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HSC Trial Examination 2003

Physics

This paper must be kept under strict security and may only be used on or after the afternoon of Thursday 14 August, 2003, as specified in the NEAP Examination Timetable.

General Instructions

Reading time 5 minutes

Working time 3 hours

Write using blue or black pen.

Draw diagrams using pencil.

Board-approved calculators may be used.

A data sheet, formulae sheets and Periodic Table are provided at the back of this paper.

Total marks – 100

Section I Pages 2–18

Total marks 75

This section has two parts, Part A and Part B.

Part A —15 marks

- Attempt Questions 1–15.
- Allow about 30 minutes for this part.

Part B —60 marks

- Attempt Questions 16–28.
- Allow about 1 hour and 45 minutes for this part.

Section II Pages 19–25

Total marks 25

- Attempt ONE question from Questions 29–33.
- Allow about 45 minutes for this section.

Students are reminded that this is a trial examination only and cannot in any way guarantee the content or the format of the 2002 Physics Higher School Certificate examination.

Section I

Total marks 75

Part A

Total marks 15
Attempt Questions 1–15.
Allow about 30 minutes for this part.

Use the multiple-choice answer sheet.
Select the alternative A, B, C, or D that best answers the question.

Sample $2 + 4 =$ (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ● B ~~●~~ C ○ D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate this by writing the word *correct* and draw an arrow as follows:

correct

A ~~●~~ B ~~●~~ C ○ D ○

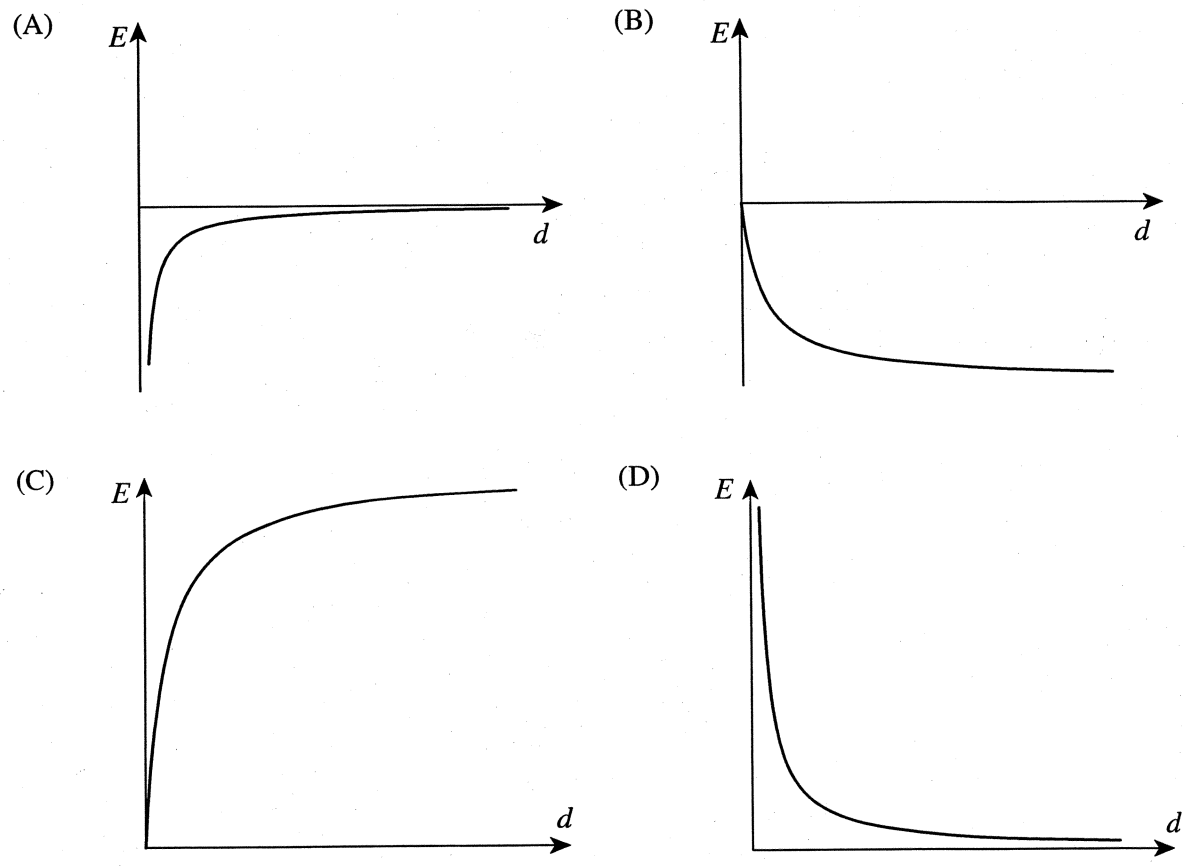
1. The table gives information about the planets Earth and Uranus.

Planet	*Mass* (10^{24} kg)	*Radius* (km)
Earth	6.0	6.4×10^3
Uranus	86	2.4×10^4

An astronaut has a weight of 800 N at the Earth's surface.
Using the information in the table, what is the astronaut's weight on the surface of Uranus?

(A) 800 N
(B) 813 N
(C) 786 N
(D) 980 N

2. A body's gravitational potential energy changes with its distance from a planet.
Which graph best describes the gravitational potential energy (E) of a body as a measure of its distance (d) from the planet's surface?



3. In order to escape from the Sun's gravitational field, interstellar spacecraft need an escape speed over 600 km s^{-1}. Pioneer 10, launched in 1972, had a launch speed of only 15 km s^{-1}.

What was the main reason Pioneer 10 was able to escape the Sun's gravitational field?

(A) The spacecraft used a solid fuel during liftoff and thus by reducing its total mass was accelerated to the required value.

(B) The rocket engines were fired once in a stable parking orbit and thus extra thrust was sufficient to accelerate the spacecraft to the required value.

(C) The spacecraft utilised the principles of conservation of momentum and energy to accelerate them through the gravitational fields of planets it encountered along the way.

(D) The spacecraft used a solid fuel rocket engine designed to burn at a constant rate during launch and thus was accelerated to the required value.

4. Galileo was able to deduce a relationship to explain parabolic projectile motion.

Which of the following statements is in agreement with Galileo's findings on projectile motion?

(A) The distance an object travels from rest is proportional to the square of the time elapsed.

(B) The rate at which an object dropped is dependent upon its mass.

(C) The square of the distance an object travels from rest is proportional to the time elapsed.

(D) The rate at which an object dropped is not dependent upon its velocity.

5. For a satellite in a low Earth orbit, the altitude above the Earth is small in comparison with the Earth's radius.

Compared to a geostationary satellite a low Earth satellite will have a period of orbit which is

(A) the same

(B) slower

(C) faster

(D) twice as slow

6. Which statement is true for a step-down transformer?

(A) It reduces current and voltage.

(B) It has more turns in the primary than in the secondary.

(C) It has less turns in the primary than in the secondary.

(D) It has a non-laminated iron core.

7. Energy is lost in transmission lines. How can this loss be reduced?

(A) Use thinner wires in the transmission line.

(B) Increase the current in the transmission line.

(C) Decrease the current in the transmission line.

(D) Heat the wire.

8. An ideal transformer has the following characteristics.

Coils in primary	100
Coils in secondary	20
Voltage produced in secondary	2 V

What is the voltage applied to the primary?

(A) 0.1 V
(B) 0.4 V
(C) 2.5 V
(D) 10 V

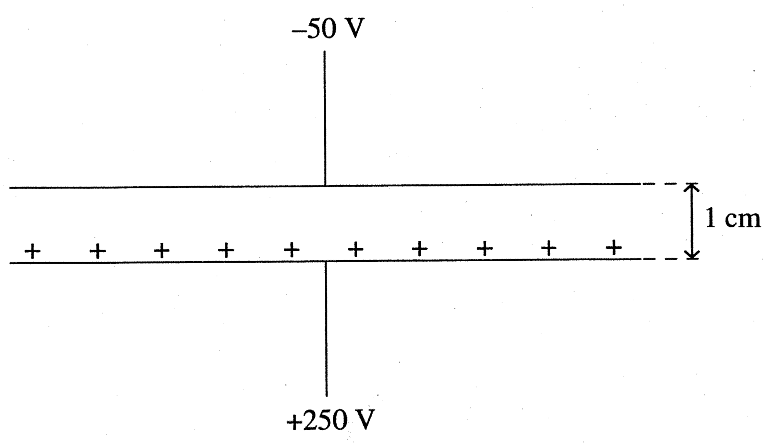
9. A coil in an electrical meter turns clockwise when a circuit is switched on. How can you make it turn anticlockwise when the circuit is switched on?

(A) Reverse the direction of the current.
(B) Turn the coil through 180°.
(C) Increase the current.
(D) Decrease the current.

10. A wire of length 10 cm is at 90° to a magnetic field B of strength 10^{-2} T. A current of 2 A flows in the wire.
What is the force on the wire caused by the field?

(A) 2×10^{-1} N, parallel to B
(B) 2×10^{-1} N, perpendicular to B
(C) 2×10^{-3} N, parallel to B
(D) 2×10^{-3} N, perpendicular to B

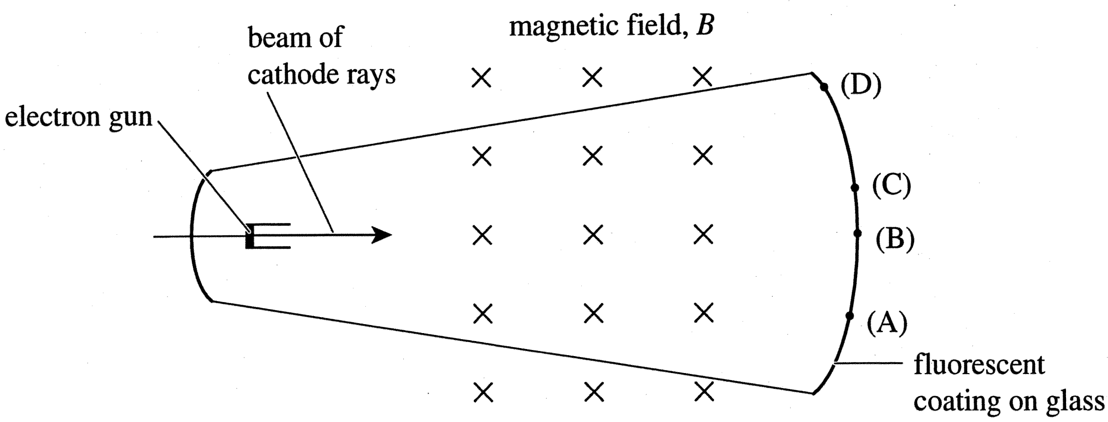
11. Two flat parallel metal plates are connected to a voltage source. The plates are charged so that a potential difference exists between them as shown in the diagram.



What is the magnitude and direction of the electric field?

(A) 3×10^{4} V m^{-1} up the page
(B) 3×10^{4} V m^{-1} down the page
(C) 2×10^{4} V m^{-1} up the page
(D) 2×10^{4} V m^{-1} down the page

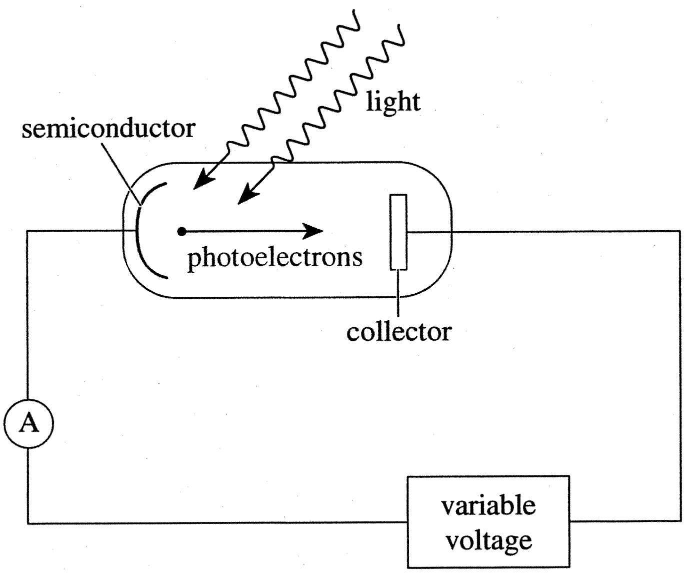
12. A beam of cathode rays passes through an evacuated glass discharge tube and makes a glow at position (B) as shown in the diagram.



A magnetic field is added so it acts into the page and is indicated by crosses (×).
Where will the glowing spot on the fluorescent coating be observed now?

(A) Below the straight-through position.
(B) At the straight-through position.
(C) Slightly above the straight-through position.
(D) Well above the straight-through position.

13. A beam of monochromatic light is shone onto a piece of semiconductor material in order to study the photoelectric effect. The flow of current is measured using an ammeter (A) as shown in the diagram below.

