BOARD OF STUDIES
NEW SOUTH WALES

2005
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, 17, 21 and 25

Total marks – 100

Section I Pages 2–27

75 marks

This section has two parts, Part A and Part B

Part A – 15 marks
- Attempt Questions 1–15
- Allow about 30 minutes for this part

Part B – 60 marks
- Attempt Questions 16–27
- Allow about 1 hour and 45 minutes for this part

Section II Pages 29–43

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

Section I
75 marks

Part A – 15 marks
Attempt Questions 1–15
Allow about 30 minutes for this part

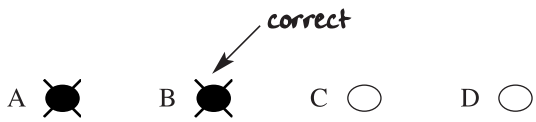
Use the multiple-choice answer sheet.

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

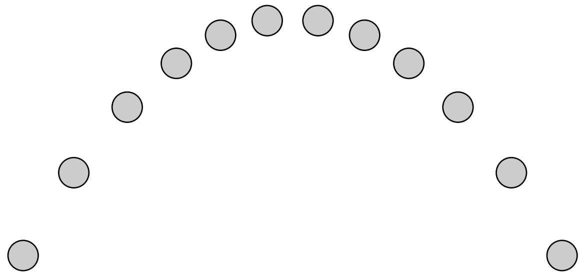
Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

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

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.



1 A ball thrown in the air traces a path as shown below.



Which of the following statements is true?

(A) The velocity of the ball keeps changing.

(B) The acceleration of the ball keeps changing.

(C) The velocity of the ball at the top of its motion is zero.

(D) The acceleration of the ball at the top of its motion is zero.

2 Why would a satellite in low orbit around Earth eventually fall to Earth?

(A) It is not in a geostationary orbit.

(B) Gravity is too strong at low orbits.

(C) The sun's solar wind pushes it out of orbit.

(D) The upper atmosphere gradually slows it down.

3 The initial velocity required by a space probe to just escape the gravitational pull of a planet is called *escape velocity*.

Which of the following quantities does NOT affect the magnitude of the escape velocity?

(A) Mass of the planet

(B) Mass of the space probe

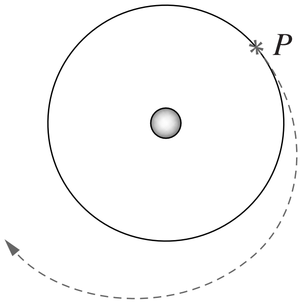
(C) Radius of the planet

(D) Universal gravitational constant

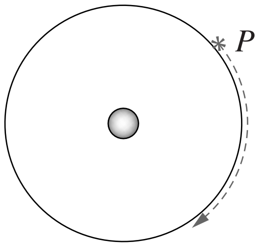
4 A space probe, P, is in a stable orbit around a small, distant planet. The probe fires a forward-facing rocket that reduces its orbital speed by half.

Which of the following best illustrates the subsequent motion of the probe?

(A)



(B)



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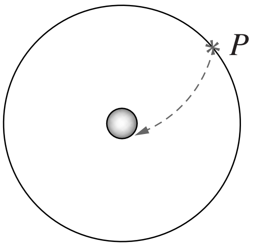
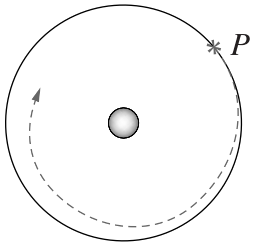


(D)



5 Napoleon attacked Moscow in 1812 with his cannon firing a shot at an elevation angle of 40°. Napoleon then decided to fire a second shot at the same speed but at an elevation angle of 50°.

Which of the following observations would Napoleon expect to be true about the second shot when compared with the first?

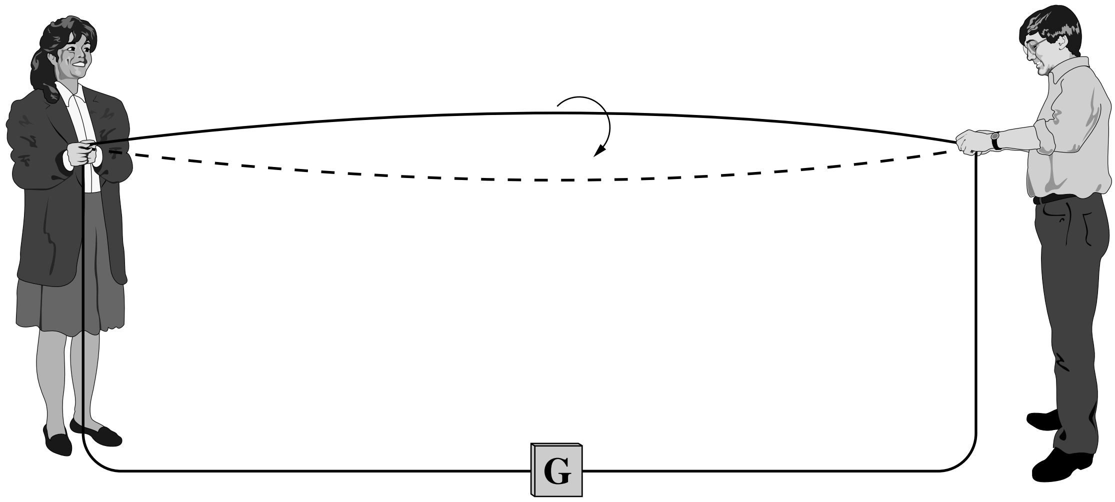
(A) Longer range

(B) Shorter range

(C) Longer time of flight

(D) Shorter time of flight

6 In a particular experiment a long length of copper wire of very low resistance is rotated by two students. The ends of the wire are connected to a galvanometer, G, and a current is detected.



Which of the following is LEAST likely to affect the amount of current produced?

(A) The length of the rotating wire

(B) The thickness of the rotating wire

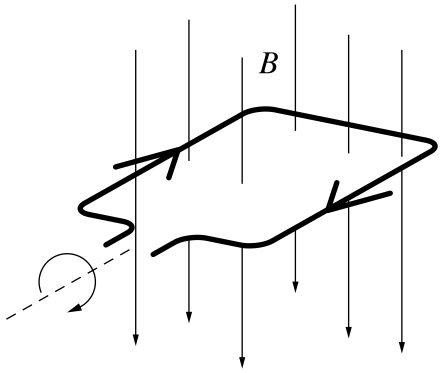
(C) The speed with which the wire is rotated

(D) Whether the wire is oriented north-south or east-west

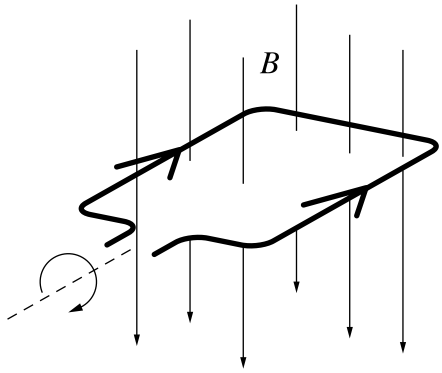
7 A single-turn coil of wire is placed in a uniform magnetic field *B* at right angles to the plane of the coil as shown in the diagrams. The coil is then rotated in a clockwise direction as shown.

