BOARD OF STUDIES
NEW SOUTH WALES

2001

HIGHER SCHOOL CERTIFICATE
EXAMINATION

Physics

General Instructions
• Reading time – 5 minutes
• Working time – 3 hours
• Write using black or blue 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
• Write your Centre Number and
Student Number at the top of
pages 13, 15, 17 and 21

Section I
75 marks

Part A – 15 marks
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 the correct answer by writing the word **correct** and drawing an arrow as follows.

correct

         A ✖   B ✖   C ◯   D ◯

1 A person has a mass of 70.0 kg. What is the weight of the person at the Earth's surface?

(A) 70.0 kg

(B) 70.0 N

(C) 686 kg

(D) 686 N

2 At a particular moment, a positively charged particle is moving with velocity v in a magnetic field as shown.

Magnetic field out of page
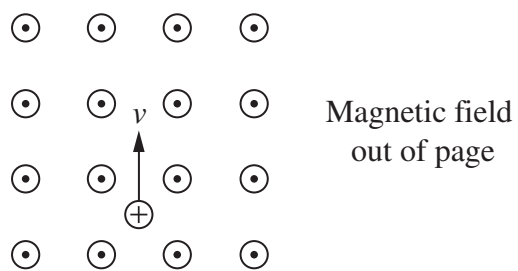
At this moment, what is the direction of the force on the positively charged particle?

(A) To the right

(B) To the left

(C) Into the page

(D) Out of the page

3 The resistance of mercury at various temperatures is shown in the graph.
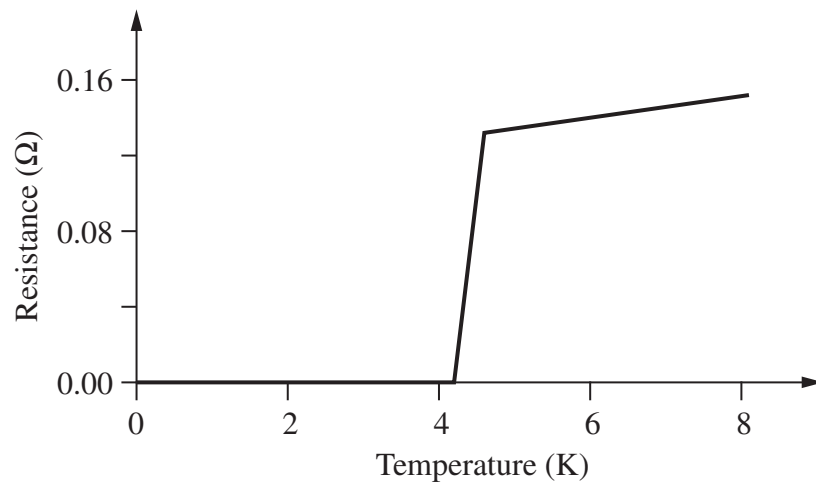
Between which two temperatures does mercury always act as a superconductor?

(A) 0 K and 4.2 K

(B) 4.2 K and 4.5 K

(C) 4.5 K and 8.0 K

(D) 0 K and 8.0 K

4 Two types of generator are shown.
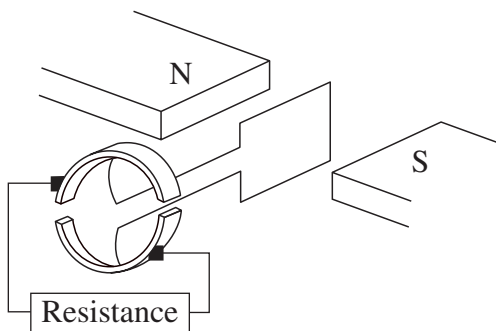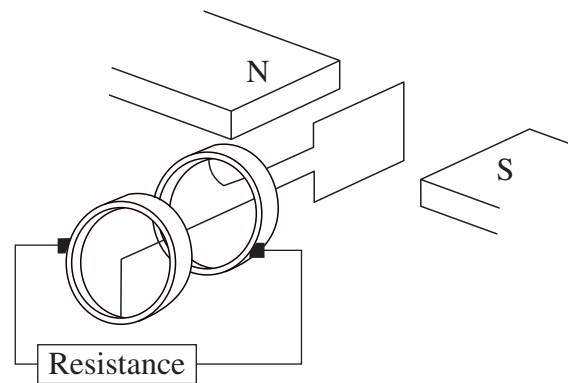
Generator 1   Generator 2

What type of current is produced by each generator when connected to an external resistance?

(A) Both produce d.c.

(B) Both produce a.c.

(C) Generator 1 produces d.c. and Generator 2 produces a.c.

(D) Generator 1 produces a.c. and Generator 2 produces d.c.