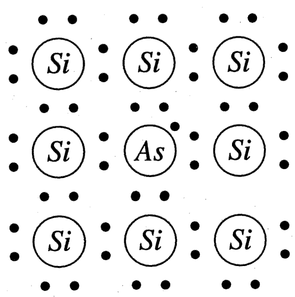


Which of the following changes will always result in an increase in the flow of current in the ammeter?

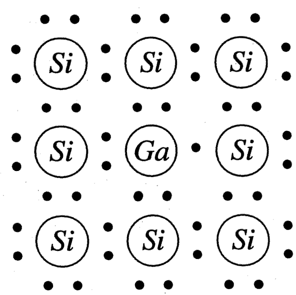
(A) Increasing the intensity of the monochromatic light.
(B) Decreasing the intensity of the monochromatic light.
(C) Increasing the frequency of the light source.
(D) Decreasing the frequency of the light source.

14. Diagrams (1) and (2) below show two possible arrangements of atoms in a substance with a silicon lattice structure. Diagrams (3) and (4) show two possible band structures for the energy relationships between the atoms of the same substance.

1.



2.



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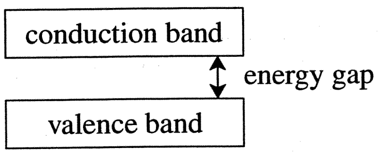

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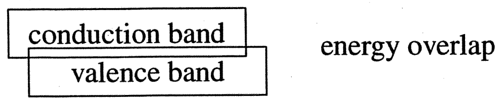

Which pair of diagrams correctly represents P-type semiconductors?

(A) 1 and 3
(B) 1 and 4
(C) 2 and 3
(D) 2 and 4

15. Problems with thermionic valves have led to them being replaced by semiconductor devices such as transistors in the communications and information technology industries.

What developments have led to this change?

(A) Increased knowledge of the properties of materials.
(B) The discovery of the elements silicon and germanium.
(C) The development of television tubes based on cathode ray discharge tubes.
(D) Transistors do not use as much electrical energy as valves.

Part B

Total marks 60
Attempt Questions 16–28.
Allow about 1 hour and 45 minutes for this part.

Answer Part B questions in the spaces provided.
Show all relevant working in questions that require calculations.

Question 16 (4 marks) **Marks**

(a) An astronaut repairing a satellite in orbit lets go of his spanner. Describe the spanner's subsequent motion after leaving the astronaut's hand. **1**

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(b) The spanner has a rest length 30 cm and a rest mass of 5 kg. If the speed of the spanner was later determined to be $0.3c$, determine the length and mass observed by a stationary observer on nearby Earth. **3**

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Marks

Question 17 (5 marks)

(a) Scientists utilise the motion of the Earth and the location of the launch site to assist in attaining the required velocity for a stable orbit. Explain the best direction and most suitable location to launch a rocket. **2**

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(b) Special precautions must be taken with spacecraft returning to the Earth's atmosphere. Discuss what precautions must be taken to ensure that a manned spacecraft safely returns to Earth. **3**

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Question 18 (2 marks)

A 1 570 kg satellite orbits a planet in a circle of radius 5.94×10^6 m. The gravitational force of attraction between this satellite and the planet is 1.57×10^6 N. Determine the mass of the planet. **2**

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Marks

Question 19 (8 marks)

During your course of study you performed a first-hand investigation to enable you to determine a value for acceleration due to gravity. **8**

Justify the appropriateness of your experimental procedure for this investigation, clearly stating what data you needed to collect and how you collected the data. Discuss the accuracy of your results and how the accuracy and reliability may be improved.

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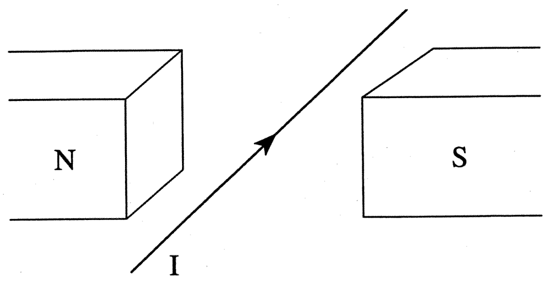
Marks

Question 20 (7 marks)

This diagram shows a wire carrying an electric current. The wire is in a magnetic field and is perpendicular to the field.



A force, caused by the field, acts on the wire.

(a) We need to change the magnitude of the force acting on the wire. One way to do this is to change the length of wire in the field. Identify two other ways of changing the magnitude of the force on the wire. **2**

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(b) Justify your answers in (a). **2**

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(c) A student attempted to measure the magnitude of the magnetic field produced by the magnets above. He supported the wire on a piece of cardboard sitting on a sensitive balance and measured the length of wire in the field. What other measurements will he need to make in order to find the field strength? **2**

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(d) When measuring the length in part (c), the student will need to make an assumption about the magnetic field. State the assumption. **1**

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Marks

Question 21 (5 marks)

(a) Michael Faraday carried out several experiments during his discovery of the generation of electric current by moving magnets. These experiments all involved a coil of wire. **2**

Using the concept of magnetic flux, explain why Faraday was able to generate electricity.

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(b) A physics class was trying a variation on Faraday's experiment by moving a wire in the Earth's magnetic field. They went outside the school building, connected both ends of a wire to a sensitive galvanometer and moved the wire up and down. No reading was seen on their meter. They thought the current must have been too small to measure. **1**

Suggest one way the students could increase the potential difference in the wire.

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(c) Justify why the method you have suggested should increase the potential difference. **2**

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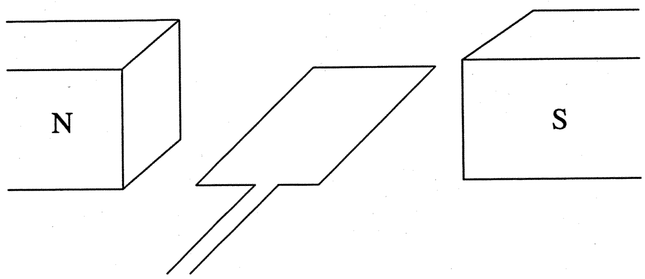
Marks

Question 22 (4 marks)

The arrangement below can be used to construct a DC motor or a DC generator.



(a) Describe how the equipment above could be used to make a DC generator. **2**

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(b) Compare the structure of a DC generator with a DC motor. **1**

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(c) How could you convert a DC generator to an AC generator? **1**

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Marks

Question 23 (5 marks)

Eddy currents are produced in many electrical devices. They are useful in some situations and cause problems in others. 5

Outline the production of eddy currents and their uses and problems.

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Marks

Question 24 (3 marks)

Examine the diagrams below.

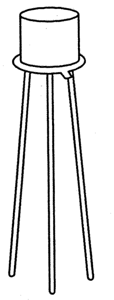

Diagram 1

scale

1 cm

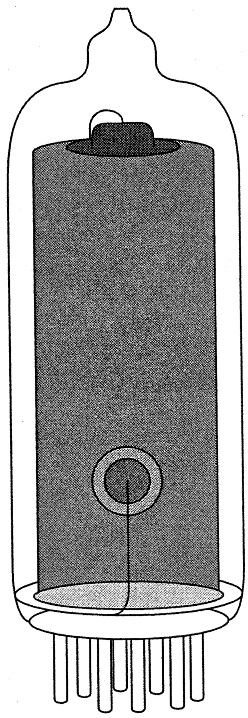

Diagram 2

(a) Name the two devices in the diagrams above. 1

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(b) Explain the reasons why solid-state devices have replaced thermionic devices in most of our modern electronic equipment. 2

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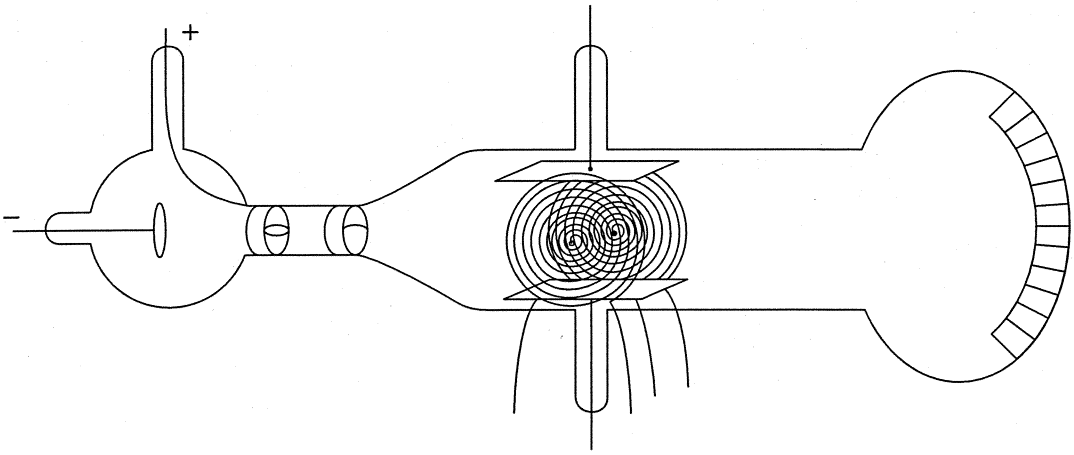
Marks

Question 25 (5 marks)

Examine the diagram below of J. J. Thomson's famous 1897 experiment that led to a new understanding of cathode rays.



(a) Name the two force fields used by J. J. Thomson in the experiment and outline how he used these to determine the charge to mass ratio $\left(\frac{q}{m}\right)$ of cathode rays. **2**

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(b) What was the nature of the debate that existed in the late 1800s over the behaviour of cathode rays and how did J. J. Thomson's experiment contribute to this debate? **3**

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Marks

Question 26 (4 marks)

Draw a labelled diagram of the apparatus Hertz used to demonstrate radio transmission. **4**

On your diagram:

1. Label a change that Hertz observed when ultraviolet light was shone onto the receiver.

2. Draw and explain a change that led Hertz to conclude that he was dealing with wave-based radiation and not particle-based radiation.

Marks

Question 27 (4 marks)

A spectral lamp in a chemical analysis machine emits a red light of wavelength 700 nm that falls onto a copper metal conductor.

(a) Calculate the frequency and the energy of each quantum of red light. **2**

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(b) If the work function of copper is 7.0×10^{-19} J, state whether photoelectrons will be emitted from the copper metal conductor and give a reason for your answer. **2**

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Question 28 (4 marks)

(a) Identify one possible use of superconductors in the power generation industry. **1**

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(b) Discuss the limitations of currently available superconductors and why these limitations prevent their widespread use in the power generation industry. **3**

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Section II

Total 25 Marks
Attempt ONE question from Questions 29–33.
Allow about 45 minutes for this section.
Answer the question in a writing booklet. Extra writing booklets are available.

Marks

Question 29 — Geophysics (25 marks)

(a) Outline the experiment of Jean Richer that showed that the Earth was not a perfect sphere. **2**

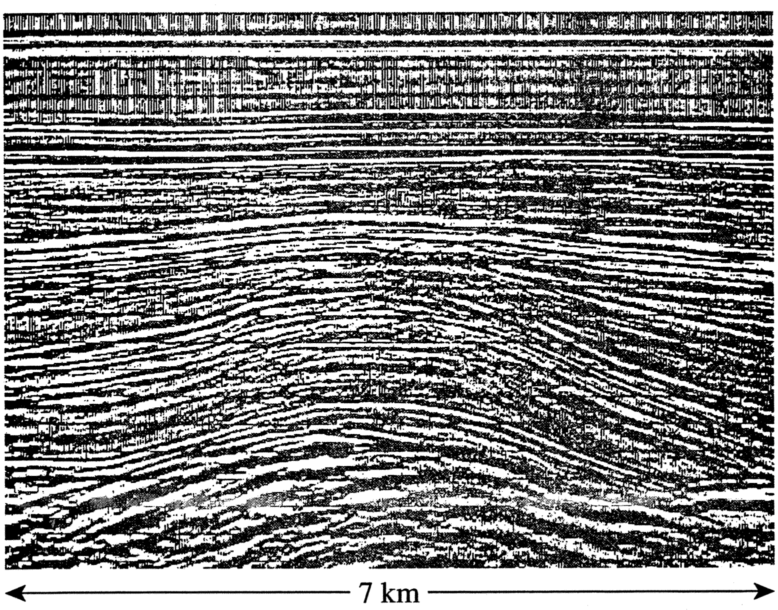
(b) (i) Name the instrument used to detect variations in the value of *g*, the gravitational field strength. **1**

(ii) Explain the operation of this instrument, with reference to the physical principles involved. **3**

(c) (i) Identify two techniques of remote sensing in mineral exploration. **2**

(ii) Choose one of these methods and briefly describe how it is utilised. **2**

(d) Explain how this seismic profile of the ocean floor has been produced. **3**



(e) Discuss how geophysical methods are used by scientists to reduce the impact of natural hazards. Refer to at least two different natural hazards in your answer. **4**

(f) Evaluate the geophysical evidence that supports the theory of plate tectonics and discuss why scientists were reluctant to accept the idea initially. **8**

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Marks

Question 30 — Medical Physics (25 marks)

(a) Identify the essential component of an endoscope that transfers the image of an internal organ so that it can be viewed by a surgeon and describe the role of total internal reflection within this component. **2**

(b) (i) Identify one radioactive isotope that is commonly used for obtaining scans of organs. **1**

(ii) Describe, with reference to one specific example, how radioactive isotopes may be metabolised by the body to produce a scan of a target organ. **3**

(c)

Tissue	*Density* (kg m^{-3})	*Velocity of sound* (m s^{-1})
brain	1090	1541
blood	1025	1570

(i) Define acoustic impedance and use the values above to determine the acoustic impedance for brain tissue. **2**

(ii) Determine, using the values above, the ultrasound ratio of reflected to initial intensity for a major blood vessel inside the brain. **2**

(d) Compare an image of bone scan employing PET with an X-ray image. **3**

(e) Relate relaxation time and the relevance of its values for tissues containing hydrogen in different forms to the production of MRI scans used in the diagnosis of disease. **4**

(f) Evaluate the value of a CAT scan in relation to other types of medical diagnostic scans. **8**

Marks

Question 31 — Astrophysics (25 marks)

(a) Name a waveband of the electromagnetic spectrum and discuss why it can be more easily detected from space. **2**

(b) Consider the following table.

