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HSC Trial Examination 2006

Physics

This paper must be kept under strict security and may only be used on or after the afternoon of Thursday 10 August, 2006, 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 16–29.
Allow about 1 hour and 45 minutes for this part.

Section II Pages 17–24

Total marks 25

Attempt ONE question from Questions 30–34.
Allow about 45 minutes for this section.

Students are advised that this is a trial examination only and cannot in any way guarantee the content or the format of the 2006 HSC Physics Examination.

Section I

Total marks 75

Part A

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

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

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.

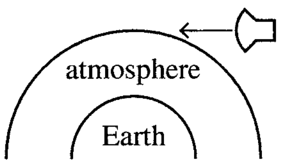
A ● B ✖ C ○ D ○

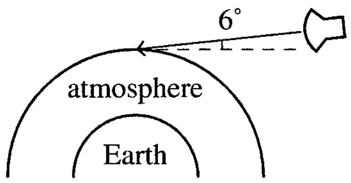
If you change your mind and have crossed out what you consider to be the correct answer, then indicate this by writing the word *correct* and draw an arrow as follows:

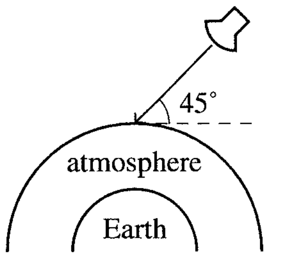
correct

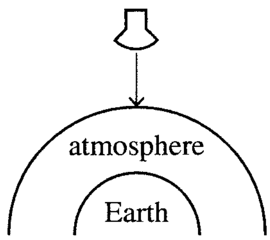
A ✖ B ✖ C ○ D ○

1. A spacecraft is attempting to re-enter the Earth's atmosphere safely.
Which of the following diagrams shows a safe approach from space?

(A)


(B)


(C)


(D)


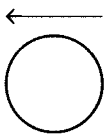
2. A physics student was attempting to compare low-Earth orbits and geostationary orbits of artificial satellites by constructing a table.
Which combination gives the most correct comparison?

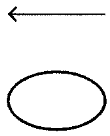
	Low-Earth orbit	*Geostationary orbit*
(A)	Fast speeds and high altitude	Slow speeds and low altitude
(B)	Fast speed and small period	Slow speed and small period
(C)	High altitude and 24-hour period	Low altitude and one-hour period
(D)	Low altitude and fast speed	High altitude and slow speed

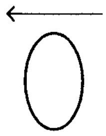
3. A group of physics students was conducting a series of investigations to distinguish between inertial and non-inertial frames of reference.
They drove in a large car at constant speed around a corner. The students in the back seat then passed a basketball between them and noticed that it was difficult to catch the ball. A student watching from the front passenger seat noticed that the ball didn't appear to be travelling in a straight path between the students passing it.
The students could conclude that
(A) they were travelling in a non-inertial frame of reference making the ball difficult to catch.
(B) they were travelling in an inertial frame of reference because the speed of the car was constant.
(C) they were travelling in a non-inertial frame of reference because the speed of the car was constant.
(D) they were travelling in an inertial frame of reference making the ball deviate from a straight line.

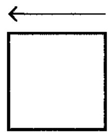
4. A spherical alien spacecraft was travelling at half the speed of light close to the Earth above a football field.

For an observer watching the alien spacecraft move across the sky, it would appear to look like:

(A) 

(B) 

(C) 

(D) 

5. According to Newton's law of universal gravitation, the strength of the gravitational force between two objects is

(A) dependent only on the masses of the two objects.

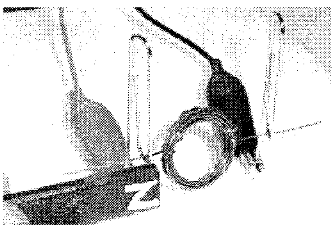
(B) proportional to the product of the masses of the two objects and the distance between them.

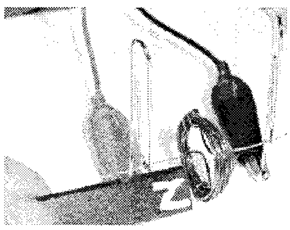
(C) proportional to the product of the two masses and inversely proportional to the distance between them.

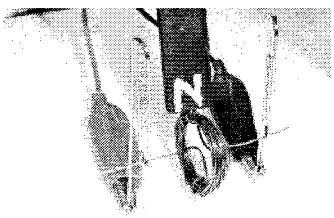
(D) proportional to the product of the two masses and inversely proportional to the square of the distance between them.

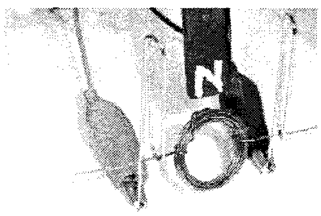
6. Some students were experimenting with simple electric motors. They wound coils from insulated wire; then, after removing the insulation from the ends of the wire, supported the coils on partially straightened paper clips that could be connected to a power supply.

In which of the "motors" shown below would there be most chance of torque on the coil when the power was turned on?

(A) 

(B) 

(C) 

(D) 

7. The trailers on some large trucks use eddy current braking. An aluminium disc attached to the wheel rotates between the poles of an electromagnet. To brake, the electromagnet is energised by current from the truck's battery. The retarding force slows the truck down.

Which of the statements below best describes what happens to the kinetic energy removed from the truck as it slows down?

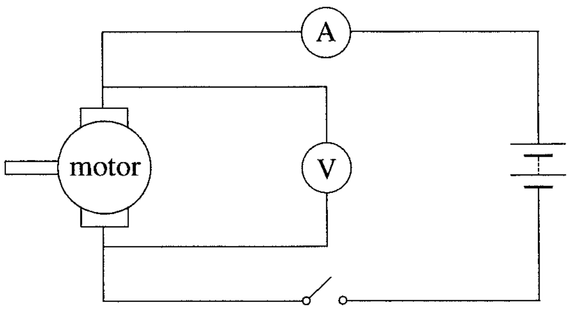
(A) Currents are induced in the electromagnet, which transfers the energy to the battery.

(B) Eddy currents are induced in the core of the electromagnet opposing the motion of the disc. The electromagnet heats up, radiating the energy away.

(C) Eddy currents are induced in the aluminium opposing the motion of the disc. The eddy currents cause the disc to heat up, radiating the energy away.

(D) The eddy currents in the disc attract it to the electromagnet and the friction removes the kinetic energy.

8. A small DC electric motor is connected to a test circuit as shown below.



When the motor is switched on and running freely, the voltmeter shows 6 V and the ammeter 1 A. A student now grasps the output shaft of the motor while it is running and slows it down. What would the most likely reading on the meters now be?

(A)	ammeter: 2 A	voltmeter: 8 V
(B)	ammeter: 3 A	voltmeter: 6 V
(C)	ammeter: 1 A	voltmeter: 6 V
(D)	ammeter: 1 A	voltmeter: 4 V

9. If you were to dismantle a transformer that is designed to produce an output of 12 V with a maximum safe current of 10 A from the 240 V power mains, then you would expect to find

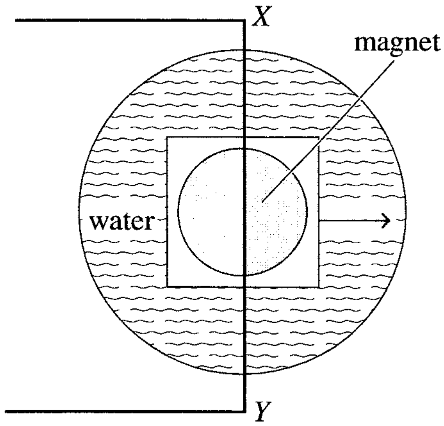
(A) 480 turns of thin wire on the primary and 24 turns of thick wire on the secondary.

(B) 480 turns of thick wire on the primary and 24 turns of thin wire on the secondary.

(C) 24 turns of thin wire on the primary and 480 turns of thin wire on the secondary.

(D) a wire designed to carry 10 amps on the primary and a lot of turns on the secondary.

10. A conducting wire was placed over a disc magnet sitting on a piece of foam that was floating in a dish of water.



When the current was passed through the wire the magnet moved to the right, as shown by the arrow. From this we can conclude that

(A) the current flowed from X to Y and the N pole of the magnet faced up.
(B) the current flowed from Y to X and the N pole of the magnet faced up.
(C) the current flowed from X to Y and the S pole of the magnet faced up.
(D) the electrons flowed from X to Y and the N pole of the magnet faced up.

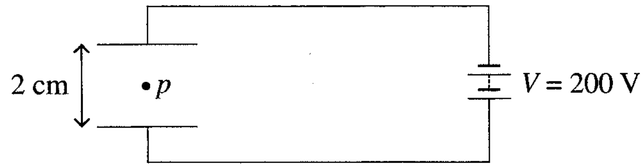
11. Which of the following statements is **false** in regards to the BCS theory of superconductivity?

(A) It explains why resistance equals zero in the superconducting state.
(B) It assumes that electrons form pairs in the superconducting state.
(C) It assumes that electrons and holes change places regularly in the superconducting state.
(D) It explains that the lattice is distorted by the passing electrons in the superconducting state.

12. Which of the following rows correctly shows the dominant charge carriers in metals, semiconductors and superconductors?

	Metal	*Semiconductor*	*Superconductor*
(A)	free electrons	electrons + holes	electron pairs
(B)	free electrons	electron pairs	electrons and holes
(C)	positive charges	electrons + holes	electron pairs
(D)	positive charges	electron pairs	electrons and holes

13. A proton (p) is located between two parallel plates as shown.



What is the electric field strength at the proton's location?

(A) $1.602 \times 10^{-19} \times 200 \text{ V m}^{-1}$

(B) $1.602 \times 10^{-19} \times \dfrac{200}{10^{-2}} \text{ V m}^{-1}$

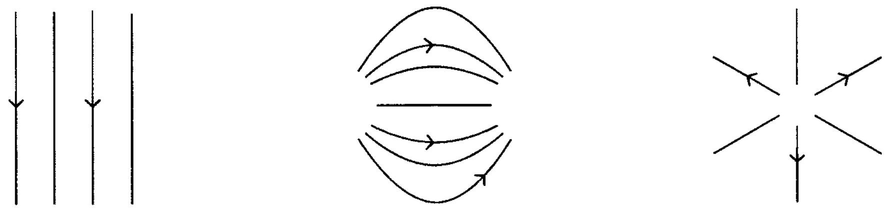
(C) $\dfrac{200}{10^{-2}} \text{ V m}^{-1}$

(D) $\dfrac{200}{2} \text{ V m}^{-1}$

14. A variety of patterns are seen when a current is passed through low-pressure gas discharge tubes. Which one of the factors below plays the most significant part in forming these patterns?