5 The graph shows the forces experienced by an astronaut during a rocket launch into a stable orbit.
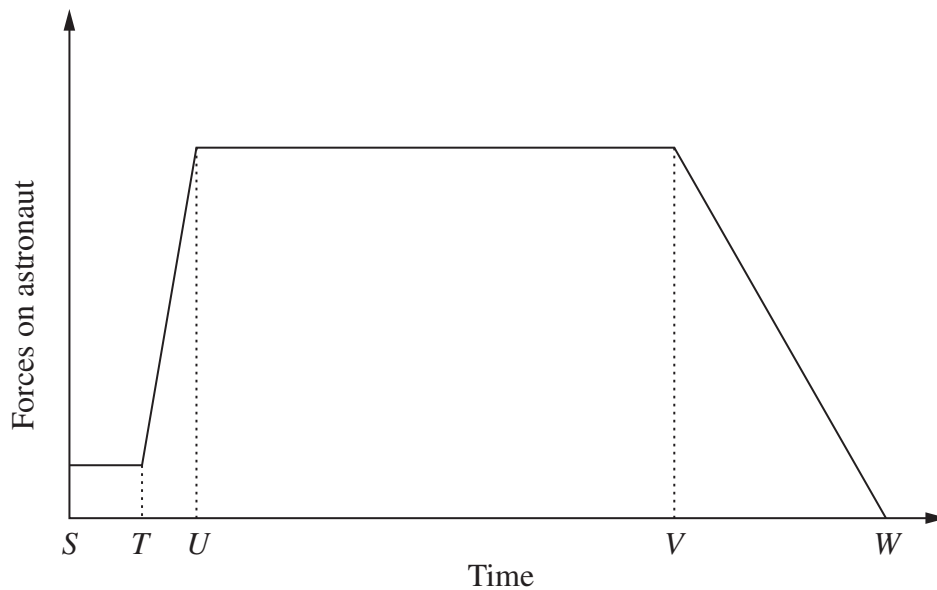
In which time interval was the acceleration of the rocket the greatest?

(A) $S-T$

(B) $T-U$

(C) $U-V$

(D) $V-W$

6 The signal from a microwave transmitter can be thought of as a beam of photons. The photons from a particular transmitter have a wavelength of 3.5×10^{-2} m.

What is the approximate energy of each photon?

(A) 7.73×10^{-44} J

(B) 5.68×10^{-24} J

(C) 2.32×10^{-35} J

(D) 1.89×10^{-32} J

7 An astronaut is standing on Mars. The astronaut throws an object of mass 0.30 kg vertically upward at an initial speed of $9.0\,\text{m s}^{-1}$. It reaches a maximum height of 11 metres.

What is the magnitude of the acceleration of the object?

(A) $1.4\,\text{m s}^{-2}$

(B) $3.7\,\text{m s}^{-2}$

(C) $9.0\,\text{m s}^{-2}$

(D) $9.8\,\text{m s}^{-2}$

8 A light rod has a coil of insulated copper wire fixed at one end and is pivoted at the other end. The result is a pendulum which is free to swing back and forth. A magnet is placed underneath this pendulum. The arrangement is shown in the diagram.
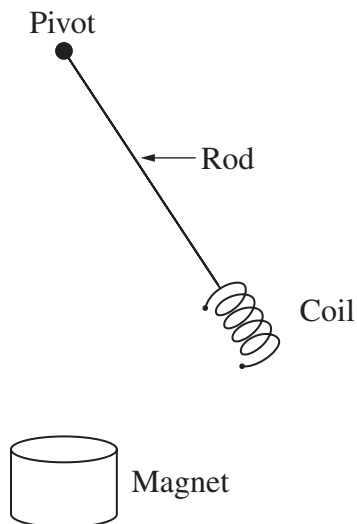
The pendulum is pulled back and then allowed to swing. Which of the following would cause the pendulum to come to rest most quickly?

(A) Replacing the magnet with a stronger one

(B) Shortening the pendulum

(C) Replacing the rod with a heavier one

(D) Connecting the ends of the coil by a piece of copper wire

9 Which is the most suitable means of reliable and continuous communication between an orbiting satellite and Earth?

(A) Light from a green laser

(B) Microwaves

(C) Radio waves

(D) Sound waves

10 An electric motor is connected to a power supply of constant voltage. The motor is allowed to run at different speeds by adjusting a brake.

Which graph best shows how the current through the motor varies with speed?

(A)

Current

0   Speed

(B)

Current

0   Speed

(C)

Current

0   Speed

(D)

Current

0   Speed
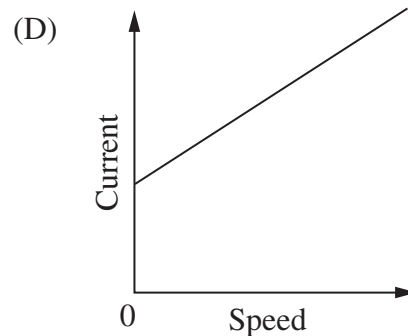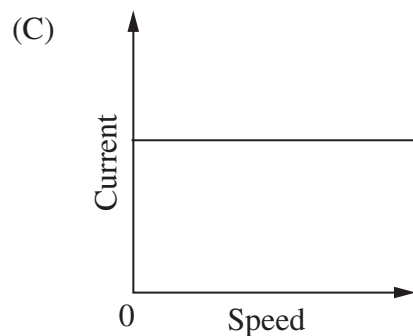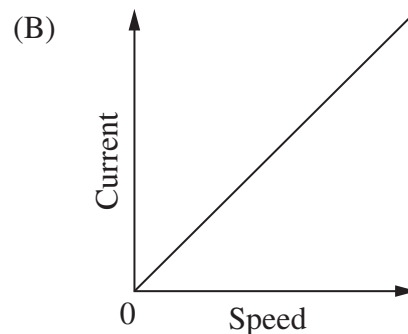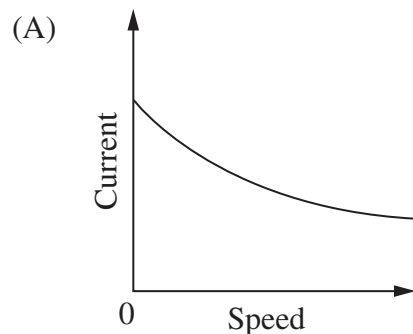
11 A transformer has a primary coil with 60 turns and a secondary coil with 2300 turns.