Star	*Apparent magnitude*	*Absolute magnitude*	*Parallax angle (arcsecs)*
X	–0.01	+4.34	0.74
Y	+0.45	–5.14	

(i) How far, in parsecs, is star X from Earth? **1**

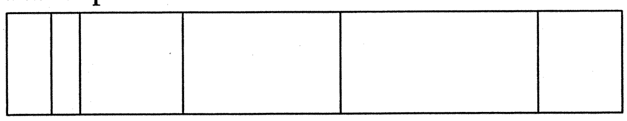
(ii) Discuss the difference in the absolute and apparent magnitude values for stars X and Y. **3**

(c) (i) Outline the light curve for a typical Cepheid variable. **2**

(ii) Explain the importance of the period–luminosity relationship for determining distances to Cepheid variables. **2**

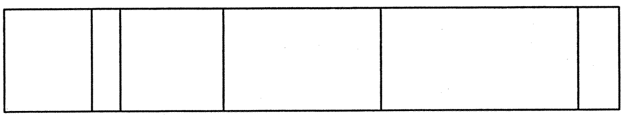
(d) The following spectrum was received from a star and then compared with a known laboratory spectrum. These spectra consist of a range of colours and five dark bands. **3**

Star's spectrum



violet red

Laboratory spectrum



violet red

Identify the information provided by the spectra and explain what the information tells us about the star.

(e) "Atmospheric distortion can be reduced using adaptive optics". Discuss. **4**

(f) Compare open and globular clusters and evaluate the usefulness of the Hertzsprung-Russell diagram in determining the age of these clusters. **8**

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Marks

Question 32 — From Quanta to Quarks (25 marks)

(a) Explain how Neils Bohr was able to adapt the concept of the quantization of energy to improve upon the Rutherford model of the atom. **2**

(b) Consider the following nuclear reaction.

$${}^{1}_{1}H + {}^{7}_{3}Li \rightarrow {}^{4}_{2}He + {}^{4}_{2}He$$

The masses are as follows:

$${}^{1}_{1}H = 1.0078\ \mu$$

$${}^{7}_{3}Li = 7.0160\ \mu$$

$${}^{4}_{2}He = 4.0026\ \mu$$

(i) State whether energy is absorbed or released during this reaction. **1**

(ii) Determine the mass defect and the energy in joules associated with this reaction. **3**

(c) (i) Explain how Neils Bohr's postulates were utilised to explain the line emission spectra of hydrogen. **2**

(ii) Calculate the wavelength of the photon of light released when an electron falls from the $n = 3$ level to the $n = 2$ level. **2**

(d) Name and describe how a particular isotope is used in agriculture. **3**

(e) Discuss how quarks and leptons feature in the standard model of matter. **4**

(f) Evaluate the contributions of Heisenberg and Pauli to the development of atomic theory. **8**

Marks

Question 33 — The Age of Silicon (25 marks)

(a) Compare the properties of an integrated circuit to the properties of a transistor. **2**

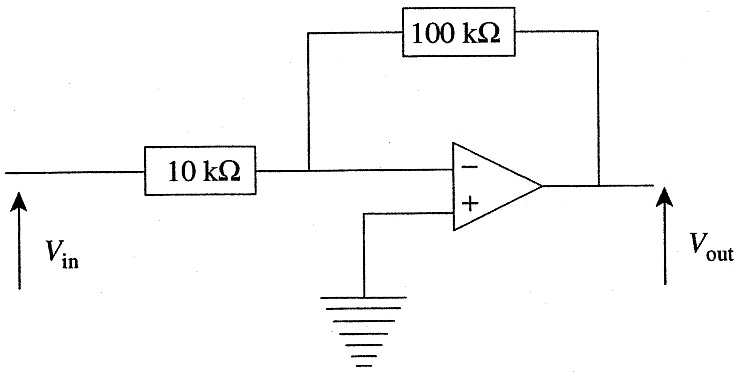
(b) (i) Compare an analogue system with a digital system with respect to its method of processing information. **1**

(ii) Explain how a thermistor can be used as an input transducer in a fire alarm and in a thermostat that controls temperature. **3**

(c) (i) Outline the semiconductor properties of an LED. **2**

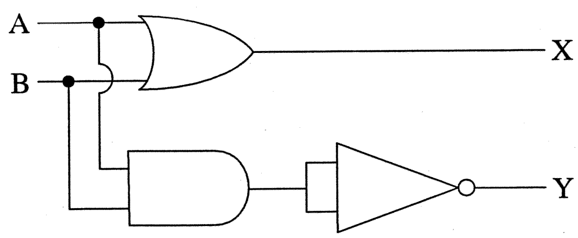
(ii) A typical LED (with a 2 volt forward voltage drop) is connected in series with a 330 Ω resistor, a milliammeter and a variable voltage supply. Explain using circuit diagrams when the LED will conduct and when it will not conduct as the voltage is varied between 0–6 V in either direction. **2**

(d) The circuit shown below is an example of an operational amplifier. **3**



Describe how the relationship between the resistors allows for the calculation of the voltage gain of an operational amplifier and state the voltage gain of the above circuit.

(e) In the arrangement shown below, several digital integrated circuits are employed. **4**



Name each of the gates shown, describe how the output of each one is related to its input, then copy and complete the truth table for this arrangement.

A	B	X	Y
0	0		
0	1		
1	0		
1	1		

Question 33 continues on page 25

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Marks

Question 33 (Continued)

(f) Evaluate the impact of the development of electronics devices employing semiconducting materials on society and comment upon whether there may be limitations to their future growth. **8**

End of paper

Data sheet

Charge on the electron, q_e	-1.602×10^{-19} C
Mass of electron, m_e	9.109×10^{-31} kg
Mass of neutron, m_n	1.675×10^{-27} kg
Mass of proton, m_p	1.673×10^{-27} kg
Speed of sound in air	340 m s^{-1}
Earth's gravitational acceleration, g	9.8 m s^{-2}
Speed of light, c	3.00×10^{8} m s^{-1}
Magnetic force constant, $\left(k \equiv \frac{\mu_0}{2\pi}\right)$	2×10^{-7} N A^{-2}
Universal gravitational constant, G	6.67×10^{-11} N m^2 kg^{-2}
Mass of Earth	6.0×10^{24} kg
Planck's constant, h	6.626×10^{-34} J s
Rydberg constant, R_{hydrogen}	1.097×10^{7} m^{-1}
Atomic mass unit, u	1.661×10^{-27} kg 931.5 MeV/c^2
1 eV	1.602×10^{-19} J
Density of water, ρ	1.00×10^{3} kg m^{-3}
Specific heat capacity of water	4.18×10^{3} J kg^{-1} K^{-1}

Formulae

$$v = f\lambda$$

$$I \propto \frac{1}{d^2}$$

$$\frac{v_1}{v_2} = \frac{\sin i}{\sin r}$$

$$E = \frac{F}{q}$$

$$R = \frac{V}{I}$$

$$P = VI$$

$$\text{Energy} = VIt$$

$$v_{\text{av}} = \frac{\Delta r}{\Delta t}$$

$$a_{\text{av}} = \frac{\Delta v}{\Delta t} \text{ therefore } a_{\text{av}} = \frac{v - u}{t}$$

$$\Sigma F = ma$$

$$F = \frac{mv^2}{r}$$

$$E_{\text{k}} = \frac{1}{2}mv^2$$

$$W = Fs$$

$$p = mv$$

$$\text{Impulse} = Ft$$

$$E_{\text{p}} = \frac{Gm_1m_2}{r}$$

$$F = mg$$

$$v_x^{\,2} = u_x^{\,2}$$

$$v = u + at$$

$$v_y^{\,2} = u_y^{\,2} + 2a_y\Delta y$$

$$\Delta x = u_xt$$

$$\Delta y = u_yt + \frac{1}{2}a_yt^2$$

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

$$F = -\frac{Gm_1m_2}{d^2}$$

$$E = mc^2$$

$$l_{\text{v}} = l_0\sqrt{1 - \frac{v^2}{c^2}}$$

$$t_{\text{v}} = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$m_{\text{v}} = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Formulae

$$\frac{F}{l} = k\frac{I_1 I_2}{d}$$

$$F = BIl\sin\theta$$

$$\tau = Fd$$

$$\tau = nBIA\cos\theta$$

$$\frac{V_p}{V_s} = \frac{n_p}{n_s}$$

$$d = \frac{1}{p}$$

$$M = m - 5\log\left(\frac{d}{10}\right)$$

$$\frac{I_A}{I_B} = 100^{(m_B - m_A)/5}$$

$$m_1 + m_2 = \frac{4\pi^2 r^3}{GT^2}$$

$$F = qvB\sin\theta$$

$$E = \frac{V}{d}$$

$$E = hf$$

$$c = f\lambda$$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\lambda = \frac{h}{mv}$$

$$Z = \rho v$$

$$\frac{I_r}{I_o} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$$

$$A_0 = \frac{V_{out}}{V_{in}}$$

$$\frac{V_{out}}{V_{in}} = -\frac{R_f}{R_i}$$

Periodic Table

Key

Atomic number	79 **Au** 197.0 Gold	**Symbol of element**
Atomic mass		Name of element

1 **H** 1.008 Hydrogen																	2 **He** 4.003 Helium
3 **Li** 6.941 Lithium	4 **Be** 9.012 Beryllium											5 **B** 10.81 Boron	6 **C** 12.01 Carbon	7 **N** 14.01 Nitrogen	8 **O** 16.00 Oxygen	9 **F** 19.00 Fluorine	10 **Ne** 20.18 Neon
11 **Na** 22.99 Sodium	12 **Mg** 24.31 Magnesium											13 **Al** 26.98 Aluminium	14 **Si** 28.09 Silicon	15 **P** 30.97 Phosphorous	16 **S** 32.07 Sulfur	17 **Cl** 35.45 Chlorine	18 **Ar** 39.95 Argon
19 **K** 39.10 Potassium	20 **Ca** 40.08 Calcium	21 **Sc** 44.96 Scandium	22 **Ti** 47.87 Titanium	23 **V** 50.94 Vanadium	24 **Cr** 52.00 Chromium	25 **Mn** 54.94 Manganese	26 **Fe** 55.85 Iron	27 **Co** 58.93 Cobalt	28 **Ni** 58.69 Nickel	29 **Cu** 63.55 Copper	30 **Zn** 65.39 Zinc	31 **Ga** 69.72 Gallium	32 **Ge** 72.61 Germanium	33 **As** 74.92 Arsenic	34 **Se** 78.96 Selenium	35 **Br** 79.90 Bromine	36 **Kr** 83.80 Krypton
37 **Rb** 85.47 Rubidium	38 **Sr** 87.62 Strontium	39 **Y** 88.91 Yttrium	40 **Zr** 91.22 Zirconium	41 **Nb** 92.91 Niobium	42 **Mo** 95.94 Molybdenum	43 **Tc** [98.91] Technetium	44 **Ru** 101.1 Ruthenium	45 **Rh** 102.9 Rhodium	46 **Pd** 106.4 Palladium	47 **Ag** 107.9 Silver	48 **Cd** 112.4 Cadmium	49 **In** 114.8 Indium	50 **Sn** 118.7 Tin	51 **Sb** 121.8 Antimony	52 **Te** 127.6 Tellurium	53 **I** 126.9 Iodine	54 **Xe** 131.3 Xenon
55 **Cs** 132.9 Caesium	56 **Ba** 137.3 Barium	57–71 Lanthanides	72 **Hf** 178.5 Hafnium	73 **Ta** 180.9 Tantalum	74 **W** 183.8 Tungsten	75 **Re** 186.2 Rhenium	76 **Os** 190.2 Osmium	77 **Ir** 192.2 Iridium	78 **Pt** 195.1 Platinum	79 **Au** 197.0 Gold	80 **Hg** 200.6 Mercury	81 **Tl** 204.4 Thallium	82 **Pb** 207.2 Lead	83 **Bi** 209.0 Bismuth	84 **Po** [210.0] Polonium	85 **At** [210.0] Astatine	86 **Rn** [222.0] Radon
87 **Fr** [223.0] Francium	88 **Ra** [226.0] Radium	89–103 Actinides	104 **Rf** [261.1] Rutherfordium	105 **Db** [262.1] Dubnium	106 **Sg** [263.1] Seaborgium	107 **Bh** [264.1] Bohrium	108 **Hs** [265.1] Hassium	109 **Mt** [268] Meitnerium	110 **Uun** — Ununnilium	111 **Uuu** — Unununium	112 **Uub** — Ununbium	113	114 **Uuq** – Ununquadium	115	116 **Uuh** – Ununhexium	117	118 **Uuo** – Ununoctium

