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HSC Trial Examination 2004

Physics

This paper must be kept under strict security and may only be used on or after the afternoon of Thursday 12 August, 2004, 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 2–16

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 16–27.
- Allow about 1 hour and 45 minutes for this part.

Section II Pages 17–25

Total marks 25

- Attempt ONE question from Questions 28–32.
- Allow about 45 minutes for this section.

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. There are a number of reasons which contribute to variations in determining the value of the acceleration due to gravity at specific locations on the surface of the Earth.

Which of the following pairs of reasons would **not** be responsible for such variations?

(A) Crustal variations and the shape of the Earth.
(B) The shape of the Earth and height above sea level.
(C) Height above sea level and the Earth's spin.
(D) Crustal variations and the Earth's orbit around the Sun.

2. The Earth, who's radius and mass are 6.38×10^6 m and 5.98×10^{24} kg respectively, has an artificial satellite. The satellite orbits at an altitude of 300 km, has a mass of 200 kg and travels with a velocity of 28 000 km h^{-1} at this altitude.

What is the centripetal force of this orbiting satellite?

(A) 1.8×10^{-3} N
(B) 2.3×10^{-1} N
(C) 1.8×10^{3} N
(D) 2.3×10^{3} N

3. One major difference between a projectile and a rocket is the ability of the rocket to be continually propelled via the thrust of its engine.

This leads to a further advantage which means that

(A) rockets can continue to accelerate.
(B) rockets can control their amount of thrust.
(C) rockets are able to reach a maximum acceleration.
(D) rockets are able to reach maximum speed.

4. A number of long range space probes have been sent to the outer planets of our solar system on fly by missions. The main reasons for using the sling shot effect were

(A) to reduce the cost of launching a heavy probe and to ensure that the mission was completed quickly.
(B) to ensure that the mission was completed quickly and to maintain the quality of transmitted information returned.
(C) to ensure that the mission was completed quickly and to reduce the need to send astronauts with the dangers involved.
(D) to reduce the need to send astronauts with the dangers involved and to maintain the quality of transmitted information returned.

5. A particle is to be used in a linear accelerator. Measured at rest relative to the laboratory it has a half-life of 2.5 μs. When measured at constant speed by an observer in the laboratory, its half life has increased to 10 μs.

What is the magnitude of the speed of the particle relative to the laboratory?

(A) 9.68×10^{-1} ms^{-1}
(B) 2.90×10^{-1} ms^{-1}
(C) 9.68×10^{7} ms^{-1}
(D) 2.90×10^{8} ms^{-1}

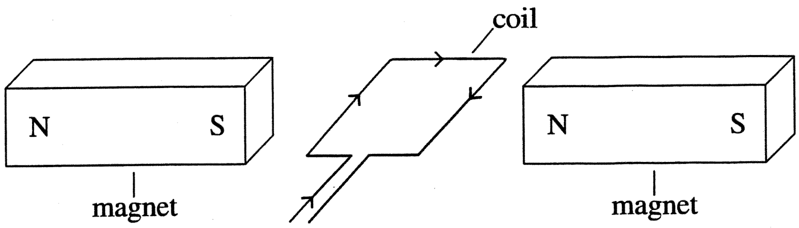
6. Identify which of the following is **not** a component of a DC generator.

(A) brushes
(B) coil
(C) magnetic field
(D) slip-rings

7. Two long parallel wires are carrying electric currents. The direction of the current in one of the wires is reversed. How does this affect the force between the wires?

(A) The force does not change.
(B) The force changes direction.
(C) The force increases.
(D) The force decreases.

8. The following diagram shows a coil of wire between two magnets.



When a current passes through the coil in the direction shown, which is now free to move, the coil will:

(A) start rotating
(B) not move
(C) move vertically
(D) move towards one magnet

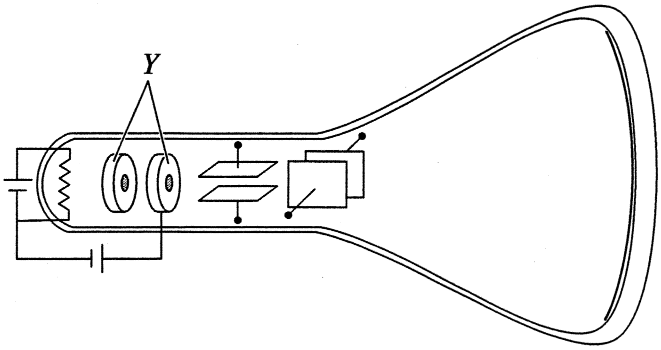
9. A piece of wire 1.0 cm long is at right angles to a magnetic field whose magnetic flux density is 1.5 T. A current of 2.0 A flows in the wire. What is the magnitude of the force on the wire?

(A) 3.0 N
(B) 0.3 N
(C) 0.03 N
(D) zero

10. A transformer is needed to convert an input voltage of 6000 V to an output voltage of 240 V. The **type of transformer** and the **ratio** of the number of turns in its secondary coil to the number of turns in its primary coil are

(A) step up, 25:1
(B) step up, 1:25
(C) step down, 25:1
(D) step down, 1:25

11. The following diagram shows a simple cathode ray tube from an oscilloscope.



The parts labelled Y have the function of

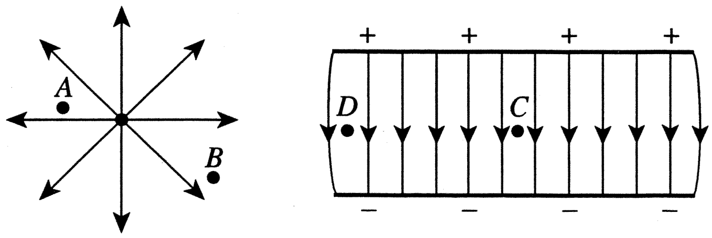
(A) producing electrons.

(B) showing the position of the beam.

(C) deflecting the beam horizontally.

(D) accelerating the electrons.

12. The following diagram shows the electric fields near a point charge and between parallel plates.



At which point is the electric field greatest?

(A) A

(B) B

(C) C

(D) D

13. Which of the following statements is correct?

(A) Einstein was the first person to observe the photoelectric effect.

(B) Planck hypothesised that energy was exchanged, in quanta amounts, by the particles of a black body.

(C) Hertz performed experiments to measure the speed of light, using radio waves.

(D) Einstein predicted that for a black body, as the wavelength shortens, the radiation intensity will increase.

14. Solid state devices replaced thermionic devices because they

(A) were much smaller and required less current in their circuits.

(B) had a much longer life as they did not become warm at all.

(C) were less reliable and were easily broken.

(D) allowed the cathode coating to evaporate, helping current flow.

15. In metal conductors, the resistance

(A) increases as the amount of impurities increases.

(B) increases as the lattice vibrations decrease.

(C) decreases as more electrons are scattered by lattice vibrations.

(D) decreases as the temperature of the metal increases.

Part B

Total marks 60
Attempt Questions 16–27.
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 (6 marks) **Marks**

Early astronauts in space only orbited the Earth at an altitude of between 80 km and 200 km. A typical rocket engine would provide a thrust of 380 000 N to a rocket with a total mass of 29 830 kg prior to lift off and would use 25 315 kg of fuel during the flight.

(a) Assuming the thrust is kept constant, calculate the final acceleration of this rocket immediately before the fuel had been used. **3**

(b) Explain the meaning of the term *g-force*. **1**

(c) Determine the g-force experienced by the astronaut immediately before the fuel had been used. **2**

Marks

Question 17 (5 marks)

A satellite with a mass of 200 kg maintains its orbit at an altitude of 300 km above the Earth's surface. The Earth has a radius of 6.38×10^6 m and a mass of 5.97×10^{24} kg.

(a) Determine the gravitational potential energy of the satellite at this altitude. **3**

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(b) Would you expect the gravitational force of this satellite in orbit to be different from its value on the surface of the Earth prior to launch. Explain any variation. **2**

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Marks

Question 18 (6 marks)

The principle of relativity was recognised as both a mechanical and optical effect. Einstein believed that the principle should hold for both situations. One of his thought experiments involves him sitting on a train travelling at the speed of light and looking at a mirror. He asked the question as to whether he would be able to see his own reflection.

(a) State the principle of relativity. 1

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(b) Outline one possible answer to Einstein's question and the problems involved in your answer in terms of the principle of relativity. 3

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(c) What was Einstein's conclusion to this thought experiment? 2

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Marks

Question 19 (3 marks)

Describe Galileo's analysis of projectile motion and clearly identify why a projectile has a parabolic path. 3

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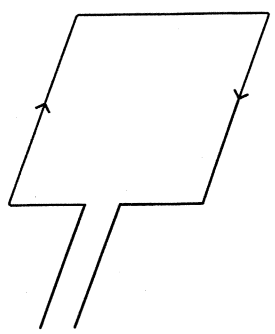
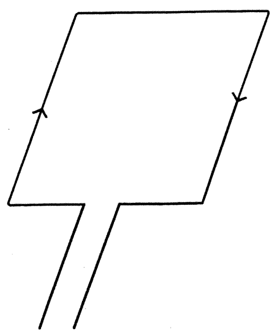
Question 20 (4 marks)

The diagram below shows 2 loops of current carrying wire, each of which are part of separate DC motors. The manufacturer of the DC motors wants to build a motor that uses two different methods of producing the magnetic fields required for its operation.

Show on the diagrams

- two different methods used to produce the required magnetic fields. Indicate north (N) and south (S) on any device used. 2
- the resultant magnetic field lines. 2





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Marks

Question 21 (5 marks)

During the course you carried out a first hand investigation to demonstrate the production of an alternating current.

(a) Describe how you carried out this investigation. Include a diagram as part of your description. **3**

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(b) Explain how you showed that you had produced an **alternating** current. **2**

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Marks

Question 22 (5 marks)

A loop of wire, carrying an electric current, is placed into a magnetic field. Describe the forces experienced by the loop and explain the results of these forces in terms of a DC motor. 5

Question 23 (6 marks)

Magnetic flux is an important concept in physics.

(a) Describe the concept of magnetic flux and show how it relates to the magnetic flux density, B. 4

(b) Use the concept of magnetic flux to explain the production of back emf in motors. 2

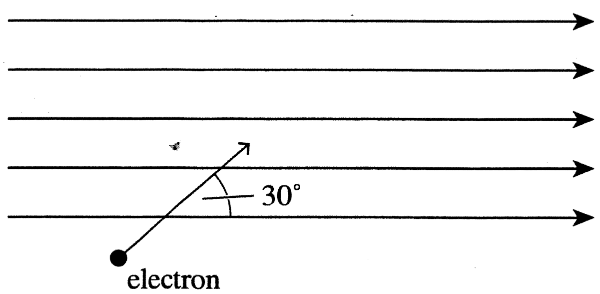
Marks

Question 24 (4 marks)

Assess Einstein's contribution to quantum theory and its relation to black body radiation. 4

Question 25 (5 marks)

An electron moves in a region whose magnetic flux density is 2.0 T with a velocity of 2×10^3 m s^{-1} at an angle of 30° to the direction of the magnetic field.