If the primary voltage to the transformer is 110 V, what is the secondary voltage?

(A) 2.4×10^{-4} V

(B) 2.4×10^{2} V

(C) 1.3×10^{3} V

(D) 4.2×10^{3} V

12 Which of the following statements best describes the reason why some materials become superconducting at very low temperatures?

(A) The ions in the superconductor form a regular crystal lattice. There are long channels through the lattice along which the electrons can pass without colliding with the lattice.

(B) Vibrations of the crystal lattice are so small that they do not interfere with the motion of the electrons.

(C) Electrons in a superconductor have very low energy. Their energy is so low that they cannot transfer energy to the crystal lattice in a collision.

(D) Electrons 'pair up'. These electron pairs pass through the crystal lattice of the superconductor without losing energy in collisions with the lattice.

13 A rocket car moves on a straight horizontal track. Half of the initial mass of the rocket car is propellant. During the run, propellant is consumed at a constant rate and ejected at a constant nozzle velocity.

Which of the following best describes the force propelling the rocket car, and the magnitude of the acceleration of the rocket car while the propellant is being ejected?

	Force	*Acceleration*
(A)	constant	constant
(B)	increasing	constant
(C)	constant	increasing
(D)	increasing	increasing

14 Two straight metal rods, P and Q, have the same length. They are each pivoted at one end and rotated with the same angular velocity so that they sweep out horizontal circular paths as shown in diagrams X and Y. A constant current I is flowing along each rod, as shown.

In diagram X, a constant magnetic field is applied *at right angles to the plane* of the circular path. In diagram Y, a uniform magnetic field of the same magnitude is applied *in the plane* of the circular path.

Diagram X Diagram Y

Which of the following statements about the forces acting on rod P and rod Q is correct?

(A) The magnitude of the force on P is exactly the same as the magnitude of the force on Q at all times.

(B) The magnitude of the force on P is constant and the magnitude of the force on Q is zero.

(C) The magnitude of the force on P is constant and the magnitude of the force on Q varies with time.

(D) The magnitude of the force on P varies with time and the magnitude of the force on Q is constant.

15   A student releases a ball from eye level. The ball bounces several times.

Which velocity vs time graph best represents the ball's motion?

(A)

(B)

(C)

(D)
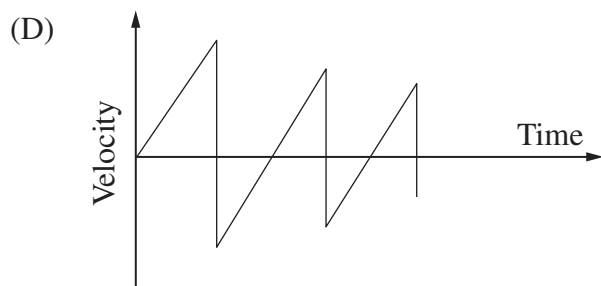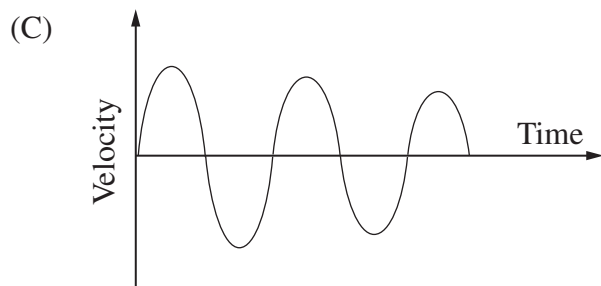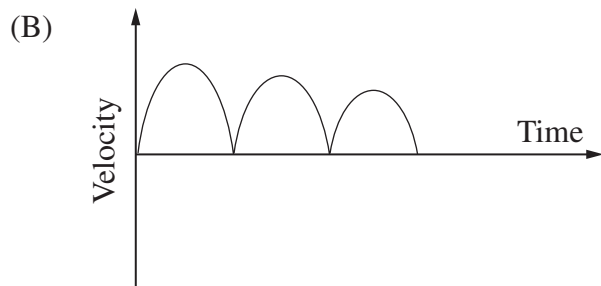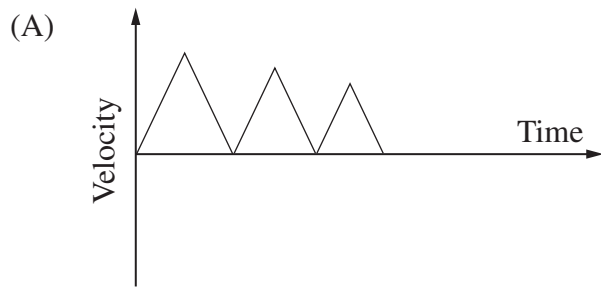
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Physics

Centre Number

Section I (continued)

Student Number

Part B – 60 marks
Attempt Questions 16–26
Allow about 1 hour and 45 minutes for this part

Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

Marks

Question 16 (4 marks)

Muons are very short-lived particles that are created when energetic protons collide with each other. A beam of muons can be produced by very-high-energy particle accelerators.

