BOARD OF STUDIES
NEW SOUTH WALES

2002

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 23

Total marks – 100

Section I Pages 2–25

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 27–37

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.

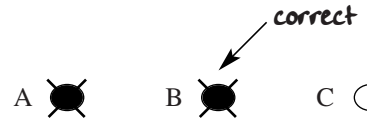
Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

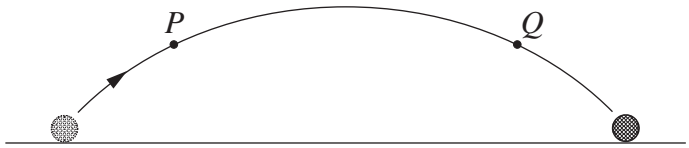
If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

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.



1 The diagram shows the trajectory of a golf ball.



Which set of arrows shows the direction of the acceleration of the ball at points *P* and *Q* respectively?

	At P	*At Q*
(A)	↑	↓
(B)	↓	↓
(C)	↗	↘
(D)	↙	↘

2 A spaceship is travelling at a very high speed. What effects would be noted by a stationary observer?

(A) Time runs slower on the spaceship and it contracts in length.

(B) Time runs faster on the spaceship and it contracts in length.

(C) Time runs slower on the spaceship and it increases in length.

(D) Time runs faster on the spaceship and it increases in length.

3 The table shows the value of the acceleration due to gravity on the surface of Earth and on the surface of Mercury.

	Acceleration due to gravity ($m s^{-2}$)
Earth	9.8
Mercury	3.8

A person has a weight of 550 N on the surface of Earth.

What would be the person's weight on the surface of Mercury?

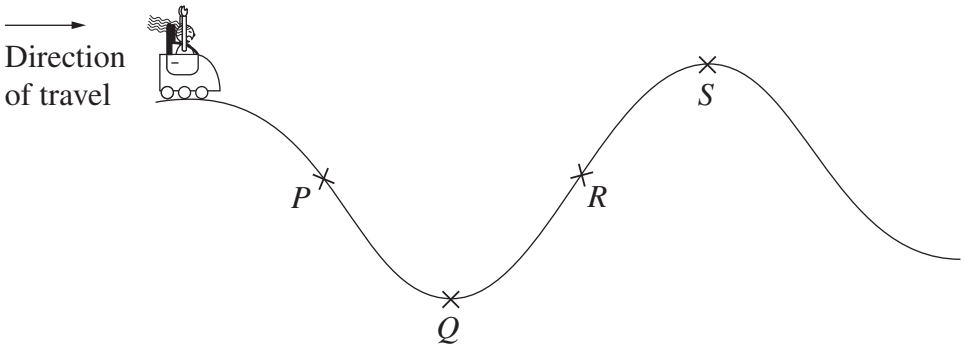
(A) 56.1 N

(B) 213 N

(C) 550 N

(D) 1420 N

4 The diagram shows four positions of a car on a roller coaster ride.



At which point during this ride would the occupant experience maximum 'g force'?

(A) *P*

(B) *Q*

(C) *R*

(D) *S*

5 The table contains information related to two planets orbiting a distant star.

Planets	*Mass* (kg)	*Orbital radius* (m)	*Radius of planet* (m)	*Length of day* (s)	*Orbital period* (s)
Alif	1.21×10^{25}	4.00×10^{11}	8.0×10^{6}	9.5×10^{4}	8.75×10^{7}
Ba	1.50×10^{24}	8.00×10^{11}	4.0×10^{6}	4.7×10^{4}	____

The orbital period of the planet Ba can be determined by using data selected from this table.

What is the orbital period of the planet Ba?