Which of the following shows the direction of current flow in the coil as it begins to rotate?

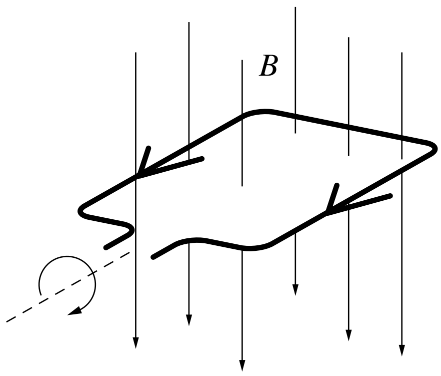
(A)



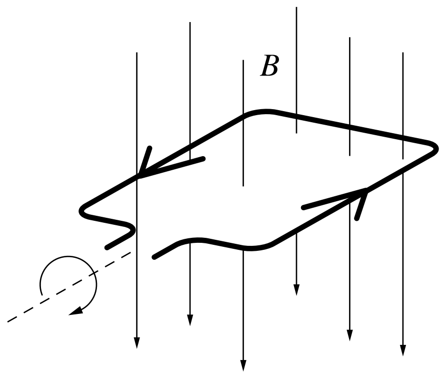
(B)



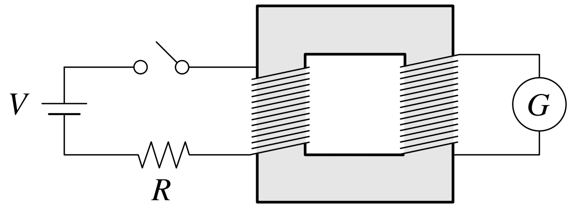
(C)



(D)

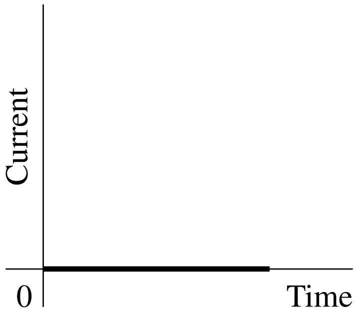


8 The primary coil of a transformer is connected to a battery, a resistor and a switch. The secondary coil is connected to a galvanometer.

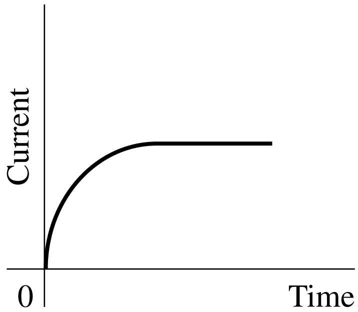


Which of the following graphs best shows the current flow in the galvanometer when the switch is closed?

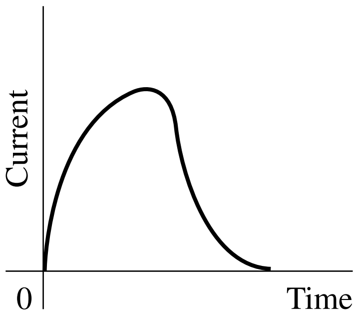
(A)



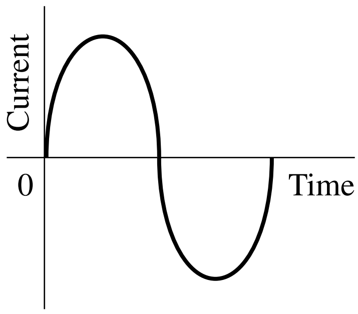
(B)



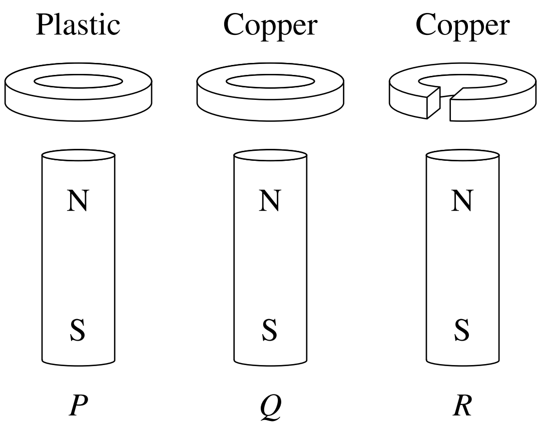
(C)



(D)



9 Three rings are dropped at the same time over identical magnets as shown below.



Which of the following describes the order in which the rings P, Q and R reach the bottom of the magnets?

(A) They arrive in the order P, Q, R.

(B) They arrive in the order P, R, Q.

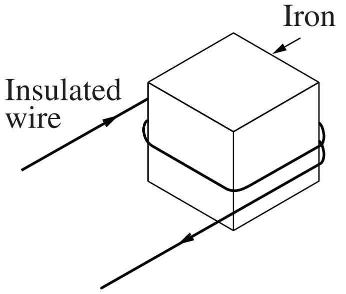
(C) Rings P and R arrive simultaneously, followed by Q.

(D) Rings Q and R arrive simultaneously, followed by P.

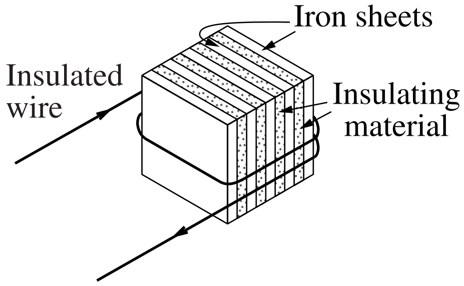
10 A transformer is to be designed so that it is efficient, with heating by eddy currents minimised. The designer has some iron and insulating material available to build the transformer core. The windings are to be made with insulated copper wire.

Which of the following designs minimises the energy losses in the core?