The high-speed muons produced for an experiment by the Fermilab accelerator are measured to have a lifetime of 5.0 microseconds. When these muons are brought to rest, their lifetime is measured to be 2.2 microseconds.

(a) Name the effect demonstrated by these observations of the lifetimes of the muons.

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(b) Calculate the velocity of the muons as they leave the accelerator.

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– 13 –

Question 17 (6 marks)

A rocket was launched vertically to probe the upper atmosphere. The vertical velocity of the rocket as a function of time is shown in the graph.
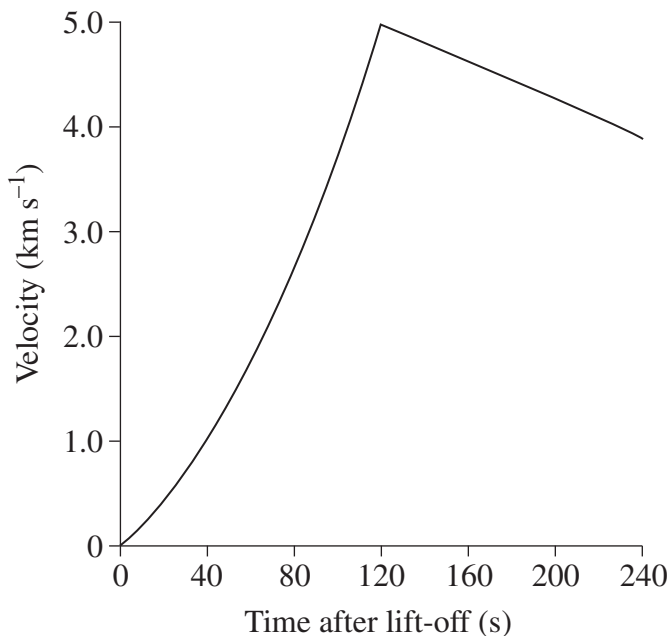
(a) Using either words or calculations, compare the acceleration of the rocket at $t = 20$ s with its acceleration at $t = 100$ s.

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(b) Account for the shape of the graph over the range of time shown.

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Physics

Centre Number

Student Number

Section I – Part B (continued)

Marks

Question 18 (6 marks)

A 30 kg object, *A*, was fired from a cannon in projectile motion. When the projectile was at its maximum height of 25 m, its speed was 20 m s^{-1}.

An identical object, *B*, was attached to a mechanical arm and moved at a constant speed of 20 m s^{-1} in a vertical half-circle. The length of the arm was 25 m.
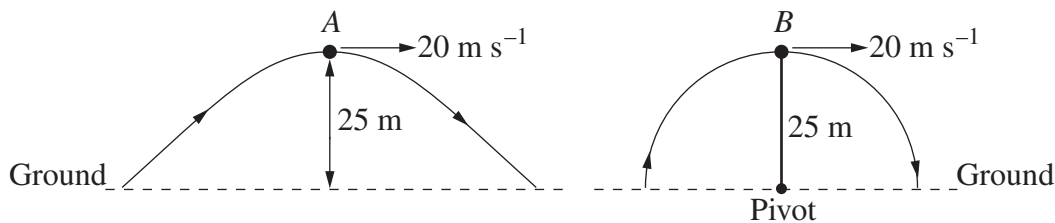
Ignore air resistance.

(a) Calculate the force acting on object *A* at its maximum height.   **1**

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(b) Calculate the time it would take object *A* to reach the ground from its position of maximum height.   **2**

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(c) Describe and compare the vertical forces acting on objects *A* and *B* at their maximum heights.   **3**

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Question 19 (4 marks)

How does Einstein's Theory of Special Relativity explain the result of the Michelson–Morley experiment? **4**

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Question 20 (4 marks)

The electrical supply network uses a.c. and a variety of transformers between the generating stations and the final consumer. **4**

Explain why transformers are used at various points in the network.

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Section I – Part B (continued)

Marks

Question 21 (3 marks)

A fan that ventilates an underground mine is run by a very large d.c. electric motor. This motor is connected in series with a variable resistor to protect the windings in the coil.

3

When the motor is starting up, the variable resistor is adjusted to have a large resistance. The resistance is then lowered slowly as the motor increases to its operating speed.