(A) 3.10×10^{7} s

(B) 5.51×10^{7} s

(C) 1.39×10^{8} s

(D) 2.47×10^{8} s

6 What is the role of a transformer at an electrical power station?

(A) To reduce heating in the transmission lines by stepping up the voltage

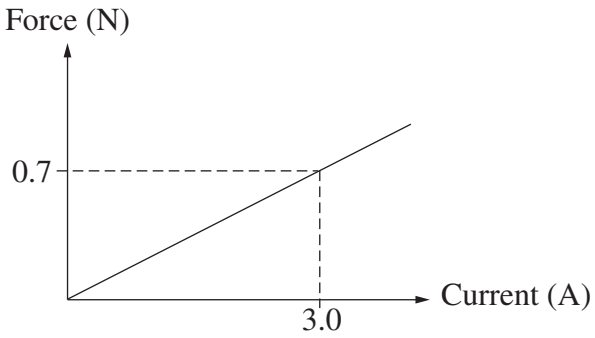
(B) To reduce heating in the transmission lines by stepping up the current

(C) To increase heating in the transmission lines by stepping up the voltage

(D) To increase heating in the transmission lines by stepping up the current

7 A student performed an experiment to measure the force on a long current-carrying conductor placed perpendicular to an external magnetic field.

The graph shows how the force on a 1.0 m length of the conductor varied as the current through the conductor was changed.



What was the magnitude of the external magnetic field in this experiment?

(A) 0.23 T

(B) 1.1 T

(C) 2.1 T

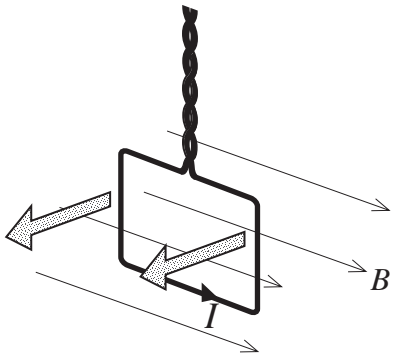
(D) 4.3 T

8 A single-turn coil of wire is placed in a uniform magnetic field B, so that the plane of the coil is parallel to the field, as shown in the diagrams. The coil can move freely.

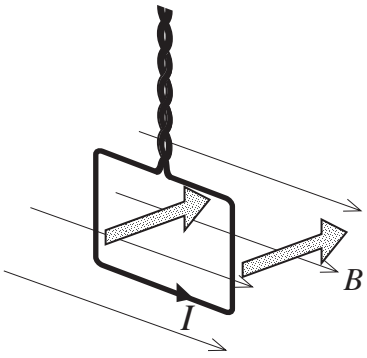
An electric current I flows around the coil in the direction shown.

In which direction does the coil begin to move as a consequence of the interaction between the external magnetic field and the current?

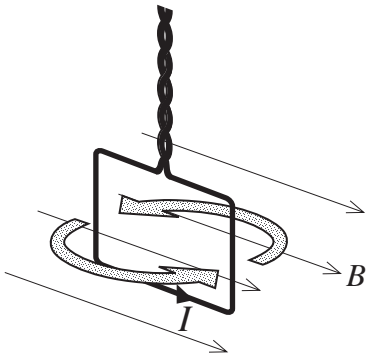
(A)



(B)



(C)



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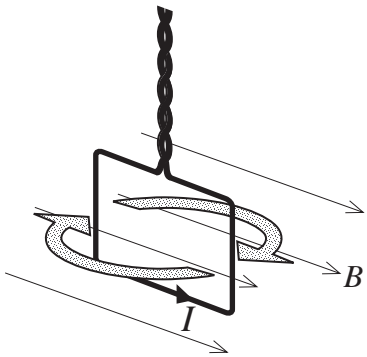
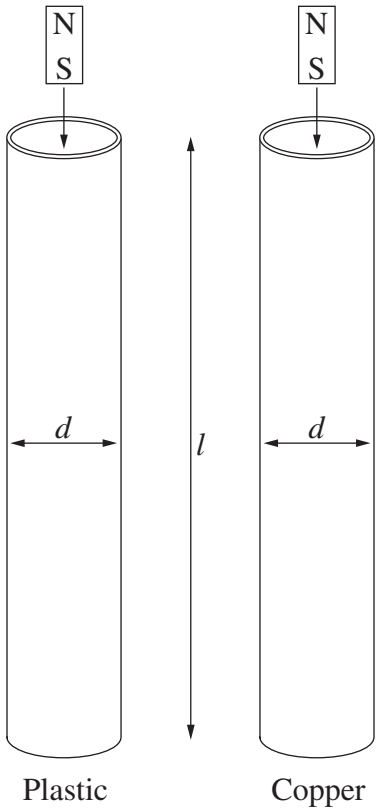


9 In a student experiment, a bar magnet is dropped through a long plastic tube of length l and diameter d. The time taken for it to hit the floor is recorded.



