Comprehension Passage 2 METAL DETECTORS

(paragraph 1)
In general, metal detectors find metal objects by looking for their electromagnetic responses. For example, you can tell when an iron or steel object is nearby by waving a magnet around. If you feel something attracting the magnet, you can be pretty sure that there is a piece of iron or steel nearby. Similarly, if you wave a strong magnet rapidly across an aluminium or copper surface, you'll feel a drag effect as the moving magnet causes electric currents to flow in the metal surface – electric currents are themselves magnetic.

(paragraph 2)
Of course, a real metal detector is much more sensitive than your hands are, but it's using similar principles to detect nearby metal. Most often, a metal detector uses a coil of wire with an alternating current in it to create a rapidly changing magnetic field around the coil. If that changing magnetic field enters a piece of nearby metal, the metal responds. If the metal is ferromagnetic – meaning that it has intrinsic magnetic order like iron or steel – it will respond strongly with its own magnetic field. If the metal is non-ferromagnetic – meaning that it doesn't have the appropriate intrinsic magnetic order – it will respond more weakly with magnetic fields that are caused by electric currents that begin to flow through it.

(paragraph 3)
In a short range metal detector, the detector looks for the direct interaction of its magnetic field and a nearby piece of metal. That nearby metal changes the characteristics of the detector's wire coil in a way that's relatively easy to detect. But in a longer range metal detector, the electromagnetic coil must actually radiate an electromagnetic wave and then look for the reflection of this electromagnetic wave from a more distant piece of metal. That's because the magnetic field of the coil doesn't extend outward forever – it dies away a few diameters of the coil away from the coil itself. For the metal detector to look for metal farther away, it needs help carrying the magnetic field through space. By combining an electric field with the magnetic field, the long range metal detector creates an electromagnetic wave – a radio wave – that travels independently through space. Electromagnetic waves reflect from many things, particularly objects that conduct electricity. So the long range metal detector launches an electromagnetic wave and then looks for the reflection of that wave. This wave reflection technique is the basis for sonar (sound waves) and radar (radio waves), and it can be used to find metals deep in the ground. Unfortunately, the ground itself conducts electricity to some extent, so it becomes harder and harder to distinguish the reflections from metal from the reflections from other things in the ground.

Source: http://www.mtxaudio.com/educate/acoustic.htm

(f) Under what conditions would interference occur **outside** of the speaker enclosure?

If interference did occur outside the speaker enclosure, would this be an advantage or disadvantage? Explain.

(4 marks)

Passage 2 **METAL DETECTORS**

(a) In paragraph 1, reference is made to a "drag effect". Explain why this drag effect is felt when a strong magnet moves across a copper surface.

(4 marks)

(b) A metal detector could be designed to use either an alternating current or a direct current in a coil of wire. “Most often”, an alternating current is used (paragraph 2). Why is an alternating current preferred?

(3 marks)

(c) Why is a metal detector more likely to detect a piece of steel buried in the ground than a similar sized nugget of gold?

(3 marks)

(d) A short range metal detector will detect a nugget of gold but not a piece of plastic of the same size and at the same depth. Explain how the gold is detected and therefore why the plastic is not detected. (paragraph 3)

(3 marks)

(e) A long range metal detector emits microwaves that are reflected from a metallic object buried in the ground. If the signal is detected 2.6 μs after being sent and then reflected from the object which is about 170 cm from the detector, **estimate** the speed of microwaves in soil?

(3 marks)

(f) The metal detector utilises the magnetic field produced when a current flows through a coil of wire. Sketch a labelled diagram to illustrate the magnetic field associated with a coil of wire.

(4 marks)

End of examination – there are no more questions!

SECTION C (**Comprehension and Interpretation** = 40 marks or 20% of total for the paper)

BOTH questions should be attempted.

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

Question 1 EXTENSION of SPRINGS

Some students were investigating a large suspension spring taken from an old truck. They measured the length of the spring while stretching it with a range of forces.

Their raw data is tabulated below.

Applied Force F (newton)	Length (X) (metre)
2.0	0.51
2.5	0.52
3.5	0.55
4.0	0.57
4.5	0.58
5.0	0.60
5.5	0.63
6.0	0.66
7.0	0.70
8.0	0.76
9.0	0.83

The raw data was plotted and the shape of the graph (which was **NOT** linear) suggested to them that the relationship could be of the following form:

$$X = A F^2 + B$$ (where **A** and **B** are constants)

Their task was to then decide whether or not this relationship seemed to be supported by their data and to find the values of **A** and **B**.

The following questions ask you to analyse the student's data.

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(a) Why didn't the students obtain a linear graph when they plotted their raw data?

[2 marks]

(b) To how many significant figures should the values of F^2 be expressed? Why?

[2 marks]

(c) Complete the following table to show the manipulated data from the experiment.

Applied Force F (newton)	Length (X) (metre)	F^2 (N^2)
2.0	0.51	
2.5	0.52	
3.5	0.55	
4.0	0.57	
4.5	0.58	
5.0	0.60	
5.5	0.63	
6.0	0.66	
7.0	0.70	
8.0	0.76	
9.0	0.83	

[3 marks]

(d) Plot a graph of **length X** (vertical axis) versus F^2 (horizontal axis). Use the graph paper provided. Draw the **line of best fit** through the data points.

[4 marks]

(e) What is the **gradient** of your graph? Include the units.

[2 marks]

(f) Hence, write the equation expressing the relationship between length of the spring and the applied force.

[2 marks]

(g) What important information about the spring does the vertical intercept of the graph provide?

[1 mark]

(h) The students then make some additional measurements using the same spring. Use this information together with your answer to (g) to estimate the value of Young's Modulus for the material used to make the spring.