(a) Determine the magnitude and direction of the magnetic force applied to the electron. 2

Marks

Question 26 (6 marks)

Describe why doping pure semiconductor materials is necessary, and how it changes the electrical properties of the material, in terms of negative charge carriers and positive holes. Include examples of materials used for semiconductors and materials used in the doping process. 6

Marks

Question 27 (5 marks)

Outline how the Braggs were able to determine the internal structure of a crystal. What did this type of investigation tell us about the structure of metals? 5

Section II

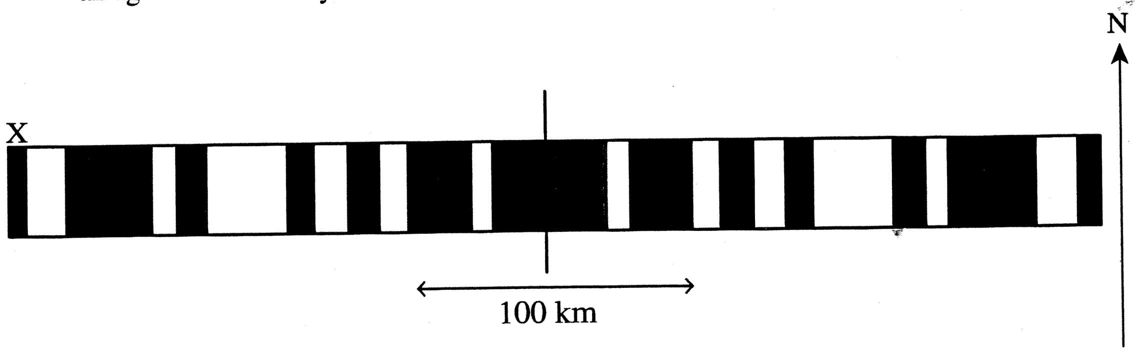
Total 25 Marks
Attempt ONE question from Questions 28–32.
Allow about 45 minutes for this section.
Answer the question in a writing booklet. Extra writing booklets are available.

Marks

Question 28 — Geophysics (25 marks)

(a) Describe the structure and function of a seismometer. **3**

(b) The diagram below shows the pattern of magnetic anomalies either side of a mid-ocean ridge (MOR) in the Atlantic ocean. Age dating has shown that the anomaly marked X has an age of 10 million years.



(i) Calculate the rate of sea-floor spreading at this locality (i.e. on the west side of the MOR) in cm/yr. **1**

(ii) Recount how this anomaly pattern is formed. **2**

(c) (i) Using suitable equations from the Formula Sheet (at the end of this paper), derive an expression for the mass of the Earth as a function of radius and surface gravity. **2**

(ii) The Moon orbits the Earth in a period of 27.3 days at a mean distance from the Earth's centre of 384 000 km. Use this information to determine the mass of the Earth. **2**

(d) Summarise the evidence that supports the theory of a liquid outer core and a solid inner core for the Earth. **3**

(e) Describe the role that geophysicists have played in natural hazard reduction. **4**

(f) Discuss the application of **two** geophysical methods in mineral exploration. **8**

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Marks

Question 29 — Medical Physics (25 marks)

(a) Certain radioactive isotopes are commonly used to obtain scans of organs. **3**

Identify one specific radioactive isotope used to obtain scans and outline the specific properties and half-life characteristics that enable it to be useful.

(b) You have conducted a first-hand investigation to demonstrate the transfer of light by optical fibres.

(i) Identify the property that enables the transfer of light by optical fibres. **1**

(ii) Describe the experimental procedure employed to demonstrate the transfer of light by optical fibres. **2**

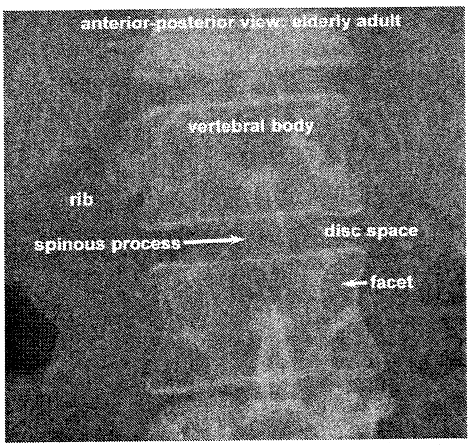
(c) The table below gives values for the density and speed of sound in a variety of body tissues.

Tissue	*Density* (kg m^{-3})	*Velocity of sound* (m s^{-1})
heart muscle	1080	1580
blood	1025	1570
fat	950	1450

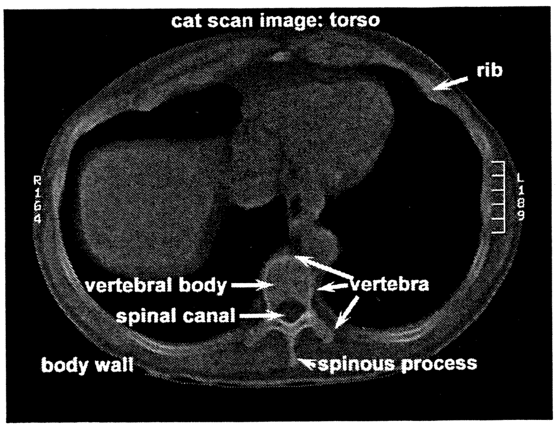
(i) Calculate the acoustic impedance of heart muscle. **2**

(ii) Contrast the intensity of reflected ultrasound pulses passing from heart muscle into fat deposits with those passing from heart muscle into blood filled chambers. **2**

(d) The spinal images below are examples of an X-ray and a CAT scan. **3**



X-ray



CAT scan

Compare the use of X-rays and CAT scans.

Question 29 continues on page 20

Marks

Question 29 (Continued)

(e) MRI scans are a product of the behavior nuclei, usually Hydrogen, that have been subjected to radio waves whilst in strong magnetic fields. **4**

Discuss the effect of subjecting precessing nuclei to pulses of radio waves and relate the resulting behavior to the production of MRI scans.

(f) 'Diagnostic imaging has expanded the knowledge of practitioners and the practice of medicine. The greatest advantage is to allow the practitioner to see inside the body without a need for surgery. As the usage of these technologies, based on the medical application of physics, becomes increasingly available and accepted as standard procedure, the impact on society will become more significant.' **8**

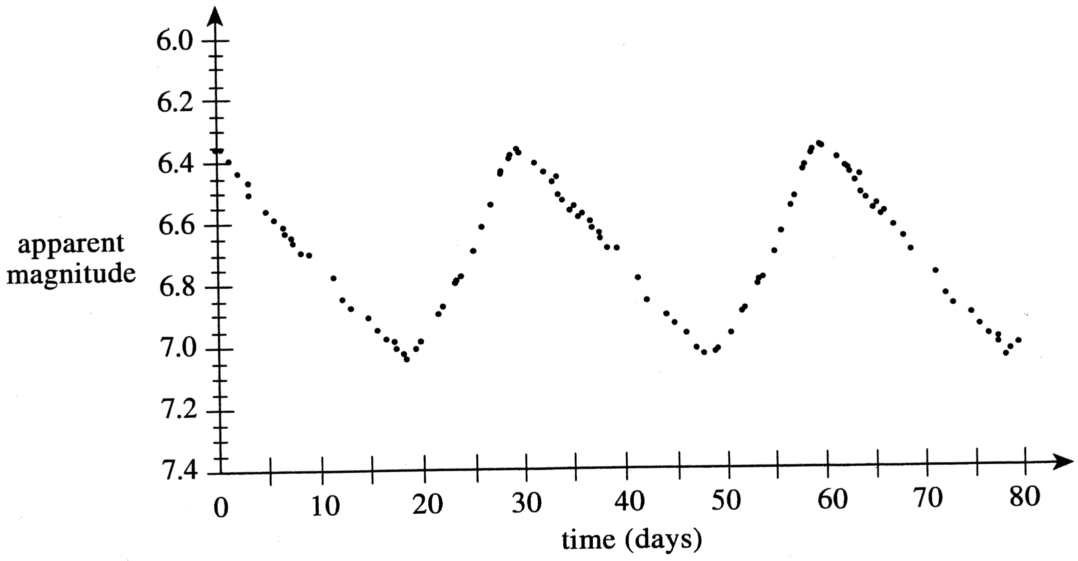
Evaluate, with reference to specific technologies, the medical application of physics.

Marks

Question 30 — Astrophysics (25 marks)

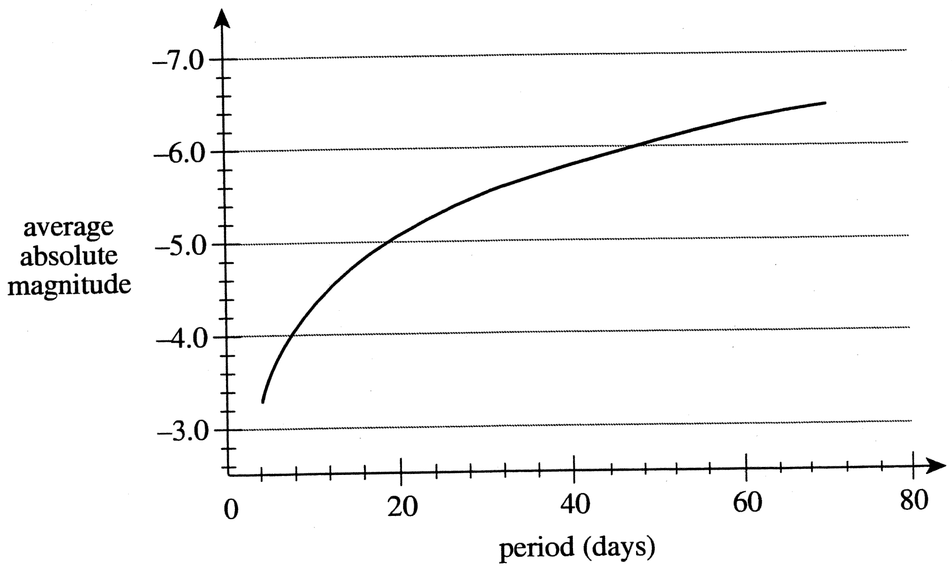
(a) Outline the methods by which the resolution and/or sensitivity of ground–based telescopes can be improved. 3

(b) The diagram below shows the light curve of a Cepheid variable star in our galaxy. The observed average apparent magnitude is m = 6.7.



(i) Determine the period of this Cepheid variable. 1

The graph below shows the period–luminosity relationship for Cepheid variable stars.