The experiment is repeated using a copper tube of the same length and diameter.

Which of the following statements is correct?

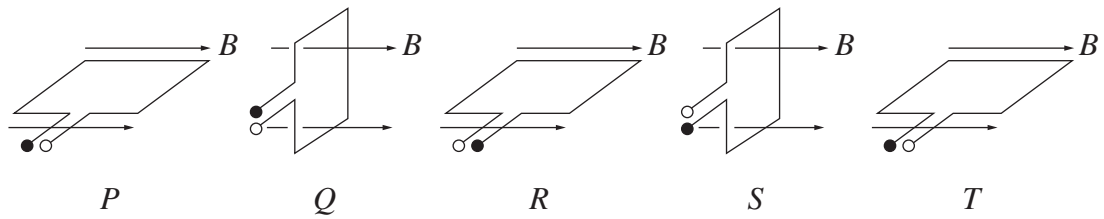
(A) The magnet will take the same time to hit the floor in both cases.

(B) The magnet will come to rest in the middle of the copper tube.

(C) The magnet will take longer to fall through the copper tube.

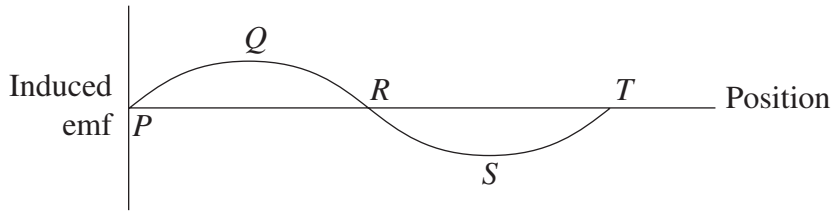
(D) The magnet will take longer to fall through the plastic tube.

10 The coil of an AC generator rotates at a constant rate in a magnetic field as shown.

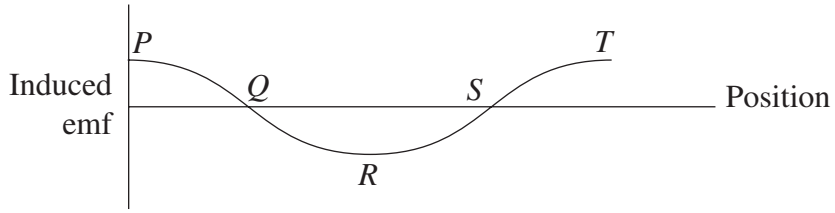


Which of the following diagrams represents the curve of induced emf against position?

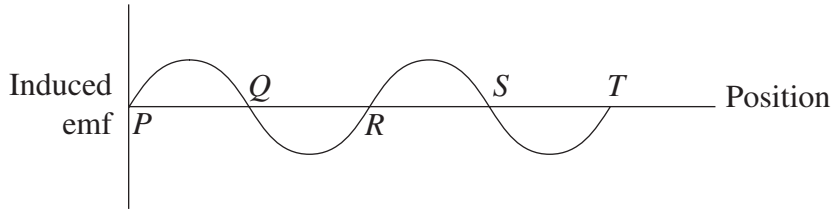
(A)



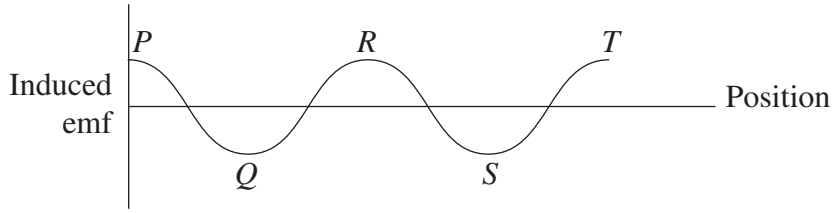
(B)



(C)



(D)



11 Which of the following describes an *n*-type semiconductor?

(A) A semiconductor doped to produce extra free electrons

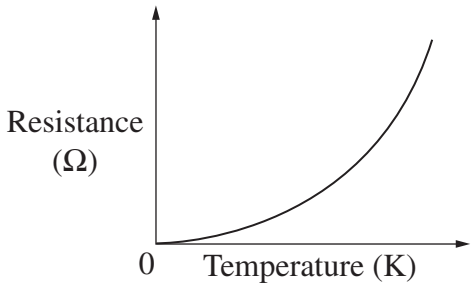
(B) A semiconductor doped to remove free electrons