(A) The material of which the electrodes are composed.
(B) The identity of the gas in the tube.
(C) The voltage applied to the tube.
(D) The gas pressure in the tube.

15. Which answer correctly identifies the origin of the following electric fields?



(A)	point charge	+ and – charge	charged parallel plates
(B)	+ and – charge	point charge	charged parallel plates
(C)	point charge	charged parallel plates	+ and – charge
(D)	charged parallel plates	+ and – charge	point charge

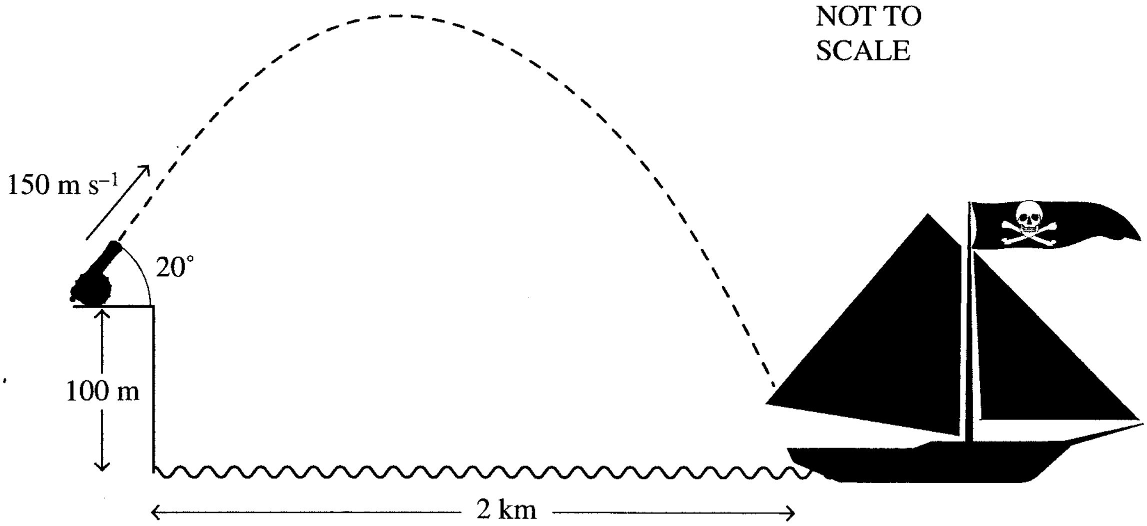
Part B

Total marks 60
Attempt Questions 16–29.
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.

Marks

Question 16 (10 marks)



An enemy ship was sailing 2 km from the coast. A cannon on a 100 metre-high cliff fired a cannon ball at an angle of 20° to the horizontal, at a speed of 150 m/s.

(a) Determine the vertical and horizontal components of the initial velocity. **2**

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Marks

(b) Calculate the time taken for the cannon ball to reach the maximum height and hence the maximum height of the cannon ball above the water. **4**

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(c) Calculate the range of the cannon ball and hence determine how far from the ship the cannon ball landed. **3**

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(d) Describe an adjustment of the cannon that is necessary for a cannon ball to be able to hit the ship. **1**

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Question 17 (2 marks)

Explain why all low-Earth satellites will eventually fall to the Earth's surface. **2**

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Marks

Question 18 (3 marks)

Evaluate the Michelson-Morley attempt to measure the relative velocity of the Earth through the aether. **3**

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Question 19 (3 marks)

Some of Einstein's predictions based on relativity were made many years before evidence was available to support them.

(a) Identify **one** of Einstein's predictions. **1**

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(b) Identify the current experimental evidence supporting this prediction. **2**

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Question 20 (2 marks)

Identify **two** consequences for spacecraft that fail to achieve the optimum angle of re-entry. **2**

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Marks

Question 21 (6 marks)

In your course you performed an investigation to demonstrate the production of an alternating current.

(a) Describe an experiment you did to produce alternating current, with particular reference to how you verified that alternating current was actually produced. **3**

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(b) Describe three advantages of using AC generators for large-scale electrical power production. **3**

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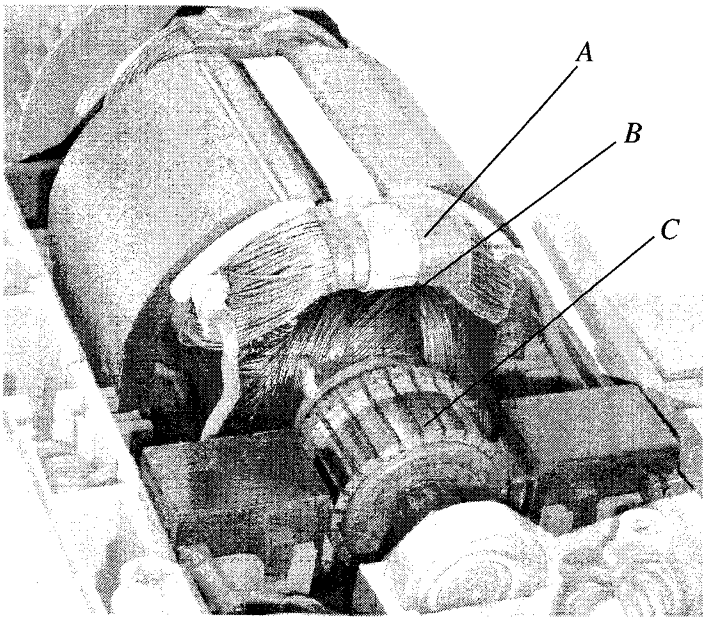
Marks

Question 22 (3 marks)

The photograph below shows a small electric motor from an electric drill. 3



Name the parts labelled *A*, *B* and *C* and describe the function of each.

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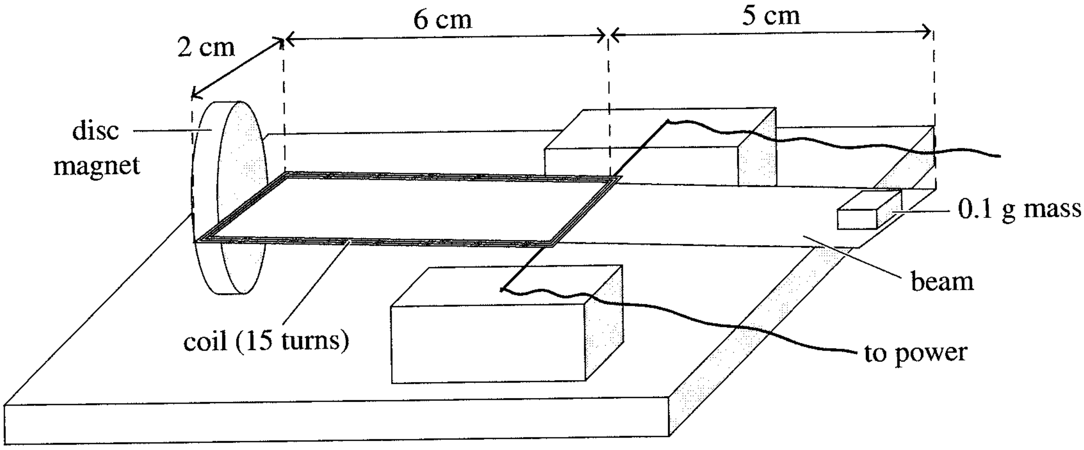
Marks

Question 23 (5 marks)

Students wished to measure the strength of a magnetic field produced by a disc magnet. They used an apparatus similar to the one shown below. 5



The beam with a 15 turn rectangular 6 cm × 2 cm coil on one end was initially horizontal. When the 0.1 gm mass was added, the beam tipped up. It was brought back to horizontal by passing a current of 1.7 amps through the coil.

Calculate the intensity of the magnetic field at the end of the coil by equating the torque due to the magnetic field with the torque due to the mass.

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Marks

Question 24 (6 marks)

Electrical energy is converted into other forms of energy in the home. 6

Name **three** different devices that convert electrical energy into some other form of energy and briefly describe the principle behind the operation of each device.

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Question 25 (4 marks)

Using silicon as an example of a semiconductor, describe how it carries a current and how doping affects the process. 4

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Marks

Question 26 (4 marks)

During your course you carried out an investigation to model the behaviour of semiconductors, including the concept of holes. **4**

Outline what you did in your investigation. Explain how it showed conduction in semiconductors.

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Question 27 (3 marks)

Describe the apparent inconsistency in the behaviour of cathode rays that caused debate about their nature. Explain how this inconsistency was resolved. **3**

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Question 28 (4 marks)

Explain the role of the fluorescent screen in a cathode ray tube and the electrodes in the electron gun. Include reference to the equation $F = qE$ in your answer. **4**

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Question 29 (5 marks)

(a) Calculate the energy of a photon of blue light of wavelength 460 nm. **2**

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(b) Identify Planck's hypothesis that allowed him to successfully predict the black body radiation curve. **1**

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(c) Outline briefly how Hertz measured the speed of radio waves. **2**

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Section II

Total marks 25
Attempt ONE question from Questions 30–34.
Allow about 45 minutes for this section.

Answer the question in a writing booklet. Extra writing booklets are available.

Show all relevant working in questions involving calculations.

Marks

Question 30 — Geophysics (25 marks)

(a) (i) Identify **two** uses of the remote sensing of radiation in mineral exploration. **2**

(ii) Outline the reason why apparent anomalies in the Earth's gravity were found in observations made by surveyors in mountainous regions such as the Andes and Himalayas. **2**

(b) Diagram A below is a simplified representation of the pattern of seafloor magnetic anomalies observed on either side of a mid-ocean ridge.

Diagram B shows the magnetic polarity time scale.