57 **La** 138.9 Lanthanum	58 **Ce** 140.1 Cerium	59 **Pr** 140.9 Praseodymium	60 **Nd** 144.2 Neodymium	61 **Pm** [146.9] Promethium	62 **Sm** 150.4 Samarium	63 **Eu** 152.0 Europium	64 **Gd** 157.3 Gadolinium	65 **Tb** 158.9 Terbium	66 **Dy** 162.5 Dysprosium	67 **Ho** 164.9 Holmium	68 **Er** 167.3 Erbium	69 **Tm** 168.9 Thulium	70 **Yb** 173.0 Ytterbium	71 **Lu** 175.0 Lutetium
89 **Ac** [227.0] Actinium	90 **Th** 232.0 Thorium	91 **Pa** 231.0 Protactinium	92 **U** 238.0 Uranium	93 **Np** [237.0] Neptunium	94 **Pu** [239.1] Plutonium	95 **Am** [241.1] Americium	96 **Cm** [244.1] Curium	97 **Bk** [249.1] Berkelium	98 **Cf** [252.1] Californium	99 **Es** [252.1] Einsteinium	100 **Fm** [257.1] Fermium	101 **Md** [258.1] Mendelevium	102 **No** [259.1] Nobelium	103 **Lr** [262.1] Lawrencium

Where the atomic wieghts are not known, the relative atomic mass of the most common radioactive isotope is shown in brackets.

The atomic weights of Np and Tc are given for the isotopes ^{237}Np and ^{99}Tc.

HSC Trial Examination 2003

Physics

Solutions and marking guidelines

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Section I

Part A

Answer and explanation	Syllabus content and course outcomes
Question 1 **B** The mass is determined from $m = \frac{F}{a}$ using the data for Earth. $m = \frac{F}{a} = \frac{800}{9.8}$. Then use $g = G\frac{M}{r^2}$ to obtain acceleration due to gravity on Uranus. $g = \frac{6.67 \times 10^{-11} \times 86 \times 10^{24}}{(2.4 \times 10^7)^2} = 9.95$ Then $F = mg = \left(\frac{800}{9.8}\right) \times 9.95 = 813$ N	9.2.1 H4, H9
Question 2 **A** The gravitational potential energy of a point in a gravitational field is defined as the work done in moving a 1 kg mass from an infinite distance to that point in the field. As gravitational potential energy at an infinite distance equals zero, the gravitational potential energy at a point at close separation must always be negative, i.e. below zero. As the distance increases, the value becomes less negative.	9.2.1 H7, H9
Question 3 **C** The principle of conservation of energy and momentum are used in a gravity assist situation. A spacecraft is able to use a planet's motion to accelerate the satellite. The rocket engines are not sufficient to accelerate the spacecraft to the required speeds.	9.2.3 H6
Question 4 **A** The horizontal velocity component of a particle undergoing projectile motion remains constant for the duration of the projectile's flight. The vertical component of velocity is influenced by acceleration due to the force of gravity. From the equation $\Delta y = u_y t + \frac{1}{2}a_y t^2$, the distance fallen is proportional to the square of the time taken, where the initial velocity is zero.	9.2.2 H2, H3
Question 5 **C** A low earth orbit satellite has a much shorter orbital radius and a much faster period than a geostationary satellite.	9.2.2 H2, H6
Question 6 **B** Since $\frac{V_p}{V_s} = \frac{n_p}{n_s}$ and a step down transformer has a lower secondary voltage, then the number of secondary turns is also less than in the primary.	9.3.4 H7, H9
Question 7 **C** Power is proportional to $(\text{current})^2$ so reducing current reduces power consumption and hence energy used.	9.3.3 H3, H9

Part A (Continued)

Answer and explanation	Syllabus content and course outcomes	
Question 8 **D** Substituting into $\frac{V_p}{V_s} = \frac{n_p}{n_s}$ gives $\frac{V_p}{2} = \frac{100}{20}$	9.3.4	H7
Question 9 **A** Changing the direction of the current caused the torque on the coil to change its sense (direction) and the coil turns in the opposite direction.	9.3.1	H9
Question 10 **D** $F = BIl\sin\theta$ $F = 10^{-2} \times 2 \times 0.1 \times \sin 90°$ $= 2 \times 10^{-3}$ N Direction is perpendicular to the current and to the field	9.3.1	H9
Question 11 **A** Electric field E is a vector quantity. Magnitude is calculated using either $\mathrm{E} = \frac{\text{voltage}}{\text{distance}} \left(E = \frac{V}{d}\right)$ or $\mathrm{E} = \frac{\text{force}}{\text{charge}} \left(E = \frac{F}{q}\right)$. The direction of the electric field is found by placing a small positive charge into the field and observing the direction that it then moves when released. The charge will move from the positive end towards the negative end of the field. $E = \frac{V}{d}$ $E = \frac{250 - (-50)}{0.01}$ $E = 3 \times 10^4$ volts/metre up the page	9.4.1	H9
Question 12 **A** The cathode ray beam is a flow of negatively charged electrons which will be deflected by the magnetic field at 90° to it. Using various 'palm' or 'hand' rules, the direction of the deflection can be predicted to be down the page towards A.	9.4.1	H9

Part A (Continued)

Answer and explanation	Syllabus content and course outcomes
Question 13 **C** The photoelectric effect is described by Planck's equation $E = hf$ where the energy that is delivered by light will increase in a set amount (i.e. a quantum of energy) as its frequency increases. Above a certain frequency (colour) threshold, photoelectrons are released from the surface of some materials. As long as this threshold level of energy is reached, called the 'work function' of the surface electrons, then the number of electrons released will increase when the frequency of the light is increased (usually blue $\rightarrow$ ultraviolet). Below a certain frequency of light the 'work function' will not be reached and no photoelectrons will be released. Even increasing the intensity of the light is not enough to give enough energy per electron to overcome the electrical attraction to the atomic lattice of the semiconductor material.	9.4.2 H7, H10
Question 14 **C** In Diagram (2), Gallium (Ga) contributes only three electrons to bond with its four adjacent Silicon (Si) atoms. This leads to a charge imbalance causing a positive 'hole' which then becomes a charge carrier. Therefore this is a P-type semiconductor. Diagram (3) is a semiconductor due to the small but significant gap between the energies of electrons of the conduction and valence bands. Diagram (4) is a metal because the bands overlap.	9.4.3 H10
Question 15 **A** Broadly speaking, the knowledge of the chemical properties of elements including extraction, purification, band structure theory, doping and more, has led to solid-state/semiconductor devices replacing thermionic valves. B) is a development but not broad enough on its own. C) TV tubes are in fact large valves! D) refers to energy savings which is a significant benefit but not a development driving the change to solid state devices.	9.4.3 H1

Part B

Sample answer		Syllabus outcomes and marking guide
Question 16		
(a)	The spanner will continue to fall around the Earth still in a weightless situation with the astronaut and spacecraft i.e. it will still appear to float as it moves at the same orbital speed as the craft OR the spanner will move with constant motion (with the speed it left the astronaut's hand).	9.2.2 H2, H6 • Clear description of spanner's motion ... 1
	$l_v = l_0\sqrt{1-\frac{v^2}{c^2}}$ $l_v = 30 \times 10^{-2}\sqrt{1-\frac{(0.3c)^2}{c^2}}$ $= 28.6$ cm $m_v = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$ $m_v = \frac{5}{\sqrt{1-\frac{(0.3c)^2}{c^2}}}$ $= 5.24$ kg	9.2.4 H2, H6 • Correct use of both formulae to achieve correct answers ... 3 • Correct use of one formula to achieve one correct answer and attempt at other . 2 • Attempted use of one correct formula to achieve an answer ... 1
Question 17		
(a)	To assist in obtaining the required radial orbital velocity a rocket is launched in an easterly direction at or near the equator. This gives the rocket an extra 470 m s^{-1} of velocity, allowing a greater proportion of the thrust to achieve the required radial velocity to leave the Earth's surface.	9.2.2 H3, H14 • Correct explanation of how the direction and location produce advantages ... 2 • An attempt to explanation of how the direction and location produce advantages ... 1
(b)	The problems with re-entry involve ensuring that the spacecraft enters the Earth's atmosphere at the correct angle, shielding the craft from the intense heat when coming from space into the atmosphere, contending with the frictional forces involved in slowing the craft and being out of communication with its Earth control centre. (See table below.)	9.2.2 H5, H9 • Discusses three precautions for safe manned re-entry ... 3 • Discusses two precautions for safe manned re-entry OR • Discusses one precaution for safe manned re-entry AND identifies two others ..... 2 • Discusses one precaution for safe manned re-entry OR • Identifies at least two precautions 1

Problem	*Precaution*
Re-entry angle	Ensure that the re-entry angle is between 5.2° and 7.2° so that the craft does enter the atmosphere and is not bounced back into space nor burnt up due to burn up.
Heat on re-entry	Even with correct re-entry angle large amounts of heat are created ablative technology or heat shielding tiles are employed.
Forces on astronauts during re-entry	Astronauts are inclined and the space is slowed over a longer period of time to reduce these forces.

Sample answer	Syllabus outcomes and marking guide
Question 18	
$F = G\frac{m_1 m_2}{d^2}$ $m_2 = \frac{Fd^2}{Gm_1}$ $m_2 = \frac{1.57 \times 10^6 (5.94 \times 10^6)^2}{6.67 \times 10^{-11} \times 1570}$ $= 5.26 \times 10^{26}$ kg	9.2.3 H9, H13 • Uses correct formula with substitution to obtain correct answer ... 2 • Uses correct formula with incorrect substitution to obtain an answer OR • Attempts to use correct formula ... 1

Part B (Continued)

Sample answer

Question 19

The mathematical model of simple harmonic motion predicts that, in the case of a pendulum executing small oscillations, the period is given by $T = 2\pi\sqrt{\frac{l}{g}}$, where T is the period of the pendulum, l is the length of the pendulum and g is the magnitude of the gravitational field strength. The theory predicts that we can measure the gravitational field strength at a locality from the knowledge of the period of the pendulum of known length.

Equipment

Ruler, stopwatch, masses, mass carrier, string.

Method

Attach a mass carrier to the end of a piece of string. Attach the other end of the string to a support so that the mass can swing freely. Attach the string so that the length can be varied without difficulty.

1. Keeping the length and amplitude constant record the time for say, 10 swings of the pendulum with a total mass of 50 g. Repeat this for a number of different masses.
2. Keeping the mass and amplitude constant record the time for 10 swings of the pendulum for a number of different lengths of the pendulum between say 20 cm and 1 m.
3. Keeping the length and mass constant record the time for 10 swings of the pendulum for different amplitudes up to an angle of 30 degrees.

Tabulate the results of the experiments. Include the units in the table similar to one like this:

Mass (g)	*Length of pendulum* (cm)	*Amplitude* (cm)	*Time for 10 swings* (s)	*Period* (s)	*Period*^{2} (s^2)

Analysis

1. The period is not affected by the mass and the amplitude of the pendulum.
2. A graph of period squared versus length of pendulum is plotted (with T^2 on the horizontal axis and length on the vertical axis).
3. A line of best fit is constructed and the gradient determined.
4. The pendulum equation is rearranged to form $T^2 = kl$ where k is a combination of constants and equivalent to $4\pi^2$. This comparison shows that T^2 forms the y axis and length, l, forms the x axis, the gradient of the graph can be expressed as a relationship.
5. The expression is then used to calculate a value for g, the acceleration due to gravity.