(C) A semiconductor doped to produce extra holes

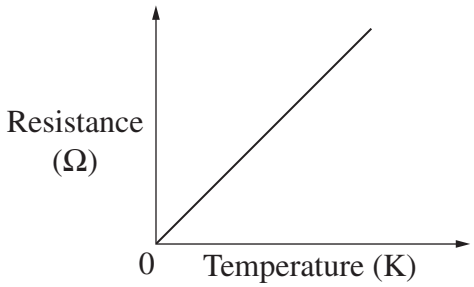
(D) An undoped semiconductor

12 Which of the following graphs shows the behaviour of a superconducting material?

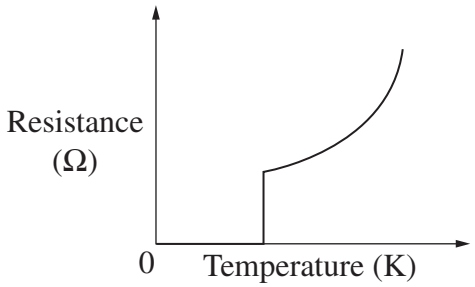
(A)



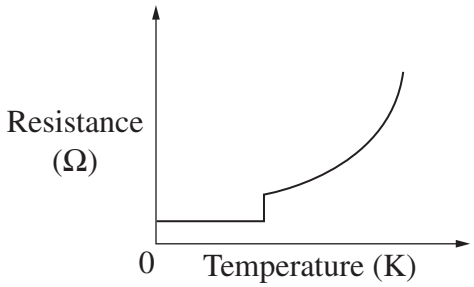
(B)



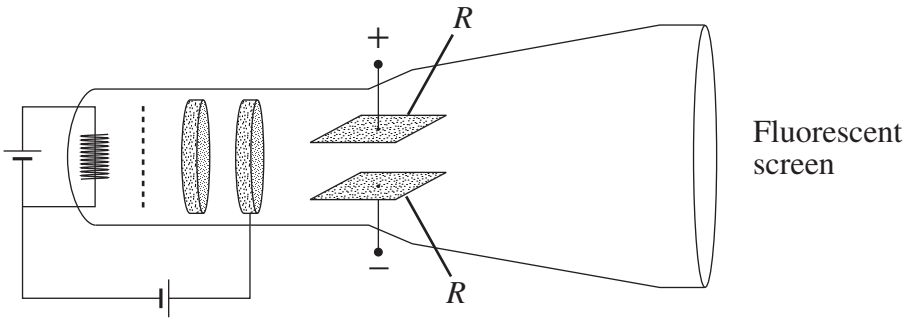
(C)



(D)



13 The diagram shows the side view of a simple cathode ray tube.



What is the function of the components labelled *R*?

(A) To produce cathode rays

(B) To stop cathode rays striking the screen

(C) To deflect the cathode rays vertically

(D) To deflect the cathode rays horizontally

14 During the early 1950s most transistors were manufactured using germanium.

Why was germanium used instead of silicon?

(A) Silicon is more brittle than germanium.

(B) Germanium could be more easily produced in a purified form.

(C) Germanium is a more abundant raw material.

(D) Silicon does not retain its semiconductor properties at high temperatures.

15 A student carried out an experiment during which light of different frequencies was shone onto a metal surface to produce photoelectrons.

The student measured the maximum kinetic energy of the emitted photoelectrons as the frequency of light was altered.

The relationship between the maximum kinetic energy of the photoelectrons and the frequency of the light incident on the metal surface is given by:

$$E_{k(max)} = hf - \phi$$

where

$E_{k(max)}$ = maximum kinetic energy of the photoelectrons

f = frequency of light used

h = Planck's constant

ϕ = a constant dependent on the metal used.

How could the student best analyse the data to determine a value for Planck's constant?

(A) Plot $E_{k(max)}$ against f and find the gradient of the line of best fit.

(B) Plot $E_{k(max)}$ against ϕ and find the gradient of the line of best fit.

(C) Plot $E_{k(max)}$ against f and find the intercept of the line of best fit.

