Curriculum Council

Tertiary Entrance Examination, 2001

Question/Answer Booklet

PHYSICS

Please place your student identification label in this box

Student Number: In figures [ ][ ][ ][ ][ ][ ][ ][ ]

In words ______________________________

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Time allowed for this paper

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

Materials required/recommended for this paper

To be provided by the supervisor
This Question/Answer Booklet
Physics: Formulae and Constants Sheet (inside front cover of this Question/Answer Booklet)

To be provided by the candidate
Standard items: Pens, pencils, eraser or correction fluid, ruler

Special items: MATHOMAT and/or Mathaid, drawing compass, protractor, set square and calculators satisfying the conditions set by the Curriculum Council for this subject.

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

 Ref: 494

Structure of this paper

Section	No. of questions	No. of questions to be attempted	No. of marks out of 200	Proportion of examination total
A Short Answers	15	All	60	30%
B Problem Solving	7	7*	100	50%
C Comprehension and Interpretation	2	All	40	20%

* Note that in Section B there may be some internal choice in some questions. For each of these questions only one alternative should be answered. Markers will be instructed to mark only the first attempt among the alternatives (unless clearly cancelled).

Instructions to candidates

1. The rules for the conduct of Tertiary Entrance Examinations are detailed in the booklet *TEE Handbook*. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in the spaces provided in this Question/Answer Booklet. Spare answer pages may be found at the end of this booklet. If you need to use them, indicate in the original answer space where the answer is continued (ie give the page number).

3. You should note that the space made available for an answer is **not** necessarily an indication of the length of the answer.

4. You may remove the enclosed *Physics: Formulae and Constants Sheet* from the booklet and use as required. This sheet is not to be handed in at the end of the examination.

5. Your answers to questions involving calculations should be evaluated and given in decimal form. It is suggested that you quote all answers to three significant figures, with the exception of questions for which estimates are required. Despite an incorrect final result, you may obtain marks for method and working, provided these are clearly and legibly set out.

6. Questions containing the specific instruction "**show working**" should be answered with a complete, logical, clear sequence of reasoning showing how your final answer was arrived at. Correct answers which do not show working will not be awarded full marks.

7. Questions containing the instruction "**estimate**" may give insufficient numerical data for their solution. You should provide appropriate figures to enable an approximate solution to be obtained.

8. When descriptive answers are required, you should display your understanding of the context of a question. An answer which does not display an understanding of Physics principles will not attract marks.

SECTION A: Short Answers **(60 Marks)**

Attempt **ALL** 15 questions in this section. Each question is worth 4 marks. Answers are to be written in the spaces provided.

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1. Circle the alternative that best completes the statement:

   The output voltage from an electrical transformer is

   a) always alternating

   b) always direct

   c) either alternating or direct

   Explain why you think this is the correct alternative.

2. Circle the alternative that best completes the statement:

   A person standing on one leg must be in

   a) stable equilibrium

   b) unstable equilibrium

   c) neutral equilibrium

   Explain why you think this is the best alternative.

3. Using an example from one of the contexts *Speaking and Hearing* or *Musical Instruments and Reproduction*, explain how audible beats are formed.

4. The graph shows a stress-strain curve for a sample of brass. Within the area of the graph, draw to the same scale the corresponding curve for bone.