Evaluation

This method usually produces very accurate results especially if measurements are repeated over a number of trials to determine the period. This will also reduce the reaction time errors. Sources of error in this experiment include: reaction time errors associated with operating the stopwatch. Using longer pendulum lengths also reduces timing problems.

Syllabus outcomes and marking guide

9.2.1 H2, H11, H14

- Evaluates extensively an experimental procedure for determining the acceleration due to gravity, showing clearly what data was collected, how it was collected and comments on the accuracy of these results together with errors encountered 7–8

- Evaluates thoroughly an experimental procedure for determining the acceleration due to gravity, showing clearly what data was collected, how it was collected and comments on the accuracy of these results together with errors encountered 5–6

- Describes an experimental procedure for determining the acceleration due to gravity, showing clearly what data was collected, how it was collected and comments on the accuracy of these results together with errors encountered 3–4

- Describes an experimental procedure for determining the acceleration due to gravity, showing clearly what data was collected

OR

- Outlines an experimental procedure for determining the acceleration due to gravity and mentions results together with errors encountered

OR

- Outlines an experimental procedure for determining the acceleration due to gravity and comments on the errors encountered....................... 2

- Outlines an experimental procedure for determining the acceleration due to gravity, showing what data was collected.......................... 1

Part B (Continued)

	Sample answer	Syllabus outcomes and marking guide
Question 20		
(a)	Change the strength of the magnetic field, the current or the angle between the wire and the field.	9.3.1 H9 • Gives two correct answers . . . . 2 • Gives one correct answer 1
(b)	Since the force depends on the product of these quantities, changing current, angle or magnetic field strength will change the force.	9.3.1 H9, H14 • Fully justifies the answers given . . . . 2 • Poor or unclear justification. 1
(c)	He will need to measure: • The reading on the balance when current is flowing • The reading on the balance when no current is flowing • The magnitude of the current	9.3.1 H9, H11 • Gives 2 correct answers . . . . 2 • Gives 1 correct answer. 1
(d)	The magnetic field is uniform.	9.3.1 H9 • Gives correct answer 1
Question 21		
(a)	Michael Faraday was able to generate electricity because he was changing the magnetic flux passing through the coil during his experiments. He achieved this by turning a current on/off or moving a magnet or moving a coil. Each of these causes changes in the flux through the coil and induces a potential difference.	9.3.2 H3, H7, H9 • Explains correctly and clearly the need for relative motion (or current changes) to produce changing flux and states that changing flux induces emf. . . . . 2 • Explains partially or gives limited explanation of one aspect. 1
(b)	Use a longer wire (or move the wire more quickly).	9.3.2 H9, H12 • Gives correct answer 1
(c)	Induced potential difference is proportional to the rate of cutting of flux. Using a longer wire increases the rate of cutting of flux.	9.3.2 H9, H11 • Gives a full justification. . . . . 2 • Gives a partial justification, including only one point 1
Question 22		
(a)	Attach a commutator and brushes to the coil and a method of turning the coil.	9.3.3 H9 • Gives a description, including all components needed . . . . 2 • Gives a partial description omitting one component 1
(b)	The structure is essentially identical (commutator, brushes, coil, magnets). The difference is in how we use it.	9.3.3 H9 • States correct answer 1
(c)	Replace the split ring commutator with two slip rings.	9.3.3 H9 • States correct answer.. 1

Part B (Continued)

Sample answer	Syllabus outcomes and marking guide
Question 23	
Eddy currents are produced when the *magnetic* flux, which is cutting a (usually) flat conductor, *changes*. This can be caused by *relative motion* between the conductor and the field or *changes* in the strength of the field. *Uses* of eddy currents include eddy current heating and braking. *Problems* include unwanted induced currents and hence energy waste in electric motors and transformers.	9.3.2, 9.3.4 H4, H7, H9 • Gives a complete outline including the main points . . . . 5 • Omits one point . . . . 4 • Omits two points . . . . 3 • Provides only two points . . . . 2 • Provides only one correct point 1
Question 24	
(a) Diagram 1 is a transistor Diagram 2 is a thermionic valve (also valve, triode valve, diode valve or tube.)	9.4.3 H3 • Correctly identifies both devices. 1
(b) Solid state or silicon-chip-based devices including transistors and integrated circuits have largely replaced thermionic devices or valves because they are: • made of readily available substances and are thus *cheaper* than valves that can contain expensive rare substances; • plastic or metal encased and are thus *more robust* than glass-encased valves; • do not wear out and are thus *more enduring* than valves that have to be replaced regularly due to their set lifespan; • control currents due to changes in their structure at the atomic level and are thus *faster* to operate than valves that are relatively large devices, take time to heat up and then work more slowly to control currents; • physically smaller and thus many more fit into the same space as larger more bulky valves making them more *space-efficient*; • smaller, cooler in operation and *more energy efficient* than valves that use large electrical currents to heat them up and then consume lots of energy as they work; • smaller (transistors may be 5 mm × 5 mm) and more able to be *further miniaturised* than valves that have reached their limit in size reduction (at about 5 cm × 2 cm). • Operate on small voltages (5 V – 20 V) and are s*afer to use and to repair* than valves that use higher voltages (100 V – 300 V). Any two, of the above are sufficient for a correct answer.	9.4.3 H3, H4, H7 • States two reasons and explains relevance of each to both types of devices OR • States three or more reasons but explains only one with relevance to both types of devices . . . . 2 • States a reason and explains its relevance to both types of devices OR • States two or more reasons, but no explanation is provided of how the reasons are connected with or related to either device. 1

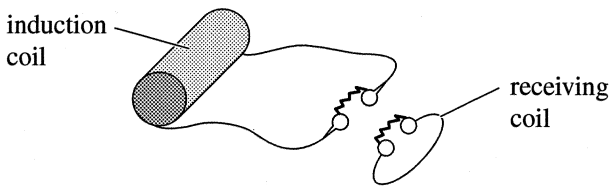
Part B (Continued)

	Sample answer	Syllabus outcomes and marking guide
Question 25		
(a)	The two fields that Thomson used in his apparatus were a magnetic field and an electric field. In one experiment with this apparatus Thomson used $F_e = qE$ and $F_B = qvB$ to establish $v = \frac{E}{B}$ and thus measure the velocity of the cathode ray beam. He continued with another series of experiments and used the electric field E to bend the cathode ray beam. He then measured its radius of curvature r and then used the magnetic field B to again straighten the beam. Thus he established a connection (equivalence or null relationship) between the two fields and used $F_B = qvB$ and $F_c = \frac{mv^2}{r}$ to give $\frac{q}{m} = \frac{v}{Br}$. Now having measured v, B and r, he could calculate the $\frac{q}{m}$ for the cathode rays. Regardless of the type of cathode he used, Thomson found $\frac{q}{m}$ to be the same for all for cathode rays.	9.4.1 H10, H9 • Correctly names both fields and explains, using either formulae or text, any link between the E, B or FC (centripetal force). . . . . 2 • Correctly names both fields 1
(b)	The nature of the debate was: • trying to answer the question of whether the cathode radiations were wave or particle; • mostly between British (particle/corpuscle) scientists and German (wave) scientists; • driven by advancing technology where new types of cathode ray devices, vacuum pumps and sources of electric and magnetic fields enabled new experiments to be done; • against a background of agreement that light and EMR (radio waves) were waves requiring an ether to travel through a vacuum; • empirical, intellectual, male dominated and not directly government funded (most research is now government or corporation based). J.J. Thomson's 1897 experiment contributed to the debate by confirming: • the discovery of the electron and that cathode rays were streams of electrons; • electric fields deflected cathode rays; • cathode rays had mass and KE, this suggesting they were particles not waves (which have no mass); • cathode rays had the same $\frac{q}{m}$ no matter from what material the cathode was made; • the discovery that $\frac{q}{m}$ was so small, smaller than the smallest atom's (hydrogen) $\frac{q}{m}$ value, that it was something more 'fundamental'; • the discovery that Dalton's 'indivisible billiard ball atoms' were in fact made of smaller, subatomic particles - starting with the electron.	9.4.1 H1, H2, H10, H13 • States one aspect of the debate and explains two contributions that Thomson's experiment added to the debate . . . . 3 • States one aspect of the debate and explains one contribution of Thomson's experiment to the debate. . . . . 2 • States one aspect of the debate. . . . . 1 OR • States one contribution of Thomson's experiment to the debate 1

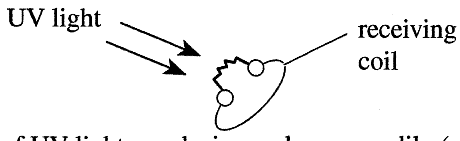
Part B (Continued)

Sample answer	Syllabus outcomes and marking guide

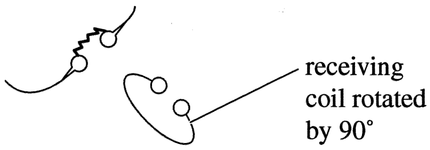
Question 26



An electrically powered induction coil makes a spark across the gap, generating radio waves.
In the receiving coil, a spark jumps the gap.



In the presence of UV light, sparks jumped more readily (more often or over a wider gap).



When the receiver loop was rotated 90°, no spark was produced.
This indicated the radiation was polarised, a wave property.
Hertz concluded he was dealing with waves.

9.4.2 — H1, H2, H8, H9, H13
- Draws a correct, labelled diagram and shows the effect of UV light (stronger sparks) and rotation of receiving coil by 90° (reduced or no spark). 3–4
- Draws a mostly correct diagram and shows the effect of either UV light or rotation of receiving coil 1–2

Question 27

(a) Use the wave equation to calculate the frequency:

$$v = f \times \lambda$$
$$3 \times 10^8 = f \times 7 \times 10^{-7}$$
$$f = 4.29 \times 10^{14} \text{ Hz.}$$

and then Planck's equation to calculate the energy of each photon:

$$E = h \times f$$
$$E = 6.626 \times 10^{-34} \times 4.29 \times 10^{14}$$
$$\therefore E = 2.84 \times 10^{-19} \text{ joules}$$

9.4.2 — H8, H10
- Calculates the correct value for a photon of red light (700nm) 2
- Identifies the correct formula for the calculation of the energy of a photon 1

(b) Photoelectrons will not be emitted because the value of the energy of the photons of red light (as calculated in (a) above) is less than the work function of copper which is 7.0×10^{-19} J. Thus the surface electrons cannot leave their atoms and the electrical attraction of their nucleus.

9.4.2 — H8, H10, H14
- States correct answer and gives correct reason 2
- States correct answer 1

Section II

Question 29 Geophysics

	Sample answer	Syllabus content, course outcomes and marking guide
(a)	Jean Richer observed that a pendulum at Cayenne (near the equator) oscillated at a slower rate than the same pendulum did at Paris (50° north). Since the period of a pendulum depends on the local gravity, g, Richer realised that, if the Earth were rotating, a centripetal acceleration would offset the gravitational acceleration. At the equator, the rotation velocity of the Earth is faster than at Paris. The measurements not only showed that the Earth was rotating, but that the Earth bulged at the equator and was flattened at the poles, as expected for a rotating object. This overturned the earlier idea that the Earth was a perfect sphere.	9.5.2 H1, H2, H9, H13 • Gives a clear response describing the experiment, mentioning how centripetal acceleration (and distance from the centre of the Earth) affects the period of a pendulum, and how Richer showed the earth bulged at the equator .. 2 • Mentions one relevant piece of information on the experiment or the result. 1
(b) (i)	Gravimeter	9.5.2 H9, H13 • Correctly names gravimeter. 1
(ii)	The most common type of gravimeter is basically a simple mass-spring system. When an accurately-known (and constant) mass is hung on a spring, the spring will be stretched by an amount that is proportional to the local value of g. The amount of stretching x is measured using a vernier scale ($x = \frac{mg}{k}$, where k is the spring constant, which varies from spring to spring). The relationship is simple and is called Hooke's law. With care, local differences in g can be detected (to more than one part in 10 million), providing density information on the subsurface rocks.	• Provides a detailed explanation of the operation of the instrument, with reference to the physical principles involved, and mention of the data produced. . . . . 3 • Gives a partial explanation of the instrument with a correct description of the data produced. . . . . 2 • Gives a basic description of the instrument with no reference to the physical principles involved. 1
(c) (i)	• Using multi-spectral imagery, e.g. Landsat, to map compositional differences. • Using synthetic aperture radar, e.g. ERS–1, to quantify topography and surface structures in vegetated terrain.	9.5.2 H10 • Identifies TWO uses of remote sensing in mineral exploration . . . . 2 • Identifies ONE use of remote sensing in mineral exploration 1
(ii)	Multi-spectral imagery uses simultaneous imaging in several optical and near-infrared bands from an orbiting satellite, e.g. the thematic mapper on Landsat–4. This allows compositional variations in vegetation and soil cover to be detected, which in turn is influenced by the underlying rock type. Landsat–7 and later satellites had better resolution and used a greater range of spectral bands, which provided detailed information on soil and underlying rock types. Mineralised areas, such as iron-rich 'gossans' associated with base-metal ore bodies can be detected. Space based remote sensing is a cost effective method to pinpoint areas for more detailed geophysical and geological follow-up on the ground.	9.5.2 H4, H10, H13 • Gives a detailed description of how this method is used . . . . 2 • Gives a less coherent or detailed description than above 1