(ii) Calculate the distance of this Cepheid (in parsecs). 2

(c) (i) Sketch a labelled Hertzsprung–Russell diagram for a typical population–II globular cluster. Numerical values on the axes are not required. 2

(ii) Describe the main spectroscopic features of the brightest stars in a globular cluster. 2

Question 25 continues on page 22

Marks

Question 30 (Continued)

(d) Explain how trigonometric parallax can be used to determine the distance to stars. **3**

(e) Describe the advantages of photoelectric technologies over photographic methods for photometry. **4**

(f) Discuss the synthesis of elements in stars by nuclear fusion reactions. **8**

Marks

Question 31 — From Quanta to Quarks (25 marks)

(a) Explain how the Bohr modifications made to the Rutherford model of the atom were related to Balmer's empirical formula for determining the wavelength of spectral lines in the hydrogen spectrum. **3**

(b) (i) State the proposal suggested by Louis de Broglie that was based on the connection between electromagnetic waves and matter. **1**

(ii) Outline the Davis-Germer experiment and show how it supported the de Broglie proposal. **2**

(c) (i) Describe how the mass defect is connected with the binding energy of an atom. **2**

(ii) Determine the energy released when a proton combines with a Lithium atom and produces two Helium nuclei, according to the following nuclear reaction: **2**

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

The atomic masses are as follows:

$$\text{proton} = 1.008\ \mu$$
$$\text{lithium} = 7.016\ \mu$$
$$\text{helium} = 4.003\ \mu$$

(d) Identify and describe the use of **one** radio-isotope in the fields of medicine and engineering. **3**

(e) Describe how the Standard Model of Matter has been utilised by physicists to suggest that all the known sub-atomic particles, such as protons and neutrons, consist of a combination of quarks and leptons. How is this model related to the evolution of the universe after the Big Bang? **4**

(f) Scientists investigating naturally occurring radioactivity could not explain the properties they observed by simply assuming the nucleus contained protons and electrons. Discuss the prediction and subsequent discovery of the neutron and neutrino with reference to the nature of alpha and beta decay and the laws of conservation of energy and momentum. **8**

Marks

Question 32 — The Age of Silicon (25 marks)

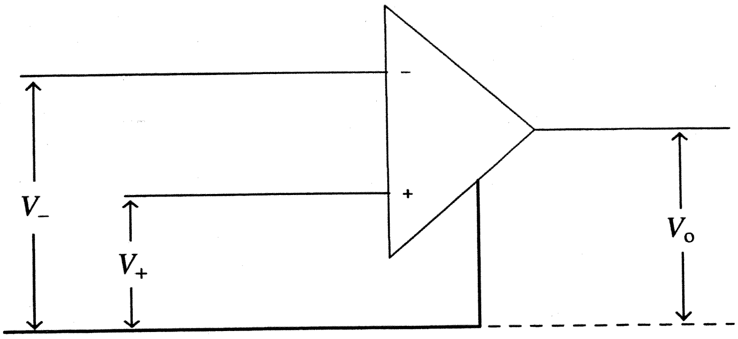
(a) Identify the desirable optical properties of silica and explain how the development of silicon into integrated circuits has impacted on the use of electronics in our society. **3**

(b) (i) Explain the difference between an electronic circuit and an electric circuit. **1**

(ii) Describe one advantage and one disadvantage of using an electronic circuit when compared with an electric circuit. **2**

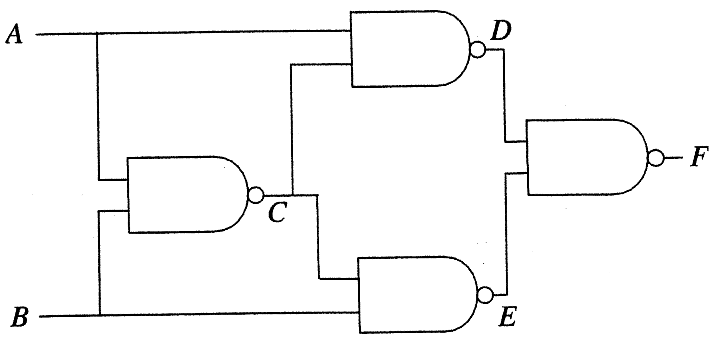
(c) (i) Outline the main features of an operational amplifier. **2**

(ii) The following diagram shows an operational amplifier as used in a circuit. **2**



Sketch a graph to show the relationship between the output potential difference and the difference in input potential difference for an operational amplifier with an open loop and an operating range of $-5\text{ V} < V_{output} < +5\text{ V}$.

(d) The diagram below shows four identical logic gates used in a circuit. Identify what logic gate is being used and complete the following truth table. **3**



A	*B*	*C*	*D*	*E*	*F*
0	0	1			
0	1	1			
1	1	0			
1	0	1			

Question 32 continues on page 25

Marks

Question 32 (Continued)

(e) Explain the use of thermistors as transducers. In particular, explain the function of thermistors in fire alarms and how the relationship between temperature and resistance is utilised. **4**

(f) Describe the structure and operation of a light-emitting diode (LED). Asses two situations where an LED would be preferable to an ordinary light source. **8**

End of paper

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HSC Trial Examination 2004

Physics

Solutions and marking guidelines

Section I

Part A

Answer and explanation	Syllabus content and course outcomes
Question 1 **D** There are a number of factors that can contribute to variations in the acceleration due to gravity. These include crustal variations, the shape of the Earth, height above sea level and the Earth's spin. However, the Earth's orbit around the Sun has no effect.	9.2.1 H2, H9
Question 2 **C** From $F = \frac{mv^2}{r}$ $= \frac{200\left(\frac{28000 \times 10^3}{3600}\right)}{(6.38 \times 10^6 + 300 \times 10^3)}$ $= 1.81 \times 10^3$ N	9.2.2 H6
Question 3 **A** Once launched, a projectile has no internal force acting upon it. A rocket has its engine to provide thrust, which means it can continue to accelerate.	9.2.2 H1
Question 4 **A** The slingshot effect can be provided by planets for space probes. It is used to gain an increase in the speed of the probe relative to the Sun. This substantially reduces time frames in completion times and also reduces costs as it saves fuel. It does not help in transmission of information nor in reducing dangers associated with space travel.	9.2.3 H2
Question 5 **D** $t_0 = \frac{t}{\sqrt{1 - \frac{v^2}{c^2}}}$ $10 \times 10^{-6} = \frac{2.5 \times 10^{-6}}{\sqrt{1 - \frac{v^2}{(3 \times 10^8)^2}}}$ $v^2 = \frac{15}{16}c^2$ $v = 2.90 \times 10^8$ m s^{-1}	9.2.4 H6
Question 6 **D** A DC generator needs a split-ring commutator.	9.3.3 H11
Question 7 **B** A change in the direction of current in a wire causes a change in the force direction.	9.3.1 H7
Question 8 **A** A current carrying coil in a magnetic field experiences a torque causing it to rotate.	9.3.1 H9

Part A (Continued)

Answer and explanation	Syllabus content and course outcomes	
Question 9 **C** $F = BIl\sin\theta$ $= 1.5 \times 2 \times 1 \times \sin 90°$ $= 0.03$ N	9.3.1	H9, H10
Question 10 **C** Since the voltage is decreased, we need a step down transformer. The ratio of turns needed is the same as the ratio of voltages (25:1).	9.3.4	H9
Question 11 **D** The electrodes labelled *Y* have the function of accelerating the electrons.	9.4.1	H9, H10
Question 12 **C** The electric field strength relates to the spacing between field lines. The closer the spacing the greater the field strength.	9.4.1	H10
Question 13 **B** Planck hypothesised that energy was exchanged between the particles of a black body and the radiant energy in the cavity and that the energy was in quantum amounts. For (C), Hertz conducted experiments to measure the speed of the radio waves going between the two loops. This was shown to be equal to the speed of light. Thus the answer is wrong.	9.4.2	H1, H2
Question 14 **A** Compared with thermionic devices, solid state devices are much smaller, more portable, more efficient, less expensive to build and are instantly ready for use.	9.4.3	H3, H4, H9
Question 15 **A** The resistance in a metal is proportional to the scattering of electrons by lattice vibrations. This is increased as the metal's temperature increases.	9.4.4	H9, H10

Part B

Sample answer	Syllabus outcomes and marking guide
Question 16	
(a) $a = \frac{T - mg}{m}$ $= \frac{380\ 000 - (29\ 830 - 25\ 315)}{(29\ 830 - 25\ 315)}$ $= \frac{335\ 753}{4515}$ $= 74 \text{ m s}^{-2}$	9.2.2 H1, H2, H6 • Clearly indicates acceleration = total force (thrust – weight) divided by mass of rocket and correctly determines final acceleration of rocket . . . . 3 • Clearly indicates acceleration = total force (thrust – weight) divided by mass of rocket but incorrectly determines final acceleration of rocket . . . . 2 • Indicates acceleration = total force (thrust – weight) divided by mass of rocket. OR • Attempts to determine final acceleration of rocket with incorrect substitution 1
(b) The g-force felt by astronauts is a measure of the total force acting divided by the weight force. Similarly, it can be calculated by dividing the total acceleration by the acceleration due to gravity.	9.2.2 H9 • Correctly explains the meaning of the term *g-force* 1
(c) g-force $= \frac{g + a}{g}$ $= \frac{9.8 + 74}{9.8}$ $= 8.5$ g	9.2.2 H9 • Correctly determines the value of the g-force . . . . 2 • Attempts to determine the value of the g-force but makes an incorrect substitution into the correct formula. OR • Clearly shows some knowledge of the relationship between g-force and total force/weight. 1
Question 17	
(a) $E_p = -\frac{Gm_1m_2}{r}$ $= -\frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times 200}{(6.38 \times 10^{6} + 300 \times 10^{3})}$ $= -1.92 \times 10^{10}$ J	9.2.1 H1, H2, H9 • Correct answer with equation and correct substitution shown . . . . 2 • Correct substitution of most data (incorrect substitution of not more than one variable) and corresponding correct calculation . . . 1
(b) Yes, there would be differences between the gravitational force of the satellite in orbit and its value prior to launch. These would be attributable to the differences in acceleration due to gravity at these different locations (one on the surface of the Earth and the other in orbit). Since acceleration due to gravity varies inversely to distance of separation squared ($g \propto \frac{1}{r^2}$) the satellite in orbit would have a lower gravitational force acting upon it.	9.2.3 H2, H9 • Shows relationship between gravitational acceleration and gravitational force. AND • Correctly explains a variation between values in orbit and prior to launch using $\left(g \propto \frac{1}{r^2}\right)$ . . . . 2 • Shows relationship between gravitational acceleration and gravitational force. OR • Correctly explains a variation between values in orbit and prior to launch 1

Part B (Continued)

	Sample answer	Syllabus outcomes and marking guide
Question 18		
(a)	The principle of relativity can be simply stated as there is no preferred inertial frame of reference or that it is not possible to detect uniform velocity in one inertial frame of reference without referring to another external inertial frame of reference.	9.2.4 H2, H6 • Correctly states principle of relativity . . . 1
(b)	There are two possible answers to this situation: No, Einstein would not see his own reflection because the train was travelling at the speed of light and the light from his face would not be able to reach the mirror and reflect back to allow him to see his reflection. This would violate the principle of relativity by those who accepted the aether theory. OR Yes, Einstein would see his image reflected from the mirror and the principle of relativity would not be violated as the light would travel at the speed of light from Einstein's viewpoint. However, an observer outside would measure the speed of light to be double its value.	9.2.4 H5, H6 • Correctly outlines one possible answer to the mirror situation. AND • Clearly outlines the problems involved with this response in terms of the principle of relativity . . . . 3 • Correctly outlines one possible answer to the mirror situation. AND • Clearly outlines the problems involved with this response in terms of the principle of relativity . . . . 2 • Correctly outlines one possible answer to the mirror situation. OR • Makes specific mention to the problems involved in terms of the principle of relativity 1
(c)	Einstein could not accept that the principle of relativity could be violated, so he decided that he should be able to see his own reflection and that the aether theory must be wrong. He further suggested that the speed of light should be a constant regardless of the motion of the observer. As a consequence of his idea, he concluded that if all observers were to have the speed of light as a constant value, the observers would have to observe different distances and different times. i.e. space and time would vary.	9.2.4 H2, H6 • Clearly and concisely relates Einstein's conclusion to the mirror thought experiment. AND • Relates the consequences of this situation . . . . 2 • Clearly relates Einstein's conclusion to the mirror thought experiment. OR • Relates the consequences of this situation 1