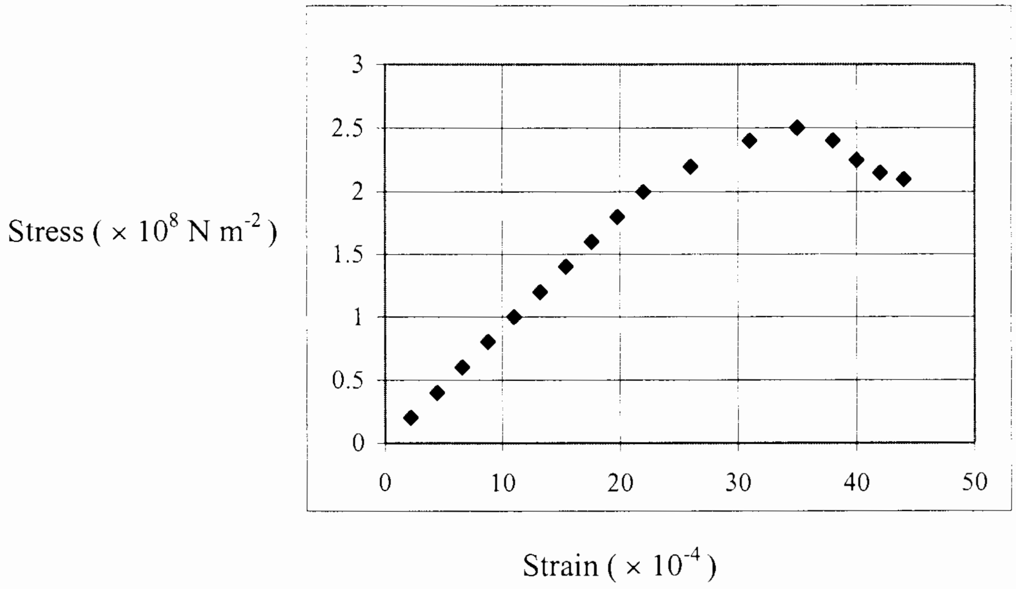

Figure 1: Stress-strain curve for brass

5. What feature of the crane helps stop it toppling over when it lifts a heavy load from the long arm at the right of the picture? Explain how this feature reduces the overturning effect of a load.

Figure 2: A crane bearing a load

6. Large symphony orchestras have more than 20 violins. One violin produces a sound intensity level of 77.5 dB in the orchestra's rehearsal room. Estimate the sound intensity level that would result if all of the orchestra's violin players sounded their instruments simultaneously in the room.

7. Is the International Space Station affected by the Earth's gravitational field when it is in its orbit? Explain your answer.

8. The Earth's magnetic field is about 50 μT. Estimate the maximum amount of magnetic flux that could be enclosed by a basketball ring.

9. Estimate the energy of a single photon of the electromagnetic energy emitted by a local radio station.

10. When sound waves pass from one medium into another, they often refract. Show in a diagram the behaviour of a series of wave fronts which refract at the boundary between two media.

State what determines whether or not the sound will refract (at angles of incidence other than 0°).

11. An eagle swoops down on its prey, following a path that is an arc of a circle of radius 85 m. The eagle's speed at the lowest point on its arc is 24 m s^{-1}.

Ignoring air resistance, estimate the force on the eagle's wings at this lowest point.

Figure 3: The eagle's path

12. A free body diagram shows all the forces exerted on a body. Draw a labelled free body diagram of an athlete running around a bend.

13. The diagram illustrates the magnetic field around the Earth. Show in the diagram a direction an electron could be travelling at the point marked with a star so that its path is **NOT** affected by the magnetic field.

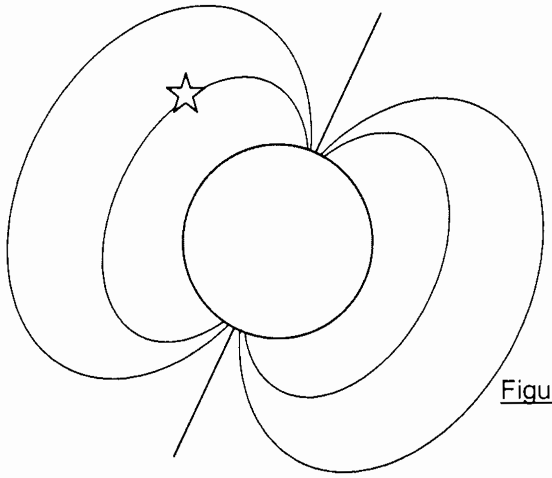

Figure 4: Magnetic field around the Earth

14. How do power companies minimize the loss of power incurred in transmitting electricity through power lines?

Explain why less power is lost this way.

15. If the Earth were perfectly spherical, the *measured* value of the acceleration due to gravity g would be different at the equator and the poles of the Earth. What is the main reason for this difference?

SECTION B: Problem Solving **(100 Marks)**

Attempt **ALL** 7 questions in this section

Note that some questions have alternatives. Follow the directions in these questions with care.

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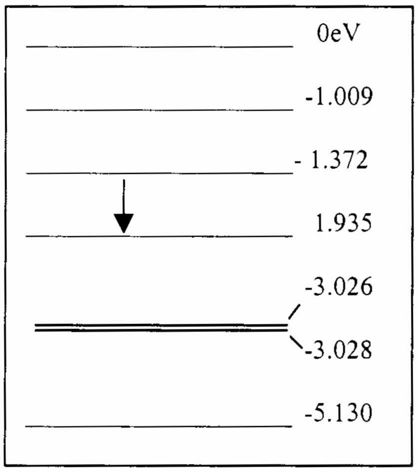
1. [Total 14 marks]

(a) Some of the energy levels of sodium are shown in the diagram. *Only the lowest energy level shown is occupied by an electron when the atom is in its ground state.* [4 marks]



(i) What is the minimum energy of a photon which can ionize a sodium atom?