Diagram A

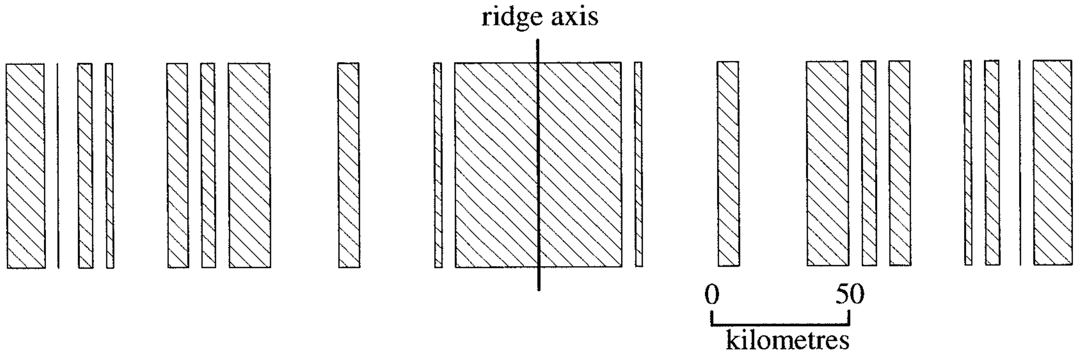
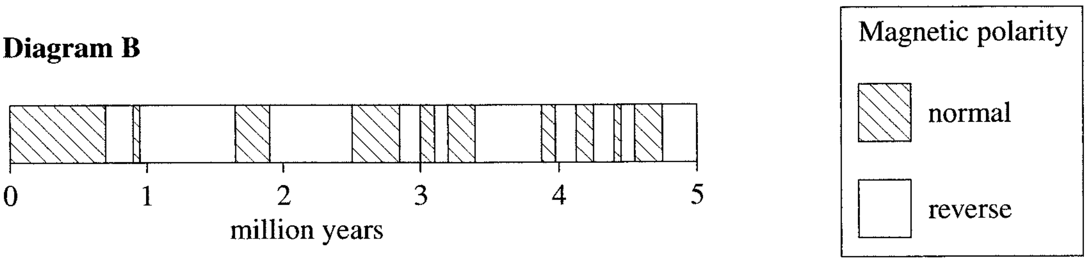


Diagram B



(i) Explain how the pattern in Diagram A supports the theory of plate tectonics. **2**

(ii) Using the information in Diagrams A and B, draw a distance versus time graph, and calculate the rate of spreading from the ridge axis. **4**

(c) Choose **two** of the principal methods used in Geophysics from the list below and describe the type of information that these methods can provide. **7**

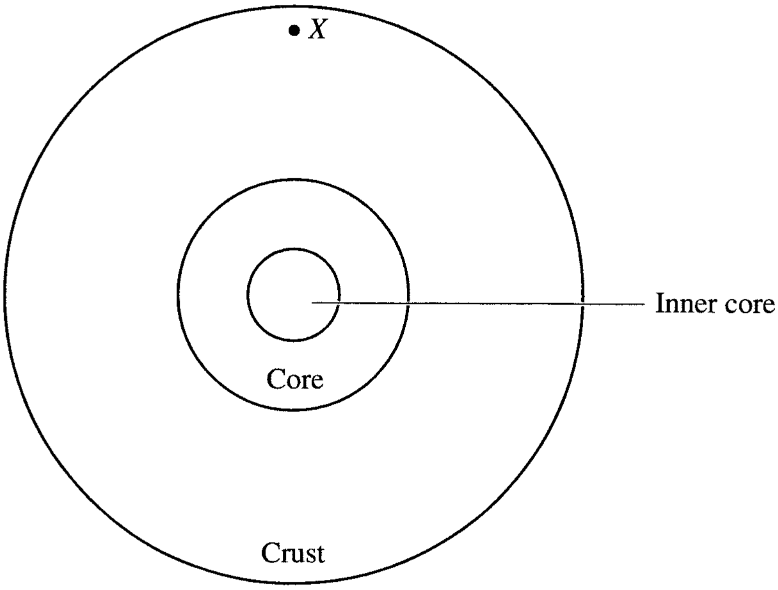
List of principal methods used in geophysics:

- Seismic
- Magnetic
- Palaeomagnetic
- Electrical
- Electromagnetical
- Radiometric
- Geothermal

Marks

Question 30 (Continued)

(d) (i) The diagram below represents the Earth's interior. 2



Transfer the diagram to your writing booklet and sketch the paths of both *S* and *P* waves as they travel through the Earth's interior from focus point *X*. Clearly label the *S* and *P* waves.

(ii) During your study of Geophysics you carried out an investigation to model the principles of refraction and reflection of seismic waves. 3

Describe the model used and its reliability.

(iii) Explain the relationship between the velocity of *S* and *P* waves and the density of the Earth's interior. 3

Marks

Question 31 — Medical Physics (25 marks)

(a) Describe how Doppler ultrasound is used to obtain blood flow characteristics in the heart. **3**

(b) This image has been created using an X-ray. It was taken during an angioplasty procedure where a blockage in a coronary artery, in the heart, is cleared.

(i) Describe how X-rays are produced. **2**

(ii) X-rays can be soft or hard. Identify which type would be used in this angioplasty procedure and explain why it is used. **2**

(c) Assess the impact on society of the use of radioisotopes to create medical images. **6**

(d) Describe the advances in technology that enabled magnetic resonance imaging (MRI) to be used for medical imaging. **5**

(e) Compare the advantages and disadvantages of the following imaging methods: X-ray, CAT and endoscope. **7**

Marks

Question 32 — Astrophysics (25 marks)

(a) (i) Describe the term **resolution** with reference to ground-based telescopes. 2

(ii) Explain **one** method used to improve the resolution of ground-based telescopes. 2

(b) (i) Outline, with the aid of a diagram, how the features of the light curve for an eclipsing binary can be used to detect its presence. 2

(ii) A variable star has been detected within a globular cluster. This star has a mean absolute magnitude of +0.5. Its apparent magnitude was observed over one night and is recorded in the following table. 4

Time of Observation	7:05 pm	8:25 pm	9:45 pm	11:05 pm	12:25 am	1:45 am	3:05 am	4:25 am	5:45 am
Apparent Magnitude	15.8	15.6	15.5	15.7	15.9	16.1	16.2	16.0	15.8

Using the information supplied, determine the variable star type to which this star may belong, its period and its distance away from the Earth.

(c) Construct a typical Hertzsprung-Russell diagram to show the three main groupings of stars (i.e. white dwarfs, red giants and the main sequence). Discuss how, by plotting its two variables, this can account for the characteristics of almost 90 per cent of all stars. Use your diagram to account for the difference in evolutionary paths for a star of one solar mass compared with another star of ten solar masses. 7

(d) Use the information in the following table to answer the questions below:

Star	*Apparent visual magnitude*	*Absolute magnitude*	*Apparent photographic magnitude*	*Approx. surface temperature (K)*	*Star type*
A	+6.1	−6.8	+6.0	15 000	B3
B	+7.3	+11.8	+7.3	10 000	A0
C	+3.9	+12.1	+5.8	3 000	M3

(i) Determine the colour index of stars *A* and *B*. 2

(ii) Calculate which of these three stars is the closest to the Earth. 3

(iii) Explain which of the three stars is most luminous. 3

Marks

Question 33 — From Quanta to Quarks (25 marks)

(a) Describe the structure of the Rutherford model of the atom. **2**

(b) What is the wavelength of the photon emitted by a hydrogen atom when an electron in the $n = 6$ level makes a transition to the $n = 2$ level? **1**

(c) Identify the major experimental evidence that supported Bohr's model of the hydrogen atom and explain how it provided this support. **2**

(d) (i) What is the momentum of an electron with a de Broglie wavelength of 3.3×10^{-10} m? **1**

(ii) Outline Heisenberg's uncertainty principle. **2**

(iii) State Pauli's exclusion principle and identify what could be explained by it. **2**

(iv) Describe Planck's contribution to the concept of quantised energy. **3**

(e) The components of the nucleus are protons and neutrons.

(i) Identify the scientist who discovered the neutron and state the **two** laws of Physics he used in his discovery. **3**

(ii) Discuss qualitatively the relative contributions of electrostatic and gravitational forces between nucleons, and account for the need for the strong nuclear force. **4**

(f) Describe the basic requirements to produce controlled nuclear fission. **5**

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Marks

Question 34 — The Age of Silicon (25 marks)

(a) Two separate circuits involving logic gates both produced the following truth table.

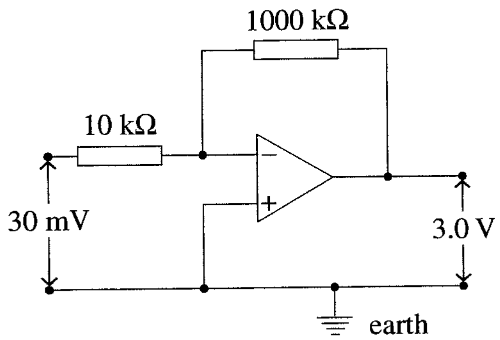
The first circuit contained only one logic gate, while the second circuit had two inverters and one logic gate. Both logic gates had two inputs and one output.

Original Input A	*Original Input B*	*Final Output C*
0	0	1
0	1	1
1	0	1
1	1	0

(i) Identify and draw the single logic gate that can produce these results. **2**

(ii) Draw a diagram to show how these same results can be obtained by using two inverters and one logic gate. **2**

(b) The diagram below represents a simplified circuit for an inverting operational amplifier.



(i) What is meant by the term **inverting**? **2**

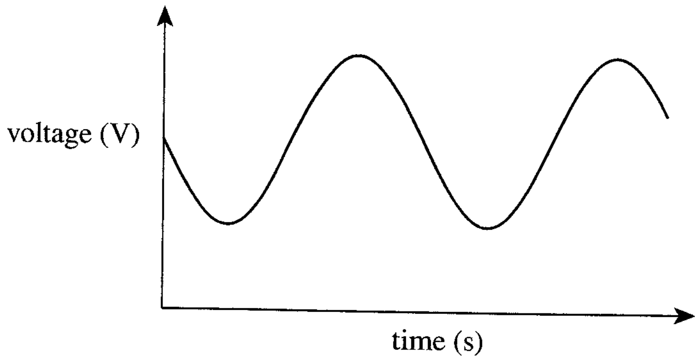
(ii) Calculate the gain of this amplifier. **1**

(iii) Explain the basic operation and describe a use of an inverting operational amplifier. **3**

(c) Integrated circuits quickly replaced miniaturised circuits made up of separate components such as diodes and transistors. Discuss the advantages of the invention of integrated circuits using silicon chips within the development of computers and communication systems. **7**

Question 34 (Continued) **Marks**

(d) The graph below shows the output voltage from an electric device plotted against time. This device is connected to a circuit containing several light-emitting diodes (LEDs).



