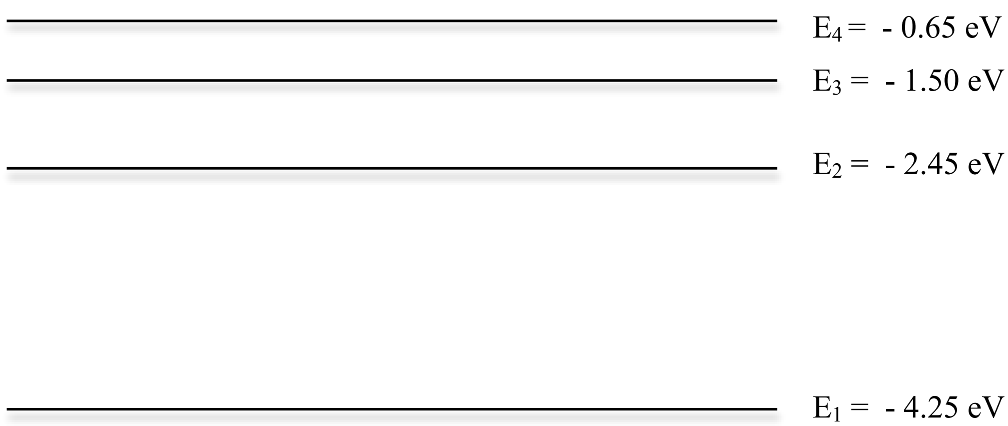
[4]

5. SmartWater is a crime prevention initiative that has been used extensively throughout the United Kingdom.

Sprinkler systems containing the SmartWater are installed in houses and businesses and can be set off (like a burglar alarm) when a crime is taking place. The person/s who are committing crimes are sprayed with SmartWater at the crime scene. The SmartWater then gets into clothing, skin and jewellery and leaves markings in the form of fingerprints, tyre marks and bootprints.

SmartWater is useful as although it is colourless in visible light, when seen under UV light it glows bright green.

A set of hypothetical energy levels is given below for SmartWater (these are hypothetical as the chemical compound used in SmartWater is a closely guarded secret!)



(a) Name the phenomena associated with the SmartWater technology and explain the process by which it glows green when observed under UV light.

[4]

(b) What would be the minimum required wavelength of an **absorbed** photon to create this effect?

[3]

(c) Determine the wavelength of the emission line with the longest wavelength and state which transition this corresponds to.

[4]

(d) SmartWater is most likely a molecular compound. State how this would affect the emission spectra observed and why.

[2]

6. Johannes Kepler, a German astronomer, carefully studied the motion of the planets over a 20 year period and devised a set of three classical laws to describe their behaviour.

Kepler's third law states that the ratio of the squares of the periods of any two planets about the sun is equal to the ratio of the cubes of their average distances from the sun:

$$\frac{T_1^{\,2}}{T_2^{\,2}} = \frac{r_1^3}{r_2^3}$$

Kepler's third law is also valid for comparing two small masses orbiting the same large mass.

(a) If the moon orbits the earth once each 27.3 days, calculate the period of an artificial satellite orbiting at an average altitude of 1500 km above the Earth.

[3]

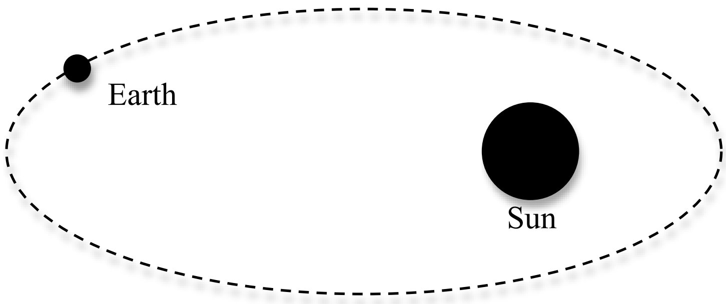
(b) Determine the velocity of this satellite.

[4]

(c) Determine the gravitational field strength the satellite experiences.