Part B (Continued)

Sample answer	Syllabus outcomes and marking guide
Question 28 (a) Superconductors have many applications in the power generation industry: • Replacing the conductors (wires used in the transmission lines to carry electricity) with superconducting wire will lead to improved efficiency and reduced energy losses (from the heating effect of high currents passing through wires with resistance). • Replacing the electromagnet field coils in the generators with superconducting wire which will increase the magnetic field strength. • The two applications above will result in vastly reduced sizes of equipment and economies in construction, resource use and environmental impact. • Superconductors will enable the storage of moving 'rings' of electric current, which is at present impossible.	9.4.4 H3, H4, H7 • States one correct application 1
(b) Currently superconductors, including metals and ceramics have practical limitations because they: • work at very low temperatures, close to absolute zero (–273°C or 0 K). • require expensive, energy consuming cryogenic refrigeration equipment before they reach their critical temperatures (often below –200°C or 73 K) Limitations are being gradually overcome with the newly-discovered 'high temperature' ceramic superconductors which have: • higher critical temperatures 140 K, which, whilst they are still well below room temperatures, are getting higher; • problems as they are ceramic and are therefore brittle and cannot easily be made into wire; • cost limitations as they are made of expensive 'rare earth' elements; • resulted from further research.	9.4.4 H4, H5 • Two correct limitations stated plus a reason or consequence for limited use in generating power .... 3 • One correct limitation stated plus a reason or consequence for limited use in generating power .... 2 • One correct limitation stated but without a consequence for generating power 1

Question 29 Geophysics (Continued)

	Sample answer	Syllabus content, course outcomes and marking guide
(f)	The theory of plate tectonics proposes that the lithosphere is divided up into a number of plates. These move relative to one another, driven by slow convection currents in the mantle. As the plates interact, earthquake and volcanic activity occurs, mainly at the edges of the plates. In the 1930s Alfred Wegener was the first scientist to provide a detailed hypothesis on continental drift, and he provided compelling geological, paleontological and climatic evidence to back it up, but his idea was only accepted by a few southern-hemisphere scientists at the time. He had proposed an incorrect mechanism for the movement of the continents (based on tidal forces from the Moon and Sun) and many scientists ignored his idea, as calculations showed that the forces were far too weak to cause large scale movements of the continents. Scientists also objected to the idea of the rigid continents "moving through" the weaker oceanic crust, and yet it was the continental crust that was usually folded and deformed. Later on, the development of geophysical techniques, especially since World War II, revived Wegener's ideas and helped to develop the theory of plate tectonics. The development of sonar (and more recently side-scan sonar) has given us a detailed picture of the ocean floor, showing its topography of deep trenches, mid-ocean ridges (MORs). Transform faults and chains of seamounts, the formation of which needs to be explained by any theory. Scientists found that the orientation of the Earth's magnetic field is preserved in magnetite grains in cooling igneous rocks — the magnetic field-lines in rocks formed near the equator have a different orientation to those formed near the magnetic poles. The study of palaeomagnetism in ancient rocks which have been dated using radiometric techniques shows that many rocks have been formed well away from their current position, providing evidence for large-scale movements of the continents. Furthermore, ship-borne and airborne magnetic surveying has revealed patterns of reversed polarity (magnetic stripes) on the ocean floor which showed that the crust gets older away from the MOR on either side in a symmetrical manner. This was the most important piece of evidence for the hypothesis of seafloor spreading. Since other lines of evidence showed that the Earth was not expanding, there must be regions on the seafloor where oceanic crust is being recycled, and the trenches were found to be where this is occurring. Seismic profiling of the ocean bottom has provided data on the sediment thickness on the basalt seafloor, and how the thickness increases away from the MOR, providing more evidence for seafloor spreading. Gravity methods can also be used to show the large scale structures beneath the oceans. Also, radar altimetry over water (from satellites such as Seasat) can be used to show the topography of the ocean floor. Deep trenches and MORs affect the local value of *g* and cause the sea surface to respond as a result. Heat flow measurements show that the ocean floor is hottest at the MOR and gets progressively cooler with distance away from it, and the lowest values occur underneath the oceanic trenches. Patterns of earthquake foci as revealed from seismic measurements (Benioff zones) support the idea of subduction at convergent plate boundaries.	9.5.4 H1, H2, H11, H13, H14 • Gives a well-structured response with a detailed evaluation of at least five different lines of geophysical evidence, including a discussion (with points for and against) of why scientists were reluctant to initially support Wegener's ideas .... 7–8 • Gives a fairly well-structured response with an evaluation of at least three different lines of geophysical evidence, including a discussion of why scientists were reluctant to accept the idea OR • Answers as above without a discussion on Wegener's ideas .... 5–6 • As above, with proportionally less information in an answer that is less well-structured and coherent .... 3–4 • A brief answer with some of the geophysical evidence described, but with no discussion of Wegener's ideas 1–2

Question 29 Geophysics (Continued)

	Sample answer	Syllabus content, course outcomes and marking guide
(d)	Seismic exploration uses a source of compressional (sound) waves produced from an explosion in the ground or a boomer towed behind a ship. The reflected (and refracted) sound waves from the crust are detected with a network of instruments called hydrophones (or geophones on land). Reflections of sound waves from subsurface layers arrive at the instruments and the time delay is accurately recorded. Knowing the speed of sound in the earth and the path that the wave has travelled, we can convert seismic travel time to depth. By measuring the arrival time at different distances from the source, we can produce a profile of seismic travel times. Modern computers perform the calculations to give a two-dimensional cross-section of the strata within the crust.	9.5.3 H8, H13 • A coherent explanation of seismic profiling including the instrumentation used, and how the resulting profile is generated ... 3 • A less detailed and/or coherent response than above ... 2 • A brief description of either the instrumentation OR • How the data is produced ... 1
(e)	Geophysical methods can be used to assess, and in some cases predict, natural hazards such as volcanic eruptions, earthquakes, landslides and severe weather conditions such as storms, floods and droughts. For example, predicting volcanic eruptions can help prevent loss of life, especially in countries where the population depends on the fertile soils surrounding many volcanoes. Recently, a network of seismometers used in conjunction with laser ranging of ground deformation on the slopes of the Soufriére Hills volcano (on the island of Montserrat) helped predict impending volcanic eruptions which given a few days in advance, helped to save lives and property. Seismic observations (of ground tremors) can help detect if magma is moving from the underlying magma chamber to the vent, but in general, scientists can not yet predict accurately the time of a volcanic eruption. Drought can affect much of eastern Australia. The cyclic El Nino phenomenon is a disruption of the normal ocean-atmosphere circulation pattern in the Pacific Ocean. It is a strong predictor of below average rainfall in Australia, with increased risk of drought and bushfires. Geophysical measurements of water temperature winds and ocean currents are measured from a network of buoys in the tropical Pacific Ocean. Remote sensing from satellites provides additional meteorological and temperature information. Scientists can now predict with reasonable accuracy when an El Nino event is underway, but rainfall predictions are hard to quantify. The information is helpful as it can give responsible landowners time to prepare for drought and reduce the impact on the land. Furthermore, the El Nino phenomenon is only a part of the total global circulation system, and scientists do not yet fully understand the mechanism and how it is influenced by global warming.	9.5.5 H3, H4, H13 • Gives detailed discussion of the geophysical methods relevant to at least two natural hazards, with the answer including predictions and limitations of the geophysical methods used ... 4 • As above concentrating on one natural hazard, with the answer being less detailed and/or organised ... 3 • Answer which concentrates on one natural hazard OR • Answer emphases description rather than discussion ... 2 • A brief description of one natural hazard with no discussion of the predictions and limitations ... 1

Question 30 **Medical Physics (Continued)**

Sample answer	Syllabus outcomes and marking guide
(ii) $\frac{I_r}{I_o} = \frac{[Z_2 - Z_1]^2}{[Z_2 + Z_1]^2}$ $= \frac{[1.679 \times 10^6 - 1025 \times 1570]^2}{[1.679 \times 10^6 + 1025 \times 1570]^2}$ $= 4.59 \times 10^{-4}$	H7, H8, H14 • Employs the correct acoustic impedance values to accurately determine the ratio of reflected to initial intensity for a major blood vessel inside the brain .... 2 • Employs the correct acoustic impedance values OR Employs the correct calculation process in determining a ratio of reflected to initial intensity 1
(d) **X-ray** Image production • X-rays are directed through the patient. Hard and high-density tissues within the patient absorb more of the x-rays than soft tissues. The transmitted x-rays expose a photographic plate or are detected and their intensities analysed to produce an image of the internal structure. Applications • Non-invasive diagnostic tool • Shows the structure of hard tissues such as bones, enabling 'breaks' and other structural problems to be diagnosed. Advantages • Inexpensive/widely available • Fast • Can be used on patients with metal devices. Limitations • Limited resolution (but greater than a PET scan) Number of scans limited due to exposure to ionizing radiation. **PET** Image Production • The patient is injected with a radiopharmaceutical that is labelled with a positron emitter. The patient is then placed inside a ring of detectors (photomultiplier tubes) which detect gamma radiation from the decaying radioisotope. • The detector ring is moved over the patient, collecting data as a series of slices (tomography). The data is analysed to determine regions of high activity and integrated to produce a scan. Applications • Non-invasive diagnostic tool • Maps the uptake and metabolism by target organs. • Study of the bone: 'hotspots' of increased uptake can indicate tumours and 'coldspots' of reduced uptake can indicate degenerative diseases such as osteoporosis. Advantages • Measures functionality of target organs. • Can be used on patients with metal devices. Limitations • Poor resolution • Slow scan time Requirement of cyclotron and radiopharmaceutical production.	9.6.2 H3, H4 • Demonstrates a thorough knowledge of the production and application of bone scans using X-ray and PET. • Presents a comparison between the two technologies .... 3 • Demonstrates a thorough knowledge of the production or application of bone scans using X-ray or PET 1–2

Question 30 Medical Physics (Continued)

	Sample answer	Syllabus outcomes and marking guide
(e)	Relaxation time is the time taken for nuclei to return to their relaxed state after an RF pulse alters their spin. Hydrogen is widely found in body tissue, in water and in other organic compounds such as fats and proteins. The bonding of hydrogen to different molecules causes differences in relaxation time, for example, hydrogen bound to water molecule compared with hydrogen bound to other molecules in body tissues. It is these large differences that provide data on the amount of hydrogen present and in what form it exists i.e. the chemical components and their relative proportions for body tissue can be determined. The integration of this data by high-speed computers provides the basis for a high-resolution image called an MRI (magnetic resonance imaging) scan. Cancerous tissues are associated with increased blood flow and therefore higher water content, in comparison with healthy tissue. This causes a lighter region to appear on the scan, making cancerous tissue easy to identify. Grey matter contains more water than white matter, providing the basis for differentiation between the two forms of brain tissue. MRI brain scans easily identify areas affected by diseases such as MS (multiple sclerosis).	9.6.4 H4, H5, H13 • Explains the variation of relaxation time of hydrogen in body tissues • Outlines the relevance of relaxation time to the production of MRI scans • Relates changes in MRI scans to tissue changes due to specific examples of disease . . . . 3–4 • Describes relaxation time AND/OR • Explains the variation of relaxation time of hydrogen AND/OR • Identifies examples of disease diagnosed by MRI 1–2