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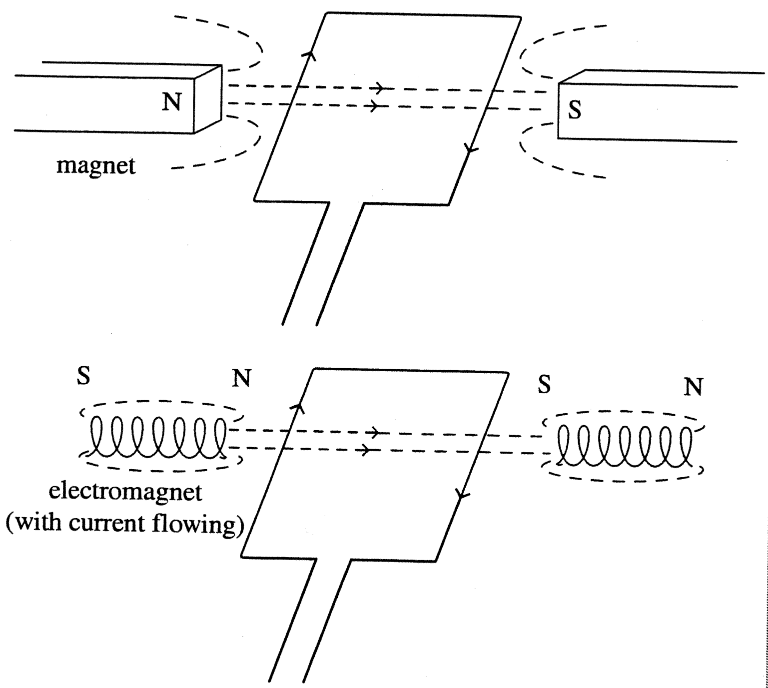
Part B (Continued)

Sample answer	Syllabus outcomes and marking guide
Question 19	
Galileo was the first to attempt a mathematical analysis of projectile motion. He had two main problems with his analysis. Firstly, the acceleration due to gravity was too quick to enable him to gain conclusive results with crude equipment and secondly, frictional forces from air resistance slowed the body's acceleration. To overcome these difficulties he designed highly polished ramps down which he rolled balls of different masses. His treatment was to ignore air resistance and consider that the only vertical force was the gravitational force provided by the acceleration due to gravity. Horizontally, the motion was not subject to any forces and therefore there was no acceleration in this direction. Whenever a constant horizontal motion combines with a vertically accelerated motion, a parabolic path results. This can be shown mathematically when the equations of horizontal motion and vertical motion are combined to reveal that the vertical displacement is of the form of the general form of a parabola (viz $y = ax^2 + bx + c$).	9.2.2 H1, H2, H6 • Clear, concise answer describing Galileo's analysis. AND • A clear identification as to why a projectile has a parabolic path .... 3 • Partial answer describing Galileo's analysis. AND • Some identification as to why a projectile has a parabolic path .... 2 • Partial answer describing Galileo's analysis. OR • Some identification as to why a projectile has a parabolic path 1
Question 20	
	9.3.1 H7, H13 • Shows two methods of producing the magnetic field. AND • Shows the two sets of resultant field lines .... 4 • Shows two methods of producing the magnetic field. AND • Shows partially correct sets of resultant field lines .... 3 • Shows two methods of producing magnetic fields. .... 2 • Shows one method of producing magnetic field. AND • Shows one correct set of resultant field lines .... 2 • Shows one method of producing magnetic field 1

Part B (Continued)

Sample answer	Syllabus outcomes and marking guide
Question 21	
(a) We attached the ends of a coil of wire to a galvanometer and pushed a bar magnet in and out of the coil. We varied the speed of the magnet going into the coil and also the pole which entered the coil.	9.3.2 H11, H13 • A clear description, including a diagram, of an investigation which actually produces an alternating current (AC) 3
	• A description of an experiment which produces only a single pulse of current. OR • A description as above omitting the diagram 2
	• A description of an investigation which produces direct current (DC) 1
(b) The galvanometer needle moved left then right about the zero point. This showed that current moved first in one direction and then in the opposite direction.	9.3.2 H14 • A complete explanation of a method which detects and demonstrates AC 2
	• A partial explanation of a method which detects and demonstrates AC 1
Question 22	
One side of the loop will experience a force upward and the other side will experience a force downward. These forces are perpendicular to both the magnetic field and the coil. This pair of opposite forces creates a torque which will tend to make a coil rotate. If the coil is free to turn, it will begin to do so. It will continue to turn if the direction of the field is reversed every half turn. The magnitude of the forces depends on the current and the number of turns in the loop. The torque also depends on the orientation of the loop in the field.	9.3.1 H7, H9 • Describes in detail the forces experienced by the loop. AND • Describes in detail the effect of the forces 5
	• Gives a detailed description but omits one significant aspect 4
	• Describes in detail the forces experienced by the loop. OR • Describes in detail the effect of the forces 3
	• Gives a partial description of the forces experienced by the loop. OR • Gives a partial description of the effect of the forces 2
	• States one aspect of the forces experienced by the loop. OR • States one aspect of the effect of the force 1

Part B (Continued)

Sample answer	Syllabus outcomes and marking guide
Question 23	
(a) Magnetic flux is a name for the magnetic field lines we draw around a magnet. The closer the flux lines are together the stronger the field. We can give a value to the flux if we count each magnetic line as one line of flux. Magnetic flux density is the number of lines of flux which pass through a given area. $$B = \frac{\text{flux}}{\text{area}}$$	9.3.2 H9 • Fully describes flux and its relationship to magnetic flux density, B. . . . . 4 • Fully describes flux and partially describes its relationship to magnetic flux density, B . . . . 3 • Fully describes flux OR • The relationship between flux and magnetic flux density, B . . . . 2 • States one aspect of flux OR • States one aspect of the relationship between flux and its relationship to magnetic flux density, B 1
(b) In a motor, when a rotating coil cuts lines of magnetic flux, a potential difference is produced in the coil. This potential difference, known as back emf, reduces the effective emf in the coil. This reduction is as stated by Lenz's law.	9.3.2 H6, H10 • Explains, using flux, the production of back emf. . . . . 2 • Explains back emf without using flux. OR • Describes back emf 1
Question 24	
Firstly, Planck hypothesised that the radiation in the black body was absorbed and emitted in small, discrete amounts called quanta, rather than continuously. The atoms of the walls could only oscillate with certain energy values. Einstein's photoelectric effect analysis showed that light was quantised. Energy is concentrated in packets of energy, or photons. A photon is the smallest amount of energy possible at a particular frequency. A photon can only transfer all or none of its energy, not just part of it. This suggested that Planck's hypothesis was correct. Radiation and the vibration of atomic oscillators in the black body could also be in the quantised form. Einstein's contribution to the quantum theory was very significant as it explained both phenomena, the photoelectric effect and black body radiation, in those terms.	9.4.2 H1, H2, H7, H8, H10 • Shows sound knowledge of quantum theory and black body radiation. AND • Assesses Einstein's contribution . . . . 4 • Shows sound knowledge of quantum theory and black body radiation . . . . 3 • Shows basic knowledge of quantum theory and black body radiation . . . . 2 • Shows basic knowledge of quantum theory. OR • Shows basic knowledge of black body radiation 1
Question 25	
(a) $F = qvB\sin\theta$ $= 1.6 \times 10^{-19} \times 2 \times 10^{3} \times 2.0 \times \sin 30°$ $= 3.2 \times 10^{-16}$ N, out of the page	9.4.1 H1, H9, H10 • Correct substitution into equation AND • Correct definition of force . . . . 2 • Correct substitution into equation OR • Correct definition of force 1

Part B (Continued)

Sample answer	Syllabus outcomes and marking guide
(b) The wheel rotated away from the cathode as the cathode rays hit the vanes. This shows that cathode rays are charged particles, being attracted to the anode. It also showed that the particles have mass and momentum, as the glass wheel rotates away from the cathode.	9.4 H2, H3 • Description of the correct motion of the glass wheel and all appropriate properties of cathode rays . . . . 3 • Description of the correct motion of the glass wheel and one appropriate property of cathode rays . . . . 2 • Description of the correct motion of the glass wheel. 1
Question 26	
Pure semiconductor material, like Si and Ge, are very poor conductors. Doping is the process of adding a tiny amount of an impurity (1:200 000 atoms) to a semiconductor to change its electrical properties. Group 4 elements, like Si and Ge, have 4 electrons in their valence band. If a group 5 atom, like P with 5 electrons in its outer shell, is substituted for an atom in a semiconductor's lattice, an extra electron goes to the conduction band, improving its electrical conductivity. This material is called an n-type semiconductor. Similarly, if a group 3 atom, like boron, with 3 electrons in its outer shell, is substituted for silicon, there is one electron missing in the crystal lattice, making a hole. This is p-type material. Holes are places in the lattice which are more positive than elsewhere and can be filled with a moving electron. The positive hole has now moved to where the electron came from. Thus, electrons move under the influence of the electric field in one direction and holes move the other way. The conductivity of p-type semiconductor material is improved due to their positive holes, even though they have fewer valence electrons.	9.4.3 H9, H10 • Thorough understanding of relative movement of electrons, holes for conduction, p-type material and n-type material AND • Gives examples of semiconductors and dopants and explains why semiconductors need doping AND • Outlines the process of doping. . . . . . . .5-6 • Sound understanding of relative movement of electrons, holes for conduction, p-type material and n-type material AND • Gives examples of semiconductors and dopants and explains why semiconductors need doping OR • Outlines the process of doping. . . . . . . .3-4 • Basic understanding of relative movement of electrons, holes for conduction, p-type material and n-type material OR • Gives examples of semiconductors and dopants and explains why semiconductors need doping OR • Outlines the process of doping. 1-2

Part B (Continued)

Sample answer	Syllabus outcomes and marking guide
Question 27	
The Braggs used X-rays to study crystals. The X-rays were made by hitting a metal anode with high energy electrons. Beams of X-rays were reflected off the layers of atoms in the crystal structure. Beams which travelled further into deeper layers of atoms interfered constructively or destructively with reflections off upper layers to produce patterns of bright spots on a photographic plate. Knowing the X-rays' wavelength, the angles between the beams and the layers and the distances between the bright spots, the Braggs were able to determine the crystal's internal structure, especially the spacing between the planes of atoms. These results were used to derive Bragg's Law. The atoms is a crystal are arranged in a regularly repeated pattern called a crystal lattice.	9.4.4 H1 – H4, H9, H10 • Thorough understanding of X-ray diffraction method used by the Braggs. AND • Identification of metal lattice structure .. 5
	• Sound understanding of X-ray diffraction method used by the Braggs. AND • Identification of metal lattice structure .. 4
	• Basic understanding of X-ray diffraction method used by the Braggs. AND • Identification of metal lattice structure .. 3
	• Rudimentary understanding of X-ray diffraction method used by the Braggs. AND • Identification of metal lattice structure .. 2
	• Rudimentary understanding of X-ray diffraction method used by the Braggs .. 1