[3]

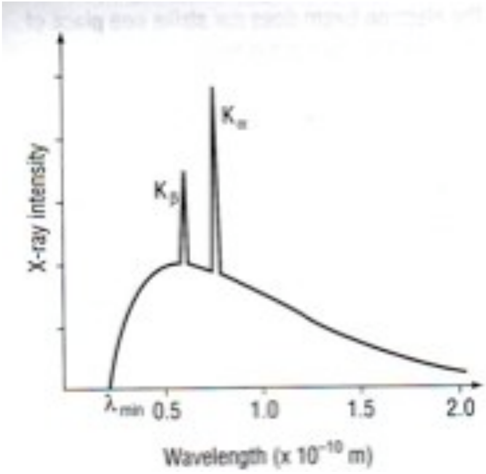
The earth moves in an elliptical orbit around the sun, as shown below. Assume the energy of the earth remains constant throughout the orbit and it is closer to the sun in November than in May.



(d) In which month (November or May) does the Earth move faster in its orbit? Explain your reasoning.

[3]

7. The questions below relate to an x-ray spectrum from a typical x-ray tube as shown below.



(a) The K_α and K_β lines are known as characteristic peaks. If the anode material in the x-ray tube were changed would the wavelength of these peaks be altered? Explain your reasoning.

[3]

(b) What feature of the x-ray tube determines the cut-off wavelength λ_{min}.

[1]

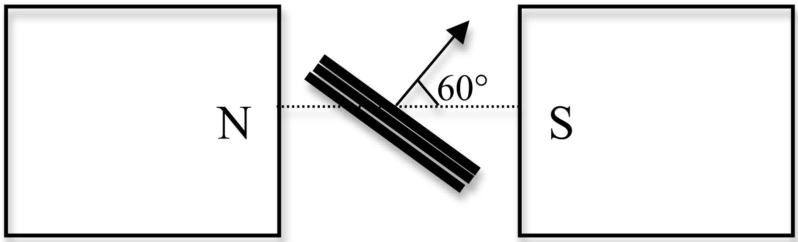
(c) What is the shortest wavelength produced if a 25.0 kV potential is used to accelerate the electrons?

[3]

(d) Explain the formation of the continuous background of radiation below the characteristic peaks.

[3]

8. A coil of wire containing 500 circular loops with a radius of 4.00 cm is placed between the poles of a large electromagnet, where the magnetic field is uniform and at an angle of 60° with the plane of the coil.



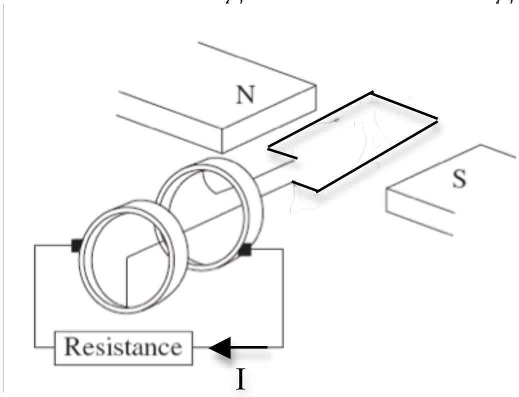
(a) If the field **decreases** at a rate of 0.20 Ts^{-1}, determine the magnitude of the induced emf.

[4]

(b) Determine the direction of the induced current (Give your answer looking at the coil **from** the **right hand side**) and explain your reasoning.

[4]

A simple ac generator is shown in the diagram below. The rotor is a square coil of side 5.00 cm and 1000 turns. It is connected to a load of 10.0 Ω and is rotating in a uniform magnetic field of 4.00×10^{-2} T.



(d) Determine the direction of rotation of the rectangular coil and explain your reasoning.

[3]

(e) If the coil is rotated at 60.0 Hz, what is the speed of the sides?

[2]

(f) Determine the **peak** emf induced in the coil and when in the cycle will this occur. Explain your reasoning.

[4]

(g) What is the current through the resistor?

[2]

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SECTION C

Name: ___________________________________

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Question 1:

Inertia is defined as the measure of the tendency of an object to resist a change in velocity. The **moment of inertia (I)** is therefore a measure of the tendency of an object to resist a change in its **rotational velocity**.