Answer: _______________ eV

(ii) What process does the arrow drawn in the diagram represent? What is the result of the process?

(b) [5 marks]

(i) Two lines in the sodium spectrum resulting from electron transitions to the ground state, in the yellow region, are very close together. Explain how this light is produced. Hence estimate the wavelength of yellow light.

(ii) Identify on the diagram a transition which will cause the emission of a photon with a wavelength longer than for yellow light. State the reason you selected this transition.

(c) Attempt **ONE** of the optional parts A **OR** B **OR** C. If you answer more than one optional part, only the first will be marked. Cancel any attempts that you do not want to have marked. [5 marks]

EITHER

A *Context: Sunlight and Starlight*

(i) Explain how the spectrum of light from a star can be used to identify elements in the star.

(ii) The Sun, a star, emits ultraviolet radiation. State one benefit of ultraviolet radiation. Also, state the important physical principle that causes the benefit.

OR

B *Context: Medical Applications*

(i) Lasers emit light of a distinct colour. Explain why this is so.

(ii) X-rays are used in medical diagnosis. State one benefit of X-rays. Also, state the important physical principle that causes the benefit.

OR

C *Context: Domestic/Industrial Applications*

(i) Many street lamps emit light of a distinct colour. Explain why such lamps do not emit white light.

(ii) X-rays are used in applications such as examining aircraft frames. State one benefit of X-rays. Also, state the important physical principle that causes the benefit.

(b) Ignoring air resistance: [8 marks]

(i) Find the time the ball is in the air from the moment it is hit to the time it reaches the ground.

(ii) Find the horizontal distance travelled in this time.

2. [Total 14 marks]

Playing a hard game of tennis, Pat Strafer hits a ball at an angle of 1.5° above the horizontal at a speed of 55 m s^{-1}. At the instant he hits it, the ball is 0.35 m above the ground.

(a) [6 marks]

(i) Sketch the trajectory (path) of the ball from the racquet to the ground, without air resistance.

(ii) On the same sketch, show how air resistance will affect this trajectory. Label your sketch clearly.

Explain why air resistance has this effect.

(iii) Is there any time at which the ball will have a zero acceleration between the time it is hit and the time it reaches the ground? Give a reason for your answer.

3. [Total 18 marks]

Geraldine was investigating the speed of waves along stretched strings. She generated these waves by plucking a 0.760 m length of guitar string. She knew the speed was given by

$$v = \sqrt{\frac{T}{\mu}}$$

where T is the tension in the string and μ is the mass per unit length. She plotted her results in the graph shown as Figure 5.

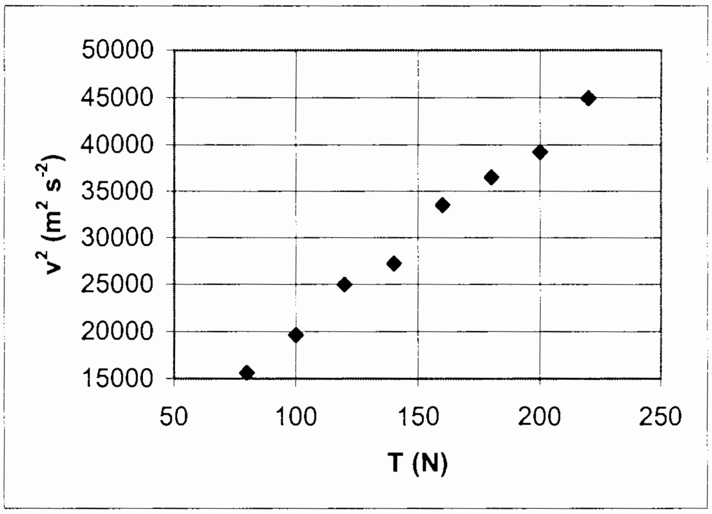


Figure 5: Geraldine's experimental results

(a) [4 marks]

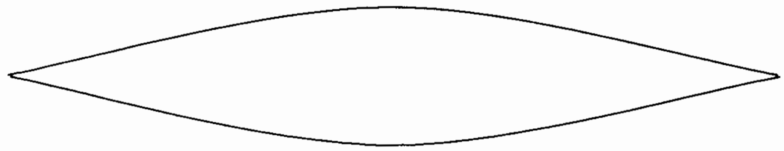
(i) Why did Geraldine plot v^2 against T and not just v against T?

(ii) What are the units of μ?