Explain why no resistance is required when the motor is running at high speed, but a substantial resistance is needed when the motor is starting up.
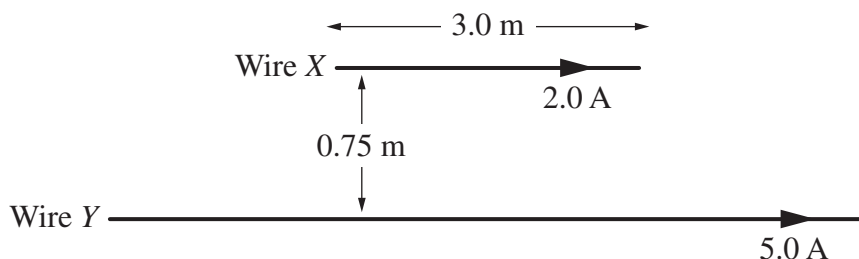
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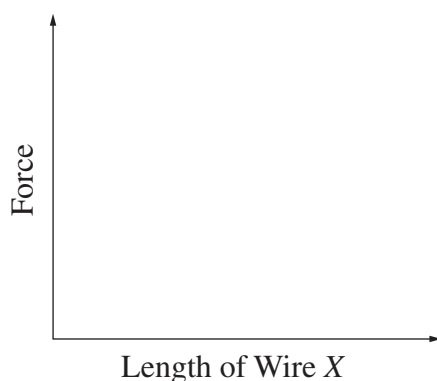
Question 22 (7 marks)

Two parallel wires are separated by a distance of 0.75 m. Wire *X* is 3.0 m long and carries a current of 2.0 A. Wire *Y* can be considered to be infinitely long and carries a current of 5.0 A. Both currents flow in the same direction along the wires.

(a)   What is the direction of the force that exists between the two wires?   **1**

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(b)   On the axes, sketch a graph that shows how the force between the two wires   **2**
    would vary if the length of Wire *X* was increased.

(c)   In your Physics course you have performed a first-hand investigation to   **4**
    demonstrate the motor effect. Explain how your results demonstrated that effect.

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Question 23 (6 marks)

Discuss the effects of the development of electrical generators on society and the environment.

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Centre Number

Section I – Part B (continued)

Student Number

Marks

Question 24 (6 marks)

Sir William Bragg and his son Sir Lawrence Bragg shared the Nobel prize for physics in 1915 for their work on X-ray diffraction and crystal structure analysis.

(a)   Describe ONE way in which an understanding of crystal structure has impacted on science.

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(b)   Outline the methods of X-ray diffraction used by the Braggs to determine the structure of crystals.

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Question 25 (6 marks)

A student carried out an experiment on the photoelectric effect. The frequency of the incident radiation and the energy of the photoelectrons were both determined from measurements taken during the experiment.

The results obtained are shown in the table:

Frequency of incident radiation $(\times 10^{14}\,\text{Hz})$	Energy of photoelectrons $(\times 10^{-19}\,\text{J})$
6.9	1.22
8.2	1.70
9.1	3.70
9.9	3.05
10.6	3.38
11.8	3.91

(a) Graph these results on the grid, including the line of best fit. **4**
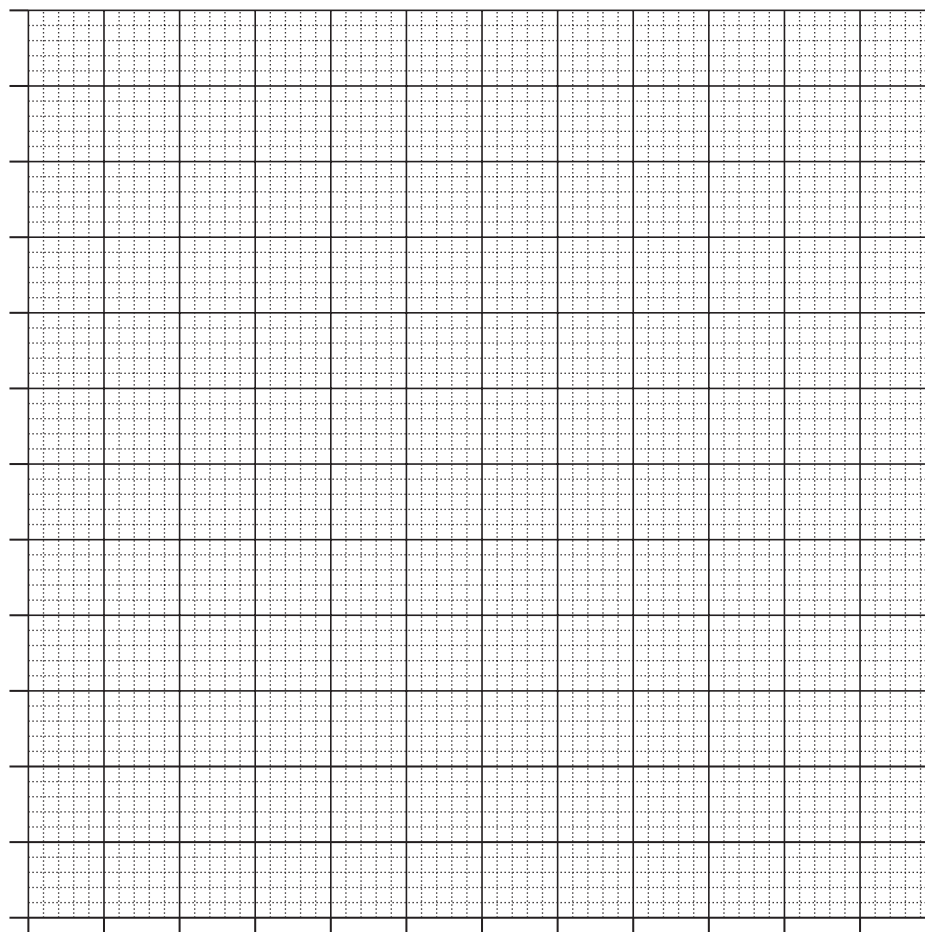
Question 25 continues on page 23

Question 25 (continued)

(b) How could the reliability of the experiment be improved?