Section II

Question 28 **Geophysics**

		Sample answer	**Syllabus content, course outcomes and marking guide**
(a)		A seismometer is an instrument that records seismic waves in the ground, generated by an earthquake or an artificial explosion such as an underground nuclear test. A seismograph consists of a heavy mass (which has a lot of inertia) connected via a spring to a case bolted to the ground. The spring is dampened, and the relative motion of the case with respect to the heavy mass causes a transducer to produce an output signal, the intensity of which is related to the magnitude of ground movement. For example, the transducer could be a simple mechanical lever system connected to a pen (obsolete), or a cylindrical coil movable with respect to a permanent magnet. A more rapid ground movement produces a greater induced voltage, which is electronically processed and read out on a chart or computer display. Generally, seismic stations have three seismometers oriented in such a way as to pick up the north-south, east-west, and up-down vector components of the P, S and L seismic waves.	9.5.1 H1, H2 • Provides a detailed description of the operation of the instrument, with reference to the physical principles involved, and its function in recording seismic waves .... 3 • Gives a partial description of the instrument with a correct account of its function.... 2 • Gives a basic description of the instrument with no reference to the physical principles involved 1
(b)	(i)	Using the scale, X is 200 km from the MOR. Average rate of movement is: $\frac{20\,000\,000 \text{ cm}}{10\,000\,000 \text{ years}} = 2 \text{ cm yr}^{-1}$.	9.5.4 H9 • Calculates rate of movement correctly .. 1
	(ii)	New basaltic crust forms at the mid-ocean ridge (MOR) and preserves a record of the Earth's magnetic field as the rocks cool. The crust is then pushed laterally away from the MOR (sea-floor spreading). At intervals of geologic time, the Earth's magnetic field reverses orientation. Hence a 'striped' pattern of magnetic anomalies is produced either side of the MOR. A positive anomaly has the magnetic field in the basalt aligned with the Earth's current field. A negative anomaly is opposite to the current field.	9.5.4 H2 • Provides an account of the production of anomalies, and mentions how rocks preserve the Earth's magnetic field. AND • Notes that there have been magnetic reversals over time, and relates this to sea-floor spreading .... 2 • Gives a partial account of the process, mentioning at least one relevant concept, i.e. seafloor spreading or field reversals 1
(c)	(i)	Use $F = mg$ and $F = \frac{GMm}{d^2}$ (symbols modified from formula sheet for clarity). Combine the two equations to get $M = \frac{gd^2}{G}$.	9.5.2 H6 • Student correctly uses the two formulas and manipulates them algebraically to get correct equation .... 2 • Writes down both formulae but does not derive equation correctly 1
	(ii)	$T = 27.3 \text{ days} = 2.359 \times 10^6 \text{sec}$ $r = 384\,000 \text{ km} = 3.84 \times 10^8 \text{ m}$ From $\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$ Derive $M = \frac{4\pi^2 r^3}{GT^2}$ Substituting, get $M = 6.0 \times 10^{24}$ kg.	9.5.2 H6 • Correctly substitutes data into equation and gets correct answer................. 2 • Writes an appropriate equation, but makes an arithmetic error or uses incorrect units 1

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Question 28 Geophysics (Continued)

	Sample answer	Syllabus content, course outcomes and marking guide
(d)	Earthquakes produce both P and S waves. P waves are compressional waves and pass through solids and liquids, but S waves are transverse (or shearing) waves and pass through solids only. Early in the 20th century, seismologists noticed that shadow zones existed on the opposite side of the Earth from an epicentre of a major earthquake. The 154° shadow zone for S waves resulted from them being stopped completely by a liquid zone in the Earth (now known as the outer core). The P waves are also refracted and slowed down by the liquid layer, and form a pair of shadow zones. Analysis of the size of the shadow zones allowed the diameter of the outer core to be determined. A solid inner core was later discovered by detecting reflections from the boundary between the inner and outer cores. Also P waves that travel through the inner core travel significantly faster than the P waves that pass through the outer core only, showing that the inner core is denser and more rigid, i.e. solid. Analysis of seismic records allowed the size of the inner core to be determined. Density calculations and examination of iron meteorites allowed geophysicists to infer that the inner core is made of a solid Fe-Ni alloy, of the same composition as the less dense liquid outer core.	9.5.3 H1, H2 • A coherent summary of the use of P and S wave shadow zones to infer the presence of a liquid outer core and solid inner core, (and their dimensions), supplemented by the use of density calculations .... 3 • A less detailed and/or coherent response than above .... 2 • A brief outline of shadow zones. OR • How S wave measurements mean a liquid layer is present. OR • How density measurements could be used 1
(e)	Geophysicists are involved in the assessment and mitigation of natural hazards, and in some cases can predict natural hazards such as volcanic eruptions, landslides, tsunamis, and severe storms and climactic effects. Geophysicists study fault systems in earthquake-prone areas for build-up of strain by monitoring seismometer networks and laser ranging stations that detect gradual movement in the Earth's surface. They work with engineers to help design buildings which are more earthquake resistant, which helps to lessen loss of life and reduce property damage. Similarly, predicting volcanic eruptions can help prevent loss of life, especially in countries where the population depends on the fertile soils surrounding many volcanoes. Laser ranging techniques and seismometer networks are used to monitor ground deformation adjacent to volcanoes that may soon erupt. In Australia, remote sensing techniques (from aircraft or satellite) can monitor severe bushfires, and in conjunction with meteorological data, can help scientists to make predictions on the likely direction of fire fronts, limiting property damage. Remote sensing can also be used to monitor the environmental damage that results, and allow better targeting of bush fire relief.	9.5.5 H3 • A detailed description of the roles the geophysicist has, and how they can predict and monitor a range of natural hazards, help to mitigate the damage caused, and liaise with other scientists. At least three examples should be used to illustrate the answer... 4 • A less detailed and/or coherent response than above......................... 3 • An answer that concentrates on two natural hazards but does not clearly indicate the roles of a geophysicist. OR • The answer is a simple recount .... 2 • Gives a brief outline of how a geophysicist monitors one natural hazard........... 1

Question 28 Geophysics (Continued)

	Sample answer	Syllabus content, course outcomes and marking guide
(f)	One geophysical method used in mineral exploration is an airborne radiometric survey, e.g. using a γ-ray spectrometer, detecting γ-rays emitted from radioactive isotopes. For large exploration programs, this is a cost-effective method compared to ground-based surveys and obtains information over large areas up to a regional scale quickly and effectively. The down side is loss of resolution and increased background noise. However, the presence of thick regolith or non-mineralised surface sediments can reduce the effectiveness of the method for detecting deeper ore-bodies. Count rates can be used to determine ground concentrations of K-40, U and Th that can be used in broad structural or lithological surveys of use to the explorationist. Interesting radiometric anomalies (due to uranium or rare-earth metal deposits) can be followed-up in more detail with a ground or subsurface technique. Being airborne, the survey has a low environmental impact. Improvements in technology such as increased detector sensitivity allow a rapid reappraisal of areas that have previously been surveyed. Airborne techniques are also easily applied to gravity, magnetic, and mapping surveys. Ground based electrical methods are useful in detecting base-metal sulfide deposits. Where such deposits are found in the weathering zone near the surface of the Earth, natural chemical reactions produce an electrical current which can then be detected. This is the basis of the self-potential (SP) method. The technique can lead to false responses and is not efficient where the surrounding country rocks are themselves mineralised. A better method than SP is induced polarisation (IP). In this method, a high AC voltage is applied to the ground, and the induced current is recorded at a number of regularly-spaced stations on the surface. The conductivity of a sulfide mineral deposit varies with the frequency of the applied current, while in general the conductivity of non-mineralised ground does not vary. This method is also open to false detections however, such as the response caused by porous zones and faults containing highly saline groundwater. In addition, the instrumentation can be difficult to set up properly, and the analysis can be time consuming.	9.5.5 H1, H3, H13 • A detailed description of two different geophysical methods as applied to mineral exploration, with examples. • A good discussion of the advantages and disadvantages of each method is also required .... 7 – 8 • A less detailed and/or coherent response than above, and with less emphasis on discussing the pros and cons of each method .... 5 – 6 • A description of the relevant methods with little or no discussion. OR • A good discussion of one geophysical method .... 3 – 4 • A basic outline of two methods. OR • A description (with no discussion of pros and cons) of ONE method .... 1 – 2

Question 29 **Medical Physics**

Sample answer	Syllabus content, course outcomes and marking guide

(a) Technetium-99 meta-stable

- Emission of highly penetrative radiation (gamma rays) so that they can be detected external to the patient.
- Tc-99m can be chemically bonded to many compounds to form radiopharmaceuticals that can be metabolised by a target organ.
- Tc-99m has a relatively short half-life of 6 hours. This coupled with the rapid removal from the body through respiration or urination. (Biological half-life is dependent on the radiopharmaceutical formed). The combination of these two factors enables the scans to be obtained with minimal exposure of radiation.
- The dosage of a radioisotope required for the taking of a scan is also very small. For example, a thyroid scan using Technetium-99 metastable exposes the patient to a dose of 480 m Sv, which is half the annual exposure to ionising radiation from everyday living.

Note: Any suitable radio-isotope could be used with its specific characteristics.

9.6.3 H4, H7, H8, H14

- Suitable radio-isotope identified.
AND
- Specific properties and half-life characteristics outlined.
AND/OR
- Properties linked to usefulness ..... 2 – 3

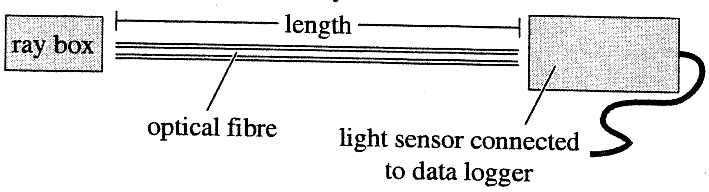
- Suitable radio-isotope identified 1

(b) (i) Total internal reflection.

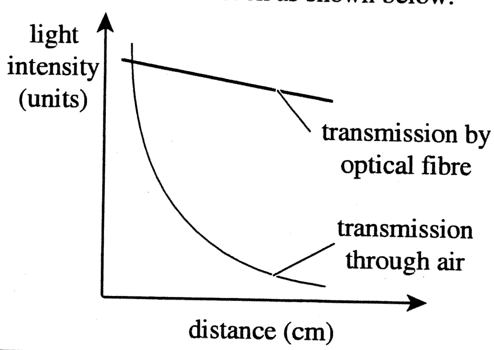
9.6.2 H8

- Property identified as total internal reflection 1

(ii) Experimental apparatus was set up as follows in a darkened laboratory:



1. The transmitted light was observed and intensity measured using a light sensor and data logger.
2. The experiment was repeated for different lengths of optical fibre using a single source of white light and recording transmitted light intensity.
3. Part 2 was repeated, without the use of optical fibres, measuring light intensity at corresponding distances.
4. All measurements were repeated three times and average values determined.
5. The average values were graphed to obtain transmission curves such as shown below:



9.6.2 H2, H8, H10, H11, H15

- Appropriate experimental procedure fully described with logical sequence and the apparatus identified with a suitable scientific diagram 2

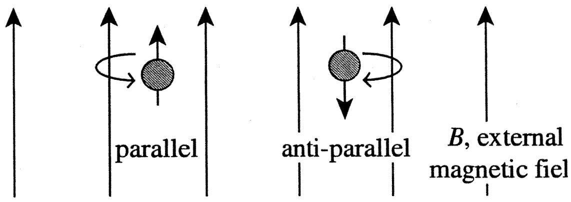
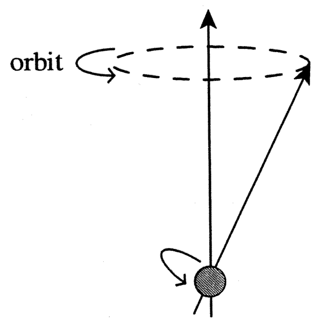
- Appropriate experimental procedure partially described 1