(i) Explain if the above graph is representative of an analogue or a digital output. **2**

(ii) Describe the structure of an LED and state exactly how it emits light when a suitable current passes through it. **3**

(e) Describe what a transducer does and explain how a light-dependent resistor (LDR) can act as a transducer. **3**

End of paper

Data sheet

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

Formulae sheet

$v = f\lambda$

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

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

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

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

$P = VI$

$\text{Energy} = VIt$

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

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

$\Sigma F = ma$

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

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

$W = Fs$

$p = mv$

$\text{Impulse} = Ft$

$E_{\text{p}} = -G\frac{m_1 m_2}{r}$

$F = mg$

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

$v = u + at$

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

$\Delta x = u_x t$

$\Delta y = u_y t + \frac{1}{2}a_y t^2$

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

$F = \frac{Gm_1 m_2}{d^2}$

$E = mc^2$

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

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

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

Formulae sheet

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

$$F = BIl\sin\theta$$

$$\tau = Fd$$

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

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

$$F = qvB\sin\theta$$

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

$$E = hf$$

$$c = f\lambda$$

$$Z = \rho v$$

$$\frac{I_r}{I_o} = \frac{[Z_2 - Z_1]^2}{[Z_2 + Z_1]^2}$$

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

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

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

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

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

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

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

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

Periodic Table of the Elements

KEY

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

1 **H** 1.008 Hydrogen																	2 **He** 4.003 Helium
3 **Li** 6.941 Lithium	4 **Be** 9.012 Beryllium											5 **B** 10.81 Boron	6 **C** 12.01 Carbon	7 **N** 14.01 Nitrogen	8 **O** 16.00 Oxygen	9 **F** 19.00 Fluorine	10 **Ne** 20.18 Neon
11 **Na** 22.99 Sodium	12 **Mg** 24.31 Magnesium											13 **Al** 26.98 Aluminium	14 **Si** 28.09 Silicon	15 **P** 30.97 Phosphorous	16 **S** 32.07 Sulfur	17 **Cl** 35.45 Chlorine	18 **Ar** 39.95 Argon
19 **K** 39.10 Potassium	20 **Ca** 40.08 Calcium	21 **Sc** 44.96 Scandium	22 **Ti** 47.87 Titanium	23 **V** 50.94 Vanadium	24 **Cr** 52.00 Chromium	25 **Mn** 54.94 Manganese	26 **Fe** 55.85 Iron	27 **Co** 58.93 Cobalt	28 **Ni** 58.69 Nickel	29 **Cu** 63.55 Copper	30 **Zn** 65.41 Zinc	31 **Ga** 69.72 Gallium	32 **Ge** 72.64 Germanium	33 **As** 74.92 Arsenic	34 **Se** 78.96 Selenium	35 **Br** 79.90 Bromine	36 **Kr** 83.80 Krypton
37 **Rb** 85.47 Rubidium	38 **Sr** 87.62 Strontium	39 **Y** 88.91 Yttrium	40 **Zr** 91.22 Zirconium	41 **Nb** 92.91 Niobium	42 **Mo** 95.94 Molybdenum	43 **Tc** [98.91] Technetium	44 **Ru** 101.1 Ruthenium	45 **Rh** 102.9 Rhodium	46 **Pd** 106.4 Palladium	47 **Ag** 107.9 Silver	48 **Cd** 112.4 Cadmium	49 **In** 114.8 Indium	50 **Sn** 118.7 Tin	51 **Sb** 121.8 Antimony	52 **Te** 127.6 Tellurium	53 **I** 126.9 Iodine	54 **Xe** 131.3 Xenon
55 **Cs** 132.9 Caesium	56 **Ba** 137.3 Barium	57–71 Lanthanides	72 **Hf** 178.5 Hafnium	73 **Ta** 180.9 Tantalum	74 **W** 183.8 Tungsten	75 **Re** 186.2 Rhenium	76 **Os** 190.2 Osmium	77 **Ir** 192.2 Iridium	78 **Pt** 195.1 Platinum	79 **Au** 197.0 Gold	80 **Hg** 200.6 Mercury	81 **Tl** 204.4 Thallium	82 **Pb** 207.2 Lead	83 **Bi** 209.0 Bismuth	84 **Po** [209.0] Polonium	85 **At** [210.0] Astatine	86 **Rn** [222.0] Radon
87 **Fr** [223.0] Francium	88 **Ra** [226.0] Radium	89–103 Actinides	104 **Rf** [261.1] Rutherfordium	105 **Db** [262.1] Dubnium	106 **Sg** [266.1] Seaborgium	107 **Bh** [264.1] Bohrium	108 **Hs** [277] Hassium	109 **Mt** [268] Meitnerium	110 **Ds** [271] Darmstadtium	111 **Rg** [272] Roentgenium							

Lanthanides	57 **La** 138.9 Lanthanum	58 **Ce** 140.1 Cerium	59 **Pr** 140.9 Praseodymium	60 **Nd** 144.9 Neodymium	61 **Pm** [146.9] Promethium	62 **Sm** 150.4 Samarium	63 **Eu** 152.0 Europium	64 **Gd** 157.3 Gadolinium	65 **Tb** 158.9 Terbium	66 **Dy** 162.5 Dysprosium	67 **Ho** 164.9 Holmium	68 **Er** 167.3 Erbium	69 **Tm** 168.9 Thulium	70 **Yb** 173.0 Ytterbium	71 **Lu** 175.0 Lutetium
Actinides	89 **Ac** [227.0] Actinium	90 **Th** 232.0 Thorium	91 **Pa** 231.0 Protactinium	92 **U** 238.0 Uranium	93 **Np** [237.0] Neptunium	94 **Pu** [244.1] Plutonium	95 **Am** [243.1] Americium	96 **Cm** [247.1] Curium	97 **Bk** [247.1] Berkelium	98 **Cf** [251.1] Californium	99 **Es** [252.1] Einsteinium	100 **Fm** [257.1] Fermium	101 **Md** [258.1] Mendelevium	102 **No** [259.1] Nobelium	103 **Lr** [262.1] Lawrencium

Where the atomic weight is not known, the relative atomic mass of the most common radioactive isotope is shown in brackets.
The atomic weights of Np and Tc are given for the isotopes ^{237}Np and ^{99}Tc.

HSC Trial Examination 2006

Physics

Solutions and marking guidelines

Section I

Part A

Answer and explanation		Syllabus content and course outcomes	
Question 1	**B**	9.2.2	H7
A safe angle of re-entry is between 5.2° and 7.2°.			
Question 2	**D**	9.2.2	H6
Artificial satellites in low Earth orbits are at an altitude of about 1000 km and they travel at fast speeds around the Earth to have a period of about 90 minutes. The geostationary orbits are at an altitude of about 36 500 km and take a slower 24 hours to orbit the earth.			
Question 3	**A**	9.2.4	H14, H6
In inertial frames of reference all Newton's laws are true, so a ball will travel in almost a straight line and be easily caught.			
Question 4	**C**	9.2.4	H6, H14
It appears to contract in length only in the direction of motion; the other sides will remain unchanged.			
Question 5	**D**	9.2.3	H9, H13
Since $F = \frac{Gm_1m_2}{d^2}$.			
Question 6	**D**	9.3.1	H9
This is the only magnet position where torque can cause rotation.			
Question 7	**C**	9.3.2	H7, H9
Eddy currents cause heating where they flow and oppose the relative motion.			
Question 8	**B**	9.3.2	H7, H9
Back EMF is reduced, thus there is greater current. The voltage is set by the power supply.			
Question 9	**A**	9.3.4	H7
The turns ratio is correct; thick wire on the secondary is required for higher current.			
Question 10	**A**	9.3.1	H9
Application of motor rule.			
Question 11	**C**	9.4.4	H9
The concept of holes is not used in superconductivity.			
Question 12	**A**	9.4.4	H9
The mode of conduction in each case is only correct for A.			
Question 13	**C**	9.4.1	H9
Field strength $E = \frac{V}{d}$, and d needs to be in m not cm.			
Question 14	**D**	9.4.1	H9, H10
The other factors have little, if any, effect on the pattern.			
Question 15	**D**	9.4.1	H9, H13
Option D correctly identifies source of the three fields shown.			

Part B

Sample answer	Syllabus content, course outcomes and marking guide
Question 16	
(a) $u_x = 150\cos(20°) = 140.95 = 141$ m/s $u_y = 150\sin(20°) = 51.30 = 51.3$ m/s	9.2.2 H9, H14 • Both components correctly determined, showing working and including units. . . . 2 • One component correctly determined, no units or working necessary 1
(b) $v_y = u_y + a_y t$ $0 = 51.30 + (-9.8)t$ $t = 5.24$ s $\Delta y = u_y t + \frac{1}{2}a_y t^2$ $= 51.30 \times 5.24 + \frac{1}{2}(-9.8)(5.24)^2$ $= 134.27$ m Hence maximum height $= 100 + 134.27 = 234.27 = 234$ m.	9.2.2 H9, H14 • Correctly calculates time and maximum height, showing working and using correct units . . . . 3–4 • Correctly calculates one of time or maximum height, showing working and using units. . . . . 2 • Correctly calculates time or maximum height, no units or working. 1
(c) Maximum height = 234.27 m Time to fall from maximum height: $\Delta y = u_y t + \frac{1}{2}a_y t^2$ $-234.27 = 0 + \frac{1}{2}(-9.8)t^2$ $t^2 = 47.81$ $t = 6.91$ s Total flight time = 5.24 + 6.91 = 12.15 = 12.2 s Range: $\Delta x = u_x t$ $= 140.95 \times 12.15$ $= 1713.2$ $= 1710$ m Hence the cannon ball falls 2000 – 1713.2 = 286.8 = 287 m short of the ship.	9.2.2 H9, H14 • Correctly calculates the range of the cannon ball and determines the distance from where it falls to the ship, showing all working and units . . . . 3 • Correctly calculates flight time or range, showing all working and units . . . . 2 • Correctly performs one step in the calculation process 1
(d) Increasing the angle of the cannon to the horizontal will increase the range of the cannon ball. **Alternative answer:** Adding more gunpowder to the cannon will increase the cannon ball's velocity and hence its range.	9.2.2 H12 • Gives one valid way of changing the cannon to increase the range of the cannon ball . . 1

Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
Question 17	
The friction between the satellite and the atmosphere results in a gradual slowing down of the satellite, causing it to move closer to Earth and eventually burn up or return to the ground.	9.2.2 H7 • Gives a valid reason for the satellite to slow down 2
	• Identifies that the satellite slows down OR • identifies friction between the satellite and the atmosphere 1
Question 18	
Michelson and Morley were awarded the Nobel Prize for this experiment because it was such a well-constructed, sensitive experiment for the time. They conducted the experiment in a variety of places on the Earth and during different seasons, in order to take into account the variations in the position of Earth around the Sun, which would determine if there was a change in the interference pattern they achieved. They were able to take very accurate measurements and if aether was there they would have detected it. But their experiment achieved a null result; they could not detect any change in the speed of the aether wind due to the motion of the earth through the aether. Thus the Michelson-Morley attempt to measure the relative velocity of the earth through the aether was a very good experiment and worthy of the Nobel Prize in physics.	9.2.4 H1, H8, H10, H14 • Gives an evaluation of the Michelson-Morley experiment, discussing the experiment and its results . . . . 2–3 • Mentions aspects of the Michelson-Morley experiment that would contribute to a discussion 1
Question 19	
(a) Time dilation	9.2.4 H2, H13 • Gives one valid prediction that Einstein based on relativity. 1
(b) One accurate atomic clock was placed on a jet plane and synchronised with another atomic clock on land. The plane flew around the earth as fast as it could and when it landed the clocks were compared. The clock on the plane was a bit slower than the clock on land and, when the calculations were done using the time dilation equations, the time difference was confirmed.	9.2.4 H2, H6, H13 • Gives a valid experimental way of providing evidence for stated prediction and states how it supports the prediction . . . . 2 • Attempts to give experimental evidence. . 1

Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
Question 20	
If a spacecraft were to come in too steeply, the friction between the atmosphere and the spacecraft would generate a lot of heat, possibly causing the spacecraft to burn up. If coming in too steeply the astronauts would experience significant *g*-forces, which could cause them to black out or die. If the spacecraft came in at too shallow an angle, it would "bounce" off the atmosphere and go back into space. The spacecraft may not have enough fuel to make another attempt.	9.2.2 H6, H7, H13 • Gives two valid consequences of not attaining the correct re-entry angle...... 2 • Gives one valid consequence of not attaining the correct angle OR • correctly identifies the correct range of re-entry angles 1
Question 21	
(a) Describes some experiments using permanent magnets oscillating or rotating near a coil with some form of detector for the current produced.	9.3.3 H9, H11, H13, H14 • A description and diagram showing production and detection of AC .... 3 • A description only, or no verification of output .... 2 • An attempt at a description of an experiment that did not work.................... 1
(b) Give advantages such as: no sliding contacts to attain generated current out of generator; ease of voltage change using transformers; simple AC motors for many devices.	9.3.3 H3, H7, H9 • One mark for each advantage over DC, correctly identified and stated..... Up to 3
Question 22	
A: Stator coils, which provide the stationary magnetic field. *B*: Rotor or armature coils, which interact with the stationary field to produce rotation. *C*: Split-ring commutator, which connects the appropriate armature coils to the power supply through the brushes.	9.3.1 H7, H9 • Correctly names the three parts and describes each one correctly .... 3 • One mark for each part correctly named with its correct function.................. 1–2

Part B (Continued)

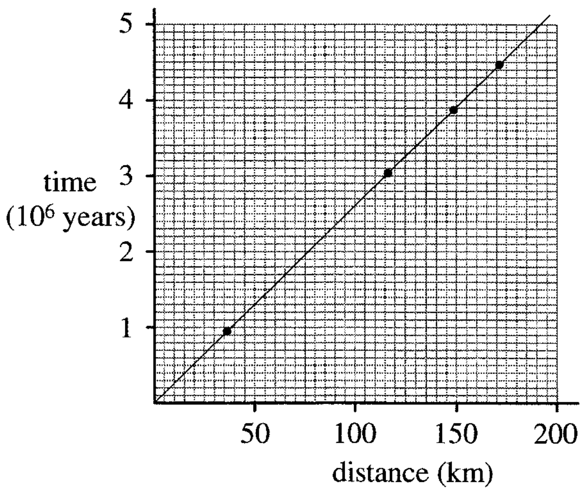
Sample answer	Syllabus content, course outcomes and marking guide
Question 23	
Magnetic force on coil × 6 = Gravitational force on mass × 5 $BIln \times 6 = mg \times 5$ $B = \dfrac{0.1 \times 10^{-3} \times 9.8 \times 5}{1.7 \times 2 \times 10^{-2} \times 15 \times 6}$ $= 1.6 \times 10^{-3}$ T	9.3.1 H6, H9 • Obtains the correct answer . . . . 5 • Shows g torque equated to B torque but makes one incorrect substitution . . . . 4 • Equates the torques but fails to use correct units in substitution. . . . . 3 • Equate the forces rather than torques and incorrectly substitutes values . . . . 2 • Attempts to relate the effect of the mass to the force on the coil 1
Question 24	
Electric motor produces mechanical energy by the interaction of currents with magnetic fields. Electric lights produce light by gas discharge and fluorescence, or by incandescence. Heaters produce heat by passing current through a suitable resistance. Theatre sound systems convert electrical signals into sound using the interaction of a current in a coil and a magnet in a speaker.	9.3.5 H7, H10, H13 • Two marks for each example correctly named with the appropriate principle. . . . . Up to 6
Question 25	
Silicon, with four electrons in its outer shell, carries a small current by the movement of some of these electrons. Doping silicon with aluminium (three electrons in the outer shell), replaces some Si atoms with Al atoms. This in effect produces holes, the movement of which (in the opposite direction to the electron flow) increases the conductivity of the now-doped silicon.	9.4.3 H2, H3, H10 • Fully describes both aspects (conduction and doping) . . . . 4 • Fully describes one aspect and another partially. . . . . 3 • Fully describes one aspect . . . . 2 • Partially describes either aspect 1
Question 26	
In our investigation we had eight chairs, with a student on each. One student was removed, modelling doping and creating a "hole". The student (electron) next to the empty chair moved to the chair to the right, then the next student moved and so on. The empty chair (the hole) moved to the left as the students moved to the right.	9.4.3 H1, H10, H11, H14 • Fully describes the investigation and explains how it models conduction. . . . . . 4 • Fully describes the investigation. . . . . 3 • Partially describes the investigation and explains how it models conduction. . . . . . 2 • Partially describes or explains modelling. 1

Part B (Continued)

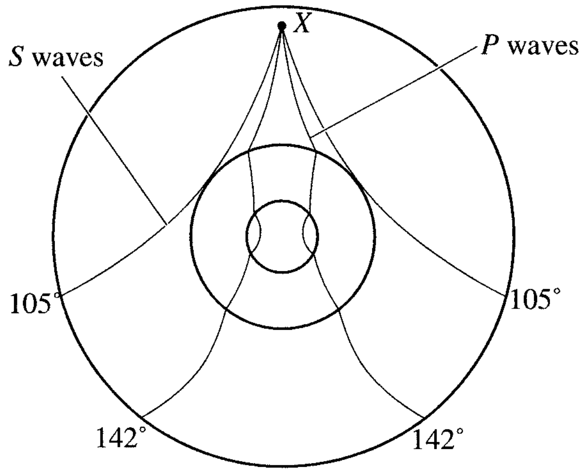
Sample answer	Syllabus content, course outcomes and marking guide
Question 27	
Initially, cathode rays were able to be deflected by magnets (indicating a "–" charge), but were not deflected by electric fields (indicating no charge). With improvements in vacuum pumps and lower-pressure tubes being used, the expected deflection by charged plates was observed.	9.4.1 H1, H9 • Clearly describes inconsistency and explains its resolution . . . . 3 • Describes inconsistency . . . . 2 • States resolution 1
Question 28	
The fluorescent screen emits light when struck by electrons, allowing an image to be formed on the screen. The electrodes in the gun produce an electric field E that causes a force on the electrons given by $F = qE$. This force accelerates the electrons towards the screen.	9.4.1 H3, H10 • Gives an adequate explanation by describing the role of each part and makes a correct reference to the equation. . . . . . . 4 • States the role of each part and uses the equation without an adequate explanation . . . . 3 • States role of each part without reference to the equation. . . . . . . 2 • States the role of one part 1
Question 29	
(a) $c = f\lambda$ and $E = hf$ $\therefore E = \dfrac{hc}{\lambda}$ $= \dfrac{(6.63 \times 10^{-34})(3 \times 10^{8})}{460 \times 10^{-9}}$ $= 4.3 \times 10^{-19}$ J	9.4.2 H9 • Correct answer including units . . . . 2 • Correct answer but no units . . . . 1 • NB: a numerical mistake but with a correct substitution is acceptable.
(b) Energy is exchanged between the walls of the black body and the nearby space in discrete, not continuous, bits of energy called "quanta".	9.4.2 H2 • Identifies hypothesis 1
(c) Hertz found the speed of radio waves by calculation. The calculation came from the equation $v = f\lambda$. The wavelength was found from a measurement of standing waves set up experimentally. The frequency came from a circuit resonance effect (a calculation from circuit theory).	9.4.2 H8, H10, H11 • All three answers correctly outlined . . . . . 2 • One factor correctly outlined 1

Section II

Question 30 **Geophysics**

		Sample answer	Syllabus content, course outcomes and marking guide
(a)	(i)	Gamma radiation detection from airborne surveys is used to detect near-surface uranium deposits. Satellite spectrometers can detect different absorption patterns of minerals being sought.	9.5.2 H1, H3 • Identifies two uses of remote sensing of radiation in mineral exploration. . . . . 2 • Identifies one use of remote sensing of radiation in mineral exploration. 1
	(ii)	In both cases there is a significant variation in the topography of the region with large mountain ranges. The Earth's gravity can vary due to both the distance the point on the surface is from the centre of the earth and variations in the density of the rocks below.	9.5.2 H1, H3 • Outlines that Earth's gravity can vary due to both distance from centre of the Earth and variation in density. . . . . 2 • Outlines one of either distance or variation in density 1
(b)	(i)	The pattern magnetic reversals shown in Diagram A depict a symmetry about the central axis (the mid-oceanic ridge), indicating that the lithosphere is moving away from the ridge on both sides of the axis over time. This supports the theory of sea-floor spreading, a fundamental concept in the overall theory of plate tectonics.	9.5.4 H2, H14 • Makes a relationship between magnetic reversal pattern and sea-floor spreading . 2 • Identifies magnetic reversal pattern. 1
	(ii)	From the graph, 150 km = 4 million years. Rate of spreading $= \frac{\text{distance}}{\text{time}}$ $= \frac{150}{4}$ = 37.5 km/million years = 3.75 cm/yr 	9.5.4 H2, H14 • Draws accurate graph with labelled axis and calculates correct rate of spreading . . . . . 4 • Draws accurate graph with labelled axis but has incorrect calculation (error in working). 3 • Draws an accurate graph with either labelled axis missing or incorrect calculation . . . . 2 • Fails to draw a graph, or shows working but has incorrect calculation 1

Question 30 **Geophysics** (Continued)

	Sample answer	Syllabus content, course outcomes and marking guide
(c)	Any two (note: gravity is not included due to other questions in the paper). Example: Seismic methods utilise the manner in which acoustic waves travel through different earth materials. As the velocity of the wave is determined by the density of the material it passes through, both rock types and structures below the Earth's surface can be determined by the reflection and refraction of these waves. Application of this method can be used in locating localised structures such as arterial anticlinal domes, which could trap oil reserves, or on a large scale in determining discontinuity between major layers of the Earth, such as the interface between the mantle and outer core.	9.5.1 H2 • Chooses two principal methods from the list and provides characteristics and features of both methods. Provides example of their use .... 7 • Chooses two principal methods from the list and provides characteristics and features of both methods. Fails to provide examples of their use .... 6 • Chooses two principal methods from the list but fails to provide sufficient characteristics and/or features for one of the methods .. 5 • Chooses two principal methods from the list and only provides characteristics or features for both. .... 4 • Chooses one principal method from the list and provides characteristics and features for that method. Provides example of its use. 3 • Chooses one principal method from the list and provides characteristics and features for that method .... 2 • Chooses one principal method from the list and provides characteristics or features for that method 1
(d)	(i) 	9.5.3 H1, H11 • Draws accurate pathways for both *P* and *S* waves .... 2 • Draws an accurate pathway for either *P* or *S* waves 1