(b) Use the graph to determine the best experimental value of μ for this string. Show your working clearly. [5 marks]

(c) Geraldine adjusted the tension to 125 N. What is the frequency of the fundamental mode of the string now? Show how you obtain the figures you use. [4 marks]

(d) The wave envelope of the string when it is oscillating in its fundamental mode is shown in the diagram below. [5 marks]



(i) Sketch the wave envelope when the string is oscillating in its second overtone (also called the third harmonic).

(ii) The wave in the string is a transverse wave but sound is a longitudinal wave. How is it possible for a transverse wave to produce sound?

4. [Total 14 marks]

My boat trailer has two wheels and when loaded with my boat the total mass is 650 kg. The loaded trailer is 3.50 m long from the back of the boat to the ball hitch at the front of the trailer, and the centre of gravity of the combination is 0.50 m in front of the trailer's axle. The trailer is in a horizontal position when attached to the tow bar of my car. The diagram below shows a side view of the loaded trailer.

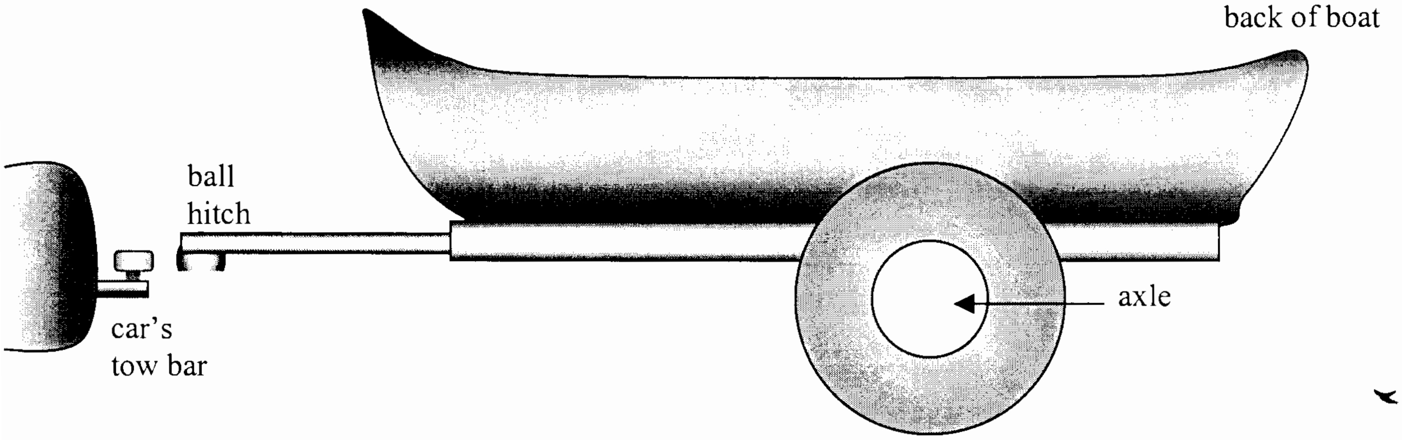


Figure 6: My boat on its trailer

(a) After the trailer is connected to the car, what is the **direction** of the force exerted on the ball hitch by the tow bar? Explain your answer. [4 marks]

(b) The boat's outboard motor has a mass of 72.0 kg, and is fitted to the back of the boat 1.20 m from the axle.

What is the **size** and **direction** of the force exerted on the ball hitch by the tow bar of my car when the outboard motor is fitted? Show your reasoning. [6 marks]

(c) Attempt **ONE** of the optional parts, A **OR** B. If you answer more than one optional part, only the first will be marked. Cancel any attempts that you do not want to have marked.
[4 marks]

EITHER

A *Context: Structures and Materials*

The boat and trailer can be lifted by one person pulling up at the ball hitch, even though they are very heavy. Explain why this is possible.

OR

B *Context: Human and Animal Frames*

When a person is doing push-ups on the floor, he needs to exert less force by his arms when his knees are on the ground than when he only has his toes on the ground. Explain why this is so.

5. [Total 16 marks]

The asteroid Ceres has a mass of 1.11×10^{21} kg and diameter 772 km. Ceres orbits the Sun at an average distance of 414 million kilometres.

(a) Calculate the acceleration due to gravity at the surface of Ceres. [4 marks]

(b) Calculate the acceleration of Ceres towards the Sun. [4 marks]

(c) Calculate the orbital velocity of Ceres. [4 marks]

(d) Estimate the change in length of a 2 m length of thin copper wire caused by hanging a 1.5 kg mass on the wire on the asteroid Ceres. [4 marks]

6. [Total 12 marks]

In a DC motor (see Figure 7), the coil consists of rectangular loops of wire mounted on an axle rotating in a magnetic field of 0.45 T. The current in the wire is 5.6 A.