Question 29 Medical Physics (Continued) Sample answer	Syllabus content, course outcomes and marking guide
(c) (i) $Z_{hm} = \rho \cdot v$ $= 1080 \text{ kg m}^{-3} \cdot 1580 \text{ m s}^{-1}$ $= 1.71 \times 10^6 \text{ kg m}^{-2} \text{ s}^{-1}$	9.6.1 H8 • Acoustic impedance correctly stated, including correct units. AND • Value justified with calculations .... 2 • Acoustic impedance correctly stated, including correct units 1
(ii) $Z_{fat} = \rho \cdot v$ $= 950 \text{ kg m}^{-3} \cdot 1450 \text{ m s}^{-1}$ $= 1.38 \times 10^6 \text{ kg m}^{-2}\text{s}^{-1}$ $Z_{blood} = \rho \cdot v$ $= 1025 \text{ kg m}^{-3} \cdot 1570 \text{ m s}^{-1}$ $= 1.61 \times 10^6 \text{ kg m}^{-2} \text{ s}^{-1}$ $\frac{I_r}{I_o} = \frac{\lvert Z_2 - Z_1\rvert^2}{\lvert Z_2 + Z_1\rvert^2}$ From heart muscle to fat: $I_r = 100 \times \frac{[1.71 \times 10^6 - 1.38 \times 10^6]^2}{[1.71 \times 10^6 + 1.38 \times 10^6]^2}$ $= 0.037$ Therefore the percentage of reflected intensity = 3.7% From heart muscle to blood: $I_r = 100 \times \frac{[1.71 \times 10^6 - 1.61 \times 10^6]^2}{[1.71 \times 10^6 + 1.61 \times 10^6]^2}$ $= 0.0009$ Therefore the percentage of reflected intensity = 0.091% The intensity of the reflected ultrasound pulses passing through heart muscle would be greater from fat deposits than from blood filled chambers.	9.6.1 H7, H8, H14 • Correct comparison of ultrasound intensities stated. AND • Justification of comparison included, e.g. calculation of values .... 2 • Correct comparison of ultrasound intensities stated. OR • Values of ultrasound intensities calculated......................... 1

Question 29 **Medical Physics (Continued)**

Sample answer	Syllabus content, course outcomes and marking guide
(d) **X-ray** Image production • An X-ray beam pass through the patient and into a detector (modern technology) or a photographic plate (early technology). The exposure is proportional to the amount of radiation reaching the plate. Thus a 2-D image is formed. Applications • Non-invasive diagnostic tool. • Study of the structure of hard tissue (bone). • Extensively used for determination of fractures and hard tissue damage due to trauma. • Low resolution imaging of the major organs. • With the injection of opaque dyes, further resolution can be achieved in the study of the internal organs. Advantages • Fast, cheap and readily available. • Low exposure to ionising radiation (modern technology with amplification and resolution enhancement). Limitations • Limited resolution on soft tissues. • 2-D images. • Number of scans limited due to exposure to ionizing radiation. • Inability to view inside bone, e.g. brain inside skull. • Inability to determine organ functionality. **CAT** Image Production • Many thin X-ray beams pass through the patient and into a detector (one of an array), which records the intensity of the beam. • Both X-ray tube and the detector array are mounted on a gantry, which rotates, recording intensities at regular angular intervals. • The intensity data is converted into many 2-D images (by a computer), which represent 'slices' through the patient. • The combination of these slices can be used to produce a 3-D image. Applications • Non-invasive diagnostic tool. • Study of the structure of hard tissue (bone). • Study of soft tissue within bone e.g. brain, spine. • Diagnosing stroke: size, type, location. • Location of tumours and soft tissue disease. • With the injection of opaque dyes, further resolution can be achieved in the study of the lungs, kidneys and bladder. Advantages • Can be used on patients with metal devices. • Rapid scan time. Limitations • Limited resolution on soft tissues that have high water content. • Number of scans limited due to exposure to ionizing radiation. • Inability to determine organ functionality.	9.6.2 H3, H4, H13, H14 • Suitable comparison of the uses of X-rays and CAT scans given. AND • Comparison supported by outlines of the applications of X-rays and CAT scans... 3 • Applications of X-rays. AND/OR • CAT scans outlined .... 1 – 2

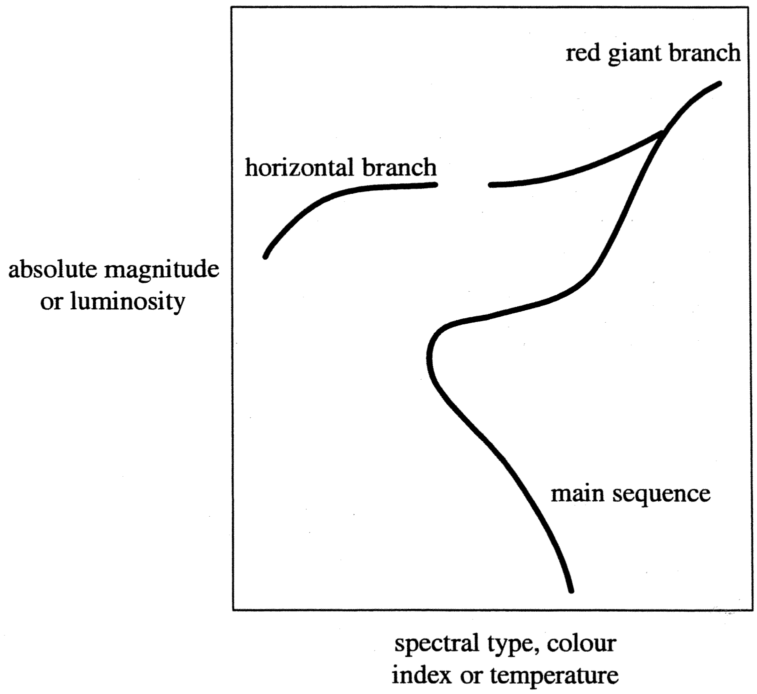
Question 29 **Medical Physics (Continued)**

	Sample answer	Syllabus content, course outcomes and marking guide
(e)	Like tiny magnets, the nucleus will align itself with an external magnetic field (just like iron filings). However the alignment is not uniform for all nuclei. There are two variations. The first variation is due to the spin-up/spin-down orientation with the field.  Most nuclei have their axis of spin aligned and in the same direction as the external field. This is called parallel orientation and is a lower energy state. Some nuclei have their axis of spin aligned but in the opposite direction to the external field. This is called anti-parallel orientation and is a higher energy state. The second variation is an effect called precession and is similar to a spinning top in a gravitational field. The axis of rotation of the nucleus orbits about the external magnetic field line.  The Lamor frequency is the frequency of precession of a nucleus. By subjecting the material to pulses of radio frequency (RF) electromagnetic radiation, many of the precessing nuclei can be flipped to the higher energy (anti-parallel) state. The frequency required is the Lamor frequency. The nuclei gradually convert back to the relaxed state by emitting radiofrequency waves, again at the Lamor frequency. The rate at which nuclei relax is proportional to the number of excited nuclei present. The greater the number, the faster the rate of relaxation, the greater the amplitude of the RF signal emitted. In simple terms, the relaxation time is the time taken for nuclei to return to their initial, relaxed state, after spins have been altered by an RF pulse. Hydrogen is a common element in all body tissue, not only in the form of water but also in all 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 changes 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.	9.6.4 H9, H13, H14 • A description of precessing nuclei. AND • An outline of the effect of pulses of radio waves on precessing nuclei including the Lamor frequency and relaxation times. AND • The relating of relaxation times the production of MRI scans. AND/OR • A coherent response.............. 3 – 4 • A description of precessing nuclei. AND/OR • An outline of the effect of pulses of radio waves on precessing nuclei .... 1 – 2

Question 29 **Medical Physics (Continued)**

	Sample answer	Syllabus content, course outcomes and marking guide
(f)	The development of diagnostic and treatment processes based on the principles of physics has enabled more accurate and earlier assessment of disease through low risk, non-invasive diagnostic techniques. Combinations of diagnostic techniques (including ultrasound, X-ray, CAT, PET and MRI) can be employed to give a full picture of a patient's condition.	9.6.4 H1, H4, H5, H13, H14, H16 • The application of physics to the practise of medicine completely evaluated. AND • A coherent response.............. 7 – 8
	Particular technologies are used for specific conditions. For example, ultrasound and the incorporation of the Doppler effect enable echocardiography to accurately determine cardiac function. X-rays are widely available, cheap and adequate for the study of fractures and often a precursor to further investigation. CAT scans and MRI produce high-resolution images of soft tissues leading to earlier detection (e.g. tumours) and more accurate diagnosis. PET scans, whilst lower in resolution, enable the determination of functionality which give a picture of the effectiveness of organs through the metabolism of radiopharmaceuticals.	• Examples of the application of physics to the practise of medicine described. AND/OR • Advantages and limitations of current technologies outlined. AND/OR • Impact of the application of physics to the practise of medicine assessed. AND/OR • Future implications for society predicted....................... 5 – 6
	Surgical intervention is often on a much smaller scale, due to the implementation of keyhole techniques employing an endoscope. This reduction of impact on the patient also reduces the possibility of post-operative infection and the extent of healing required due to decreased tissue trauma.	• Examples of the application of physics to the practise of medicine described. AND/OR • Advantages and limitations of current technologies outlined............. 3 – 4
	The application of physics has enhanced the ability of medical practitioners to plan and execute treatment in order to minimise trauma, maximise recovery rates and produce a better outcome for individual patients. The overall effect has been a reduction in mortality and the potential (in combination with lifestyle education initiatives on diet and physical activity) for a healthier, more productive society. There is a direct link between individual outcomes and the overall health of society.	• Examples of the application of physics to the practise of medicine identified...... 1 – 2
	The early intervention in disease, enabled by medical physics, is an expensive process, which requires a considerable investment by society. However, if one considers the slower recovery rates, higher mortality rates (including the expense of long term palliative care) and less successful patient outcomes associated with medical treatment prior to these initiatives, the implementation of large scale screening programs, employing modern techniques could provide a relatively cost efficient way of dealing with many diseases associated with developed societies and significantly improve the quality of life. The difficulty is in the transition phase, which requires massive capital outlay and further technological development and training of personnel, whilst continuing to bear the burden of care for those who have not benefited from these developments. In the long term, this burden of care should diminish.	

