BOSTES BOARD OF STUDIES TEACHING & EDUCATIONAL STANDARDS NSW

2015 HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using 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 2–28

75 marks

This section has two parts, Part A and Part B

Part A – 20 marks

- Attempt Questions 1–20
- Allow about 35 minutes for this part

Part B – 55 marks

- Attempt Questions 21–30
- Allow about 1 hour and 40 minutes for this part

Section II Pages 29–39

25 marks

- Attempt ONE question from Questions 31–35
- Allow about 45 minutes for this section

Section I
75 marks

Part A – 20 marks
Attempt Questions 1–20
Allow about 35 minutes for this part

Use the multiple-choice answer sheet for Questions 1–20.

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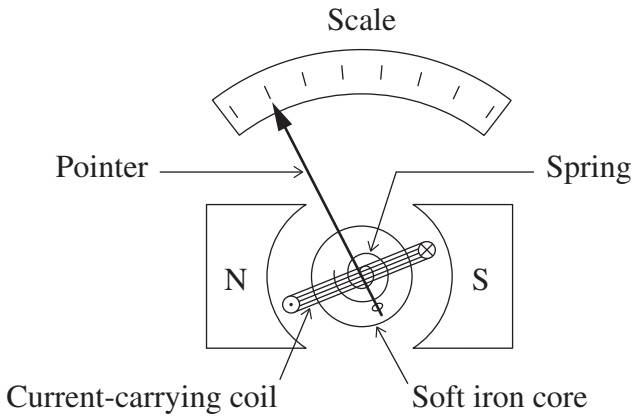
1 The components of a galvanometer are shown.



What is the purpose of the spring in the galvanometer?

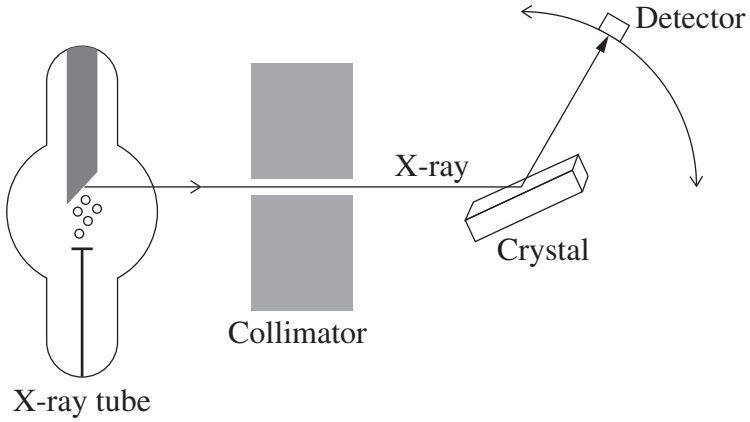
(A) To ensure a uniform force on the coil

(B) To complete the circuit through the coil

(C) To counteract the motor effect on the coil

(D) To increase the magnetic flux through the coil

2 The diagram shows an apparatus that can be used to investigate properties of crystals.



Using this apparatus, what significant information was determined about crystals by the Braggs?

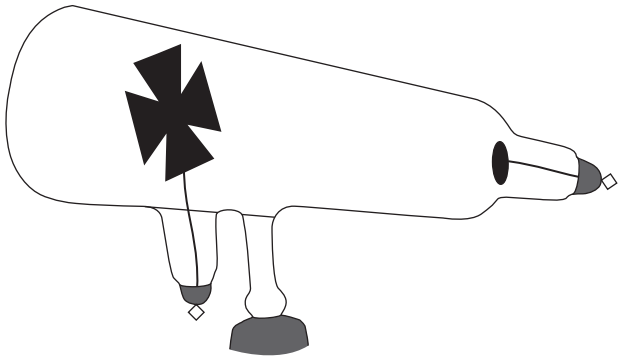
(A) How well crystals reflect X-rays

(B) How the atoms in crystals are arranged

(C) Whether crystals exhibit the property of superconductivity

(D) Whether the electrical resistance of crystals is increased by impurities

3 The diagram shows a type of cathode ray tube.



Which of the following statements CANNOT be inferred from observations made when using the apparatus shown?

(A) Cathode rays possess energy.

(B) Cathode rays possess momentum.

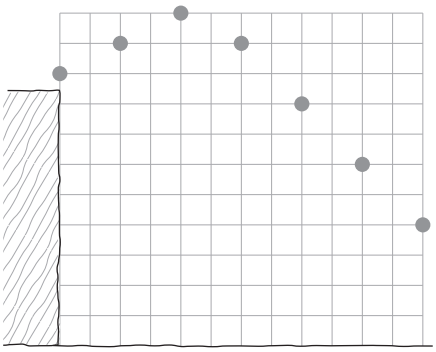
(C) Cathode rays travel in straight lines.

(D) Cathode rays cannot pass through metals.

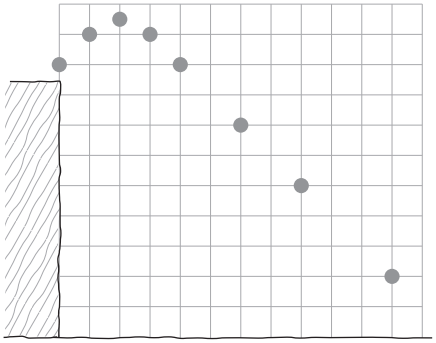
4 A projectile is launched from a cliff top. The dots show the position of the projectile at equal time intervals.

Assuming negligible air resistance, which diagram best shows the path of the projectile?

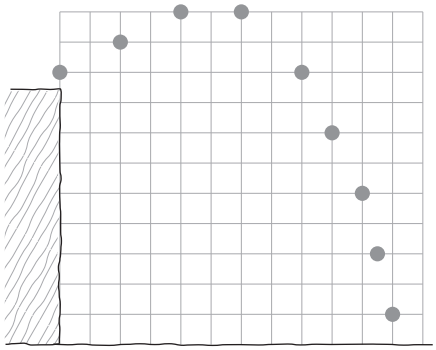
(A)



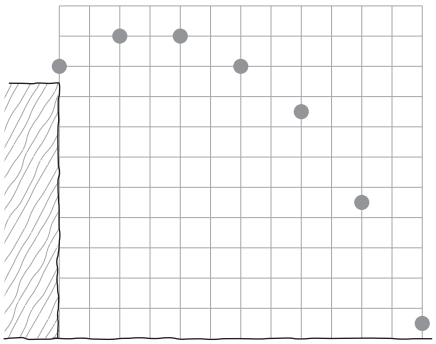
(B)



(C)



(D)



5 Why does the electrical resistance of a metal increase as temperature increases?

(A) Lattice vibrations increase, scattering more electrons.

(B) Electrons pair up, increasing their interactions with the crystal lattice.

(C) Fewer electrons are free to move, as they fill the holes in the conduction band.

(D) Electrons move more freely through the metal, unimpeded by the crystal lattice.