Question 30 **Geophysics** (Continued)

		Sample answer	Syllabus content, course outcomes and marking guide
(d)	(ii)	A simple method of modelling the principles of refraction and reflection of seismic waves is to follow the following experimental procedure: 1. Obtain a litre beaker and place it in the centre of a circle that is twice its diameter. 2. Place a light source on the outer perimeter of the circle and shine it towards the beaker. Sketch the shadow pattern. 3. Remove the beaker, fill it with water and place it in the centre of the circle again. Sketch the resultant shadow pattern. The first pattern, while dim, shows the *S* wave reflection. The second pattern shows the refraction of light rays (P waves) through the change in medium. A measurement of the angle from the focus to the reflected and refracted light rays does not fully match the theoretical angles of 105° to 142° for shadow zone.	9.5.4 H1, H11 • Describes the model, mentioning BOTH characteristics of reflection and refraction, AND • Assesses its reliability .... 3 • Describes the model, mentioning two of the characteristics of reflection or refraction OR • Assesses its reliability .... 2 • Describes the model, mentioning one of the characteristics of reflection or refraction.. 1
	(iii)	*P* and *S* waves generated from earthquake activity in the crust or upper mantle travel through the earth at different velocities. *P* waves travel the farther of the two and measurement shows that they increase their velocity as they travel further into the Earth's interior. It is also apparent that the density of the Earth's interior increases as depth below the surface increases; therefore, the relationship is that *P* wave velocities increase with the density of the medium in which they travel. *S* waves have the same relationship, although their properties show that they do not pass through a liquid medium and as a result reflect off the interface between the mantle and the outer core. There are major interfaces within the Earth's interior where significant changes in density occur. *P* waves are seen to refract at these discontinuities while *S* waves reflect off a liquid core.	9.5.1, 9.5.3 H1, H11 • States the correct relationship between velocity of *P* and *S* waves and the density of the Earth's interior. Includes discontinuities or areas of density change .... 3 • States the relationship between velocity of *P* and *S* waves and the density of the Earth's interior .... 2 • Identifies the correct characteristics of *P* and *S* wave velocities or that velocity increases with depth but does not relate the two ... 1

Question 31 Medical Physics

	Sample answer	Syllabus content, course outcomes and marking guide
(a)	Ultrasound uses sound waves with frequencies above the human hearing range. These ultrasounds are produced in a transducer, held on the skin of the patient. When the sound waves hit a boundary, in this case the blood cells, they are reflected back to the transducer. The computer can determine the difference in the frequency of the received ultrasound pulse compared to the emitted pulse. If the frequency has increased then the blood is moving towards the transducer, and if it has decreased it is moving away. The larger the difference in frequency, the faster the velocity of the blood. This is the Doppler effect. The differences in direction are shown by different colours; e.g. blue and red. The velocity of the blood is shown by the intensity of the colour. In this way it is easy to see malformations in the valves of the heart.	9.6.1 H8 • Relates the Doppler effect to ultrasound images of the heart, using appropriate ultrasound terminology .... 3 • Describes the Doppler effect and uses some ultrasound terminology .... 2 • Gives some correct information about ultrasound......................... 1
(b) (i)	X-rays are produced by firing electrons at a metal (e.g. tungsten) target. The electrons are decelerated very quickly when they hit the target and hence give off X-rays with a large amount of energy. (Bremsstrahlung or braking radiation.)	9.6.2 H10, H13 • Gives details of one method of producing X-rays (may draw a diagram) .... 2 • Gives one correct idea; e.g. fast-moving electrons are used in the production of X-rays........................... 1
(ii)	This angioplasty would use hard X-rays because imaging inside the body requires hard X-rays (soft X-rays are not used in medical imaging) to penetrate the body and produce a detailed image.	9.6.2 H10, H13 • Correctly states hard X-rays AND • Gives a valid reason................. 2 • Correctly states hard X-rays OR • Gives a valid reason................. 1
(c)	Radioisotopes can be used in bones scans, PET or SPECT scans. They give functional information that is not able to be obtained by other methods. They show how a particular organ is using blood which tells the doctors how active the site is. This information is then used to determine a treatment regime. It can detect cancer at a very early stage, so treatment can begin early and more lives can be saved. Radioisotopes can also be used to monitor the treatment of various diseases. Radioisotopes used in medical imaging have a short half-life so they do not stay in the body too long; this prevents damage to other body cells. Radioisotopes are produced in either a nuclear reactor or a cyclotron. Both processes produce radioactive waste that needs to be disposed of. It is usually buried and must stay in the ground for a long time. This may cause damage to the surrounding environment. Radioisotopes have been of great benefit when used in medical imaging. Their use has saved many lives and enabled sick people to live longer or have a better quality of life. There are some negative impacts on society, but overall the impact is very positive.	9.6.3 H4, H7 • Gives an assessment of the impact of the use of radioisotopes AND • Discusses both sides of the argument (both positive and negative impacts)....... 5–6 • Discusses both positive and negative impacts on society of the use of radioisotopes .... 3–4 • Gives some examples of the uses of radioisotopes OR • States either positive or negative impacts on society 1–2

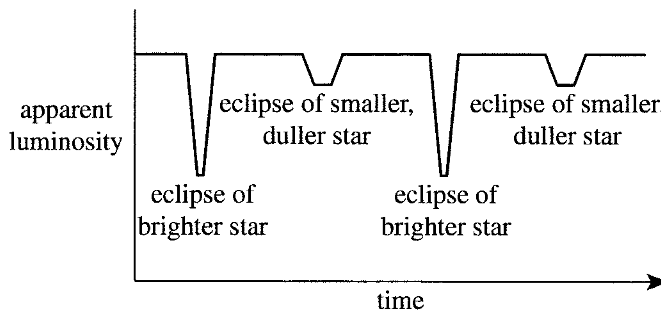
Question 31 **Medical Physics** (Continued)

	Sample answer	Syllabus content, course outcomes and marking guide
(d)	MRI could not have been produced without the development of the following technologies: superconductors and semiconductors (used in computers). In MRI a large magnetic field is produced by a superconducting electromagnet that draws a lot of electricity. Without the superconductors they would not be able to achieve the required magnetic field with the same amount of electricity. Fast computers take all the data received during the MRI scan to create an image. These computers have developed because of the use of semiconductors. Valve-based computers were much larger and slower than the modern semiconductor computers.	9.6.4 H3, H9 • Identifies two technological advances required for MRI AND • Describes their use in MRI and their requirements. . . . . 5 • Identifies two technological advances required for MRI AND • Describes their use in MRI . . . . . 3–4 • Identifies one or two technological advances required for MRI 1–2
(e)	(see table below)	9.6.4 H10, H4 • Clearly states at least one advantage and one disadvantage for each method to compare them; may use a table or paragraphs . . 6–7 • Clearly states at least one advantage and one disadvantage for two methods to compare them . . . . . 4–5 • Clearly states at least one advantage and one disadvantage for one method. . . . . 2–3 • States an advantage or disadvantage for one method 1

	Advantages	Disadvantages
X-ray	• Able to see bone clearly • Cheap and readily available to all	• Difficult to image soft tissue • High-energy radiation may harm cells
CAT	• Able to see anatomy clearly • Uses a large number of scales of grey to create detailed image • Able to "remove" bone from image • Many small slices taken to get detail	• Larger dose of X-ray radiation for patient • Expensive machine; may not be available to all • Does not give functioning information
Endoscope	• Can fit into small incisions (key-hole surgery) to give a real-time image of inside the body • Soft and flexible to see every inside part	• May need anaesthetic for viewing inside the body; small number of stitches (minimally invasive)

Question 32 **Astrophysics**

	Sample answer	Syllabus content, course outcomes and marking guide
(a) (i)	Resolution is connected with how close two stars can appear and still be seen as two separate stars. It depends on the wavelength of the electromagnetic radiation being used to record the observation, and on the diameter of the collecting surface of the ground-based telescope used. Resolution is usually measured as an angle (in radians), so the smaller the number the better the resolution. Similarly, the smaller the wavelength, the better the resolution. Light telescopes thus have better resolution than radio telescopes.	9.7.1 H4, H8 • Clear and comprehensive description explaining the term and its direct reference to ground-based telescopes . . . . 2 • Clear description explaining the term OR • Some explanation of its direct reference to ground-based telescopes 1
(ii)	Adaptive optics is one such method to improve resolution by compensating for atmospheric distortion of the incident radiation. It refers to optical systems that adapt to compensate for optical effects introduced by the medium between the object and its image. In astronomy, the turbulent atmosphere blurs images even at the best sites. Adaptive optics provides appreciably sharper images and an additional gain in contrast. It works by determining the shape of the distorted wavefront and uses an "adaptive" optical element (usually a deformable mirror) to restore the uniform wavefront by applying an opposite cancelling distortion.	9.7.1 H8, H12 • Clear and comprehensive explanation of one method to improve resolution . . . . 2 • Some explanation of one method to improve resolution 1
(b) (i)	A light curve generally shows the variation of luminosity against time for stars. Variable stars may show regular variations over time. An eclipsing binary is a close pair of stars in which one star moves in front of the other, and for a short time blocks some of the light from its partner. From the light curve of an eclipsing binary, shown below, the more luminous star is eclipsed from our view by the second star; there is a noticeable reduction in the luminosity for a short period of time. Later, when the less luminous star is eclipsed, there will be another drop in the total observed luminosity of the two stars, although much less than in the former incident.	9.7.5 H2, H14 • Correct general outline of the main features of a light curve used to detect an eclipsing binary, and a related light curve showing variations in the luminosity against time . . . . 2 • Either a generally correct outline of the main features of a light curve used to detect an eclipsing binary OR • A related light curve showing variations in the luminosity against time 1