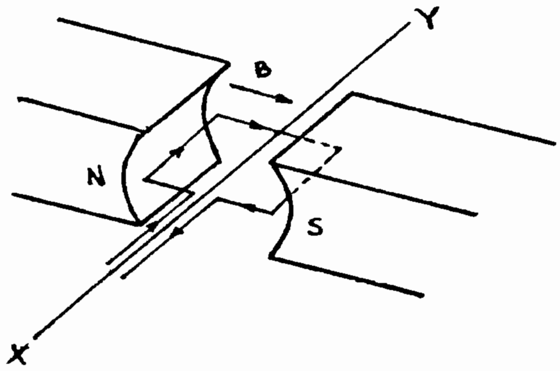


Figure 7: Simplified view of a DC motor

(a) What force acts on each centimetre length of this wire? [4 marks]

(b) The coil is made of 420 loops, each 225 mm long and 120 mm wide. The axle is mounted parallel to the long axis of the loops. Calculate the torque produced by this motor. [4 marks]

(c) Figure 8 below shows a coil with several turns at varying stages in its rotation. The coil is viewed along the axle of the motor (line XY in Figure 7). In each diagram, the symbols are as follows:

The axle (or axis of rotation) is a shaded circle. ○

A wire carrying current into the page is shown as ⊗

A wire carrying current out of the page is shown as ⊙

A line of magnetic flux is shown as ⟶

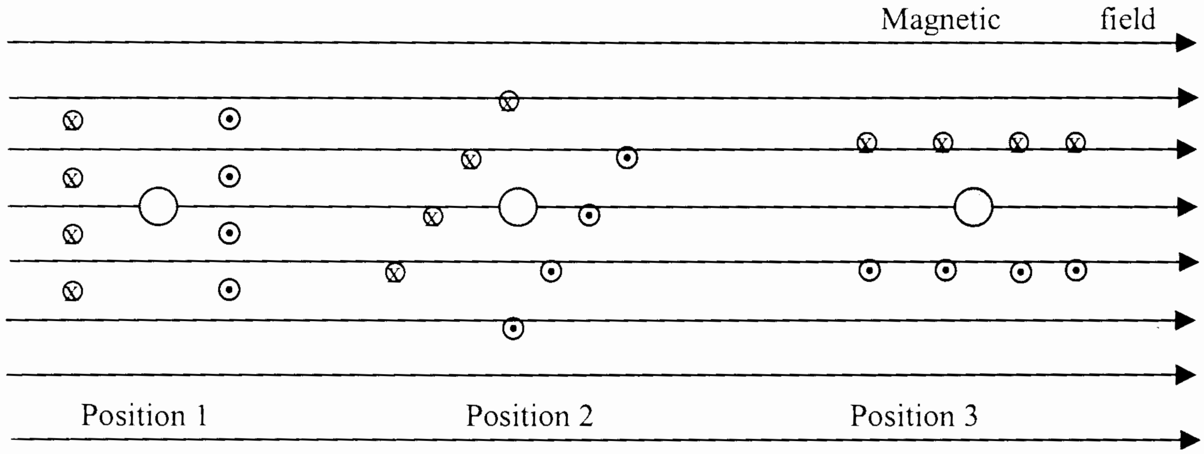


Figure 8: Three views of a coil rotating in a magnetic field at three different times

State clearly which of the diagrams show (or shows) the coil when its torque is a **maximum**, and which of the diagrams show (or shows) the coil when its torque is a **minimum**. [4 marks]

7. [Total 12 marks]

(a) Near the North Pole the Earth's magnetic field is almost vertical. Is the field direction here vertically upwards, or is it vertically downwards? Give a reason for your answer.

[4 marks]

(b) Brigette, who lives near the North Pole, has a swing. The swing consists of a 400 mm wide seat, supported by a 2.5 m long vertical wire attached to each end, all hung from a sturdy frame. All the parts of the swing are made of steel.

When Brigette swings on this apparatus, at what point in its movement does the seat generate a **maximum** emf by passing through the Earth's magnetic field? Explain.