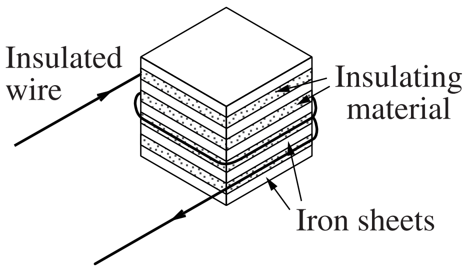
(A)



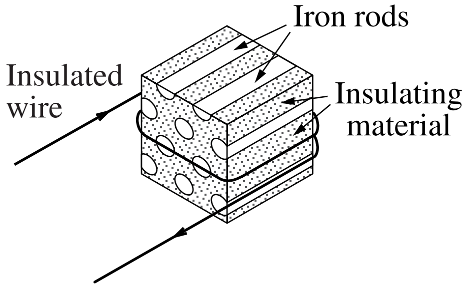
(B)



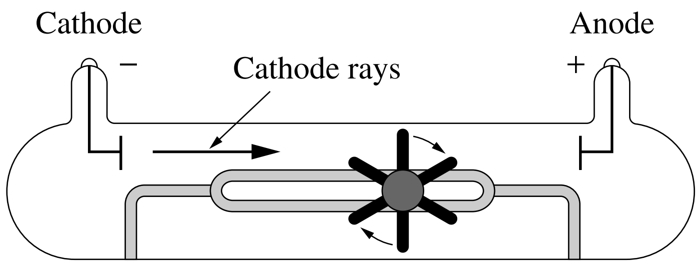
(C)



(D)



11 The discharge tube shown below contains a rotating paddle wheel that is free to move. The tube's electrodes are connected to a high-voltage source.



Which of the following statements about cathode rays does this apparatus provide evidence for?

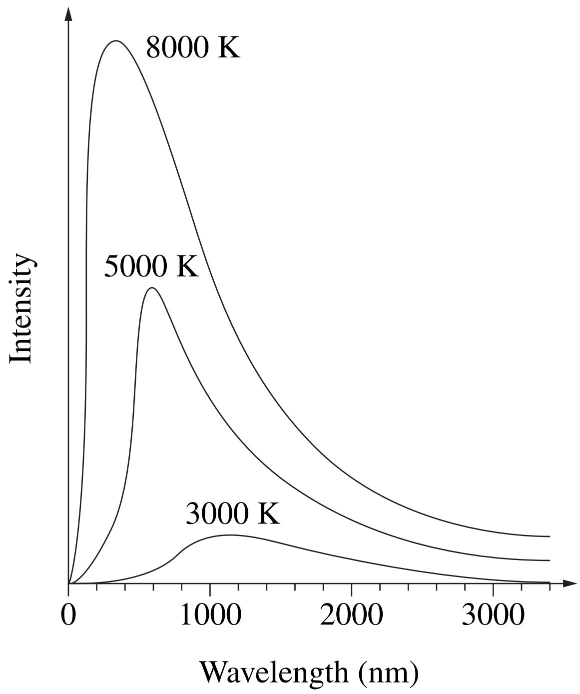
(A) Cathode rays travel in straight lines.

(B) Cathode rays are particles that have momentum.

(C) Cathode rays can only be produced in vacuum tubes.

(D) Cathode rays are waves of high frequency and short wavelength.

12 The family of curves below shows the relationship between the intensity of black body radiation and its wavelength for various Kelvin temperatures.



Who was the first to correctly explain this relationship?

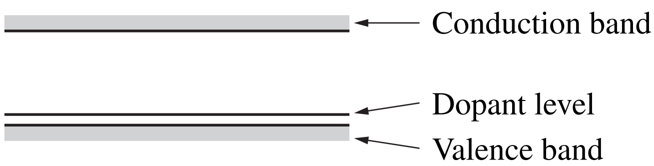
(A) Planck, in 1900, when he suggested energy at the atomic level was quantised

(B) Einstein, in 1905, when he suggested light was a stream of particles called photons

(C) Rutherford, in 1911, when he suggested the nuclear model of the atom

(D) Bohr, in 1913, when he suggested electrons exist in stationary states

13 A doped silicon semiconductor has the following energy-level diagram.



What element was most likely used to dope the silicon?

(A) Boron

(B) Germanium

(C) Phosphorus

(D) Sulfur

14 An FM radio station transmits at a frequency of 102.8 MHz.

What is the energy, in joules, of each photon emitted by the transmitter?

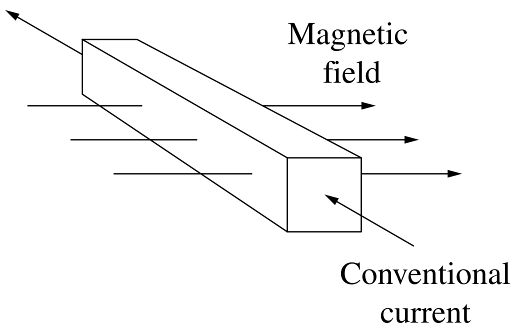
(A) 6.446×10^{-42}

(B) 6.812×10^{-26}

(C) 2.918

(D) 3.084×10^{16}

15 A current is passed along a square semiconductor rod as shown. Half of the current is carried by electrons and half by holes. A magnetic field is then applied to the rod at right angles to its axis.



Which of the following correctly describes the movement of the electrons and holes in the rod when the magnetic field is applied?

(A) They speed up.

(B) They slow down.

(C) They move to the same side of the rod.

(D) They move to opposite sides of the rod.

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2005 HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

Centre Number

Student Number

Section I (continued)

Part B – 60 marks
Attempt Questions 16–27
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 (5 marks)

From nearest to furthest, the four satellite moons of Jupiter first observed by Galileo in the year 1610 are called Io, Europa, Ganymede and Callisto. For the first three moons, the orbital period **T** of each is exactly twice the period of the one orbiting immediately inside it. That is,

$$\mathbf{T}_{\text{Europa}} = 2 \times \mathbf{T}_{\text{Io}}$$

$$\mathbf{T}_{\text{Ganymede}} = 2 \times \mathbf{T}_{\text{Europa}}$$

The mass of Jupiter is 1.90×10^{27} kg, and the orbital radius of Io is 421 600 km.

(a) Use Kepler's Law of Periods to calculate Ganymede's orbital radius. **2**

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(b) Calculate Ganymede's orbital speed. **3**

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Marks

Question 17 (6 marks)

Einstein's 1905 theory of special relativity made several predictions that could not be verified for many years.

(a) State ONE such prediction. **1**

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(b) Describe an experiment to test this prediction. **2**

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(c) Explain how technological advances since 1905 have made it possible to carry out this experiment. **3**

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Marks

Question 18 (4 marks)

The idea of a universal aether was first proposed to explain the transmission of light through space. Michelson and Morley attempted to measure the speed of Earth through the aether. **4**

Evaluate the impact of the result of the Michelson and Morley experiment on scientific thinking.

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Please turn over

Marks

Question 19 (4 marks)

In 1970 NASA launched Apollo 13, their third mission planned to land humans on the Moon. Half-way to the Moon a huge explosion crippled the spacecraft. The only way home for the astronauts was to fly around the back of the Moon and then fire the rocket engine to take the craft out of lunar orbit and put it into an Earth-bound trajectory. **4**

At the completion of the rocket engine burn, mission leader Jim Lovell was heard to say, ‘We just put Isaac Newton in the driver’s seat’.

Given that the spacecraft returned safely to Earth, justify Jim Lovell’s statement.

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2005 HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

Centre Number

Student Number

Section I – Part B (continued)

Marks

Question 20 (6 marks)

In your course you had to gather information to explain how induction is used in certain applications. **6**

With reference to TWO applications, describe how you assessed the reliability of information you found.