Question 30 Astrophysics

	Sample answer	Syllabus content, course outcomes and marking guide
(a)	*Active optics* systems work to control the deformations of the telescope mirror as the instrument moves. The primary mirror is constantly adjusted with computer–controlled actuators to keep the shape of the mirror optimised. *Adaptive optics* systems correct image blurring from atmospheric turbulence (poor seeing). Usually a small deformable mirror located behind the focus of the telescope is used, which cancels out the wavefront errors produced by the atmosphere. The errors are monitored by observing a bright star in the field of view or an artificial reference star, e.g. laser guide star. *Interferometry* increases angular resolution by optically linking two or more telescopes together to simulate a much larger telescope. Sensitivity is only increased modestly but the technique has linked radio telescopes separated by thousands of km with a proportional increase in resolving power.	9.7.1 H3 • Student correctly outlines the methods of *active optics*, *adaptive optics* and *interferometry* as applied to ground based telescopes . . . . 3 • Correctly outlines two of the above technologies . . . . 2 • Correctly outlines one of the above technologies 1
(b)	(i) The period is 30 days.	9.7.5 H6 • Estimates period correctly from graph. . . 1
	(ii) From the P–L relationship, the absolute magnitude of a 30 d Cepheid, M = –5.5. Since the mean apparent magnitude, m = 6.7, the distance modulus = 12.2. Use the distance modulus formula, $M = m - 5 \log (d/10)$, solving for distance, d = 2750 pc.	9.7.5 H2 • Correctly estimates absolute magnitude from the P–L relationship, and correctly substitutes into the distance modulus formula to get d (value accepted is 2600 to 2900 pc, or other value if period is incorrect but no further mistakes made) . . . . 2 • Correctly estimates absolute magnitude and substitutes into distance modulus formula, but makes arithmetic error, or quotes *distance modulus* only 1
(c)	(i) Hertzsprung-Russell diagram.  	9.7.6 H2, H13 • Student sketches a reasonably correct globular cluster Hertzsprung–Russell diagram and shows the red giant branch, horizontal branch and main sequence of the cluster. . . . . 2 • Sketches a GC Hertzsprung–Russell diagram with only some of the relevant labels (teacher to judge). 1

Question 30 Astrophysics (Continued)

	Sample answer	Syllabus content, course outcomes and marking guide
(ii)	The brightest stars in a globular cluster are cool red giants of spectral types K and M. The spectra of such stars show molecular bands, e.g. from TiO and VO molecules, especially in the red stars, and lack lines of the Balmer series of hydrogen. The spectra are much stronger in the red, i.e. there is little blue light in these stars.	9.7.6 H2 • Identifies correctly main features, e.g. TiO molecules, and the lack of the Balmer series of H, and that the spectrum is much stronger in the red, i.e. there is little blue light in the star . . . . . 2 *Note: An excellent student might comment on the general weakness of the absorption lines due to the low metal content of a globular cluster.* • Student describes that the spectrum is faint in the blue, or states that molecular bands are found in a red giant star (M–type spectrum) 1
(d)	Trigonometric parallax can be used to determine the distance to stars. It is a direct method using the Earth's orbit as a baseline. As the Earth orbits the Sun, a fairly close star is viewed from slightly different directions and the star appears to shift relative to more distant stars in the background. This small shift is called the parallactic angle, and the parallax, p, is half this angle. Knowing the Earth–Sun distance (1 AU = 150 x 10^6 km), the distance of the star is easily calculated from trigonometry. Generally two or three years worth of data are needed to unravel the parallax from the proper motion of the star. Using HST or Hipparcos, the limit is currently around 500 pc before the error of measurement exceeds the angle itself.	9.7.2 H12 • Gives a coherent explanation of trigonometric parallax, pointing out that it is direct method using the Earth's orbit as a baseline. Should mention that the method is only applicable for nearby stars, and that more than a pair of observations six months apart is needed . . . . . 3 • A less coherent response than above . . . . 2 • States that this is a geometric method due to the Earth orbiting the Sun 1
(e)	Photographic methods were commonly used in the first half of the 20th century to measure the brightness of stars (photometry). The non–uniformity of the photographic emulsion meant that the accuracy attainable was limited (typically 0.1 to 0.25 magnitude error). Also emulsions suffered from reciprocity failure, meaning that doubling the exposure would not record stars twice as faint. They were also not a 'linear' detector, and have very poor quantum efficiency. Errors could not often be quantified. Photoelectric photometers became available after 1950 and have the advantages of much better efficiency (can measure fainter stars) and accuracy (to 0.01 magnitude) as well as giving a linear response, i.e. twice as many photons produced twice as much current, up to a limit. Silicon-based solid-state CCD detectors are now in widespread use in photometry. They offer the linear response of a PEP detector with the advantage of measuring many stars simultaneously, i.e. all stars within the field of view. With care, stars can be measured to an accuracy of 0.002 magnitude. CCDs have up to 90% quantum efficiency and a deep exposure can go many times fainter than a photographic plate taken with the same instrument. Due to the regular pixel arrangement on a CCD compared to randomly positioned silver halide grains in an emulsion, the photometric errors from a CCD are much smaller and can be much better quantified.	9.7.4 H1, H3 • Student describes in detail the advantages of modern detectors over photographic plates. Describes how photoelectric photometers and CCDs have achieved better accuracy, have much better quantum efficiency, and are linear detectors. Mentions that they give more reproducible results and that errors can be better quantified . . . . . 4 • A less detailed and coherent response than above . . . . . 2–3 • A basic outline with little or no emphasis placed on advantages of PEP and CCD methods 1

Question 30 Astrophysics (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(f) The Big Bang produced hydrogen and helium with smaller amounts of deuterium. The first stars used these elements as raw material to produce the heavier elements that are the basis for silicate–rich planets and carbon-rich life. Stars get their energy from thermonuclear fusion reactions, in the process producing heavier elements from lighter ones. Only in the core of a star are the pressures and temperatures sufficient so that protons and nuclei can overcome the Coulomb repulsion. In a low mass star like our sun, hydrogen is converted to helium via the proton–proton chain reaction. In this process two protons fuse to produce a deuterium nucleus, which then fuses with another proton to form ^{3}He. The last step is the formation of an α–particle (^{4}He) via the fusion of two ^{3}He nuclei, with the production of another two protons. Other chain reactions occur simultaneously, with the emission of neutrinos and photons. However, more massive stars with higher–temperature cores ($T > 15 \times 10^6$ K) convert H to He via the CNO cycle, with the production of positrons, neutrinos and gamma–ray photons. The cycle can be summarized by, $4^1\text{H} \rightarrow {}^4\text{He} + 2e^+ + 3\nu + 4\gamma$. Carbon is a catalyst for the reactions and O and N are formed as intermediates. Eventually the star will run out of hydrogen in the core and begins to fuse hydrogen in a shell surrounding it. The outer layers of the star re-adjust and the star becomes a red giant. Helium ignition will commence once the core T and P have increased sufficiently. The star settles on the horizontal branch. Helium is fused to carbon via the *triple alpha process*, $3^4\text{He} \rightarrow {}^{12}\text{C} + \gamma$. As helium is depleted the star becomes a *second–ascent* red giant. Often such stars lose their outer envelopes as a planetary nebula, which seeds He, C, O and N into the interstellar medium. Stars greater than 6 solar masses convert helium into carbon and oxygen, with these isotopes being fused to produce Ne, Na, Mg, S and Si. Very massive stars can produce elements like calcium, nickel and iron. Eventually massive stars achieve an iron core surrounded by concentric nuclear–burning shells of lower temperature and pressure with the hydrogen–burning shell at the greatest distance from the centre of the star. As iron cannot be fused to release energy, gravitational collapse follows the cessation of energy production in the core and a type–II supernova occurs. This seeds the interstellar medium with the elements formed in the interior of the star. Production of elements heavier than iron (up to actinides) also occurs via neutron capture in the rapid or *r–process*. This is due to a huge flux of free neutrons that is available in the supernova explosion. Another way to produce elements heavier than iron is via the slow or *s–process* in red giants, which is again based on neutron capture, but at a much slower rate. Neutrons are produced in reactions such as ${}^{13}\text{C} + {}^4\text{He} \rightarrow {}^{16}\text{O} + n$, in the core of the red giant. Addition of neutrons to seed nuclei in the *s–process* can produce nuclei up to the mass of ^{209}Bi. Deep convection in the red giant can then bring these elements to the surface whereby mass loss can seed these elements into the ISM. Larger mass stars will form supernovae, so the heavier elements become mixed into the interstellar gas, from which the next generation of stars will be formed.	9.7.6 H1, H2, H13 • A detailed discussion of the various processes of nucleosynthesis, e.g. p–p chain, CNO cycle, triple–alpha process and *r–* and *s–processes*. The student should use some simple summary equations. The student should look at the relative contributions of each cycle and relate these to the evolutionary stages of stars of different masses, and note how these elements are returned to the interstellar medium . . . 7–8 • A less detailed and/or coherent response than above, or one that lacks summary equations . . . . 5–6 • A basic description of the relevant cycles but the answer does not relate these to concepts of stellar evolution . . . . 3–4 • A basic outline of how He is produced from H via fusion reactions in stars 1–2

Question 31 From Quanta to Quarks

	Sample answer	Syllabus content, course outcomes and marking guide
(a)	Bohr extended the Rutherford model by proposing two postulates that allowed him to apply the quantum ideas of Planck and Einstein to the Rutherford model of the atom. These modifications enabled him to describe an atom in which electrons existed in stable states in which they did not emit electro-magnetic radiations. Only the transition of an electron from one stationary state to another involved energy. A photon of electromagnetic radiation was emitted when an electron in an excited or higher state dropped to a lower state. Bohr was able to derive a mathematical expression for the wavelengths of the spectral lines of hydrogen which was in agreement with the empirical formula of the wavelengths of the hydrogen emission spectrum previously determined by Balmer.	9.2.2 H1, H13 • Clearly explains the modifications of the Bohr atom AND relates these directly to the equation of Balmer. . . . . . 3 • Describes some of the modifications of the Bohr atom AND attempts to relate these directly to the equation of Balmer . . . . . . 2 • Describes some of the modifications of the Bohr atom. OR • Attempts to relate these directly to the equation of Balmer. 1
(b) (i)	De Broglie proposed that matter must have a wave nature as well as a particle nature, i.e. the wave and particle nature of matter are linked	9.2.2 H2, H10 • States correct proposal about matter waves 1
(ii)	Davisson and Germer studied the scattering of electrons from the surface of metallic nickel. The electrons were firstly accelerated in an electron gun and fired at the surface of the nickel crystal. As the angle to the direction of the detector was changed so too was the observed pattern shown by the scattered electrons. They recognised that the electrons were being diffracted. However, diffraction was considered to be a wave property. Being familiar with de Broglie's idea and X-ray diffraction, the experimental results established that electrons must have a wave nature as well as a particle nature. The wavelength of the electrons in the diffracted beam was in agreement with the value predicted by the de Broglie hypothesis. Together these were supportive experimental evidence for de Broglie's theory.	9.2.2 H8, H10, H14 • Clearly outlines the method of the experiment. AND • Relates the results and or conclusion that electrons being diffracted from the metallic surface relate to their wave like nature. . . 2 • Clearly outlines the method of the experiment . OR • Relates the results and or conclusion that electrons being diffracted from the metallic surface relate to their wave like nature . . 1
(c) (i)	The mass defect is the missing mass when the mass of any nucleus is compared to the sum of the separate masses of its protons and neutrons. In other words, combining protons and neutrons together somehow causes some of their mass to disappear. The binding energy of a particular isotope is the amount of energy released at its creation. This can be calculated by finding the amount of mass defect and using Einstein's equation. The binding energy is also the amount of energy needed to supply to a nucleus to break it up into protons and neutrons. The difference in binding energy between reactants and products is related to the energy available from a nuclear reaction.	9.2.2 H2, H10 • Clearly describes the mass defect. AND • Relates its connection to the binding energy of the atom . . . . . . 2 • Describes the mass defect. OR • Relates the connection of the mass defect to the binding energy of the atom 1
(ii)	mass of defect = mass of products – mass of reactants $= (2 \times 4.003) + (7.016 + 1.008)$ $= 0.018\mu$ binding energy $= 0.018 \times 931.5 = 16.7$ MeV	9.2.2 H10 • Correctly calculates the energy involved by determining the mass defect and uses related equations . . . . . . 2 • Correctly determines the mass defect and attempts to use related equations 1