6 Which of the following is a true statement about scientific theories, such as Einstein's theory of special relativity?

(A) They are valid but unreliable ideas.

(B) They are useful in making predictions.

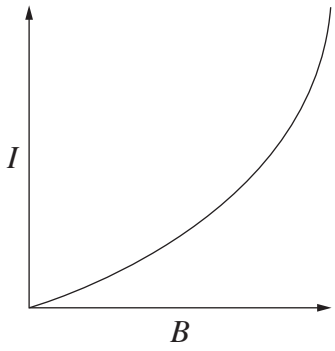
(C) They are concepts that lack an experimental basis.

(D) They are ideas that can't be accepted until they have been tested.

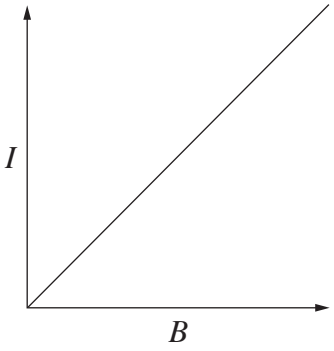
7 A current-carrying wire is placed perpendicular to a magnetic field.

Which graph correctly shows the relationship between magnetic field strength (B) and current (I) if the force is to remain constant?

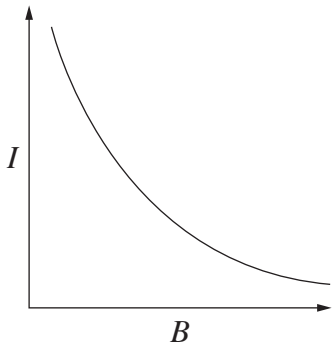
(A)



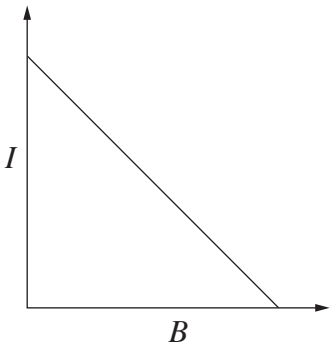
(B)



(C)

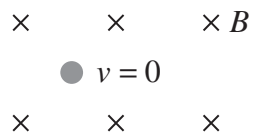


(D)

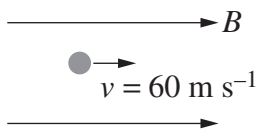


8 In which of the following situations does the magnetic field exert the greatest force on the proton (●), given that all of the fields are of equal magnitude?

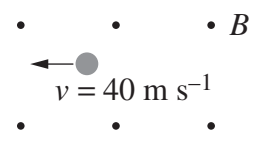
(A)



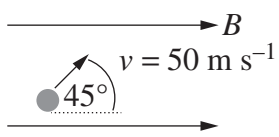
(B)



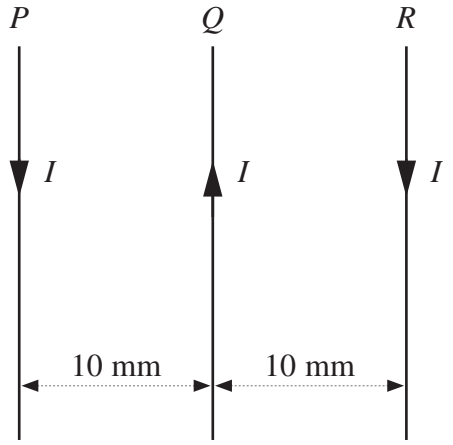
(C)



(D)



9 *P*, *Q* and *R* are straight, current-carrying conductors. They all carry currents of the same magnitude (I). Conductors *P* and *Q* are fixed in place. The magnitude of the force between conductors *Q* and *R* is F newtons.



What is the net force on conductor *R* when it is in the position shown?

(A) $\frac{F}{2}$ newtons to the left

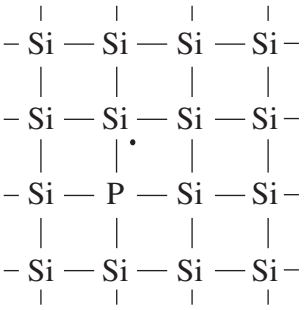
(B) $\frac{F}{2}$ newtons to the right

(C) $\frac{3F}{2}$ newtons to the left

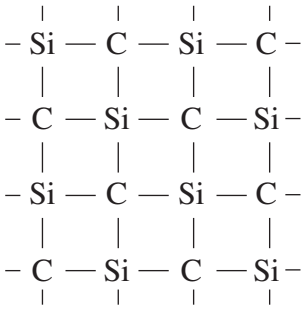
(D) $\frac{3F}{2}$ newtons to the right

10 Which of the following represents a doped semiconductor?

(A)



(B)



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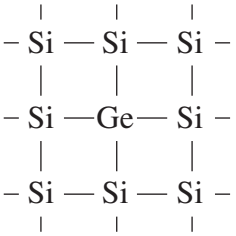
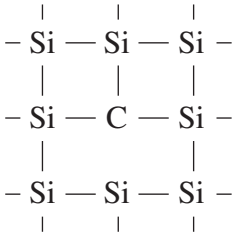


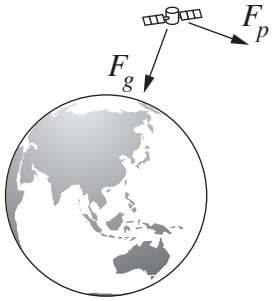
(D)



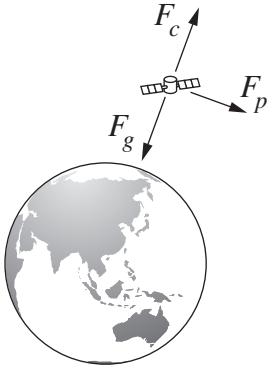
11 Which of the following diagrams correctly represents the force(s) acting on a satellite in a stable circular orbit around Earth?

F_g = gravitational force	F_p = propulsive force
F_c = centripetal force	F_r = reaction force

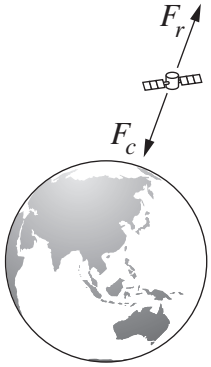
(A)



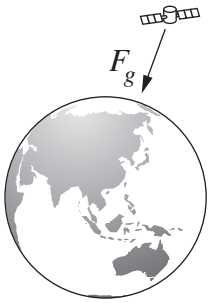
(B)



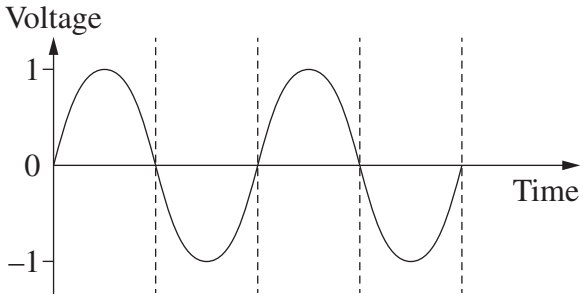
(C)



(D)

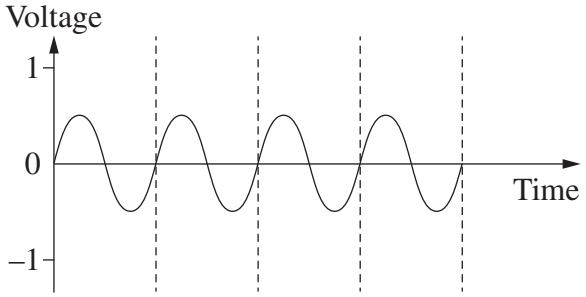


12 A simple AC generator was connected to a cathode ray oscilloscope and the coil was rotated at a constant rate. The output is shown on this graph.