Question 30 **Medical Physics**

	Sample answer	Syllabus outcomes and marking guide
(a)	A coherent bundle consisting of optical fibres is the essential component of an endoscope. Optical fibres rely on total internal reflection to guide light along the entire fibre length without significant loss of intensity. The light from each fibre of the coherent bundle forms a clear, upright, non-inverted image of the internal organ for the surgeon to view.	9.6.2 H10, H13 • Correctly identifies the coherent bundle AND • Describes the role of total internal reflection within the optic fibres of the coherent bundle . . . . 2 • Correctly identifies the coherent bundle OR • Describes the role of total internal reflection within the optic fibres of the coherent bundle 1
(b) (i)	Any common radioisotope used e.g. technetium-99m, iodine-131, iodine-123, indium-111, gallium-67 etc.	9.6.3 H10 • Correctly identifies a radioisotope used for obtaining scans of organs. . . . . 1 • Identifies a radioisotope that is metabolised by the body OR • Describes the use of a radioactivity to produce an organ scan 1
(ii)	Radioactive isotopes are chemically bonded to a compound that can be metabolised (used in a body function) by a target organ. When such a compound is 'labelled' in this way it is called a radiopharmaceutical. The radiopharmaceutical is injected into the bloodstream allowing it to accumulate in the target organ or body system because the chemistry of the compound is not altered by its radioactive nature. The emissions are detected by a gamma camera and analysed by a computer to produce a scan, which provides information on organ function (e.g. rate of uptake of the radiopharmaceutical/hotspots/coldspots). An example of a radiopharmaceutical is Sodium pertechnetate. It can be used when scanning blood flow in the brain. The radioisotope present is Tc-99m.	9.6.3 H10 • Describes the production of a radiopharmaceutical and its metabolism by a specific target organ AND • Describes the process of obtaining a scan of the identified target organ . . . . 3 • Identifies a radioisotope that is metabolised by the body AND • Describes the use of a radioactivity to produce an organ scan . . . . 2 • Identifies a radioisotope that is metabolised by the body OR • Describes the use of a radioactivity to produce an organ scan 1
(c) (i)	Acoustic impedance Z is a measure of the resistance to the transmission of a wave by the medium through which it is being transmitted. Acoustic impedance for brain tissue is given by: $Z = \rho v$, where ρ = density (kg m^{-3}) and v = speed of sound (ms^{-1}). $\therefore Z = 1090 \times 1541$ $= 1.679 \times 10^6$ kg m^{-2} s^{-1}	9.6.1 H8, H14 • Correctly defines acoustic impedance • Accurately calculates the value of acoustic impedance of brain tissue . . . . 2 • Correctly defines acoustic impedance OR • Accurately calculates the value of acoustic impedance of brain tissue 1

Question 29 **Geophysics (Continued)** **Sample answer**	**Syllabus content, course outcomes and marking guide**
All these lines of evidence provide support for plate tectonic theory, which has been confirmed by recent techniques such as the Global Positioning System. GPS data has allowed the direct measurement of plate movements for the first time (of the order of a few cm per year) from observations made over a baseline of a few years. In the future, geophysicists will try to unravel the details of the mantle convection currents, as the mechanism which drives plate movement, which is not fully understood at present (i.e. the competing ideas of 'slab-pull' versus 'trench-push').	

Question 31 Astrophysics (Continued)

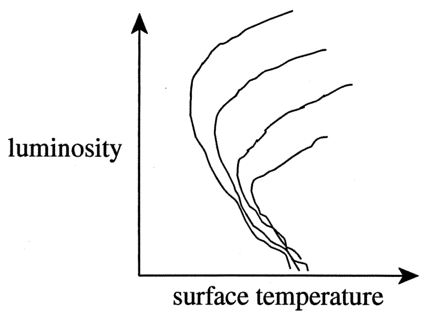
	Sample answer	Syllabus outcomes and marking guide
(e)	Atmospheric distortion is caused by small cells of atmosphere with variable refractive index. Refraction changes within a cell or from cell to cell, causing the image to be out of focus or moving. Adaptive optics is very effective in reducing distortion. Starlight is sampled and computer corrected, up to 1000 times/second. The system uses adjustable and deformable mirrors to straighten the light's wavefront.	9.7.1 H7, H8, H13 • Discusses effectiveness of adaptive optics to reduce distortion; gives clear and detailed description of nature and causes of distortion and adaptive optics . . . . . . 4 • Gives clear and detailed description of nature and causes of distortion and adaptive optics . . . . . . 3 • Gives detailed, correct descriptions of nature of distortion or adaptive optics . . . 2 • Gives basic descriptions of nature of distortion or adaptive optics 1
(f)	See table, text and diagram below	9.7.6 H1, H2, H10, H13 • Demonstrates a sound understanding of the importance of the H-R diagram as a most useful tool • Compares the H-R diagrams for both types of clusters • Demonstrates a detailed understanding of the methods used to date clusters, using the H-R diagrams . . . . . . 7–8 • Discusses how the H-R diagram varies for open and globular clusters • Indicates understanding of how the H-R plot provides an age for a cluster • Gives a good description of each type of cluster's H-R diagram • Gives detail on how 4 features are similar or different . . . . . . 5–6 • Outlines 4 features of globular and open clusters that are similar or different • Shows how the H-R diagram looks for either an open or globular cluster. 1–4

(f)

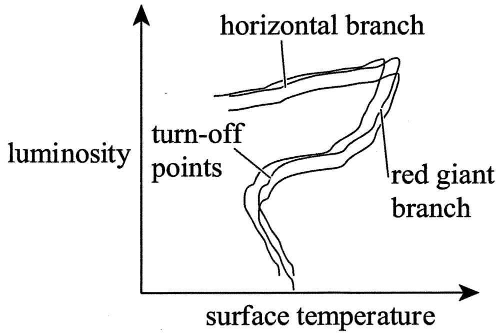
Open clusters	*Globular clusters*
Loose array of stars	Spherical shaped group
Held together by own gravity	Held together by own gravity
Up to 1 thousand stars	Up to 1 million stars
Small diameter	Large diameter
Brightest stars are reddish blue-white	Brightest stars are reddish
Star density relatively low	Star density high
Contain young stars, (Population I) born later, with more heavy elements	Contain old stars (Population II) with fewer heavy elements
Located in the galactic plane	Located in a halo around the galaxy

The H-R diagram is the best diagram for determining and comparing the ages of clusters. It is an essential tool for astronomers.

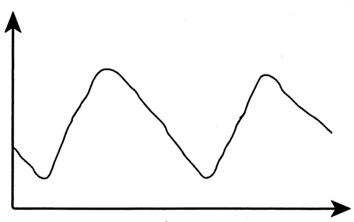
For an open cluster the H-R diagram will show stars mainly on the Main Sequence, with a few stars into the red giant phase.



Question 31 **Astrophysics (Continued)**

Sample answer	Syllabus outcomes and marking guide
For globular clusters, the H-R diagram looks very different, with a strong red giant and horizontal branch also.  As the cluster ages, the turn-off point moves off the Main Sequence. Hence the turn-off point's position indicates the cluster's age. The shorter the main sequence part or the lower down the turn-off point, the older the cluster's age. Also, the age of clusters can be compared using the H-R diagram. Open clusters show turn-off points that vary greatly in age, from well above the Sun to near the top end of the Main Sequence. This indicates that open clusters have a large range of ages. On the other hand, the H-R plot for globular clusters indicates the turn-off points are roughly the same. This says that globular clusters have very similar ages.	

Question 31 **Astrophysics**

	Sample answer	Syllabus outcomes and marking guide
(a)	Gamma rays are absorbed by the Earth's atmosphere, due to ionisation. OR Visible light is absorbed by the Earth's atmosphere as it causes atoms and molecules to break apart or be excited.	9.7.1 H7, H8, H10 • Correctly names ray and briefly describes how it interacts with the atmosphere .... 2 • Correctly names gamma, x, visible, IR rays.............................. 1
(b)	(i) $d = \frac{1}{p}$ $= \frac{1}{0.74}$ $= 1.35$ pc	9.7.2 H7, H8, H10, H13 • Correctly calculates distance 1
	(ii) Star Y, with a negative absolute magnitude, is more luminous than star X. When placed at 10 parsecs star Y would be very much brighter than star X. Star X, with a negative apparent magnitude, is brighter than star Y, in the night sky. Because star X gets fainter when viewed at 10 pc it is closer than 10 pc from Earth.	• Correctly applies values to concepts of luminosity/distance .... 3 • Clearly understands the difference between absolute and apparent magnitude......................... 2 • Understands absolute or apparent magnitude......................... 1
(c)	(i) 	9.7.5 H7, H8, H10, H13 • Correctly sketches a light curve with correct slopes, from which period can be determined...................... 2 • Poorly sketches a light curve, showing variation in luminosity with time....... 1
	(ii) Knowing that Cepheids with a longer period are more luminous with a smaller M, their distance can be calculated. This was very important. Cepheid variables are very luminous, yellow supergiant stars so the distance to these distant stars in our galaxy or in neighbouring galaxies could now be determined.	• Explains that, because Cepheids are very bright, this relationship gave astronomers a new yardstick to very distant stars .... 2 • Correctly identifies the relationship between period and luminosity 1
(d)	The star's light has dark bands in particular positions. OR dark bands moved slightly towards the red end. The particular positions / wavelengths / frequencies tell us what is the composition of the gases through which the light has passed. OR The star has a translational velocity away from Earth.	9.7.3 H7, H8, H10, H13 • Identifies both pieces of information and explains one.................... 3 • Correctly indicates and explains one piece of information................. 2 • Identifies that dark bands are in a particular position OR • Identifies that dark bands have moved slightly towards red end.............. 1

Question 30 **Medical Physics (Continued)**

	Sample answer	Syllabus outcomes and marking guide
(f)	CAT scans of the brain produce a high-resolution image enabling the diagnosis of stroke, tumours, aneurisms and other problems. Exact location, size and often more specific details associated with each problem can be determined from CAT scans. The slice by slice images can be compiled to form an accurate 3-D image. In contrast, X-rays produce a very low-resolution image with little detail due to the high density of the skull bone and the relatively uniform density of brain tissue, while PET scans give very poor resolution but measure functionality. PET scans are less widely available and with a cyclotron required to produce many of the positron emitters, PET scans are more expensive. MRI gives greater resolution without the exposure to ionising radiation. However it is much more expensive and less available. CAT scans of the lungs use opaque dyes to obtain a detailed scan with fine structural detail, whereas chest X-rays give outlines of the major organs and do not provide detailed structural information. CAT scans of the kidney provide fine detail and can differentiate between kidney stones (solid), cysts (fluid filled) and tumours (amorphous tissue). In comparison, ultrasound produces detailed images of kidneys but can only differentiate on tissue and density, not between solid- and liquid-containing structures. **Evaluation:** CAT is a very valuable diagnostic tool with a wide range of applications. It provides detailed structural information, which can be used for the accurate diagnosis for many diseases affecting both soft and hard tissues. It is becoming widely available in modern societies and, as a non-invasive diagnostic tool, is becoming more cost-effective as the advantages of earlier and more accurate diagnosis improve patient treatment and prognosis resulting in a reduction of the overall cost on society. As more detailed information is acquired on the structural effects of specific diseases, through CAT technology, the possibility of screening programs for high risk candidates, allowing preventative intervention, could reduce the impact of that disease on society (e.g. Calcium scores in major blood vessels of the heart as a precursor to the onset of Cardiovascular disease). It is often used in conjunction with other diagnostic techniques. Its limitations include the lack of information on organ functionality and it does expose the patient to ionising radiation. Even so, the improved diagnostic capacity provided by CAT technology makes it an increasingly important weapon in the medical arsenal against disease.	9.6.2, 9.6.3, 9.6.4 H1, H4, H5, H8, H10, H13, H14, H16 • Demonstrates a thorough knowledge of the advantages and limitations of the use of CAT in comparison to at least one other diagnostic tool. • Demonstrates an accurate understanding of the physical principles involved in generating a CAT scan. • Clearly evaluates the use of this technology. • Presents the information coherently . . 7–8 • Demonstrates some knowledge of the advantages and or the limitations of the use of CAT. • Demonstrates an accurate understanding of some of the physical principles involved in generating a CAT scan. . . . . 5–6 • Demonstrates some knowledge of the advantages and or the limitations of the use of CAT. OR • Demonstrates an accurate understanding of some of the physical principles involved in generating a CAT scan. . . . . 3–4 • Demonstrates a basic knowledge of the advantages and/or limitations of the use of CAT. 1–2