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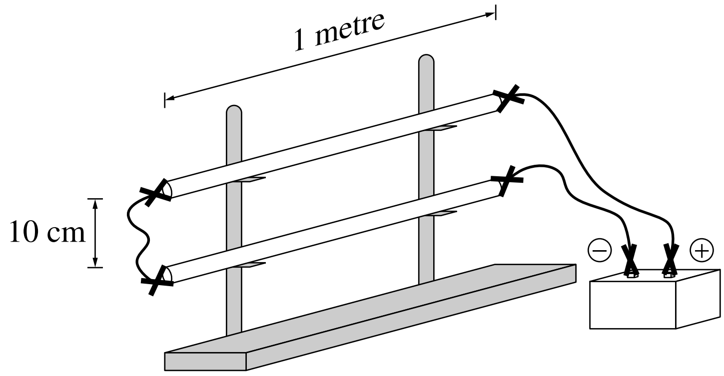
Marks

Question 21 (6 marks)

Two thin metal tubes one metre long were supported in a vertical wooden rack as shown in the diagram.



The two ends were connected together, then the other two ends were connected briefly to a car battery as shown in the diagram. It was observed that one of the tubes jumped upward as the connection was made.

(a) Explain why only one tube jumped upward. **2**

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(b) Each tube has a mass of 1×10^{-2} kg, and the tubes lie on the rack 10 cm apart. **3**

What minimum current flows when one tube jumps?

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(c) What is the implication of this result for power distribution networks? **1**

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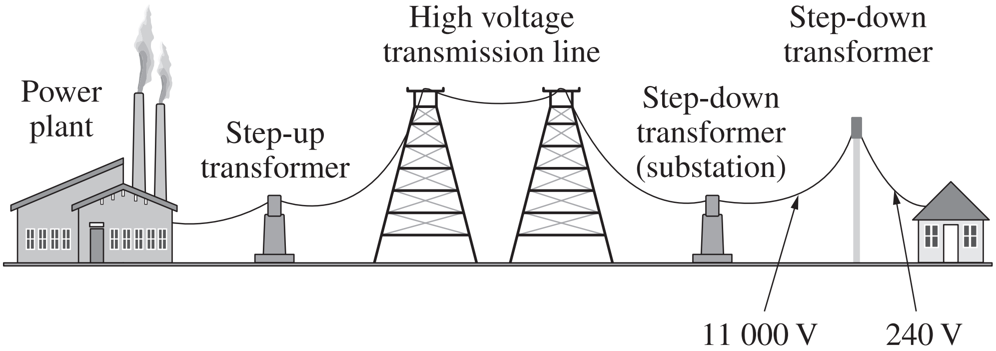
Marks

Question 22 (5 marks)

A schematic diagram of a system to supply electricity to a house is shown below.



J D Cutnell & K W Johnson, 2001, *Physics*, 5th edn. Reprinted with permission of John Wiley & Sons, Inc.

The step-down transformer in the substation has a turns ratio of 30 : 1.

(a) What is the voltage carried by the high voltage transmission line? **1**

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(b) Identify the causes of the two main energy losses in the transmission of electricity between the power plant and the house. **2**

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(c) Explain how the application of superconductivity could minimise energy loss in the system. **2**

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Marks

Question 23 (3 marks)

Explain how an understanding of black body radiation changed the direction of scientific thinking in the early twentieth century. **3**

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Centre Number

Section I – Part B (continued)

Student Number

Marks

Question 24 (4 marks)

Using labelled diagrams and text, explain how superconductivity occurs according to the BCS theory. **4**

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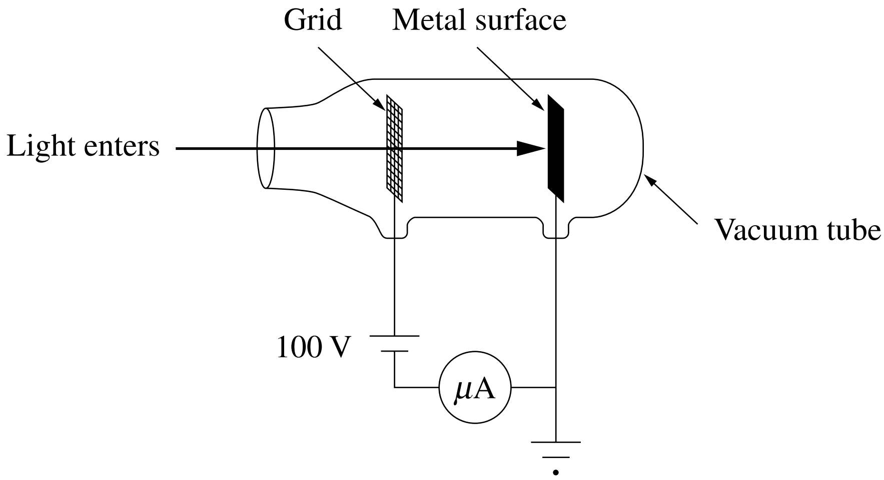
Question 25 (6 marks)

A student conducts an experiment using a photoelectric cell as shown in the diagram.



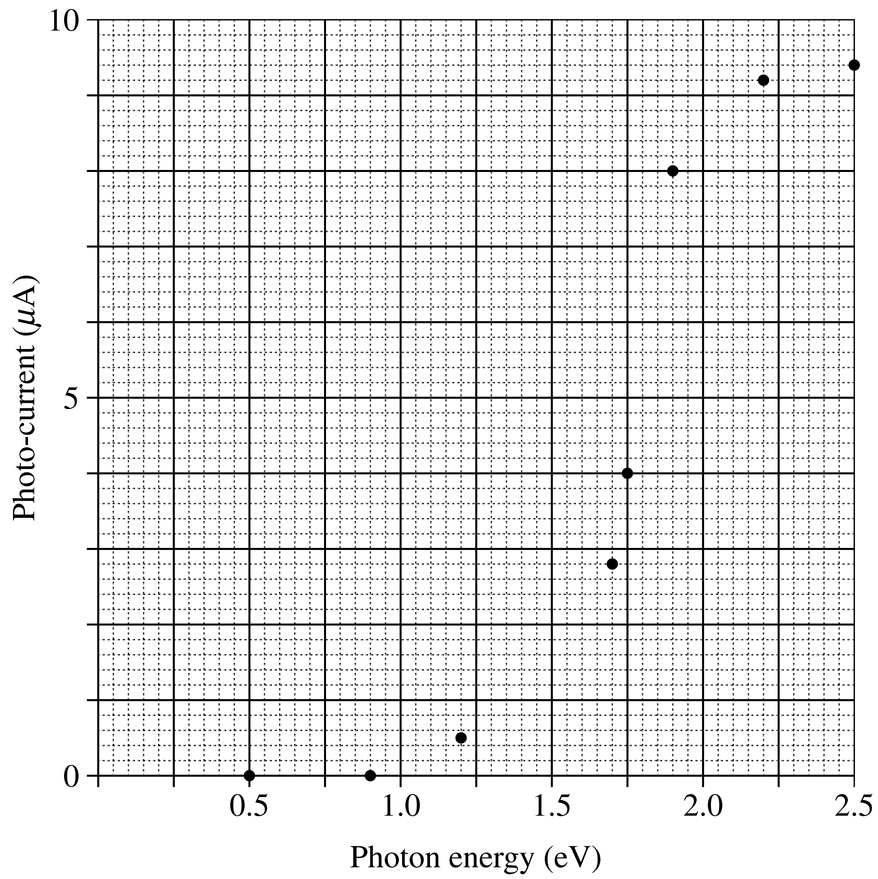
Light is shone through a grid onto a metal surface. The metal is at earth potential and the grid is at 100 V, so that any electrons emitted from the surface produce a current in the external circuit.