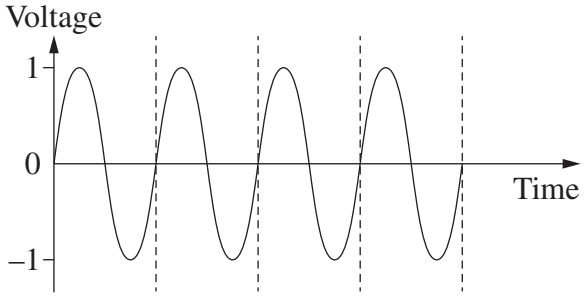


Which of the following graphs best represents the output if the rate of rotation is decreased to half of the original value?

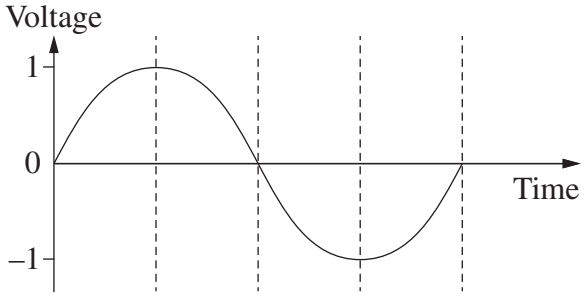
(A)



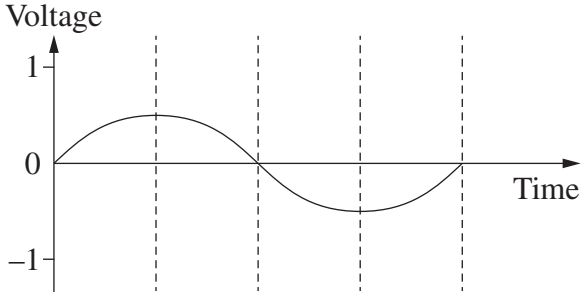
(B)



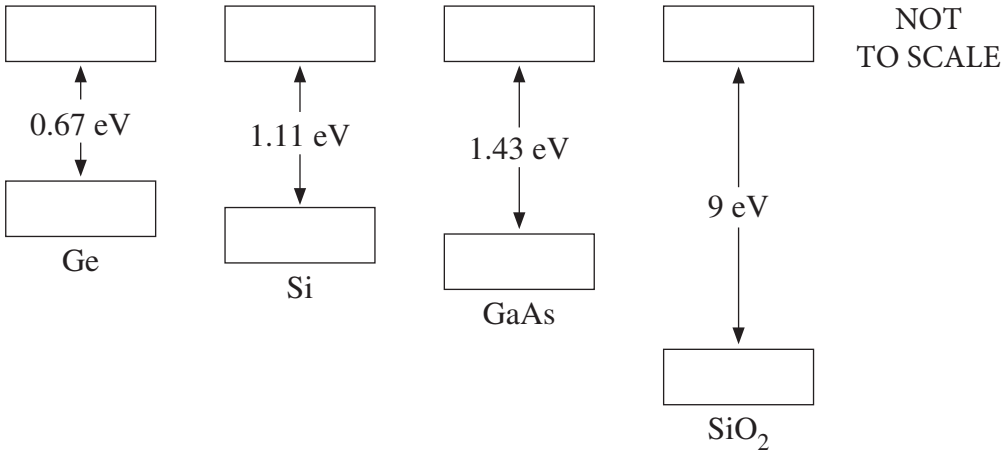
(C)



(D)



13 The following diagram represents the band structure of four materials.



Which material would absorb a photon of wavelength 8.60×10^{-7} m, causing an electron to *just* jump the band gap?

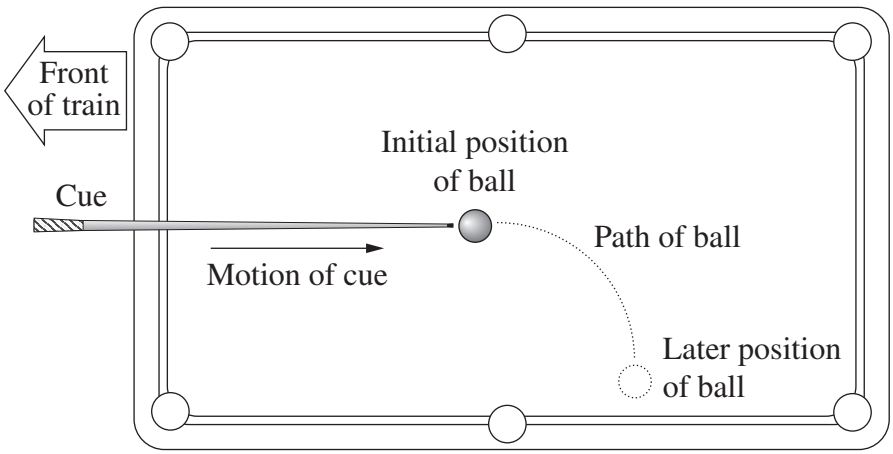
(A) Ge

(B) Si

(C) GaAs

(D) SiO_2

14 A passenger is playing billiards on a train that is travelling forwards on a level track. The ball takes the path shown when hit by the cue.



What can be inferred about the motion of the train?

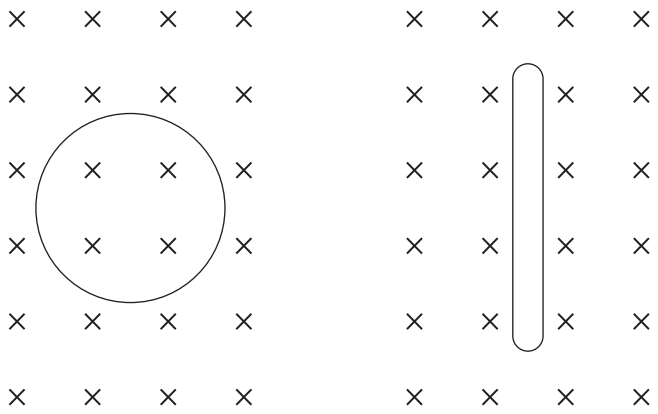
(A) It is turning left.

(B) It is speeding up.

(C) It is turning right.

(D) It is slowing down.