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Question 26 (8 marks)

In the context of semiconductors, explain the concept of *electrons* and *holes*.

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Physics

Section II

25 marks
Attempt ONE question from Questions 27–31
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.

Question 27 — Geophysics (25 marks)

(a)   (i)   Name the instrument used in local gravity surveys.   **1**

        (ii)   Describe how that instrument is used in resource exploration.   **2**

(b)   The diagram shows a map of the part of an ocean that includes two chains of features, a chain of islands and a chain of seamounts.
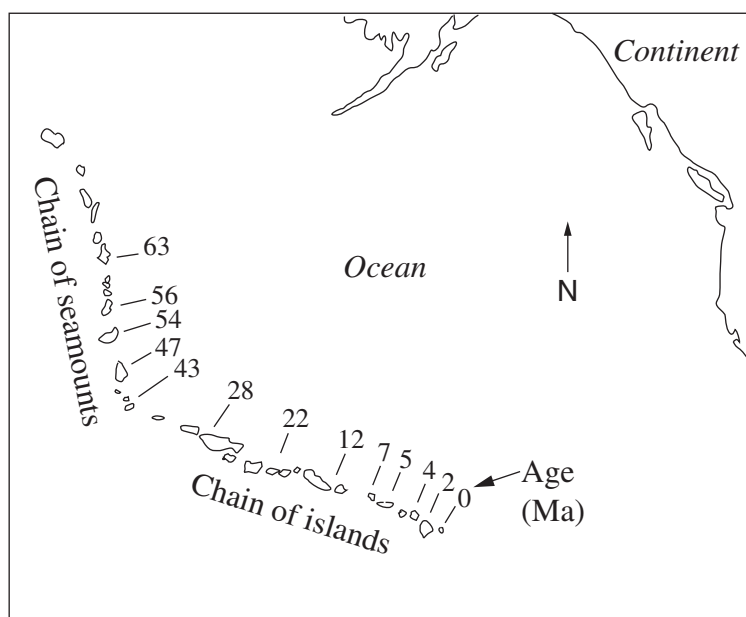
    (i)   Name the geophysical phenomenon that accounts for the shape of the chain of islands.   **1**

    (ii)   Account for the formation and alignment of the chain of islands and the chain of seamounts.   **3**

(c)   Describe how you carried out a first-hand investigation to determine the relationship between the nature of a surface and the radiation reflected from it.   **4**

(d)   When the theory of plate tectonics was first proposed, some parts of the scientific community were reluctant to accept it.   **6**

    Discuss the theory of plate tectonics and the evidence leading to its acceptance.

(e)   Discuss how information gathered from seismic observations has led to greater understanding of the structure of the Earth.   **8**

Question 28 — Medical Physics (25 marks)

(a)   (i)   Identify the purpose of a coherent bundle of optical fibres in an endoscope.   **1**

(ii)   An optical fibre consists of a central core surrounded by cladding. Describe the role of the core and cladding.   **2**

(b)   The table shows information relating to the transmission of sound through some types of body tissue.

Tissue	Acoustic impedance $(\times 10^6 \, \text{kg m}^{-2} \text{s}^{-1})$	Density (kg m^{-3})	Velocity of sound (m s^{-1})
Muscle	1.70	1040	1630
Fat	1.38	945	1460
Bone	7.80	2560	3050

(i)   Identify ONE property of ultrasound.   **1**

(ii)   Justify why, in an ultrasound scan, a boundary between muscle and bone would show up more clearly than would a boundary between muscle and fat.   **3**

(c)   You have conducted a first-hand investigation to demonstrate the Doppler effect. Describe your investigation and conclusions.   **4**

(d)   'CAT scans provide more information than X-rays, so they should be used whenever possible.' Discuss this statement.   **6**

(e)   Explain why MRI can be used to detect cancerous tissues.   **8**

Question 29 — Astrophysics (25 marks)

(a)   (i)   Define the term *binary stars*.   **1**

    (ii)   Describe the characteristics of its spectrum that identify a spectroscopic binary.   **2**

(b)   The table shows information about three stars in the Milky Way galaxy.

Name	Spectral class	Distance from Sun (parsecs)	Apparent magnitude
Betelgeuse	M2	184	+0.41
Achernar	B5	20	+0.47
Deneb	A2	429	+1.24

    (i)   Identify which of the stars has the greatest surface temperature.   **1**

    (ii)   If Deneb and Betelgeuse were viewed from the same distance, which would appear brighter? Justify your answer.   **3**

Question 29 (continued)