The student shines light sources of different photon energies onto the metal surface and records the current flowing for each. The light sources are adjusted so that their intensities are equal. The results are recorded in the table and shown on the graph.

Photon energy (eV)	*Photo-current* (μA)
0.50	0
0.90	0
1.20	0.5
1.70	2.8
1.75	4.0
1.90	8.0
2.20	9.2
2.50	9.4

Question 25 continues on page 23

Question 25 (continued)



(a) On the grid provided, draw the straight line of best fit in the region where the photo-current varies greatest with photon energy. **1**

(b) From the line drawn on your graph, estimate the minimum energy (work function) for photoelectric emission. **1**

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(c) The experiment is repeated, but the intensities of the light sources are doubled. Predict the results of this new experiment by drawing a second line on the graph. **2**

(d) Justify the line you have drawn in part (c). **2**

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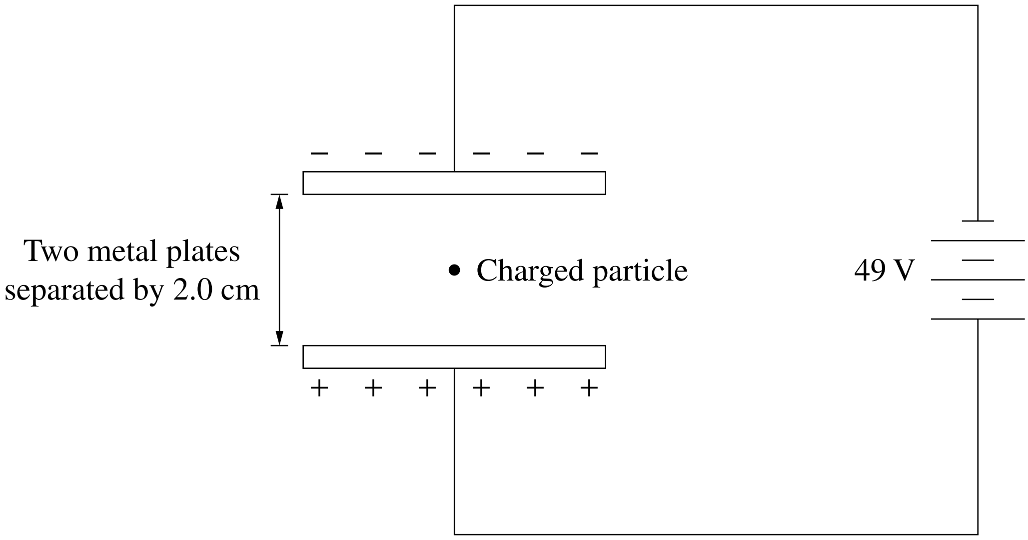
End of Question 25

Marks

Question 26 (5 marks)

The diagram shows two parallel horizontal metal plates connected to a DC source of electricity. Suspended between the plates is a charged particle of mass 9.6×10^{-6} kg.



(a) Using conventional symbols, draw the electric field between the metal plates on the diagram above. **1**

(b) Determine the magnitude of the electric field between the plates. **1**

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(c) Determine the sign and magnitude of the charge on the particle if it is suspended motionless between the plates. **3**

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Centre Number

Section I – Part B (continued)

Student Number

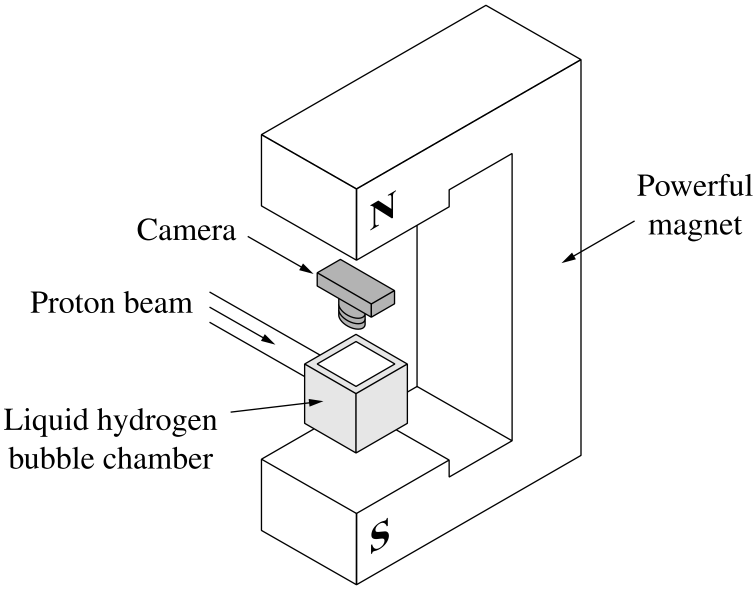
Question 27 (6 marks)

Please turn over

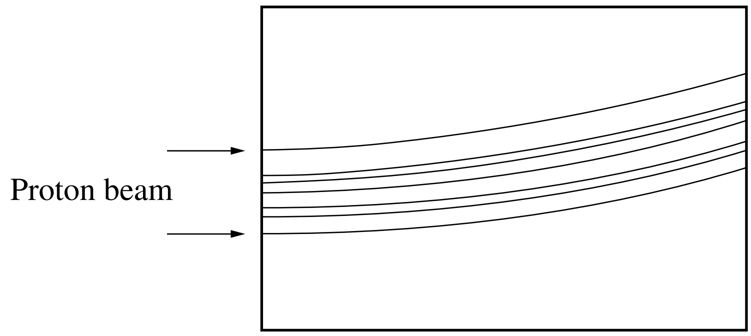
Question 27 (6 marks)

Bubble chambers are used in conjunction with particle accelerators to photographically record the tracks of fast-moving charged particles. An intense magnetic field is applied at right angles to the path of the particles to deflect them according to their charge and momentum.

The diagram shows a beam of protons travelling horizontally at 6.0×10^{7} m s^{-1} and entering a liquid hydrogen bubble chamber in a vertical magnetic field of 1.82 T.



Examination of the photograph taken by the camera, as sketched below, shows that the protons were deflected along a circular path of radius 0.350 metres.