(D) Plot $E_{k(max)}$ against ϕ and find the intercept of the line of best fit.

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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.

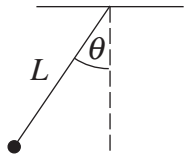
Show all relevant working in questions involving calculations.

Question 16 (8 marks)

Please turn over

Question 16 (8 marks)

Two students, Kim and Ali, performed an experiment to determine the acceleration due to gravity (g) using a simple pendulum consisting of a small mass hanging from a light string.



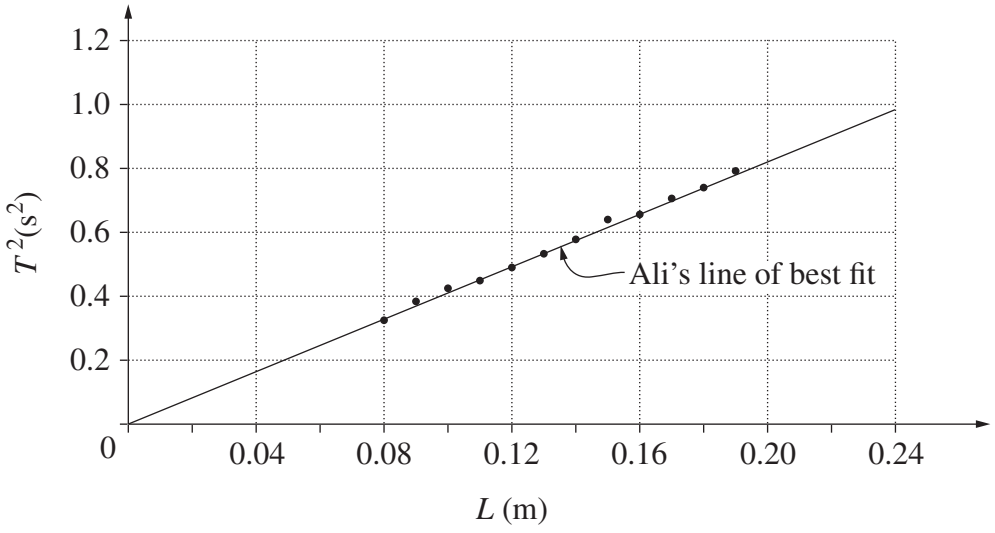
Their procedure was as follows:

1. Adjust the length of the string (L) to measure 0.08 m.
2. Hold the mass to the side to give a small angular displacement, θ.
3. Release the mass and measure the time for one period (T).
4. Record the result in a table.
5. Repeat using a string length (L) of 0.09 m and continue until the string length is 0.19 m (going up in 0.01 m increments, using the same initial angular displacement each time).
6. Calculate g using the relationship $T = 2\pi\sqrt{\frac{L}{g}}$.

The results are shown in the table:

L (m)	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19
T (s)	0.57	0.62	0.65	0.67	0.70	0.73	0.76	0.80	0.81	0.84	0.86	0.89

Kim used the data in the table to obtain a mean value for g. Kim's result was $g = 9.3\ \text{m s}^{-2}$. Ali used the results to produce the following graph. Ali's line of best fit was used to calculate g.



Question 16 continues on page 15

Marks

Question 16 (continued)

(a) Outline TWO changes that could be made to the experimental procedure that would improve its accuracy. **2**

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(b) Compare Kim's and Ali's methods of calculating g and identify the better approach. **3**

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(c) Calculate the value of g from the line of best fit on Ali's graph. **3**

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End of Question 16

Marks

Question 17 (4 marks)

Describe TWO difficulties associated with effective or reliable communications between satellites and Earth. **4**