15 A circular loop of wire is stationary in a magnetic field. The sides are then pushed together to change the shape, as shown in the diagram.



As the loop is compressed, a current is induced.

Which row of the table shows the direction of the current and explains why it is induced?

	Current direction	*Why the current is induced*
(A)	Clockwise	Change in magnetic flux
(B)	Anticlockwise	Change in magnetic flux
(C)	Clockwise	Change in magnetic flux density
(D)	Anticlockwise	Change in magnetic flux density

16 Astronauts travel at a velocity of $0.9c$ to Alpha Centauri. Newtonian physics predicts that this journey would take 4.86 years.

How many years will the journey take in the frame of reference of the astronauts?

(A) 0.923

(B) 1.54

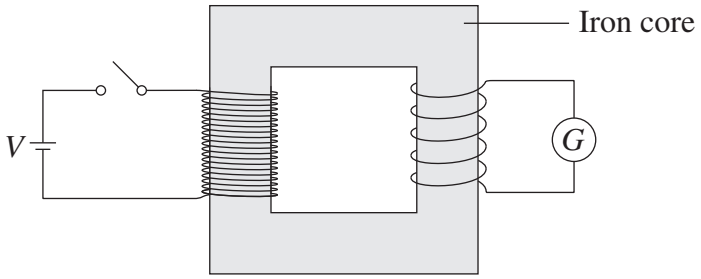
(C) 2.12

(D) 11.1

17 Which row of the table correctly shows ideas that Planck and Einstein contributed to quantum theory?

	Planck	*Einstein*
(A)	Hot objects emit radiation in discrete amounts.	Light consists of packets of energy with specific values.
(B)	Planck's constant determines the energy of photons.	Objects emit energy that increases exponentially with frequency.
(C)	No energy is lost from black body radiators.	Energy is absorbed if the band gap is less than the photon energy.
(D)	The energy of photons decreases as the wavelength increases.	Photons have energy proportional to their frequency.

18 The diagram shows an ideal transformer.



When the switch is closed, the pointer on the galvanometer deflects.

How could the size of the deflection be increased?

(A) Decrease the number of primary coils

(B) Decrease the number of secondary coils

(C) Replace the iron core with a copper core

(D) Place a resistor in series with the galvanometer

19 An astronaut working outside a spacecraft in orbit around Earth is not attached to it.

Why does the astronaut NOT drift away from the spacecraft?

(A) The force of gravity acting on the astronaut and spacecraft is negligible.

(B) The spacecraft and the astronaut are in orbit around the Sun with the Earth.

(C) The forces due to gravity acting on both the astronaut and the spacecraft are the same.

(D) The accelerations of the astronaut and the spacecraft are inversely proportional to their respective masses.

20 A projectile was launched from the ground. It had a range of 70 metres and was in the air for 3.5 seconds.

At what angle to the horizontal was it launched?

(A) 30°

(B) 40°

(C) 50°

(D) 60°

Physics

Centre Number

Student Number

Section I (continued)

Part B – 55 marks
Attempt Questions 21–30
Allow about 1 hour and 40 minutes for this part

Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Show all relevant working in questions involving calculations.

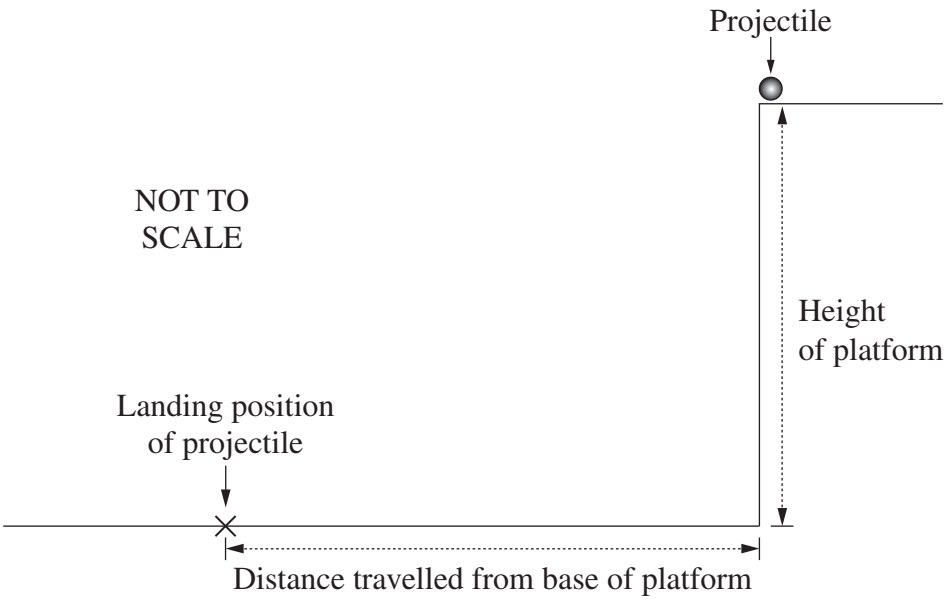
Extra writing space is provided on pages 27 and 28. If you use this space, clearly indicate which question you are answering.

Write your Centre Number and Student Number at the top of this page.

Please turn over

Question 21 (4 marks)

A projectile is fired horizontally from a platform.



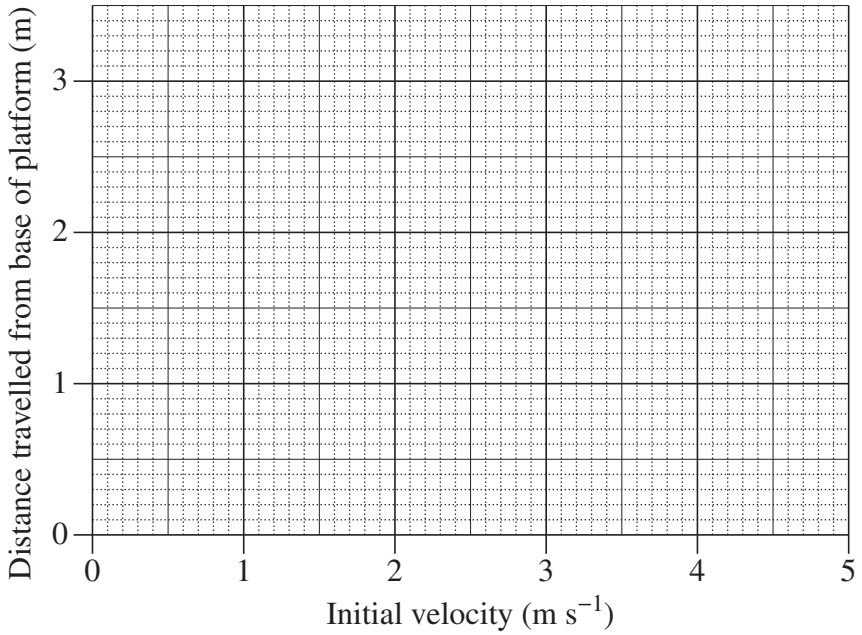
Measurements of the distance travelled by the projectile from the base of the platform are made for a range of initial velocities.