The moment of inertia of an object varies with the shape of the object. In general I can be determined by the formula;

$$\tau = I\alpha \quad \text{-- ①}$$

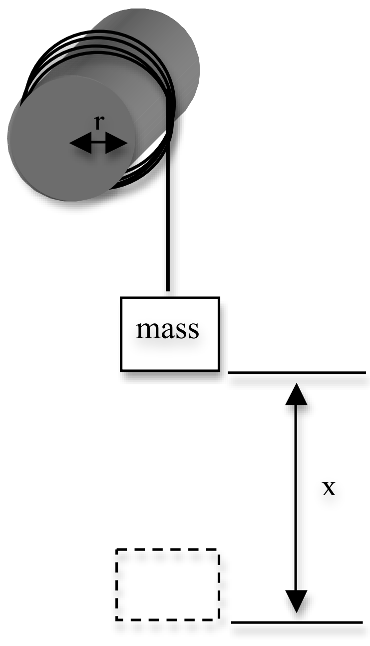
Where: I is the moment of Inertia
τ is the torque the object experiences
α is angular acceleration

Angular acceleration (α) is related to linear acceleration (a) by:

$$\alpha = \frac{a}{r}$$

Therefore we can rewrite ① as $\tau = I\frac{a}{r}$ -- ②

A group of students performed an experiment to determine the **moment of inertia (I)** of a solid lead cylinder of radius **r**.
They wrapped a string around the solid cylinder and hung various masses from the string, as shown in the diagram below.



The students then measured the time it took for the mass to fall a given distance **x**. The falling mass creates tension in the string and this creates a torque on the cylinder, which causes it to rotate. The students used a forcemeter to determine the tension in the string in each trial. The results the students collected are given below.

x = 1.43 m r = 4.00 cm

m (kg)	t (s)	T (N)	
0.05	10.6	0.49	
0.10	7.4	0.97	
0.15	6.1	1.46	
0.20	5.2	1.94	
0.25	4.6	2.42	
0.30	4.2	2.89	

(a) If the mass falls through a distance **x** derive an expression for the acceleration (a) of the mass in terms of x and t.

[2]

(b) Derive an expression for the torque exerted on the cylinder in terms of r and T.

[2]

By substituting the expressions from (a) and (b) into ②, it can be shown that the tension in the string is given by:

$$T = \frac{2Ix}{r^2t^2} \qquad \text{-- ③}$$

(c) From expression ③ determine what should be plotted to obtain a straight line graph.

[1]

(d) What would be the gradient of this straight line graph?

[1]

(e) Use the fourth column in the table on the previous page to process the given data to allow you to plot a linear graph.

[1]

(f) Plot the graph on the graph paper provided.

[5]

(g) Determine the gradient of your line.

[3]

(h) Use the gradient of your curve to determine the moment of inertia of the cylinder used.

[2]

(i) Car tyres are normally made hollow and filled with air. If they were instead made of solid rubber, would an increase or decrease in torque would be required to make it undergo the same angular acceleration as a hollow tire? Explain your reasoning.

[3]

Question 2:

Magnetic Resonance Imaging (MRI)
Adapted from: Bloomfield, L. A., Medical Imaging and Radiation, John Wiley & Sons Inc, 1997

Magnetic resonance imaging (MRI) is one of the most useful medical imaging tools. It produces two-dimensional and three-dimensional images of the body that provide important medical information. They are especially effective at imaging tissue and do not provoke the biological concerns associated with x-rays. MRI is based on an effect called **nuclear magnetic resonance (NMR)** in which an externally applied magnetic field interacts with the nuclei of certain atoms, particularly those of hydrogen (ie protons). These nuclei have magnetic fields, similar to those of electrons.

NMR has been used for more than 50 years as an analytical tool and in the past three decades has been developed to produce detailed images in a process now called MRI [see Figure 1], a name coined to avoid the use of the word 'nuclear' and the concomitant implication that nuclear radiation is involved – to appease the general public.

In most medical images [see Figure 2], the protons (that are hydrogen nuclei) are imaged. Their location and density gives a variety of medically useful information, such as organ function, the condition of the tissue (as in the brain) and the shape of structures, such as vertebral disks and knee joint surfaces.

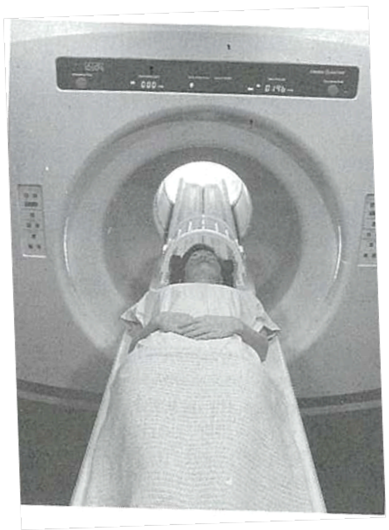


Figure 1: A Magnetic Resonance Imaging Unit

The nucleus of a hydrogen atom is a proton. Similar to an electron a proton is effectively a spinning object with a charge – ie it is a moving charged particle and as such will have a magnetic field associated with it. If the proton is placed in a magnetic field it will tend to align itself with the field. But while all the protons would align themselves perfectly with the field at absolute zero, at higher temperatures they are only aligned with the field on average.