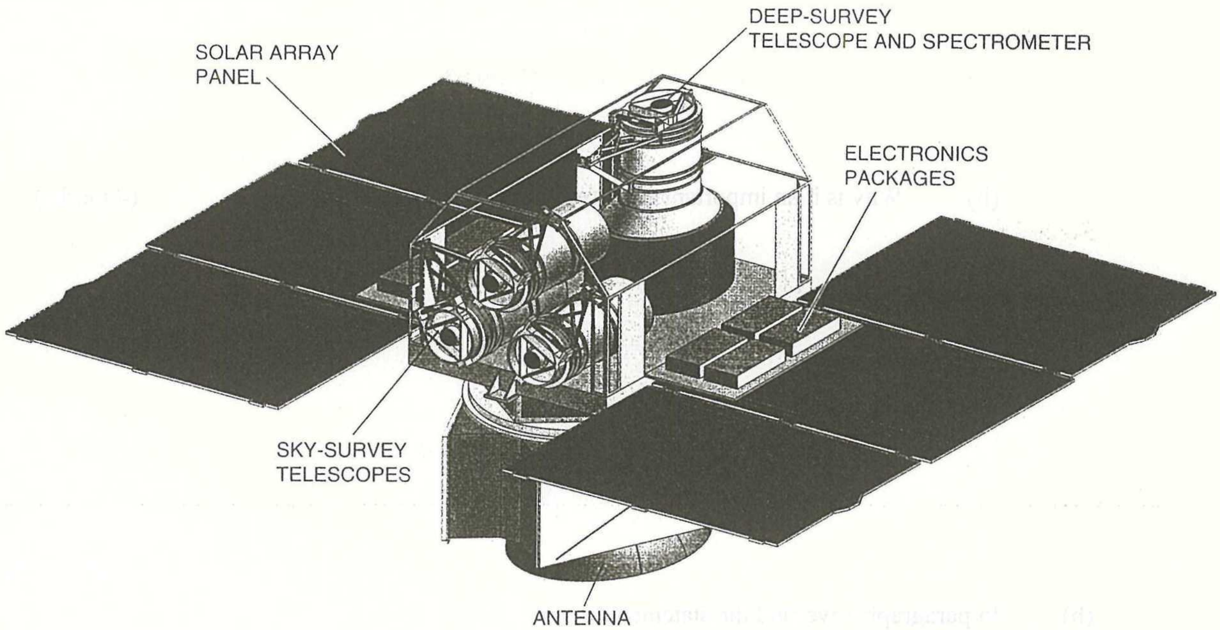
Diameter of spring = 5.0 mm

Load used = 6.5 N

Extension produced = 17.3 cm

[4 marks]

2. EXTREME ULTRAVIOLET ASTRONOMY [20 marks total]



(Paragraph 1)
On June 7, 1992, the National Aeronautics and Space Administration's *Extreme Ultraviolet Explorer (EUVE)* satellite was placed into an orbit 550 kilometres above the earth. Soaring over the atmosphere, which prevents extreme ultraviolet radiation from reaching earthbound telescopes, *EUVE* has detected a wide variety of astronomical objects. Among them are white dwarfs, coronally active stars and planetary objects in our solar system, all radiating in this high-frequency band. *EUVE* has even seen 10 sources of extreme ultraviolet (EUV) radiation beyond the Milky Way galaxy. This observation was all the more satisfying because of the long-standing prediction that interstellar gas would absorb all EUV radiation coming from even nearby stars, let alone that from extragalactic objects.

(Paragraph 2)
During the 1960s and early 1970s, astronomers believed that extreme ultraviolet radiation – having wavelengths between roughly 10 and 100 nanometres – would be completely absorbed by the interstellar medium. Thus, such light, if emanating from any star other than the sun, could not reach the earth's vicinity. This calculation was based on an estimate of the average density of gas in interstellar space: one hydrogen atom per cubic centimetre, with lesser amounts of helium and other elements. If this material were uniformly distributed throughout the galaxy, EUV astronomy would indeed be impossible.

(Paragraph 3)
G. B. Field, a leading expert on the interstellar medium, proposed that interstellar matter might be distributed quite unevenly. Its density in many directions might be only one tenth of the average. In that case, extreme ultra-violet radiation would penetrate – in those directions – 10 times farther than was normally assumed. Therefore, a volume of space 1,000 times greater than was commonly believed to exist would be observable by EUV light.

(Paragraph 4)
There are four telescopes on *EUVE* (see diagram). Three of these, the "sky survey" telescopes, point in the same direction and explore the EUV sky in four wavelength bands. The direction in which the survey telescopes look out is perpendicular to the axis of rotation of the *EUVE* satellite. As the satellite spins, the telescopes scan a strip of the sky; the strip shifts daily as the earth travels in its orbit around the sun. The entire sky is mapped in six months. The fourth, "deep survey" telescope is aligned parallel to the axis of rotation of *EUVE.* The prolonged exposure allows more sensitivity than does the main survey and reveals fainter sources.

(a) In paragraphs 2 and 3 there is a discussion concerning the **density of interstellar gas**.

(i) What does this refer to? (2 marks)

(ii) Why is it an important consideration in this discussion? (4 marks)

(b) In paragraph 1 we find the statement:

"Soaring over the atmosphere, which prevents extreme ultraviolet radiation from reaching earthbound telescopes..."

Describe one way in which EUV is absorbed by the components of the atmosphere. [3 marks]

(c) Sketch a portion of the electromagnetic spectrum which includes EUV and visible light. Indicate clearly appropriate wavelengths and the average energies of photons of EUV and visible light. (Note: these will need to be calculated.) [6 marks]

(d) How long does it take for the EUV Explorer to make one orbit of the Earth? [5 marks]

END OF QUESTIONS

END OF PAPER