Initial velocity of projectile ($m\ s^{-1}$)	*Distance travelled from base of platform* (m)
1.4	1.0
2.3	1.7
3.1	2.2
3.9	2.3
4.2	3.0

Question 21 continues on page 15

Question 21 (continued)

(a) Graph the data on the grid provided and draw the line of best fit. **2**



(b) Calculate the height of the platform. **2**

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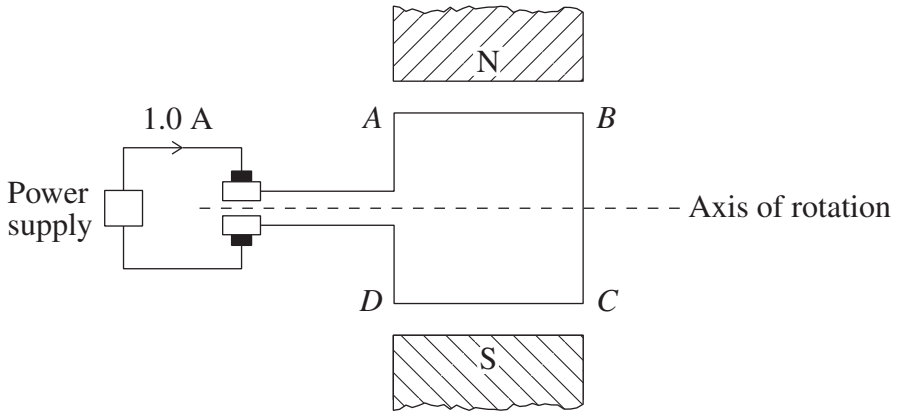
End of Question 21

Question 22 (5 marks)

The diagram represents a simple DC motor. A current of 1.0 A flows through a square loop *ABCD* with 5 cm sides in a magnetic field of 0.01 T.



(a) Determine the force acting on section *AB* and the force acting on section *BC* due to the magnetic field, when the loop is in the position shown. **3**

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(b) How is the direction of the torque maintained as the loop rotates 360° from the position shown? **2**

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Do NOT write in this area.

Question 23 (5 marks)

(a) Outline a procedure that could be used to model electrical conduction in a semiconductor. **3**

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(b) Explain a limitation of the model outlined in part (a). **2**

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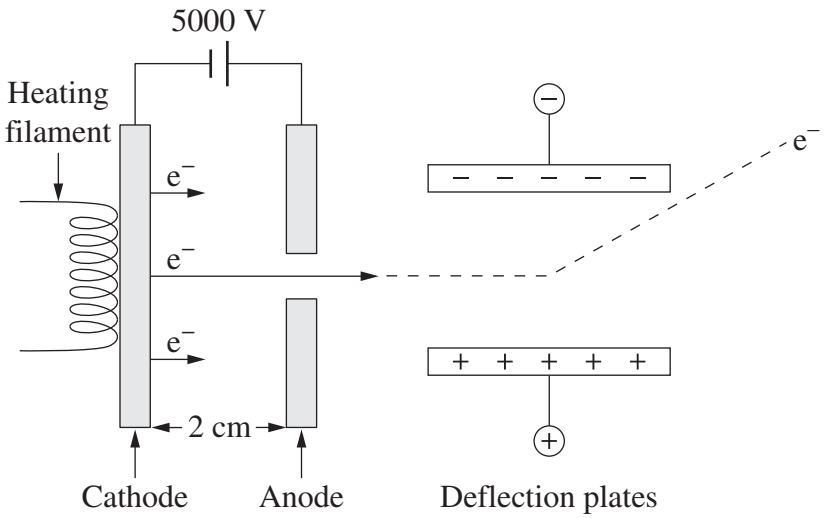
Question 24 (7 marks)

A part of a cathode ray oscilloscope was represented on a website as shown.



Electrons leave the cathode and are accelerated towards the anode.

(a) Explain why the representation of the path of the electron between the deflection plates is inaccurate. **3**

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Question 24 continues on page 19

Question 24 (continued)

(b) Calculate the force on an electron due to the electric field between the cathode and the anode. **2**

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(c) Calculate the velocity of an electron as it reaches the anode. **2**

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End of Question 24

Do NOT write in this area.

Question 25 (6 marks)

(a) Outline the conversion of electrical energy by devices in the home into TWO other forms of energy. **3**

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(b) The diagram shows a label on a transformer used in an appliance. **3**

Input:	240 V AC	5.0 A
Output:	2 kV AC	1.0 A

Explain why the information provided on the label is not correct. Support your answer with calculations.

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Do NOT write in this area.

Question 26 (6 marks)

Consider the following two models used to calculate the work done when a 300 kg satellite is taken from Earth's surface to an altitude of 200 km.

You may assume that the calculations are correct.

Model X	*Model Y*
Data: $g = 9.8 \text{ m s}^{-2}$ $m = 300 \text{ kg}$ $\Delta h = 200 \text{ km}$ $W = Fs$ $= mg\Delta h$ $= 3 \times 10^2 \times 9.8 \times 2.0 \times 10^5$ $= 5.9 \times 10^8 \text{ J}$	Data: $G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$ $r_{\text{Earth}} = 6.38 \times 10^6 \text{ m}$ $r_{\text{orbit}} = 6.58 \times 10^6 \text{ m}$ $M = 6.0 \times 10^{24} \text{ kg}$ $m = 300 \text{ kg}$ $W = \Delta E_P$ $\Delta E_p = E_{p\,\text{final}} - E_{p\,\text{initial}}$ $= -\frac{GMm}{r_{\text{orbit}}} - \left(\frac{GMm}{r_{\text{Earth}}}\right)$ $= -1.824 \times 10^{10} - \left(-1.881 \times 10^{10}\right)$ $= 5.7 \times 10^8 \text{ J}$

(a) What assumptions are made about Earth's gravitational field in models *X* and *Y* that lead to the different results shown? **2**

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(b) Why do models *X* and *Y* produce results that, although different, are close in value? **1**

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Question 26 continues on page 22

Question 26 (continued)

(c) Calculate the orbital velocity of the satellite in a circular orbit at the altitude of 200 km. **3**

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End of Question 26

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Question 27 (6 marks)

In 1865, James Clerk Maxwell developed the theory of electromagnetism. This theory explained the nature of light. It also predicted the existence of other electromagnetic waves. **6**

How did Hertz test and validate Maxwell's theory?