(c)   A student carried out an experiment to examine the spectra of various light   **4**
      sources through spectroscopes as shown in the diagram. The student observed
      three different spectra.
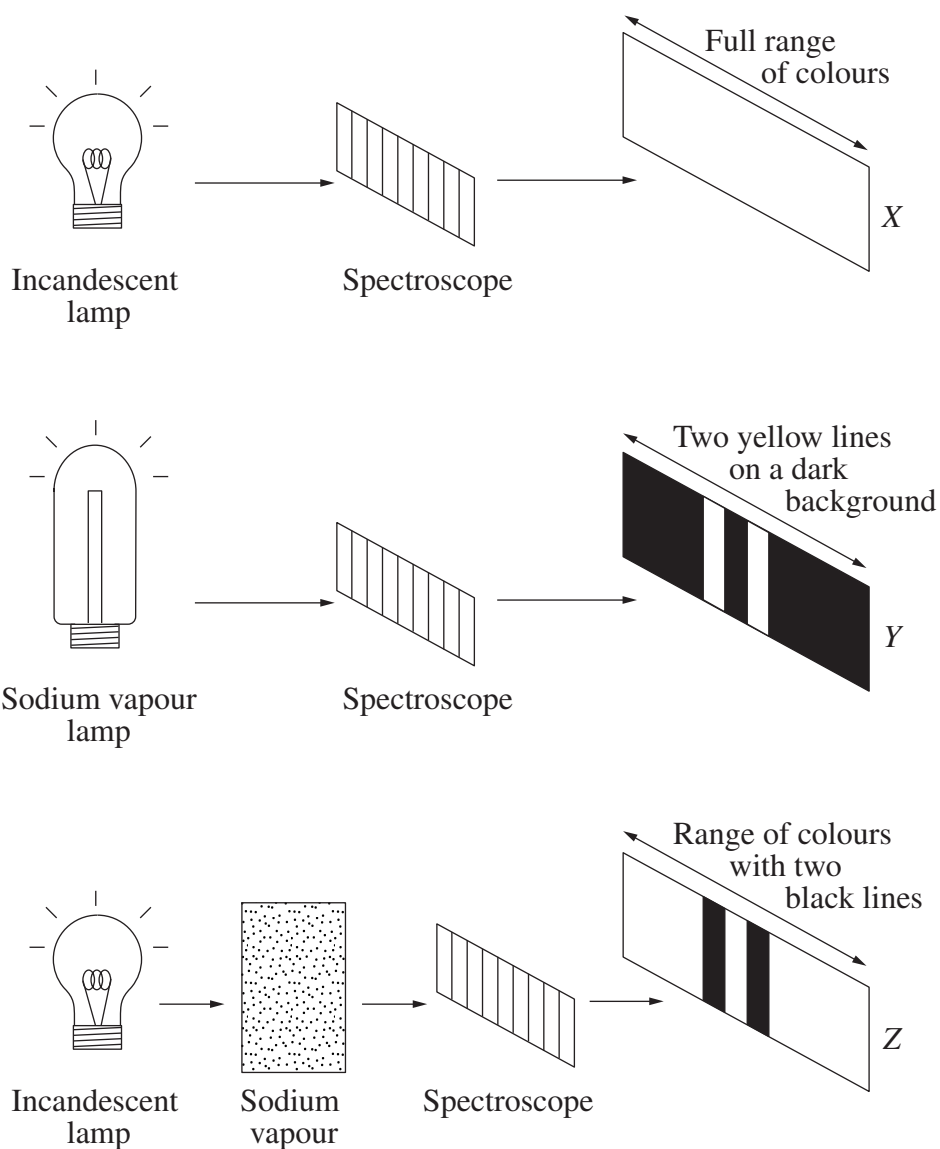
      Account for the differences in the three observed spectra.

(d)   A new generation of Earth-based optical telescopes is advancing optical   **6**
      astronomy. Describe the advances in design that have been incorporated in large
      telescopes over recent years.

(e)   Explain how the data presented in Hertzsprung–Russell diagrams may be used   **8**
      to understand the evolution of stars.

End of Question 29

Question 30 — From Quanta to Quarks (25 marks)

(a)   (i)   Define *nucleon*.   **1**

        (ii)   Contrast ONE property of nucleons.   **2**

(b)   The table shows the quantum numbers of the four lowest states of the hydrogen atom, together with the energies of those states.

Quantum number, n	Energy (joule)
1 (Ground state)	0
2	1.63×10^{-18}
3	1.94×10^{-18}
4	2.04×10^{-18}

        (i)   What is the energy of the photon emitted when an electron in the $n = 4$ level makes a transition to the $n = 3$ level?   **1**

        (ii)   Use the data to draw the energy level diagram for hydrogen, and indicate on this diagram where the energy levels lie for quantum numbers greater than 4.   **3**

(c)   Describe how you carried out a first-hand investigation to determine the penetrating power of alpha, beta and gamma radiation on a range of materials.   **4**

(d)   The Manhattan Project is the codename given to the development of atomic (nuclear fission) bombs during World War II.   **6**

        Discuss the significance of this project for society.