Proton tracks in bubble chamber

Question 27 continues on page 27

Marks

Question 27 (continued)

(a) Derive an expression for the momentum of a proton from the forces it experiences in this experiment. **2**

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(b) Calculate the mass of a proton in the bubble chamber. **2**

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(c) Calculate the rest mass of a proton found from this experiment. **2**

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End of Question 27

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Section II

25 marks
Attempt ONE question from Questions 28–32
Allow about 45 minutes for this section

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

Show all relevant working in questions involving calculations.

		Pages
Question 28	Geophysics	30–31
Question 29	Medical Physics	32–35
Question 30	Astrophysics	36–38
Question 31	From Quanta to Quarks	39–41
Question 32	The Age of Silicon	42–43

Marks

Question 28 — Geophysics (25 marks)

(a) During your study of geophysics you investigated the radiation reflected from various surfaces.

(i) Identify the equipment you used to obtain your results. **2**

(ii) Describe the use of reflected radiation in obtaining information about Earth from a distance. **2**

(b) On 6 December 2004 a meteor exploded in the atmosphere above northern NSW. The blast was detected by sensitive microphones in Hobart at 5.25 am (AEST) and in Tennant Creek at 6.12 am (AEST).

AEST = Australian Eastern Standard Time

Awaiting Copyright Clearance

(i) If Hobart is 1320 km from the explosion, how far is Tennant Creek from the explosion? **2**

(ii) Similar microphones have detected volcanic explosions such as the Mount St Helens (USA) volcanic explosion in 1980. **4**

Identify another geophysical technique and explain how it is used to locate a volcanic explosion.

Question 28 continues on page 31

Marks

Question 28 (continued)

(c) The development of technologies that increased our understanding of Earth's magnetic field led to the acceptance of the principle of plate tectonics. **7**

Evaluate this statement.

(d) The diagram below shows the deflection of a plumb-bob near a large mountain range. The diagram exaggerates the amount of deflection.

Awaiting Copyright Clearance

(i) Explain why the plumb-bob is deflected towards the mountain range. **2**

(ii) The observed deflection towards the mountain range is not as great as predicted due to the mountains alone. **3**

What is the implication of this for plate tectonics?

(iii) Describe how Jean Richer used a pendulum to show that Earth is not spherical. **3**

End of Question 28

Marks

Question 29 — Medical Physics (25 marks)

(a) (i) The images show a person's heart before and after a medical procedure. **2**

Awaiting Copyright Clearance

Abnormal heart before procedure

Heart after procedure

Describe how radioactive isotopes have been used to identify the abnormality and confirm its correction.

(ii) The table provides examples of some radioactive isotopes and their properties. **2**

Radioactive source	*Radiation emitted*	*Half-life*
^{11}C	Gamma	20.30 minutes
^{99}Tc	Gamma	6.02 hours
^{201}Tl	Gamma	3.05 days
^{131}I	Gamma	8.04 days
^{137}Cs	Alpha	30.17 years
^{238}U	Alpha	4.47×10^9 years

Which radioactive isotope from the table would most likely be used to investigate the abnormality shown in the image above? Justify your choice.

Question 29 continues on page 33

(b) (i) The acoustic impedance of fat is $1.38 \times 10^{6}\ \text{kg m}^{-2}\ \text{s}^{-1}$.

The acoustic impedance of bone is $7.80 \times 10^{6}\ \text{kg m}^{-2}\ \text{s}^{-1}$.

What percentage of the incident intensity of an ultrasound wave is reflected as it crosses from fat into bone?

(ii) Compare the physics involved in producing X-ray images with that used for endoscopies.

(c) The images demonstrate advances in the use of ultrasound as a tool in medical diagnosis.

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Describe advances in technology that have enabled the improvements shown in these images, and discuss current issues that have arisen from these advances.

Question 29 continues on page 34

Marks

Question 29 (continued)

(d) (i) The following diagram shows the constituent parts of an MRI system. **2**

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State the functions of the superconducting magnet assembly and the radio frequency (RF) coils in the MRI system.

Question 29 continues on page 35

Marks

(ii) The use of MRI may be improved by the introduction of gadolinium into the body. **2**

T_1 curves for tissues *A* and *B* without gadolinium in the body

T_1 curves for tissues *A* and *B* with gadolinium in the body

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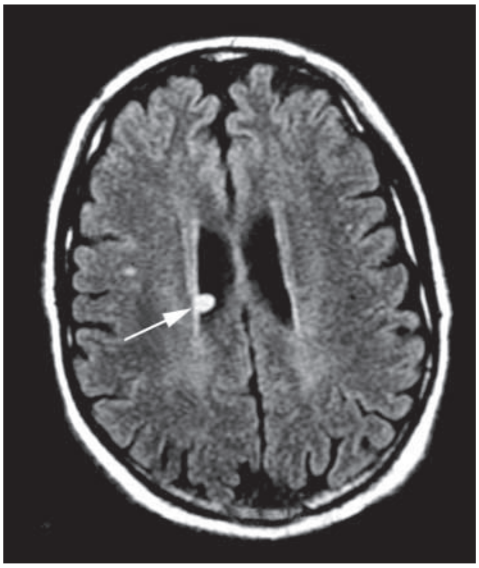
Explain why gadolinium has been introduced.

(iii) The arrow indicates an abnormality that has been detected in one hemisphere of the brain.

MRI brain scan



Identify the advantages of MRI over a CAT scan in detecting this abnormality.

End of Question 29

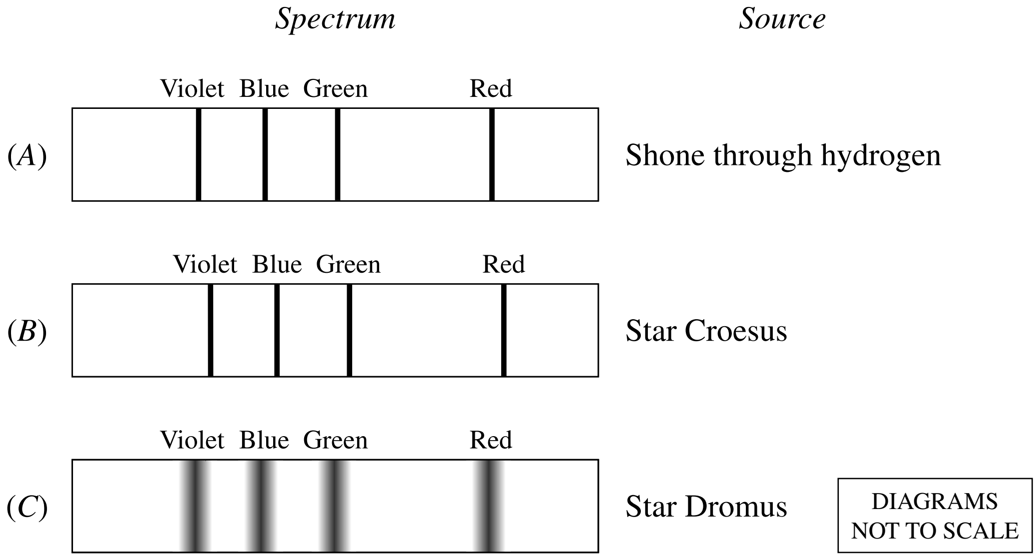
Marks

Question 30 — Astrophysics (25 marks)

(a) Part *A* of the figure shows the absorption spectrum of light, produced by an incandescent filament, after it has been shone through a quantity of hydrogen gas.