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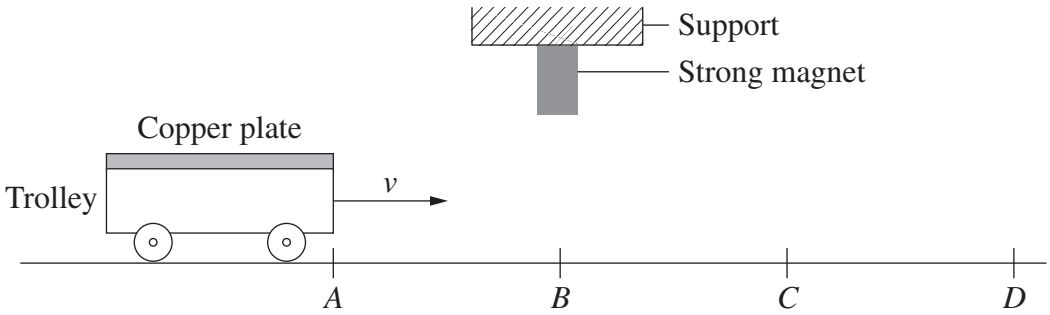
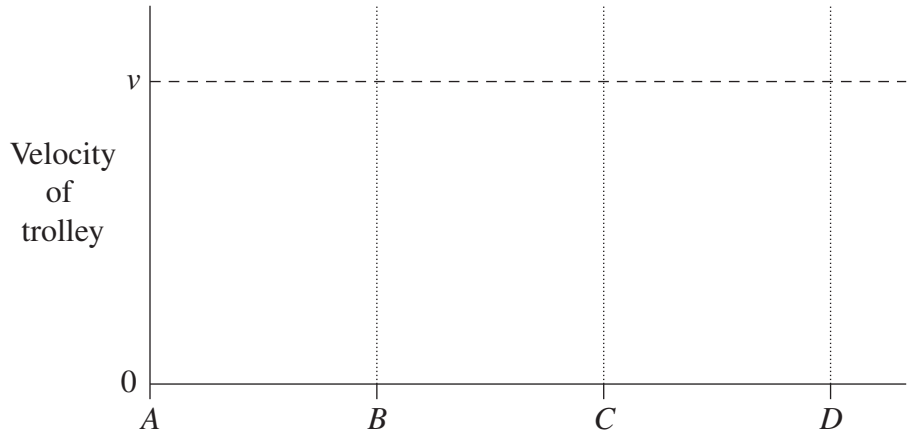
Question 28 (5 marks)

A copper plate is attached to a lightweight trolley. The trolley moves at an initial velocity, v, towards a strong magnet fixed to a support. **5**



The dashed line on the graph shows the velocity of the trolley when the magnet is not present.

On the axes, sketch the graph of the velocity of the trolley as it travels from A to D under the magnet, and justify your graph.



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Question 29 (5 marks)

In the Large Hadron Collider (LHC), protons travel in a circular path at a speed greater than 0.9999 *c*.

(a) What are the advantages of using superconductors to produce the magnetic fields used to guide protons around the LHC? **2**

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(b) Discuss the application of special relativity to the protons in the LHC. **3**

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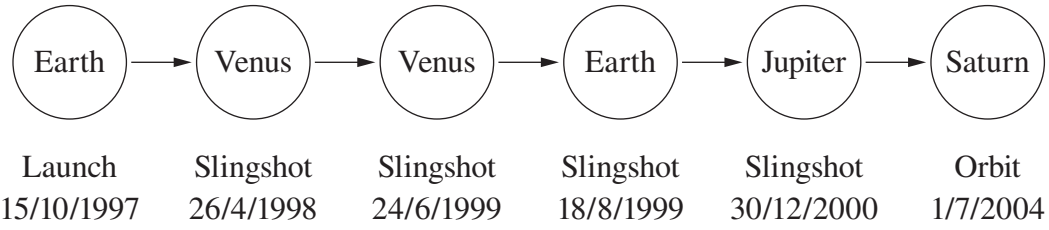
Question 30 (6 marks)

The following is a timeline for the Cassini space probe mission to Saturn. **6**



Explain how Newton's Laws of Motion and Universal Gravitation were applied to the Cassini mission.

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Section I Part B extra writing space

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Section I Part B extra writing space

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Office Use Only – Do NOT write anything, or make any marks below this line.

Physics

Section II

25 marks
Attempt ONE question from Questions 31–35
Allow about 45 minutes for this section

Answer parts (a)–(e) of one question in the Section II Writing Booklet. Extra writing booklets are available.

Show all relevant working in the questions involving calculations.

Question 31 — Geophysics (25 marks)

Answer parts (a), (b) and (c) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) The table shows measurements taken by a student to determine the density of two types of rocks.

Rock sample	*Initial volume of water* (mL)	*Volume after adding rock sample* (mL)	*Mass* (g)
granite	150	185	92.4
basalt	150	190	119.0

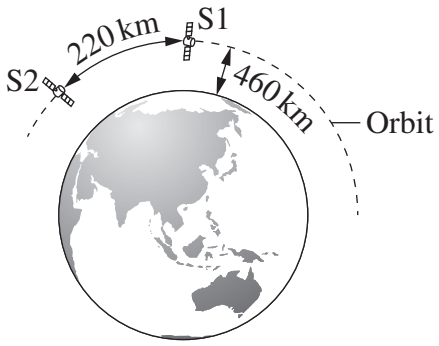
(i) Quantitatively compare the densities of granite and basalt. **2**

(ii) Describe physical properties of these rocks, other than density, that can be studied. **3**

(b) (i) Describe a long-term change in Earth's magnetic field. **2**

(ii) Account for changes in Earth's magnetic field. **3**

(c) One method of studying Earth uses two satellites in the same orbit as shown. **4**



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Microwave signals transmitted between the satellites are used to accurately measure changes in their separation.

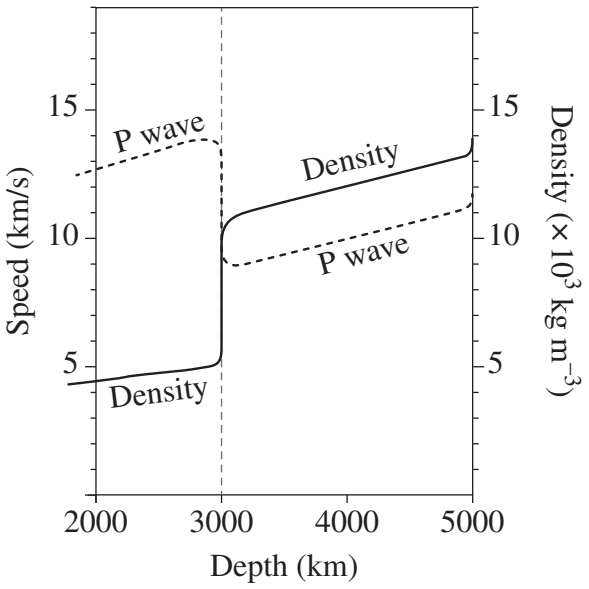
Explain what can be deduced about Earth by using these satellites.