(e)   Analyse how Chadwick's and Fermi's work resulted in a greater understanding of the atom.   **8**

Question 31 — The Age of Silicon (25 marks)

(a) (i) State the name of the transducer that is commonly used in a light meter of a camera.   **1**

  (ii) Describe the relationship between the amount of light incident on the transducer referred to in part (i), and its resistance.   **2**

(b) An ideal differential-input operational amplifier is connected into the following circuit.
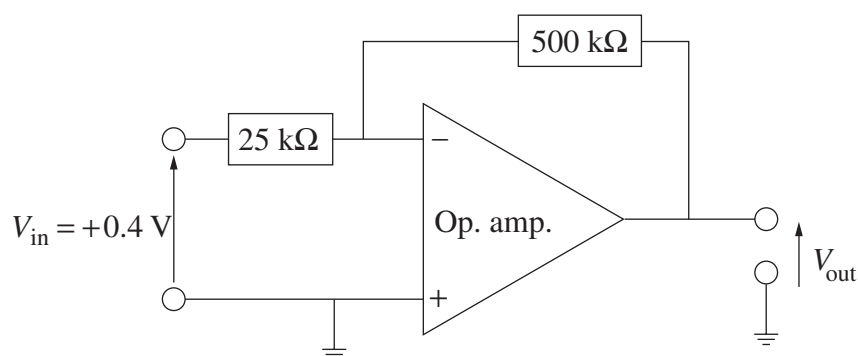
  (i) Explain the function of the 500 kΩ resistor in this circuit.   **1**

  (ii) Determine the output voltage, V_{out}.   **3**

(c) A student constructed the following circuit in which four different logic gates were used. The circuit had two inputs, A and B, and one output, S.   **4**

Gate	Function
1	NAND
2	NOT
3	NOR
4	OR

Key
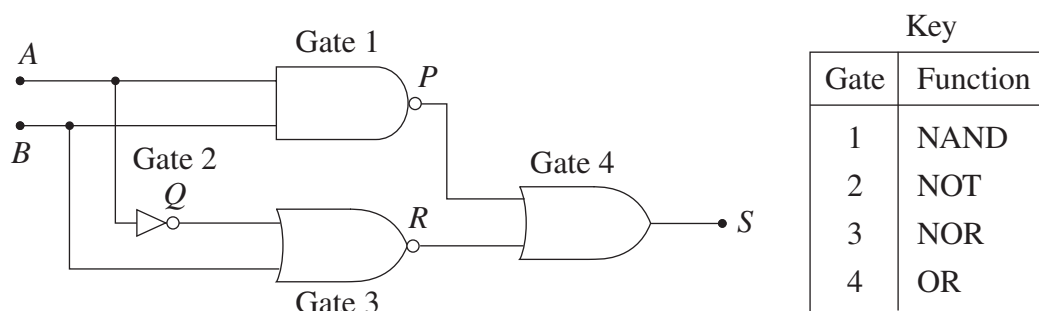
  For each of the possible input states of A and B, construct a truth table showing the output of Gate 1 at P, Gate 2 at Q, Gate 3 at R and Gate 4 at S.

(d) Discuss the possibility that there may be a limit on the growth of computer power.   **6**

(e) Discuss the impact that developments in electronics have had on society.   **8**

End of paper

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Physics

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, $\left(k \equiv \dfrac{\mu_0}{2\pi} \right)$	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's constant, h	6.626×10^{-34} J s
Rydberg's constant, R_H	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

$c = f\lambda$

Intensity $\propto \dfrac{1}{d^2}$

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

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

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

$P = VI$

$\text{Energy} = VIt$

$v_{\text{av}} = \dfrac{\Delta s}{\Delta t}$

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

$\Sigma F = ma$

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

$p = mv$

$\Delta p = Ft$

$F = -\dfrac{Gm_1 m_2}{r^2}$

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

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

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

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

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

$F = BIl \sin\theta$

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

$\tau = Fd$

$\tau = nBIA \cos\theta$

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

FORMULAE SHEET

$$E_p = -\frac{Gm_1m_2}{r}$$

$$v = u + at$$

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

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

$$\Delta x = u_x t$$

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

$$\frac{s}{t} = \frac{u+v}{2}$$

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

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

$$F = qvB\sin\theta$$

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

$$E = hf$$

$$Z = \rho v$$

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

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

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

$$\text{Amplifier gain} = \frac{V_{out}}{V_{in}}$$

$$A_o = \frac{V_o}{V_+ - V_-}$$

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
	Au
Atomic Weight	197.0
	Gold → Name of element

(Au = Symbol of element)

Group 1	Group 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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 65.39 Zinc	31 Ga 69.72 Gallium	32 Ge 72.61 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc [98.91] Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanides	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.8 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po [210.0] Polonium	85 At [210.0] Astatine	86 Rn [222.0] Radon
87 Fr [223.0] Francium	88 Ra [226.0] Radium	89–103 Actinides	104 Rf [261.1] Rutherfordium	105 Db [262.1] Dubnium	106 Sg [263.1] Seaborgium	107 Bh [264.1] Bohrium	108 Hs [265.1] Hassium	109 Mt [268] Meitnerium	110 Uun — Ununnilium	111 Uuu — Unununium	112 Uub — Unununium	113	114 Uuq — Ununquadium	115	116 Uuh — Ununhexium	117	118 Uuo — Ununoctium

Lanthanides

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm [146.9] Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.0 Ytterbium	71 Lu 175.0 Lutetium

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 [239.1] Plutonium	95 Am [241.1] Americium	96 Cm [244.1] Curium	97 Bk [249.1] Berkelium	98 Cf [252.1] Californium	99 Es [252.1] Einsteinium	100 Fm [257.1] Fermium	101 Md [258.1] Mendelevium	102 No [259.1] Nobelium	103 Lr [262.1] Lawrencium

Where the atomic 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.