Quantum mechanically it arises that there are only two possible alignments of the protons with an external magnetic field – with the field (aligned) or opposite to the field (anti-aligned). For simplicity the aligned photons will be said to have 'spin-up' orientation and the anti-aligned photons will be said to have 'spin-down' orientation.

When a patient enters the strong magnetic field of an MRI machine, the protons in their body respond to the field and an excess of spin-up protons appears. We are interested in those excess spin-up protons. To convert some of these excess spin-up protons to spin-down requires energy. An MRI machine uses radio wave photons to flip the extra spin-up protons.

When a radio wave photon with just the right amount of energy passes through a spin-up proton, the proton will absorb it and become a spin-down proton. The energy required to flip a proton depends on how strong the magnetic field is around the proton.

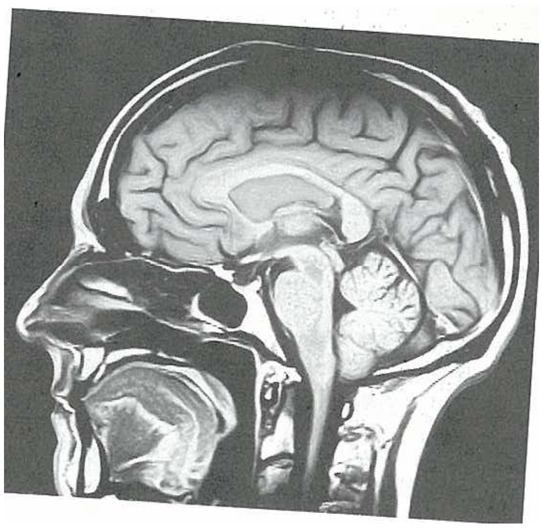


Figure 2: An MRI Scan

The MRI machine applies a spatially varying magnetic field to the patient's body. It then sends various radio waves through the patient and looks for those radio waves to be absorbed by protons. Since only a proton that is experiencing the right magnetic field can absorb a particular radio wave photon, the MRI can determine where each proton is by which radio waves it absorbs. By changing the spatial variations in the magnetic field and adjusting the energies of the radio waves, the MRI machine gradually locates the protons in the patient's body.

The largest part of the MRI unit is a superconducting magnet that creates a magnetic field, typically about 2.00 T in strength, over a relatively large volume. Strong magnetic fields are preferable as they produce lower noise levels and better spatial resolution. However, the magnetic fields of these advanced MRI machines are so strong that they can erase credit cards from across the room and rip steel objects out of your pockets.

Questions:

1. Determine the wavelength and energy of 100 MHz radio waves used in a MRI unit?

[3]

2. Most modern MRI units use extremely strong magnetic fields.

   (a) If the magnetic field of a unit becomes stronger, will higher or lower frequency radio photons be required to flip the spin-up protons?

   [1]

(b) When preparing to undergo an MRI scan, patients and operators are required to remove eyeglasses, watches, jewellery and other metallic objects. One reason for this is that they may be damaged by or attracted towards the large magnets. What could be another possible reason for the removal of these items (particularly if those items themselves possessed remnant magnetisation)?

[2]

3. Why are the protons not aligned perfectly with the applied magnetic field at temperatures greater than absolute zero?

[2]

4. Why are x-rays not effective at imaging tissue?

[2]

5. Why are x-rays considered dangerous?

[2]

6. MRI units utilise non-ionising radiation. Why aren't the photons of this radiation able to ionise atoms?

[2]

7. Define the term resonance and explain why MRI is considered to be a resonant effect.

[3]

8. A patient with a pacemaker is mistakenly being scanned for an MRI image. A 10.0 cm long section of pacemaker wire moves at a speed of 10.0 cms^{-1} perpendicular to the MRI unit's magnetic field and a 20.0 mV voltage is induced. What is the magnetic field strength?

[3]

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