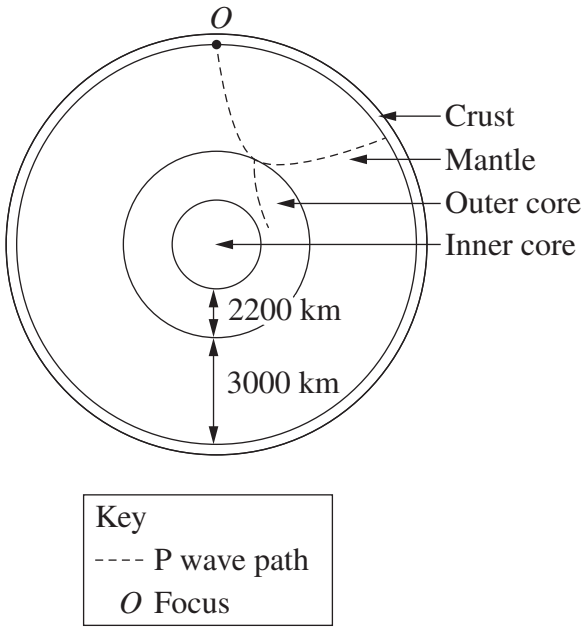
Question 31 continues on page 31

Question 31 (continued)

Answer parts (d) and (e) of the question on pages 6–8 of the Section II Writing Booklet. Start each part of the question on a new page.

(d) Use the following information about earthquake waves to answer parts (i) and (ii).





(i) What is the relationship between density and P wave speed between depths of 3500 km and 4500 km? **2**

(ii) Account for the paths of the P waves produced at *O*, as shown in the second diagram. **3**

(e) Assess the impact of applications of remote sensing on society. Support your answer using THREE examples. **6**

End of Question 31

Question 32 — Medical Physics (25 marks)

Answer parts (a), (b) and (c) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) (i) Describe how ultrasound can be used to distinguish between different types of tissue in the body. **2**

(ii) Use data from the table below to calculate the acoustic impedance of bone and hence determine the ratio of reflected to initial intensity for ultrasound striking a muscle–bone boundary. **3**

Material	*Density* (ρ) $kg\ m^{-3}$	*Acoustic Velocity* (v) $m\ s^{-1}$	*Acoustic Impedance* (Z) $\times 10^6\ kg\ m^{-2}\ s^{-1}$
Muscle	1075	1590	1.71
Liver	1050	1570	1.65
Brain	1025	1540	1.58
Bone	1910	4080	

(b) After a patient had been treated for lung cancer, no tumours were detected in an X-ray image of the lungs.

The doctor has now recommended that the patient have a whole-body PET scan.

(i) Outline TWO differences between the method used to produce an X-ray image and the method used to produce a PET scan. **2**

(ii) Justify the doctor's recommendation to use the whole-body PET scan. **3**

(c) Describe how the structure of an endoscope enables it to be used to detect the presence of a tumour in the stomach wall and to collect a tissue sample for analysis. **4**

Question 32 continues on page 33

Question 32 (continued)

Answer parts (d) and (e) of the question on pages 6–8 of the Section II Writing Booklet. Start each part of the question on a new page.

(d) (i) How does a magnetic resonance image (MRI) scan distinguish between grey and white matter in the brain? **2**

(ii) How is the process of resonance used in the production of an MRI scan? **3**

(e) Assess the impact of advances in understanding of waves on the development of imaging technologies. Support your answer using THREE examples. **6**

End of Question 32

Question 33 — Astrophysics (25 marks)

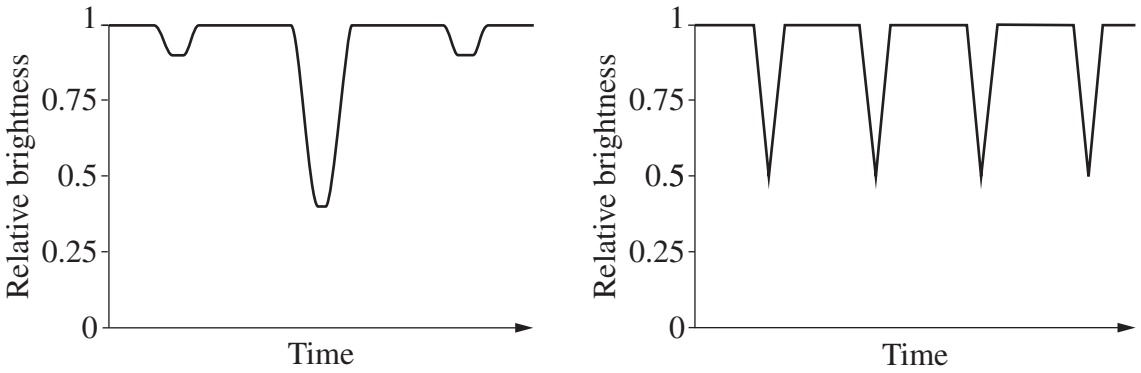
Answer parts (a), (b) and (c) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) (i) The star Canopus has an absolute magnitude of –5.51. Its distance from Earth is 95.9 pc. **2**

Calculate its apparent magnitude.

(ii) Outline TWO methods of determining distances to stars. **3**

(b) The light curves of two binary systems are shown.



(i) Explain why many binary star systems do not produce the types of light curves shown. **2**

(ii) Account for the different shapes of the light curves shown in the graphs. **3**

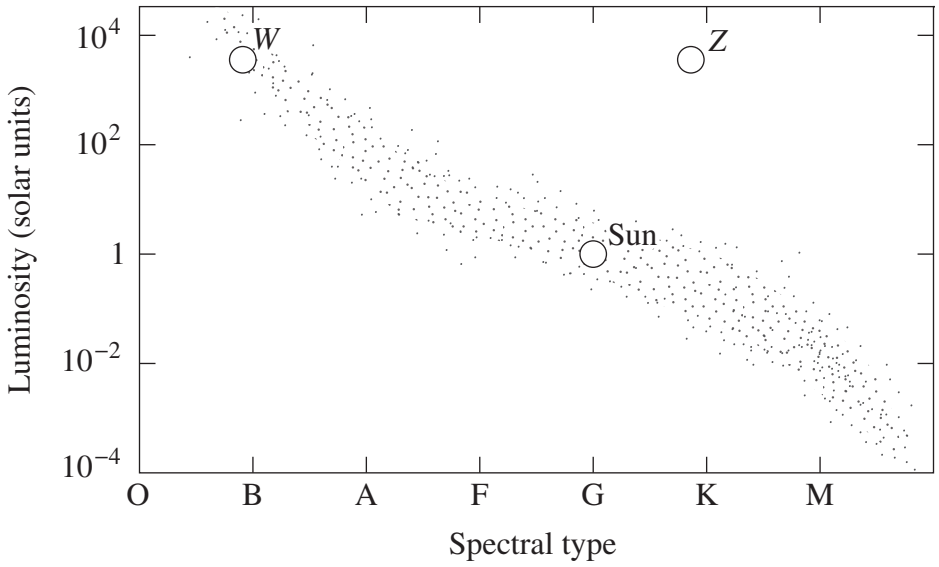
(c) Explain how emission spectra and absorption spectra are produced by specific types of celestial objects. **4**

Question 33 continues on page 35

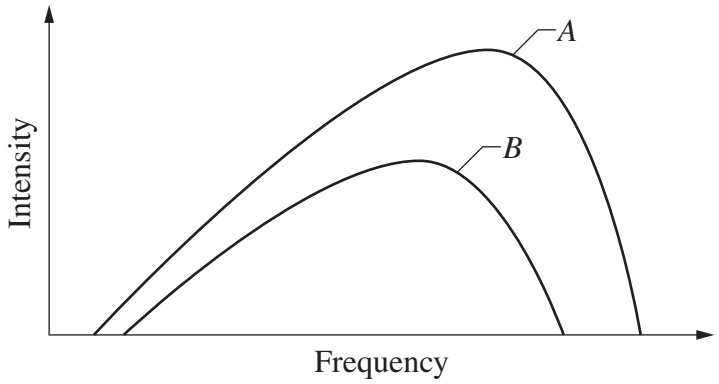
Question 33 (continued)

Answer parts (d) and (e) of the question on pages 6–8 of the Section II Writing Booklet. Start each part of the question on a new page.