[4 marks]

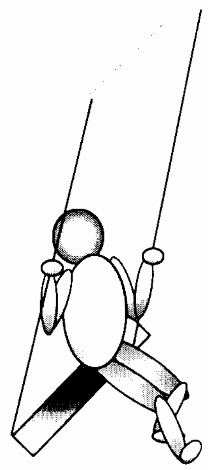
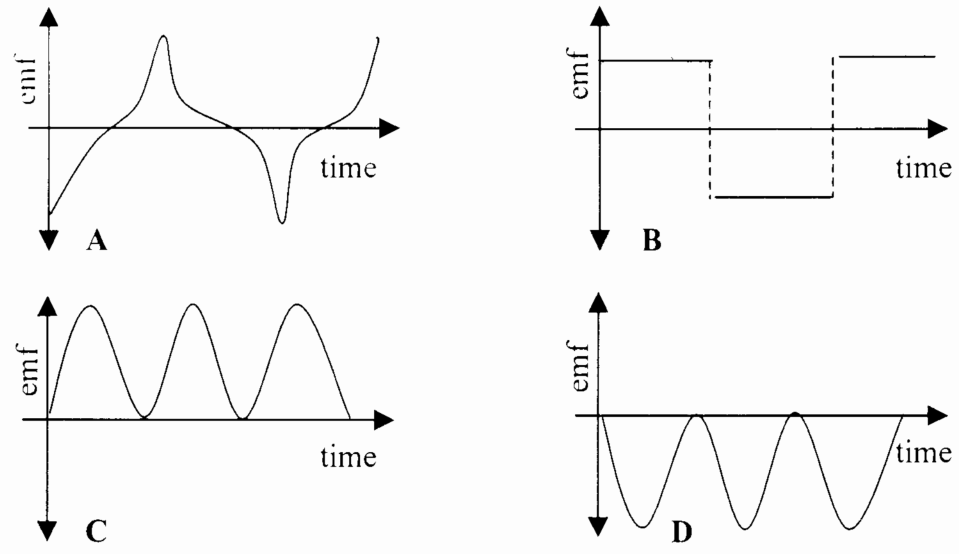


Figure 9: Brigette on a swing

(c) Which of the following is a likely graph of the emf generated across the seat as a function of time, as Brigette swings to and fro? Explain your choice. [4 marks]



Your choice of graph: ________

Explanation:

SECTION C: Comprehension and Interpretation (40 Marks)

BOTH questions should be attempted.

Read both passages carefully and answer all questions at the end of each passage. Candidates are reminded of the need for clear and concise presentation of answers. Diagrams (sketches), equations and/or numerical results should be included as appropriate.

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1. The Compton Effect (Total 24 marks)

(Paragraph 1)
The Compton effect is one of the more remarkable discoveries in modern physics. Young had shown that light could be diffracted, which convinced everyone that this was the end of the controversy about whether light was a wave or consisted of particles, as contended by Newton. In this context, the Compton effect was quite unexpected, and it made it necessary to revise the theories of electromagnetic radiation.

(Paragraph 2)
It was well known that particles such as electrons have a momentum given by p = mv. In the development of his theory of relativity, Albert Einstein found it necessary to assign to photons a momentum given by $p = h/\lambda$, where h is Planck's constant and λ is the wavelength of the photon. This is something that Young had never anticipated. Experiments confirmed that this relationship is true.

(Paragraph 3)
One of the applications of this property is in the phenomenon of Compton scattering. In this process, a photon collides with a stationary electron, after which the electron and the photon fly off in different directions. One of the laws of physics is that momentum has to be conserved. When you consider the momentum in both the x and the y directions, there are constraints on the final directions the scattered electron and photon can go. In addition, the total energy of the electron and the photon has to be the same before and after the collision. Putting this all together, it comes out that

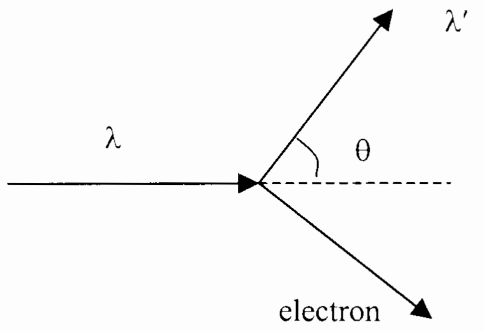

Figure 10: Compton scattering

$$\lambda' - \lambda = \frac{h}{mc}(1 - \cos\theta)$$

where λ is the wavelength of the incident photon, λ' is the wavelength of the scattered photon, h is Planck's constant, m is the mass of the electron, c is the velocity of light and θ is the angle at which the photon is scattered.

(Paragraph 4)
The equation shows that the photon loses energy in the scattering process, and that the larger the angle of scatter, the larger the energy lost.

(Paragraph 5)

This discovery that photons have momentum has some rather interesting consequences. One is that photons reflected from a surface create a force on the surface. One of the more imaginative proposals that has been made is to construct giant solar sailboats with huge sails, that could be used to assist travel in the solar system. There are some technical difficulties, but one of the great advantages of such a sailboat is that the Sun provides the driving force and no fuel is necessary.