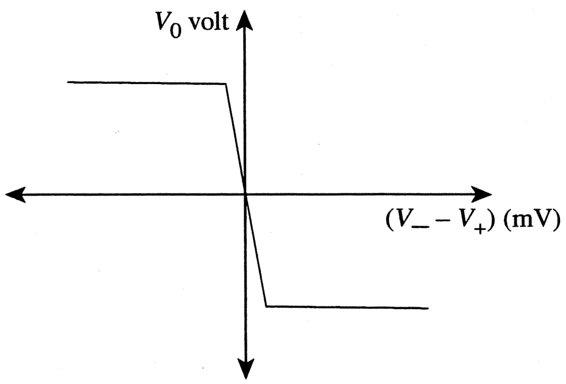
Question 31 From Quanta to Quarks (Continued)

	Sample answer	Syllabus content, course outcomes and marking guide
(d)	Colbalt-60 has a half life of 5.27 years emitting both γ radiation and β particles. Its gamma radiation can penetrate deep into living tissue and therefore can be used to kill cancer cells in a tumour. Its beta radiation can be used as a source to control the thickness of thin metal sheeting.	9.2.2 H3, H4 • Clearly names AND describes ONE radio-isotope both in a medical AND engineering situation . . . 3 • Names AND describes ONE radio-isotope in either a medical OR engineering situation . . . 2 • Describes ONE radio-isotope in a medical OR engineering situation . . . 1
(e)	Physicists have developed The Standard Model to explain 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 and force carrier particles. All the known matter particles are composites of quarks and leptons, and they interact by exchanging force carrier particles. A proton is a combination of two up quarks and one down quark and a neutron is a combination of two down quarks and one up quark.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 electro-magnetic forces. In doing so, the model suggests that prior to the Big Bang all four fundamental forces were reduced to a single force and after the Big Bang, the four forces evolved as the universe expanded. Even with the non-inclusion of gravitational forces, the Standard Model does explain many of the features of our current universe, especially its early stages after its creation in the Big Bang.	9.2.2 H1, H5, H10 • Describes the main features of the Standard Model AND outlines how protons and neutrons are combinations of quarks. AND • Relates the evolution of the universe to the model . . . 3 – 4 • Describes the main features of the Standard Model. AND • Outlines how protons and neutrons are combinations of quarks. OR • Relates the evolution of the universe to the model . . . 2 • Describes the main features of the Standard Model. OR • Outlines how protons and neutrons are combinations of quarks. OR • Relates the evolution of the universe to the model . . . 1

Question 31 From Quanta to Quarks (Continued)

	Sample answer	Syllabus content, course outcomes and marking guide
(f)	Initially it was thought that the nucleus of atoms somehow consisted of combinations of protons and electrons. Problems with the masses of atoms and electron spins suggested that an undiscovered neutral nuclear particle existed. This particle suggested by Rutherford would have no charge and approximately the same mass as a proton. Experiments by Bothe and Becker and later Curie and Joliot suggested that a new radiation was produced when alpha particles were allowed to bombard beryllium and that this radiation in turn liberated protons from paraffin wax. Chadwick showed that this new radiation thought to be emitted from beryllium after being struck by alpha particles was in fact the neutron. He achieved this by applying the Laws of Conservation and Momentum and suggested that the unknown radiation had to be about the same size as a proton with no charge (since this radiation was capable of removing protons from paraffin). Beta radiation from radioactive decay also poses some problems, since the beta particles emitted do not all have the same energies. These beta particles were found to exhibit a range of energies from zero up to a maximum value. This fact seems to violate the Laws of Conservation of Energy and Momentum, as the total energy and the total momentum of the particles thought to be involved before and after do not equate. To account for this discrepancy a new particle, the neutrino, was postulated by Fermi. The neutrino was thought to have no electric charge and no mass, but able to posses both energy and momentum. Thus in beta decay, both an electron and neutrino would be emitted simultaneously. This was confirmed to be accurate in a nuclear reaction conducted in 1956 when a neutrino was induced to strike a proton and a neutron and positron (β^+ particle) were emitted.	9.2.2 H1, H2, H10, H13 • Discusses in detail the prediction and discovery of BOTH the neutron and neutrino AND • Relates their prediction and discovery to applications of the conservation laws .... 7 – 8 • Describes clearly the prediction and discovery of BOTH the neutron and neutrino AND • Relates their prediction and discovery to applications of the conservation laws .... 5 – 6 • Describes clearly the prediction and discovery of BOTH the neutron and neutrino. OR • Describes clearly the prediction and discovery of Either the neutron OR neutrino. AND • Relates their prediction and discovery to applications of the conservation laws .... 3 – 4 • Describes clearly the prediction and discovery of Either the neutron OR neutrino. OR • Relates their prediction and discovery to applications of the conservation laws .... 1 –2

Question 32 **The Age of Silicon**

	Sample answer	Syllabus content, course outcomes and marking guide
(a)	Silicon has several desirable optical properties including a high refractive index, ability to be made into fibres and ability to have non-linear optical properties. The development of silicon into the integrated circuit has impacted greatly upon our society. The circuits small size has meant less power is required to operate them. They operate at faster speeds and are more reliable. Since a large number of components can be placed on a single chip they are far cheaper to produce. The negative impacts are that they handle relative low voltage and cannot operate power equipment.	9.9.1 H4 • Clearly identifies at least TWO desirable optical features of silicon AND • Clearly explains the impacts on society. . 3 • Identifies ONE desirable optical features of silicon AND • explains the impacts on society . . . . 2 • Identifies ONE desirable optical features of silicon OR • Explains the impacts on society briefly . . 1
(b) (i)	An electric circuit has a constant electric current (this may be in one or alternating in directions), while an electronic circuit handles small changing electric currents	9.9.2 H3 • Clear explanation of the difference between an electronic and electric circuit 1
(ii)	Electronic circuits that employ the use of solid state components work faster than electric circuits. They use less power than electric circuits. Electric circuits are more robust and can carry larger currents and operate at higher voltages.	9.9.2 H4 • Describes one advantage AND one disadvantage of the use on the use of an electronic circuit over an electric circuit . . . . 2 • Describes one advantage. OR • One disadvantage of the use on the use of an electronic circuit over an electric circuit 1
(c) (i)	An operational amplifier is a direct current coupled, very high gain, voltage amplifier designed to be used over a wide range of frequencies.	9.9.6 H13 • Outlines at least two features of an operational amplifier . . . . 2 • Outlines one feature of an operational amplifier 1
(ii)		9.9.6 H13 • Sketches accurately the relationship between the output potential difference and the difference in the input potential difference . . . . 2 • A reasonable attempt to sketch the relationship between the output potential difference and the difference in the input potential difference 1

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Question 32 **The Age of Silicon (Continued)**

Sample answer		Syllabus content, course outcomes and marking guide
(d)	The logic gates used in this question are all NAND gates.	9.9.5 H2 • Identifies correctly the logic gate. AND • Completes the truth table completely . . . 3 • Identifies correctly the logic gate. AND • Partially completes the truth table . . . . . . 2 • Identifies correctly the logic gate. OR • Partially completes the truth table 1
(e)	A thermistor is a device that can affect or be affected by the environment and therefore can be classified as a transducer. They are considered to be input transducers because they transform thermal energy into a voltage when used in potential dividers. Thermistors come in two types, a positive coefficient device where the resistance increases as the temperature increases and a negative coefficient device where the resistance decreases as the temperature increases. As the resistance of the thermistor varies with temperature, it can be utilised as a switching device to turn on or turn off an alarm system.	9.9.3 H3 • Clearly explains the operation of a thermistor as a transducer. AND • Relates the difference manners a thermistor can vary with temperature. AND • Explain its function in a fire alarm system . . . . 3 – 4 • Explains the operation of a thermistor as a transducer. AND • Relates one way a thermistor can vary with temperature. AND • Explain its function in a fire alarm system OR • Explains the operation of a thermistor as a transducer. AND • Relates one way a thermistor can vary with temperature. AND • Explain its function in a fire alarm system . . . . 2 • Explains the operation of a thermistor as a transducer. OR • Relates one way a thermistor can vary with temperature. OR • Explain its function in a fire alarm system 1

Truth table for (d):

A	*B*	*C*	*D*	*E*	*F*
0	0	1	1	1	0
0	1	1	1	0	1
1	1	0	1	1	0
1	0	1	0	1	1

Question 32 **The Age of Silicon (Continued)**

	Sample answer	Syllabus content, course outcomes and marking guide
(f)	A light emitting diode is a semiconductor diode that emits light when a current passes through it. LEDs usually consist of a small piece of semiconductor mounted on a metallic base with which it is in electrical contact. The metallic base is connected to the cathode, while the upper surface of the chip leads to the anode. The whole assembly is then covered with an epoxy resin. This acts as a lens to intensify the light passing through the top of the LED. They can be made to emit any colour dependent upon the choice of impurity added to the base semiconductor used. The most common colours are red, green and yellow. The chip of the LED is constructed of a junction of a p type semiconductor with an n type semiconductor. Light is emitted when it is forward biased and a current flows through it. This is achieved when electrons combine with holes at the junction producing light. LEDs can be used in situations where excessive vibrations may be damaging to the filament wires in incandescent globes (such as in the space shuttle or within machinery). LEDs can operate for over 500 000 hours compared to about 1000 hours for a normal household globe. This makes them extremely dependable and economically cheaper to operate. However since they can only carry small amounts of current they must always be used in association with current limiting resistors.	9.9.4 H4 • Describes fully the operation and structure of LEDs. AND • Assesses two situations fully where an LED is preferable to an ordinary light source .... 7 – 8 • Describes fully the operation and structure of LEDs. AND • Assesses two situations briefly where an LED is preferable to an ordinary light source .... 5 – 6 • Describes briefly the operation and structure of LEDs. AND • Assesses two situations partially where an LED is preferable to an ordinary light source .... 3 – 4 • Describes fully the operation and structure of LEDs. OR • Assesses ONE situation fully where an LED is preferable to an ordinary light source 1

Marks

Question 31 — From Quanta to Quarks(25 marks)

(a) Explain how the Bohr modifications made to the Rutherford model of the atom were related to Balmer's empirical formula for determining the wavelength of spectral lines in the hydrogen spectrum. **3**

(b) (i) State the proposal suggested by Louis de Broglie that was based on the connection between electromagnetic waves and matter. **1**

(ii) Outline the Davis-Germer experiment and show how it supported the de Broglie proposal. **2**

(c) (i) Describe how the mass defect is connected with the binding energy of an atom. **2**

(ii) Determine the energy released when a proton combines with a Lithium atom and produces two Helium nuclei, according to the following nuclear reaction: **2**

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

The atomic masses are as follows:

proton = 1.008 μ

lithium = 7.016 μ

helium = 4.003 μ

(d) Identify and describe the use of **one** radio-isotope in the fields of medicine and engineering. **3**

(e) Describe how the Standard Model of Matter has been utilised by physicists to suggest that all the known sub-atomic particles, such as protons and neutrons, consist of a combination of quarks and leptons. How is this model related to the evolution of the universe after the Big Bang? **4**

(f) Scientists investigating naturally occurring radioactivity could not explain the properties they observed by simply assuming the nucleus contained protons and electrons. Discuss the prediction and subsequent discovery of the neutron and neutrino with reference to the nature of alpha and beta decay and the laws of conservation of energy and momentum. **8**