Question 32 From Quanta to Quarks

Sample answer	Syllabus outcomes and marking guide
(a) The basic feature of quantum mechanics that was incorporated in the Bohr Model was that the energy of the particles in the Bohr atom was restricted to certain discrete values i.e. the energy is quantized. This meant that only certain orbits with certain radii were allowed; orbits in between do not exist. Atoms could make transitions between the orbits allowed by quantum mechanics by absorbing or emitting exactly the energy difference between the orbits. The Bohr model was a breakthrough in the development of atomic structure by improving upon several predictions based on Rutherford Atom that were flawed. Bohr overcame these problem by suggesting that the electrons in an atom can only move between stable stationary states. Atoms should be unstable since the electron should spiral into the nucleus and a continuous spectrum should be obtained. Bohr suggested that electrons in stationary states do not emit energy.	9.8.1 H1, H2, H7, H10 • An explanation of how the Bohr's model adapted quantization . . . . 2 • A reasonable description of Bohr's model OR • Describes quantization of energy in atoms 1
(b) (i) Energy is released in this reaction.	9.8.3 H7 • The correct response 1
(ii) Mass difference = mass of products – mass of reactants $= (4.0026 + 4.0026) - (7.0160 + 1.0078)$ $= 8.0052 - 8.0238$ $= 0.0186$ Binding energy ($1\mu = 931.5$ MeV) $0.0186 \times 931.5 = 17.3$ MeV $17.3 \times 1.6 \times 10^{-13} = 2.77 \times 10^{-12}$ J	9.8.3 H7, H10 • Correctly calculates both mass defect and binding energy. . . . . 3 • Correctly calculates both mass defect and attempts to determine binding energy . . . 2 • Applies formula for mass defect OR • Applies formula for biding energy 1
(c) (i) Bohr related his allowed quantized energy levels directly to the emission spectrum of the hydrogen atom. The lowest energy state was termed the ground state. The states with successively more energy than the ground state are called excited states. Electrons can make transitions between the orbits allowed by quantum mechanics by absorbing or emitting exactly the energy difference between the orbits. An atom can absorb or emit only certain discrete wavelengths (or equivalently, frequencies or energies). Isolated atoms can absorb and emit packets of electromagnetic radiation having discrete energies dictated by the detailed atomic structure of the atoms. When the corresponding light is passed through a prism or spectrograph it is separated into a spectrum, according to wavelength. Note: transitions to state $n = 2$ produce light in the visible region of the EM spectrum.	9.8.1 H1, H2, H10 • Complete understanding of Bohr's postulates to explain line emission spectra . . . . 2 • Describes Bohr's postulates OR • Outlines the emission spectrum and states Bohr's model 1
(ii) $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2 n_i^2}\right)$ $= 1.097 \times 10^7\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$ $= 1.52 \times 10^6$ $\lambda = 6.56 \times 10^{-7}$ m	H2, H10 • Correct use of formula to determine wavelength. . . . . 2 • Applies formula to determine wavelength. 1

Question 32 From Quanta to Quarks (Continued)

	Sample answer	Syllabus outcomes and marking guide
(d)	Phosphorous–32 is used in agriculture for tracking a plant's uptake of fertiliser from roots to leaves by addition of this radioactive tracer to the soil water. As it has a half-life of 14.3 days and emits β particles it passage through the plant can be traced and the tagged fertiliser's rate of uptake mapped. β particles have sufficient penetration power to emerge from root systems and from inside plant tissues. They can be detected using devices such as Geiger-Muller tubes. Only small and safe quantities need to be used.	9.8.4 H2, H7, H13 • Describes thoroughly and names an isotope used in agriculture . . . . 3 • Outlines and names an isotope used in agriculture . . . . 2 • Outlines an isotope used in agriculture OR • Names an isotope used in agriculture . . . 1
(e)	The Standard model is an attempt to describe the behaviour of all known subatomic particles within a single theoretical framework. This model incorporates the quarks and leptons as well as their interactions through the strong, weak and electromagnetic forces. Gravity, alone remains outside the standard model. According to the standard model, the basic forces are transmitted between the quarks and leptons by a third family of particles called bosons. Physicists have developed a theory called The Standard Model that explains what the world is and what holds it together. It is a simple and comprehensive theory that explains all the hundreds of particles and complex interactions with only: • 6 quarks. • 6 leptons. The best-known lepton is the electron. • Force carrier particles, like the photon. All the known matter particles are composites of quarks and leptons, and they interact by exchanging force carrier particles. While the Standard Model provides a very good description of phenomena observed by experiments, it is still an incomplete theory. The problem is that the Standard Model cannot explain why some particles exist as they do. For example, even though physicists knew the masses of all the quarks except for top quark for many years, they were simply unable to accurately predict the top quark's mass without experimental evidence because the Standard Model lacks any explanation for a possible pattern for particle masses. According to the standard Model, a proton would be a combination of two up quarks (charge $+\frac{2}{3}$ e) and one down quark (charge $-\frac{1}{3}$ e) giving it an overall charge of +1e, while a neutron would consist of two down quarks and one up quark (thus having zero overall charge).	9.8.4 H1, H2, H5, H10 • Discusses extensively how quarks and leptons feature in the Standard Model . . 3-4 • Discusses how quarks and leptons feature in the Standard Model . . . . 2 • Outlines features of quarks and leptons OR • Outlines the Standard Model 1

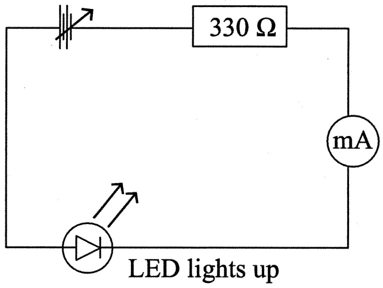
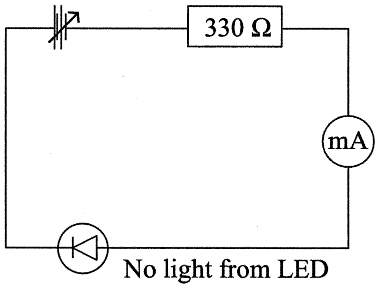
Question 32 From Quanta to Quarks (Continued)

	Sample answer	Syllabus outcomes and marking guide
(f)	Pauli proposed a number of items that contributed greatly to the development of atomic theory. Firstly he put forward the suggestion that only two electrons could occupy any one energy level in an atom, and that the electrons in such a pair have opposite spins. This became known as the Pauli Exclusion Principle. Secondly the process of β decay seemed to contradict the conservation laws (especially those of energy, linear momentum, and angular momentum). To account for these discrepancies, Pauli proposed the existence of a new particle, the neutrino. The neutrino has no electric charge and no mass, but is able to possess both energy and momentum. According to neutrino theory, a neutrino and an electron are simultaneously emitted in beta decay. This allows energy and momentum to be conserved. This theory was accepted for almost a quarter of a century without any direct evidence to support it. In 1956, an experiment was performed in a nuclear reactor that could only occur if the neutrino actually existed, thus confirming its existence.	9.8.2 H1, H4, H10 • Evaluates extensively the contribution of Fermi and Pauli and discusses how they have contributed to our understanding of atomic theory 7–8
		• Evaluates thoroughly the contribution of Fermi and Pauli and discusses how they have contributed to our understanding of atomic theory 5–6
		• Discusses the contribution of Fermi or Pauli and discusses how he contributed to our understanding of atomic theory OR • Discusses how they both contributed to our understanding of atomic theory... 3–4
	Heisenberg using the idea that particles have wave properties reasoned that it would be difficult to know exactly where particles are located. Thus the particles physical presence would be spread out by its wave nature. This implied that our knowledge of the physical world cannot be absolute and we could not define the exact location of electrons in the atom. His uncertainty principle implies that if we are able to calculate a particle's momentum we cannot locate its position and visa versa. His contribution enhanced the distinction between quantum mechanics and classical physics.	• Outlines the features of a nuclear chain reaction and the Exclusion Principle 2
	Both of these scientists had a significant impact on our understanding of the nature of the atom, on the way other scientists thought and conducted research into atomic structure and its composition and led to further developments of how our universe is constructed.	• Outlines the features of a nuclear chain reaction OR • Outlines the Exclusion Principle 1

Question 33 **The Age of Silicon**

	Sample answer	Syllabus outcomes and marking guide
(a)	A transistor is a single electronic device consisting of one type of semiconductor between two layers of the other type, which can amplify or act as a switch. An integrated circuit may have thousands of transistors all sharing the same semiconductor crystals substrate, so that the output may be a complex function of the input.	9.9.1 H1, H2 • Clearly distinguishes between an integrated circuit and a transistor....... 2 • Gives reasonable description of an integrated circuit OR • Gives reasonable description of a transistor.......................... 1
(b) (i)	An analogue system uses a continuous display of information while a non-continuous form is used in digital systems. The digital system achieves this by transmitting pulses produced because a circuit's output voltage is either high or low in a series of 0's or 1's. Analogue systems regulate the current and produce a continuously changing range of voltages and currents. Digital signals can be regenerated i.e. amplified and cleaned of noise. Analogue signals can be amplified but so too is the noise.	9.9.2 H3, H4 • Correctly compares analogue and digital systems.......................... 1
(ii)	A thermistor is a resistor in which resistance depends upon temperature (the higher the temperature, the lower its resistance). Input transducers such as these can act as a sensor and can be linked to a circuit in such a way that any change they detect causes a change in the input voltage. Ideally the input voltage is in proportion to the external change causing it. They can thus be used to alter the input voltage with varying resistance and thermistors can be connected to a processor that either sounds an alarm or regulates the temperature of a particular area. input device (thermistor) → processor → output device (fire alarm or temperature controller)	9.9.3 H4 • Explains how a thermistor acts as a transducer in both situations .... 3 • Describes how a thermistor acts as a transducer in both situations .... 2 • Describes how a thermistor acts as a transducer in one situation............ 1
(c) (i)	LEDs are diodes that give out light when current flows through them. Current can only flow when they are forward biased, but not when it is reversed biased. At a p-n junction between a p-type and n-type semiconductor, electrons can only flow across the junction in one direction, but not in the other. The reason for this being that at close to the junction there are neither electrons nor holes and a region (called the depletion layer) which is non conductive is formed. If the positive from the battery is connected to the n type material any free electrons are pulled away towards the battery, while at the other side the positive holes are pulled towards the negative terminal increasing the depletion layer, so that no current can flow. In an LED when electrons combine with positive holes at the junction, light is produced.	9.9.4 H1, H2, H3 • Outlines two properties of LEDs ...... 2 • States one property................. 1

Question 33 — The Age of Silicon (Continued)

Sample answer	Syllabus outcomes and marking guide
(ii)  LED lights up When the LED is forward biased, it conducts and current flows, when the voltage is greater than 2 volts.  No light from LED When the LED is reversed biased, it does not conduct and no current flows NOR when forward biased and voltage is less than 2 V. Note: Most LEDs have a maximum reverse voltage of 5 V. Any higher and the LED is likely to fail i.e. no light when next connected correctly. For forward voltages below 2 V there is no current and hence no light.	9.9.4 — H2, H10 • Correct use of circuit diagrams to show both situations correctly . . . . 2 • Correct use of circuit diagrams to show one correct situation 1
(d) The voltage gain is determined by the 100 kΩ resistor (which provides the negative feedback) and the 10 kΩ resistor. $\frac{V_o}{V_i} = \frac{-R_1}{R_2}$ Voltage gain $= \frac{-100\ \text{k}\Omega}{10\ \text{k}\Omega}$ $= 10$ This amplifier is an inverting amplifier with the amplitude of the output signal being times (or 10 times) greater than the input signal.	9.9.6 — H2, H7, H13 • Describes thoroughly the relationship and states voltage gain . . . . 3 • Outlines the relationship and states voltage gain . . . . 2 • Outlines the relationship OR • States voltage gain 1

Question 33 **The Age of Silicon (Continued)**

	Sample answer	Syllabus outcomes and marking guide
(e)	This combination of logic gates uses one OR gate, one AND gate and one NOT gate. The OR gate gives a HIGH output when either input is HIGH, while the AND gate followed by a NOT gate gives an output equivalent to an inverted AND gate, i.e. it gives a LOW output only when both inputs are HIGH.	9.9.5 H7, H13 • Completes the truth table correctly and explain how each of the gates provides its output. . . . . 3–4 • Complete the truth table for this arrangement OR • Explain how each of the gates provides its output. . . . . 2 • Explain how one of the gates provides its output. OR • Attempts to complete truth table 1
(f)	The development of electronic devices, particularly those using semi-conductive materials, has had a great impact on society. Such innovations allowed: inexpensive components to be mass-produced, improved reliability due to a lack of moving parts and fragile construction, lower energy consumption and portability, miniaturisation and high speed operation. The small size of these devices is a large advantage; they can be used in electronic watches, hand-held calculators and spacecraft capable of travelling to outer space. The amount of voltage used by these devices means that they can be used to process information easily. On the home front and in industry, electronic devices such as transistors and integrated circuits have provided cheap labour-saving equipment. Central processing units and amplifiers are used in communication information technology and ensure that our society is now a global one with instantaneous coverage of events and transfers of money and ideas. Science and medicine have also been impacted upon by the vast quantity of information that can be readily accessed and processed. Unfortunately there may be some negative impacts as well, this technology has been used by the military to create more efficient weapon systems and laser guided missiles. These impacts have occurred extremely rapidly particularly in the last decades of the twentieth century and their impacts should they continue to happen especially with increased research into additional applications. This will ensure that our society will continue to benefit from these developments.	9.9.1, 9.9.7 H1, H4, H10 • Evaluates extensively the impact of electronic devices and comments on their future limitations . . . . 7–8 • Evaluates thoroughly the impact of electronic devices and comments on their future limitations . . . . 5–6 • Discusses the impact of electronic devices OR • Describes the impact of electronic devices and comments on their future limitations . . . . 3–4 • Outlines two impacts of electronic devices and mentions future limitations . . . . 2 • Describes two impacts of electronic devices OR • Describes one impact and comments on future limitations 1

Truth table for (e):

A	B	X	Y
0	0	0	1
0	1	1	1
1	0	1	1
1	1	1	0