(a) Does Compton scattering demonstrate the wave nature or the particle nature of radiation? Justify your answer. [3 marks]

(b) Verify that the units for the momentum of a photon and an electron are consistent. [4 marks]

(c) [7 marks]

(i) Which will have the higher momentum, an ultraviolet photon or an X-ray photon? State your reason.

(ii) Calculate the momentum of a photon with an energy of 110 keV.

(c) (iii) Through what angle must a photon be scattered in order for it to have the lowest possible amount of energy after it is scattered? Justify your answer.

(d) A photon with an energy of 1.76×10^{-14} J is scattered at an angle of 60°. What is the energy of the scattered electron? [6 marks]

(e) Explain why reflection of photons from a surface should exert a force on the surface (Paragraph 5). Show in a diagram the direction of the force on the sail of a solar sailboat. [4 marks]

2. Magnetic Domains and the Barkhausen effect (Total 16 marks)

Paragraph 1

In a ferromagnetic material such as iron, each atom has its own permanent magnetic field. The atomic magnetism results from the spins of the electrons. In atoms of many substances, the effects of the electron spins cancel out, or are very weak; but in atoms of ferromagnetic substances, the magnetic spins (also called magnetic moments) reinforce each other. Every piece of iron, for example, contains regions where all the atoms are aligned so their magnetic moments add up. These regions, or domains, behave like tiny permanent magnets in which the direction of the magnetic field is the same as the magnetic moment of the domain. Domains vary in size and shape. A piece of iron 0.1 mm across may contain up to 10^5 domains, yet in other samples domains may be as large as 1 mm across.

Paragraph 2

In an unmagnetised piece of ferromagnetic material the magnetic moments of neighbouring domains are arranged in roughly closed loops (see Figure 11 below), so the sum of the magnetic moments around a loop is approximately zero. Thus, the piece of ferromagnetic material, as a whole, also has a total magnetic moment that is approximately zero.

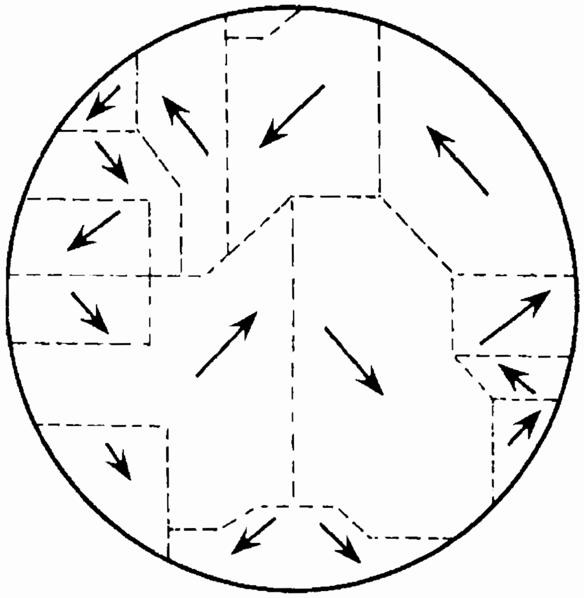

Figure 11: Magnetic moments in an unmagnetised piece of iron.
The arrows show the direction of the magnetic moment.

Paragraph 3

The magnetic moments of the domains in an unmagnetised piece of iron are more or less randomly arranged, but they can be aligned. An iron bar in which many domains are approximately aligned is called a bar magnet. This alignment uses energy, however. The energy source may be another bar magnet being moved (or "stroked") across the iron bar. As a bar magnet moves along an iron bar, individual domains "snap" into alignment and the total magnetic moment increases in a stepwise fashion (see Figure 12 on next page). This is known as the "Barkhausen effect".