(d) The position of the Sun, star *W* and star *Z* are shown on the H-R diagram.



The curves *A* and *B* show intensity versus frequency for star *W* and the Sun, measured from the same distance.



(i) Identify which curve (*A* or *B*) represents star *W* and justify your choice. **2**

(ii) Account for differences between stars *W* and *Z* that can be deduced from the H-R diagram. **3**

(e) Assess the impact of the development of space-based telescopes on the understanding of celestial objects. **6**

End of Question 33

Question 34 — From Quanta to Quarks (25 marks)

Answer parts (a), (b) and (c) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) Polonium-218 is an unstable isotope that can decay to either lead-214 by alpha decay, or astatine-218 by beta decay.

(i) How could a Wilson Cloud Chamber, or similar device, be used to distinguish between alpha decay and beta decay? **2**

(ii) The mass of a polonium-218 nucleus is 218.00897 u, the mass of a lead-214 nucleus is 213.99981 u, and the mass of an alpha particle is 4.00260 u. **3**

Calculate the energy released by this alpha decay.

(b) An instrument uses a beam of neutrons with a wavelength of 0.2 nm to study the structure of new materials.

(i) Calculate the speed of the neutrons. **2**

(ii) Explain why this beam of neutrons is useful in determining the structure of materials. **3**

(c) Explain why the spectroscope was important in the development of the Bohr model of the atom. **4**

Question 34 continues on page 37

Question 34 (continued)

Answer parts (d) and (e) of the question on pages 6–8 of the Section II Writing Booklet. Start each part of the question on a new page.

(d) In 1927, Davisson and Germer reported the results of an experiment in which they fired electrons at a crystal of nickel and observed how the electrons were scattered.

(i) State their conclusion, with reference to the results they obtained. **2**

(ii) Explain the significance of this experiment to the Rutherford-Bohr model of the atom. **3**

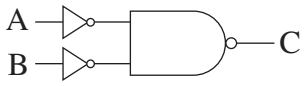
(e) Assess the impact of THREE advances in knowledge about particles and forces on the understanding of the atomic nucleus. **6**

End of Question 34

Question 35 — The Age of Silicon (25 marks)

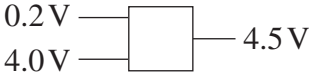
Answer parts (a), (b) and (c) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) The diagram shows a logic circuit with two inputs.



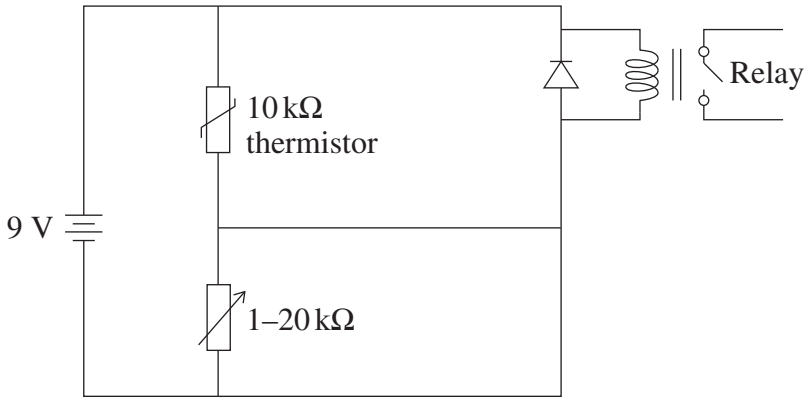
(i) Construct a truth table for this logic circuit. **2**

(ii) A student measured the inputs and output from an unknown gate and obtained the following readings. **3**



Is it valid to substitute this gate for the logic circuit? Justify your answer.

(b) The diagram shows a circuit incorporating a positive temperature coefficient thermistor.



(i) Calculate the range of possible voltages across the diode when the thermistor has a resistance of 10 kΩ. **2**

(ii) Explain an application for this circuit. **3**

(c) Explain how amplifiers and feedback loops are used in control systems. Support your answer with a diagram. **4**

Question 35 continues on page 39

Question 35 (continued)

Answer parts (d) and (e) of the question on pages 6–8 of the Section II Writing Booklet. Start each part of the question on a new page.

(d) (i) Explain ONE advantage of integrated circuits compared to circuits constructed from individual components. **2**

(ii) Between 1970 and 2015 the number of transistors that an integrated circuit could contain doubled every two years. **3**

Explain why this trend is unlikely to continue into the future.

(e) Assess the impact on society of applications of transducers other than thermistors. Use one input and one output transducer to support your answer. **6**

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Physics

DATA SHEET

Charge on 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, $\left(k \equiv \frac{\mu_0}{2\pi}\right)$	2.0×10^{-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

$$v = f\lambda$$

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

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

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

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

$$P = VI$$

$$\text{Energy} = VIt$$

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

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

$$\Sigma F = ma$$

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

$$E_k = \frac{1}{2}mv^2$$

$$W = Fs$$

$$p = mv$$

$$\text{Impulse} = Ft$$

$$E_p = -G\frac{m_1 m_2}{r}$$

$$F = mg$$

$$v_x^2 = u_x^2$$

$$v = u + at$$

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

$$\Delta x = u_x t$$

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

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

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

$$E = mc^2$$

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

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

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

FORMULAE SHEET

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

$$F = BIl\sin\theta$$

$$\tau = Fd$$

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

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

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

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

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

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

$$F = qvB\sin\theta$$

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

$$E = hf$$

$$c = f\lambda$$

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

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

$$Z = \rho v$$

$$\frac{I_r}{I_0} = \frac{\left[Z_2 - Z_1\right]^2}{\left[Z_2 + Z_1\right]^2}$$

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

$$\frac{V_{\text{out}}}{V_{\text{in}}} = -\frac{R_{\text{f}}}{R_{\text{i}}}$$

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

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 Phosphorus	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 65.38 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 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc 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 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 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 Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium						

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm 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 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Elements with atomic numbers 113 and above have been reported but not fully authenticated.

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of data. Some data may have been modified.