Also shown in the figure are the spectra obtained from two stars, Star Croesus in part *B* and Star Dromus in part *C*.

The dark lines are absorption bands in *A*, *B* and *C*.



(i) For each star, Croesus and Dromus, identify the principal way in which its spectrum differs from the spectrum shown in part *A* of the figure. **2**

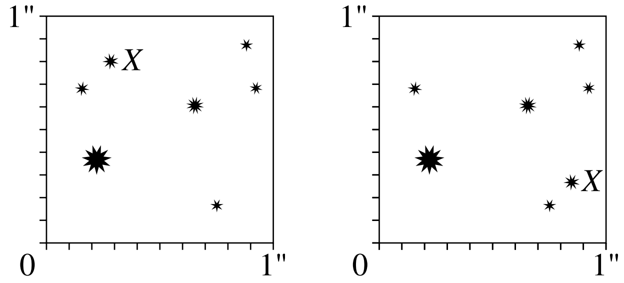
(ii) For each star, Croesus and Dromus, state what its spectrum tells us about the motion of that star. **2**

Question 30 continues on page 37

Marks

Question 30 (continued)

(b) (i) Photographs taken of a one arcsecond by one arcsecond sector of the night sky show a group of fixed stars. Scales have been added to the photographs. One star appears to change position, swinging backward and forward over a period of one year. Two photographic negatives taken when the star was at the furthest ends of its apparent travel are shown. The star is marked *X*. **2**



Calculate the distance of the star *X* from Earth.

(ii) When viewed through a telescope, the star Alpha Centauri is seen to be three stars close together. Two of them are the very bright Alpha Centauri *A* and the very faint Proxima Centauri. These stars are 1.3 pc from Earth. Their magnitudes are given in the table below. **4**

Star	*Absolute magnitude*
Alpha Centauri *A*	+ 4.33
Proxima Centauri	+14.93

What is the ratio of their apparent brightnesses?

(c) The Hertsprung–Russell (or H–R) diagram relates the magnitude or brightness of stars to their spectral classes or temperatures. **7**

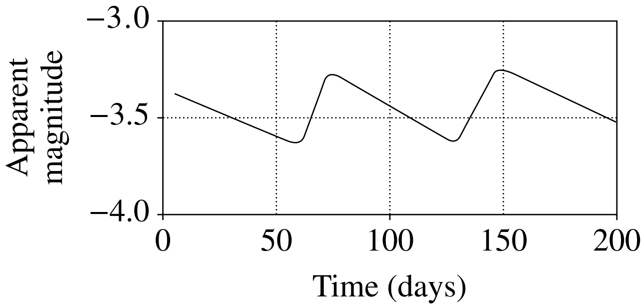
Describe the technological advances that have made it possible to add astrophysical data to the H–R diagram, and explain how this data contributes to our understanding of stellar evolution.

Question 30 continues on page 38

Marks

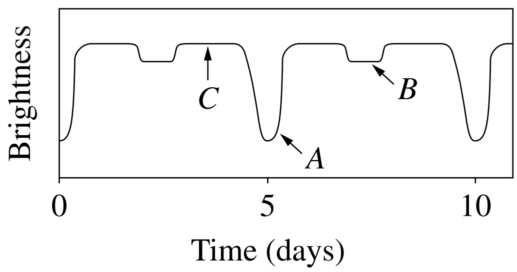
Question 30 (continued)

(d) (i) The graph shows the apparent magnitude of a supergiant star recorded over a period of time. The star is identified as a Type I Cepheid variable. **2**



Explain how the period of oscillations in apparent magnitude may be used to determine the distance of the star.

The graph shows the brightness of a star system recorded over a period of time. The star system is identified as a binary pair, and measurements show them to be 5.0×10^{10} m apart. One star is known to have four times the mass of the other.



(ii) Explain what causes each of the features *A*, *B* and *C* labelled on the graph. **3**

(iii) Determine the mass of the star with the smaller mass. **3**

End of Question 30

Marks

Question 31 — From Quanta to Quarks (25 marks)

(a) During your study of From Quanta to Quarks you either performed a first-hand investigation, or you gathered information to observe nuclear radiation using a Wilson cloud chamber, or similar detection device.

Below is a true-size photograph in this type of device showing the tracks made by α-particles.

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(i) Explain the appearance of these tracks in terms of properties of α-particles. **2**

(ii) Name another type of nuclear radiation, and describe differences in the tracks it would make. **2**

Question 31 continues on page 40

Question 31 (continued)

(b) Naturally occurring uranium-238 spontaneously disintegrates according to the equation

$$\text{U} \rightarrow \text{Th} + \alpha + \gamma.$$

The thorium radionuclide undergoes further decay according to the equation

$$\text{Th} \rightarrow Q + \beta + \overline{v} + \gamma.$$

(i) Identify the mass number of the thorium radionuclide. **1**

(ii) Identify the nuclide Q, stating its mass number. **2**

(iii) Describe Wolfgang Pauli's contribution to Enrico Fermi's explanation of beta decay. **3**

(c) An understanding of the nucleus led to the Manhattan Project, which was based in laboratories in Los Alamos between 1942 and 1945. **7**