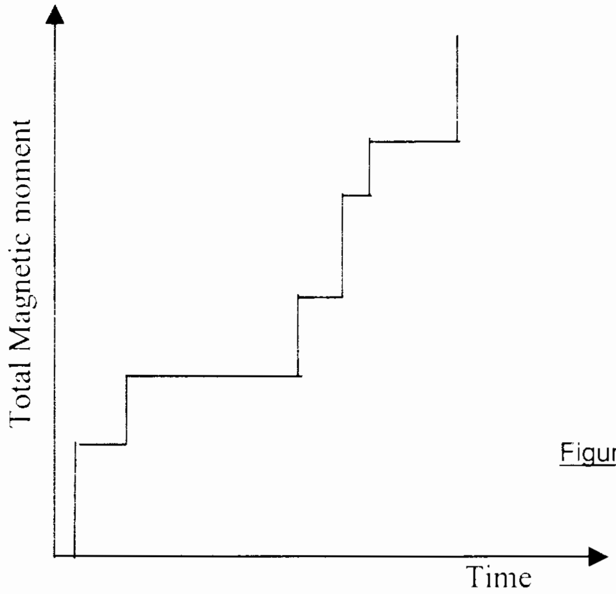

Figure 12: The Barkhausen effect

Paragraph 4

The Barkhausen effect can be demonstrated convincingly by using an electromagnet, connected to a loudspeaker, as the stroking magnet. As each domain snaps into line, the suddenly changing magnetic field in the electromagnet coil produces a click from the loudspeaker. The speed with which the stroking magnet moves decides how you hear the sounds, a slow movement producing a series of discrete clicks, while a faster movement produces a buzzing sound. The graph below shows the loudness of the sounds made by such a loudspeaker, as a function of time, when the stroking magnet was moved across the domains at a constant rate.

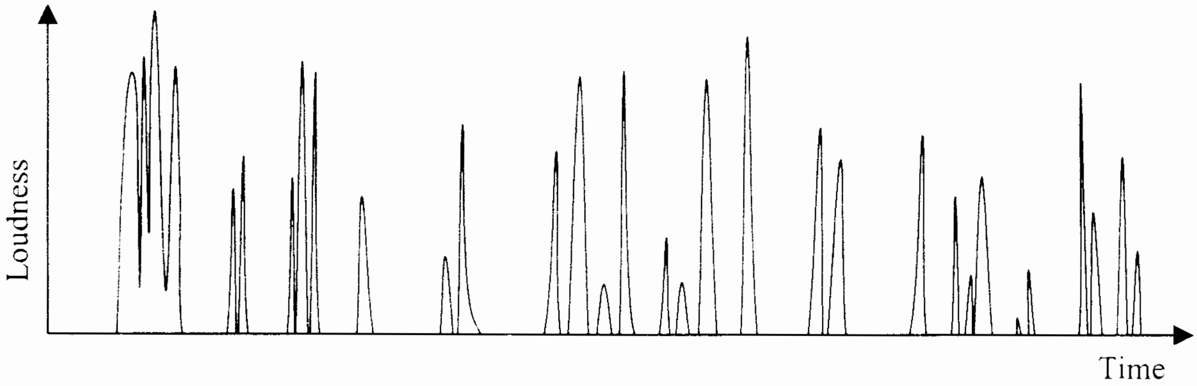

Figure 13 : Loudness-time graph for the Barkhausen experiment

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(a) Is "magnetic moment" a scalar or a vector quantity? Explain. (Paragraph 2) [4 marks]

(b) If the stroking magnet moves at an even rate, would you expect the buzzing sound to have a constant frequency? Explain. (Paragraphs 1, 3 & 4 and Figure 13)

[4 marks]

(c) Consider Figure 13, the graph of amplitude against time. Is the buzzing sound mentioned in Paragraph 4 best described as a noise, or as a musical note? Explain.

[4 marks]

(d) Show, on Figure 14 below, the magnetic moments in the domains after the piece of iron shown in Figure 11 was stroked by the north pole of a magnet. On the diagram, show the direction of the magnet's motion. [4 marks]

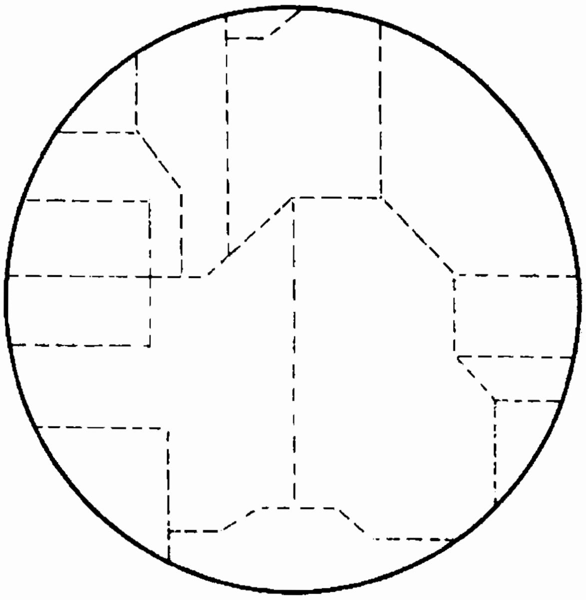

Figure 14: Magnetic moments of domains in a piece of iron after it has been stroked by the north pole of a bar magnet.

END OF PAPER

Check that you have written your Student Number on the front cover of this booklet.