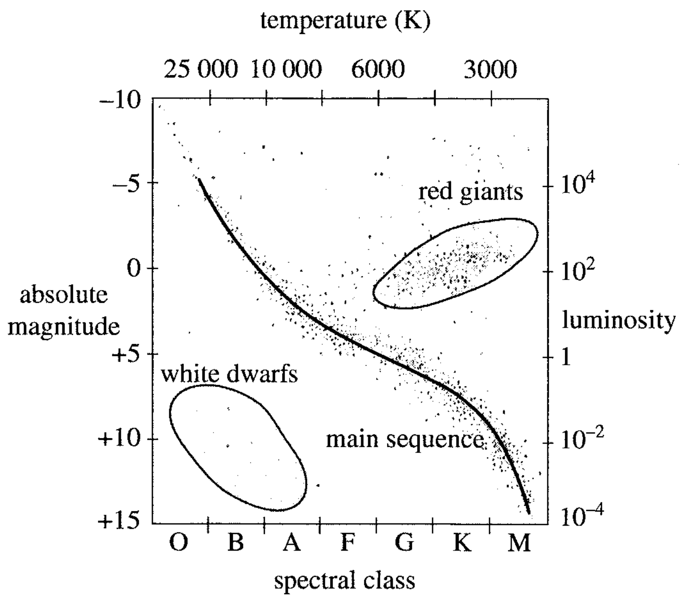


Question 32 **Astrophysics** (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(b) (ii) This variable star has a period of less than one day (10 hours and 40 minutes from the time when its apparent magnitude is detected to be 15.8 until it is again recorded). This period, together with the fact that its mean apparent magnitude can be calculated to be 15.84, as well as its absolute magnitude value of +0.5 and the fact it was detected within a globular cluster, suggest it to be an RR Lyrae variable. Such stars are variable stars whose light output, surface temperature and spectrum change because of a periodic expansion and contraction of the stars' upper layers. Its distance can be determined from the formula $M = m - 5\log\left(\frac{d}{10}\right)$, hence $d = 11\ 749 = 11\ 700$ pc.	9.7.4, 9.7.5 H2, H4, H14 • Comprehensive and well-explained description of the correct variable star, period and distance . . . . 4 • Comprehensive and well explained description of any two of the correct variable star, period and distance. . . . . 3 • Brief description of any two of the correct variable star, period and distance. . . . . . . 2 • Brief description of any one of the correct variable star, period and distance. 1

(c) The Hertzsprung-Russell (HR) diagram relates the absolute magnitude (or luminosity) of stars to their spectral class or surface temperature. The ability to plot these variables enables astronomers to examine the similarities in the way most stars behave. Generally, absolute magnitude (or luminosity) is plotted on the vertical axis while spectral class or surface temperature, or even colour index, is placed on the horizontal axis.

The HR diagram shows that stars can be grouped into three broad sections.



The vast majority of stars that are visible from the Earth are grouped into the broad band running across the diagram known as the main sequence. In this section are stars that are in the process of burning their core reserves of hydrogen and converting it to helium. This section comprises over 90 per cent of all stars. The main sequence stars are, in descending order of diameter, hot blue stars with relatively short life spans to less massive, lower-luminosity and cooler red stars with extremely long life spans. The sun is a typical main sequence star.

9.7.6 H2, H3, H13, H14

- Detailed and comprehensive discussion of the construction of Hertzsprung-Russell diagram and how it characterises stars, including a correctly labelled HR diagram showing all three main groupings. Must have an accurate account of the difference in the evolutionary paths of both named stars 6–7
- General discussion of the construction of Hertzsprung-Russell diagram and how it characterises stars, inclusive of a correctly labelled HR diagram showing all three main groupings. Must have a clear account of the difference in evolutionary paths of both named stars 4–5
- General discussion of the construction of Hertzsprung-Russell diagram and how it characterises stars, inclusive of a correctly labelled HR diagram showing all three main groupings.
  OR
- Some discussion of the Hertzsprung-Russell diagram and a clear account of the difference in evolutionary paths of both named stars. 2–3
- General discussion of the construction of Hertzsprung-Russell diagram and how it characterises stars.
  OR
- A correctly labelled Hertzsprung-Russell diagram showing all three main groupings.
  OR
- A clear account of the difference in evolutionary paths of both named stars.. . 1

Question 32 **Astrophysics** (Continued) **Sample answer**	**Syllabus content, course outcomes and marking guide**
(c) (continued) The second main grouping of stars is the RED GIANTS. These are orange or red in colour but are far more luminous than main sequence stars of the same spectral class. These are believed to be older stars that have exhausted their hydrogen supplies within their cores, but not in their atmosphere or regions outside the core. These stars convert helium into carbon and so are more massive. While the core gets hotter the surface becomes cooler or red in colour. These stars are placed on the higher right-hand side of a typical HR diagram. The third section contains stars that are found in the lower left-hand side. These are known as the WHITE DWARFS. Such stars have far less luminosity than their equivalent main sequence stars. Almost all of the fuel of their cores has been converted. Once this fuel is exhausted and the size of the star limits its ability to utilise the product of any previous fusions as a new source of fuel, there is no longer sufficient radiation pressure to balance the inward gravitational pressure and the star's density increases. HR diagrams are also able to provide evidence for the evolution of stars. Using information relating to populations of stars known as clusters, it is possible to identify the main regions of the HR diagram and relate them to the developmental stages of a star and the progression of stars through these stages in an evolutionary cycle. A star of one solar mass, like our Sun, begins as a protostar and then contracts until it is a stable main sequence star. As the core runs out of its hydrogen fuel it further contracts, which increases the temperature. This in turn starts hydrogen burning in the shell around the core and increases the size of the star to a red giant. When the star does run out of fuel it collapses and fusion ceases, to form a white dwarf. Stars that are more massive, say ten solar masses, are usually brighter and have a rapid evolution, but are relatively short-lived. Their evolutionary sequence is from protostar to main sequence then to red giant. However, the very large mass of such stars mean they continues to grow until they become a red supergiant. When such a star is exhausted of fuel, its gravity collapses the star and the energy is suddenly released in a supernova. However, due to its size, there is nothing to stop the gravitational collapse, and it disappears from sight as a black hole.	

Question 32 **Astrophysics** (Continued)

	Sample answer	Syllabus content, course outcomes and marking guide
(d) (i)	The colour indices are: for Star A: $B - V = +6.0 - +6.1 = -0.1$ for Star B: $B - V = +7.3 - +7.3 = 0.0$	9.7.4 H11 • Correctly calculated colour indices for both stars . . . . 2 • Correctly calculated colour index for one star. . . . 1
(ii)	Noting the distance modulus $(m - M)$. Here, for Star A, $(m - M)$ is 12.9 (positive, so $M < m$ and the star lies beyond 10 pc from Earth). For Star B, $(m - M)$ is –4.5 (negative, so $M > m$ and the star lies closer to us than 10 pc). For Star C, $(m - M)$ is –8.2 (negative, so $M > m$ and the star lies closer to us than 10 pc, but closer than star B as it is a greater negative number). OR Using the distance formula $M = m - 5\log\left(\frac{d}{10}\right)$: For Star A $d = 3800$ pc For Star B $d = 1.25$ pc For Star C $d = 0.2$ pc Hence the closest star is star C.	9.7.4 H2, H13 • Correct use of either distance formula or distance modulus for each star to determine which star is the closest . . . . 3 • Some evidence of correct use of distance formula or distance modulus for two stars to determine which star is the closest . . . . . 2 • Some evidence of correct of use distance formula or distance modulus for one star to determine which star is the closest 1
(iii)	The luminosity is a measure of the total energy radiated from the surface of the star. The luminosity of any two stars can be deduced from their absolute magnitude (this is the magnitude if it were possible to view each star from the same set distance of 10 parsecs) as well as reference to their temperature and exact distance from the Earth. Hence the greater the negative value of their absolute magnitude, the greater their luminosity. Hence, Star A, with a value of –6.8, is the most luminous star of the three.	9.7.4 H13, H14 • Displays a detailed understanding of the term luminosity and how it is related to the absolute magnitude of its star. Uses the information to correctly predict the most luminous star . . . . 3 • Displays a sound understanding of the term luminosity and how it is related to the absolute magnitude of its star. Uses the information to correctly predict the most luminous star . . . . 2 • Displays some understanding of the term luminosity and relates this to the absolute magnitude of its star. OR • Uses the absolute magnitude information to correctly predict the most luminous star.. 1

Question 33 **From Quanta to Quarks**

Sample answer	Syllabus content, course outcomes and marking guide
(a) The atom is mostly empty space, with all of the positive charge and most of the mass located at the centre (nucleus), and with electrons orbiting the nucleus.	9.8.1 H1 • States that the mass is located at the centre (nucleus) AND • States that electrons orbit the nucleus . . . 2 • States that the mass is located at the centre (nucleus) OR • States that electrons orbit the nucleus . . . 1
(b) $\frac{1}{\lambda} = R_H\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ $= 1.097 \times 10^7 \times \left(\frac{1}{2^2} - \frac{1}{6^2}\right)$ $= 2437777.8$ $\lambda = 4.1 \times 10^{-7}$ m	9.8.1 H8, H14 • Correctly calculates the wavelength 1
(c) The major experimental evidence that supported Bohr's model of the hydrogen atom was the hydrogen spectrum. Rydberg provided a modified form of Balmer's empirical equation that allowed the wavelength of all the hydrogen spectral series to be determined. When Bohr produced his postulates and began to apply them to hydrogen, he was able to create an equation to determine the wavelength of light that would be emitted when an electron in his proposed atom underwent a transition from one energy level (stationary state) to another. The equation he produced was identical in form to the one already produced by Rydberg, except that Rydberg's constant could now be explained as being the energy of the hydrogen electron in the ground state (lowest energy level), divided by Planck's constant times the speed of light.	9.8.1 H2, H9 • Identifies the hydrogen spectrum AND • Explains how it provided the support . . . 2 • Identifies the hydrogen spectrum. OR • Explains how it provided the support . . . 1
(d) (i) $\lambda = \frac{h}{mv}$ $mv = \frac{h}{\lambda}$ $= \frac{6.626 \times 10^{-34}}{3.3 \times 10^{-10}}$ $= 2.0 \times 10^{-24}$ kg m s^{-1}	9.8.2 H8 • Correctly calculates the momentum 1
(ii) Heisenberg showed that uncertainty is an inherent property of quantum mechanics. There are pairs of quantities that cannot be determined simultaneously. Example: For an elementary particle such as an electron the more precisely the position is determined, the less precisely the momentum is known in the instant, and vice versa.	9.8.2 H1, H10 • States the principle AND • Gives an example of the principle for momentum/position or energy/time. . . . . 2 • States the general principle OR • Gives an example of the principle for momentum/position or energy/time. 1