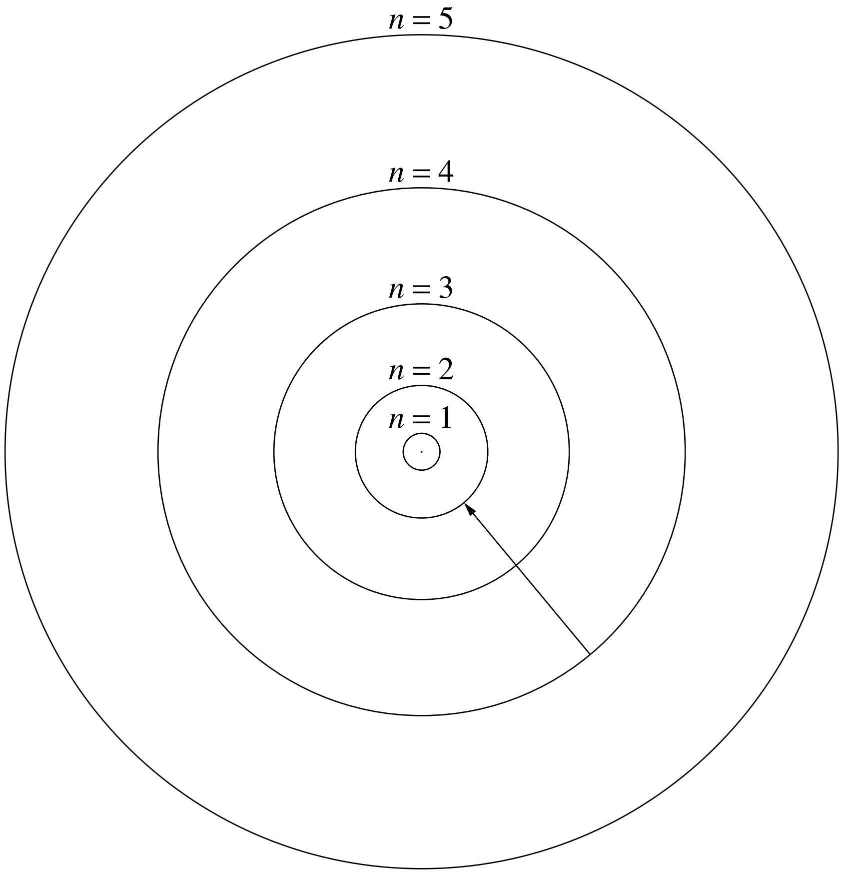
Describe the technologies developed from this project, and assess the significance to science and society of their applications.

Question 31 continues on page 41

Marks

Question 31 (continued)

(d) The diagram below shows the first five circular Bohr orbits or 'stationary states' for the electron orbiting the nucleus of the hydrogen atom.



(i) For the electron transition shown on the diagram, calculate the wavelength of the emitted photon. **2**

(ii) State de Broglie's hypothesis, and calculate the wavelength of the electron in the first stationary state if its speed is $2.188 \times 10^6 \text{ m s}^{-1}$. **3**

(iii) Describe how de Broglie's hypothesis extended the work of Bohr in explaining the stability of electron orbits in the hydrogen atom. **3**

End of Question 31

Marks

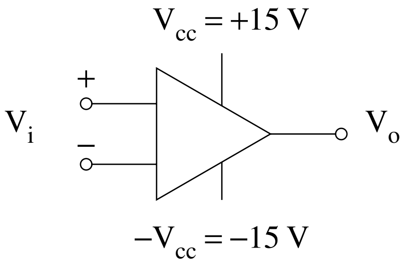
Question 32 — The Age of Silicon (25 marks)

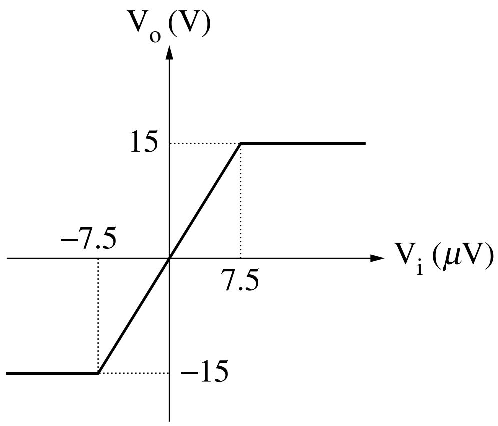
(a) (i) Write down the truth table for the logical expression **2**

$$C = \text{NOT } (A \text{ AND } B)$$

(ii) Describe the function of a half-adder, and draw a circuit diagram to show how logic gates can be used in combination to make a half-adder. **2**

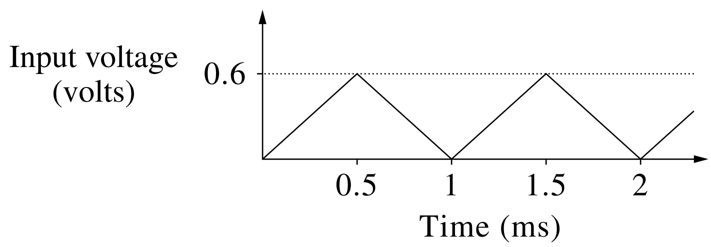
(b) An operational amplifier has the transfer characteristic shown.





(i) Design an amplifier with a gain of −50 using the above operational amplifier, and describe the difference between open-loop and closed-loop gain in your amplifier. **4**

(ii) In your writing booklet, sketch the output voltage of your amplifier as a function of time if the input voltage is a triangular wave as shown. **2**



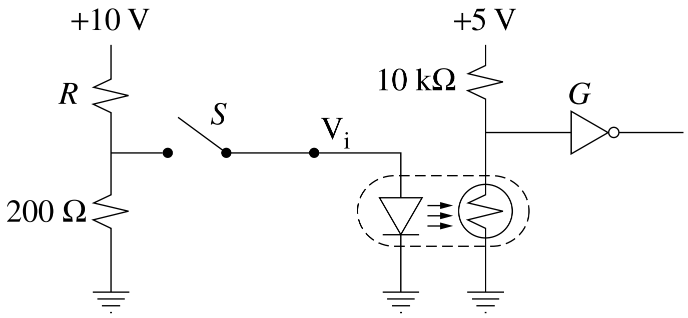
Question 32 continues on page 43

(c) Over the last ten years the ability to acquire, store and manipulate digital images has increased dramatically. **7**

Describe the advances in semiconductor technology responsible for this increased ability, and explain how such changes have led to new consumer electronics applications.

(d) (i) Distinguish between input and output transducers, giving an example of each. **2**

(ii) The circuit below uses an optical isolator (comprising a LED and LDR) to electronically isolate a switch *S* from a digital gate *G*. **3**



When switch *S* is closed, a current of 20 mA flows through the LED and the voltage V_i is 1.6 V.

Determine the resistance *R*.

(iii) The following table shows a variation of the resistance of the LDR as a function of LED current. **3**

LED current	*LDR resistance*
30 mA	190 Ω
20 mA	290 Ω
10 mA	600 Ω
1 mA	20 kΩ
< 0.1 mA	> 1 MΩ

Show, using calculations, how the digital output of the gate *G*, either ‘1’ or ‘0’, depends on whether the switch is open or closed.

End of paper

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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

$$v = f\lambda$$

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

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

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

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

$$P = VI$$

$$\text{Energy} = VIt$$

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

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

$$\Sigma F = ma$$

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

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

$$W = Fs$$

$$p = mv$$

$$\text{Impulse} = Ft$$

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

$$F = mg$$

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

$$v = u + at$$

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

$$\Delta x = u_x t$$

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

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

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

$$E = mc^2$$

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

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

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

FORMULAE SHEET

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

$$F = BIl\sin\theta$$

$$\tau = Fd$$

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

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

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

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

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

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

$$F = qvB\sin\theta$$

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

$$E = hf$$

$$c = f\lambda$$

$$Z = \rho v$$

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

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

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

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

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

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79	Symbol of element	
	Au		
Atomic Weight	197.0	Name of element	
	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 65.41 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 [97.91] 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 144.2 Neodymium	61 Pm [144.9] 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.