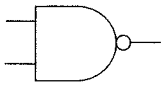
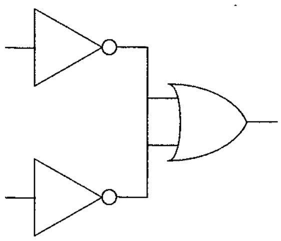
Question 33 **From Quanta to Quarks** (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(d) (iii) No two identical fermions can occupy the same quantum state. No two electrons can occupy the same quantum state of an atom. This principle led to an explanation of the regularity of elements in the periodic table.	9.8.2 H2, H10 • States the general principle OR • States the principle in the case of electrons in an atom AND • States what could be explained by it 2
	• States the general principle OR • States the principle in the case of electrons in an atom OR • States what could be explained by it 1
(iv) Planck found that he could only get agreement between theory and experiment for black body radiation by making a fundamental change to the laws of physics. He proposed that energy is not emitted by a hot object continuously, as classical physics said it should be; rather, it is emitted in little "packets of energy" – quanta of energy. Mathematically, he wrote $E = hf$, where h is a constant called Planck's constant, and f is the frequency.	9.8.1 H1, H2 • States Planck's explanation of black body radiation AND • States his introduction of energy quanta AND • States the formula $E = hf$ 3
	• States Planck's explanation of black body radiation AND • States his introduction of energy quanta OR • States the formula $E = hf$ 2
	• States Planck's explanation of black body radiation OR • States his introduction of energy quanta OR • States the formula $E = hf$ 2
(e) (i) Chadwick was the scientist who discovered the neutron. His neutron identification depended on the laws of conservation of energy and momentum.	9.8.3 H1, H6 • Identifies Chadwick and both physical laws 3
	• Any two of the above 2
	• One of the above. .1

Question 33 **From Quanta to Quarks** (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(ii) The electrostatic Coulomb force between two protons is repulsive, and it might be expected that the nucleus should blow itself apart. The gravitational force is attractive but much too small to hold the protons together. Obviously, another attractive force is required. Experiments indicate that an extremely powerful but short-range force acts equally between the following combinations: proton-proton, proton-neutron and neutron-neutron.	9.8.3 H13, H14 • Outlines that repulsive electrostatic force is much stronger than attractive gravitational force between protons AND • States the need for another attractive force that is extremely powerful but short-ranged 4
	• Outlines that repulsive electrostatic force is much stronger than attractive gravitational force between protons. AND • States the need for another attractive force that is extremely powerful. OR • States the need for another attractive force that is short-ranged. 3
	• Outlines that repulsive electrostatic force is much stronger than attractive gravitational force between protons 2
	• Outlines repulsive electrostatic force. OR • Outlines attractive gravitational force between protons 1
(f) The basic requirements to produce controlled nuclear fission include: 1. A suitable fissionable element, e.g. U-235, arranged in sufficient concentration in fuel rods. 2. A substance, e.g. heavy water, to act as a moderator through collisions to reduce the velocity of the neutrons produced during fission. 3. A substance, e.g. cadmium, to absorb excess neutrons to control the number available to create fission reactions. This controls the rate at which the fission reactions occur. 4. A heat extractor to remove the heat produced by the fission reactions and cool the fuel rods. 5. A radiation shield to protect the walls from radiation damage and to protect the reactor personnel.	9.8.4 H3, H5 • Describes five requirements. . . . . 5 • Describes four requirements . . . . 4 • Describes three requirements. . . . . 3 • Describes two requirements. . . . . 2 • Describes one requirement. 1

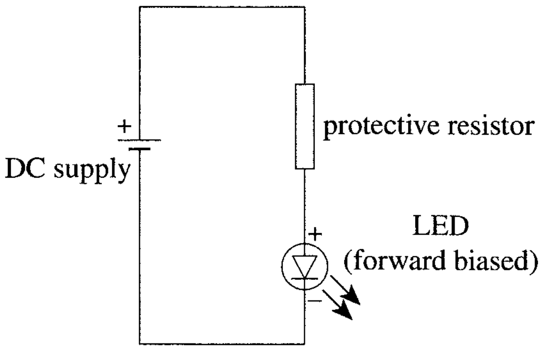
Question 34 **The Age of Silicon**

		Sample answer	Syllabus content, course outcomes and marking guide
(a)	(i)	 NAND gate	9.9.5 H13, H14 • Correctly identifies logic gate AND • Correctly draws logic gate . . . . 2 • Correctly identifies logic gate OR • Correctly draws logic gate 2
	(ii)		9.9.5 H13, H14 • Correctly draws combination of inverters AND • Correct selection of logic gate . . . . 2 • Correctly drawn combination of inverters but incorrect selection of logic gate. OR • Correct selection of logic gate 1
(b)	(i)	An operational amplifier is an inverting amplifier if its output signal wave is inverted with respect to its input wave. When a voltage signal enters the inverting input, the output signal is inverted (i.e. if the input voltage is positive, then output voltage will be negative).	9.9.6 H9 • Clear comprehensive description of the term as applied to the operational amplifier. . . 2 • A general description of the term 1
	(ii)	$A_0 = \frac{V_{\text{out}}}{V_{\text{in}}}$ $= \frac{3.0}{30 \times 10^{-3}}$ $= 100$	9.9.6 H4 • Correctly calculated value of gain 1
	(iii)	Operational amplifiers are high-gain amplifiers, usually constructed with two fixed resistors and comprised of two input terminals (one inverting and the other non-inverting). An inverting operational amplifier has the input signal connected to the inverting (negative sign) input and the non-inverting input (positive sign) connected to earth. It essentially subtracts the voltage at the inverting input from the voltage at the non-inverting input and amplifies the result. Originally designed for analogue computers, inverting operational amplifiers have expanded their applications to include signal amplification in audio systems and converting analogue signals to digital signals in digital cameras and sound recordings.	9.9.6 H4 • Comprehensive and detailed explanation of the operational amplifier AND • A clear description of the use of an inverting operational amplifier . . . . 3 • General explanation of the operational amplifier AND • Description of the use of an inverting operational amplifier . . . . 2 • General explanation of the operational amplifier. OR • Description of the use of an inverting operational amplifier 1

Question 34 **The Age of Silicon** (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(c) The development of integrated circuits using the silicon chip gave rise to tremendous advantages over devices such as diodes and transistors. They play an essential role in virtually every field of human endeavour. Whenever signals containing information are being processed or wherever power needs to be controlled, you will generally find a multitude of integrated circuits. They are vital to computers and within communications systems.	9.9.1, 9.9.7 H1, H3, H5 • Detailed and comprehensive discussion of the advantages of integrated circuits using silicon chips, together with specific examples of these advantages in both computers and within communication systems. 6–7
The introduction of standardised integrated circuits allowed electronics to move into an area where it is practicable to made a vast array of electronic devices using relatively few basic building components. Although originally conceived for use in guidance systems for the military, integrated circuits led to a wide range of applications since they were far more durable, space-saving and faster than separate components. Additionally, they operate at faster speeds and are more reliable.	• Comprehensive discussion of the advantages of integrated circuits using silicon chips, together with specific examples of these advantages in either computers or within communication systems. 4–5
Integrated circuits eliminated the need for connecting wires, as all components were available to be connected on the silicon wafer, thus dispensing with the need to be individually connected.	• General discussion of the advantages of integrated circuits using silicon chips, with some examples of these advantages in either computers or within communication systems. 2–3
As the parts of these integrated circuits are of the order of one millionth of a metre in diameter, and the individual components need to be magnified to be clearly seen, they have a huge advantage in their extremely small size. Also, as a large number of components can be placed on a single chip they are far cheaper to produce. In computers, integrated circuits have changed the way people work and the number of people actually working (as increased efficiency has reduced the numbers of workers involved). Computers, containing integrated circuits, can be found in almost every Western workplace, school and home. Almost all forms of communication systems involve the use of integrated circuits, either to enable the communication or monitor its global systems (including ground-based installations and satellites as well as virtually all forms of media). Although they have numerous advantages, integrated circuits do have some disadvantages, not least of which is their inability to handle high voltage. They operate with and can handle only relatively low voltages, and therefore cannot deal with situations involving large amounts of power. Thus, today integrated circuits are of minute size, consume only very small amounts of power, and perform as well as, and in some regards much better than, the individual components they replaced. They also sell at a price that enables them to be used with little regard to their component cost.	• General discussion of the advantages of integrated circuits using silicon chips. OR • Some examples of these advantages in either computers or within communication systems. 1

Question 34 **The Age of Silicon** (Continued)

	Sample answer	Syllabus content, course outcomes and marking guide
(d)	(i) If a source signal varies smoothly without any evidence of rapid changes, then we have an analogue source. If, however, the signal contains only certain specific and discrete values it is from a digital source. Here, with the continuously changing and time-dependent oscillations, we have a clear example of an ANALOGUE source.	9.9.2 H8, H14 • Clear and comprehensive description that explains both terms and a correct selection of the source. . . . . 2 • Clear description explaining one term and a correct selection OR • Some general explanation of both terms.. 1
	(ii) A light-emitting diode is a device that will allow current to flow in one direction (in the direction of its forward bias). When this current flows it gives out light. LEDs are constructed on a base piece of semiconductor chip with specific impurities added to emit a particular colour of light. The chip is mounted on and in contact with a reflective metallic base. It is a fusion of a piece of n-type semiconductor with a p-type piece. When an electron at the bottom of the conduction band falls into a hole at the top of the valence band, an amount of energy is released. This energy is in the form of electromagnetic radiation within the visible spectrum. They are widely used to indicate whether electrical devices are on or off. Bar-shaped LEDs are used to form numbers in digital displays.  	9.9.4 H3, H7 • Clear and comprehensive description of the structure of an LED AND • A detailed explanation of how it emits light in a circuit . . . . 3 • Clear description of the structure of an LED AND • A general explanation of how it emits light in a circuit . . . . 2 • Clear description of the structure of an LED OR • A general explanation of how it emits light in a circuit 1
(e)	A transducer is a device that converts a signal from one form to another form. A light-dependent resistor (LDR) is a device whose resistance changes when the amount of light falling onto it changes. In dim light, the LDR has a high resistance and allows little current though. In bright light, the resistance of the LDR is low and it permits much more current through. It therefore can either be affected by or affect the environment, and can act as an interface between the environment and an electrical system. An LDR can be used as an input transducer to produce a voltage signal when light falls upon its surface. It thus transforms a light signal into an electrical signal and can be used in circuits to detect changes in light intensity. Such is the case when LDRs are used as switches for street lighting. They are used to switch on street lights when it gets dark and off when it gets bright again.	9.9.3 H5, H10 • Correctly stated definition of a transducer AND • A detailed and comprehensive explanation of how an LDR can act as a transducer . . 3 • Correctly stated definition of a transducer AND • A clear explanation of how an LDR can act as a transducer . . . . 2 • Correctly stated definition of a transducer. OR • A clear explanation of how an LDR can act as a transducer 1