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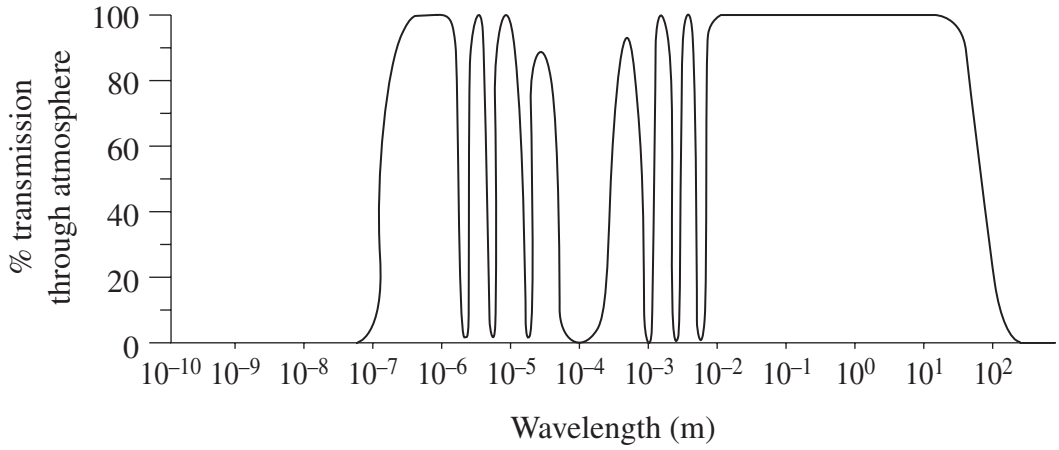
Marks

Question 18 (3 marks)

The graph shows the percentage transmission of electromagnetic radiation of various wavelengths through the Earth's atmosphere. **3**



The Voyager II spacecraft transmits electromagnetic radiation to Earth at a frequency of 2295 MHz.

Use the graph to justify the use of this transmission frequency.

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Marks

Question 19 (4 marks)

In one of Einstein's famous thought experiments, a passenger travels on a train that passes through a station at 60% of the speed of light. According to the passenger, the length of the train carriage is 22 m from front to rear.

(a) A light in the train carriage is switched on. Compare the velocity of the light beam as seen by the passenger on the train and a rail worker standing on the station platform. **1**

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(b) Calculate the length of the carriage as observed by the rail worker on the station platform. **3**

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Marks

Question 20 (3 marks)

A student is investigating inertial and non-inertial frames of reference. The student carries out a series of activities on a boat floating on a large, calm lake. The boat remained level during these activities. **3**

Each activity and the student's observed results are recorded in the table.

Activity	*Observation*
Dropped a ball from a set height	Ball fell vertically with increasing velocity
Rolled a ball from one side of the boat to the other	Ball rolled across the floor with a constant velocity
Rolled a ball from the back of the boat towards the front of the boat	Ball rolled across the floor with a constant velocity

Justify the student's conclusion that: 'The boat can be regarded as an inertial frame of reference'.

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Marks

Question 21 (4 marks)

In his science fiction novel *From the Earth to the Moon*, Jules Verne describes how to launch a capsule from a cannon to land on the moon. To reach the moon, the capsule must leave the cannon with a speed of 1.06×10^4 m s^{-1}. The cannon has a length of 215 m, over which the capsule can be assumed to accelerate constantly.

(a) Calculate the magnitude of the acceleration required to achieve this speed using this cannon. **2**

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(b) Referring to your answer in part (a), explain why Jules Verne's method is unsuitable for sending a living person to the moon. **2**

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Physics

Centre Number

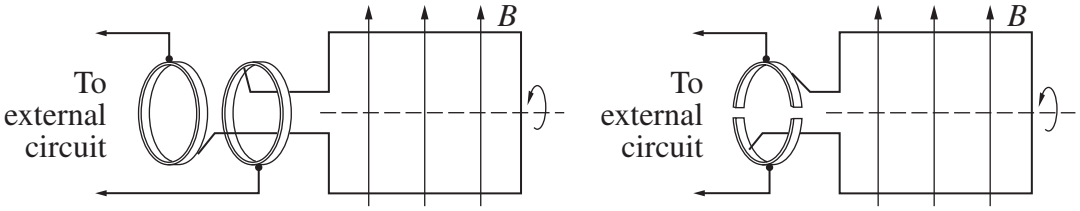
Section I – Part B (continued)

Student Number

Marks

Question 22 (6 marks)

Two types of generator are shown in the diagram.



Generator *P* Generator *Q*

(a) What is the function of the brush in a generator? **1**

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(b) Which of these generators is a DC generator? Justify your choice. **3**

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(c) Outline why AC generators are used in large-scale electrical power production. **2**

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Marks

Question 23 (7 marks)

(a) State Lenz's law. **1**

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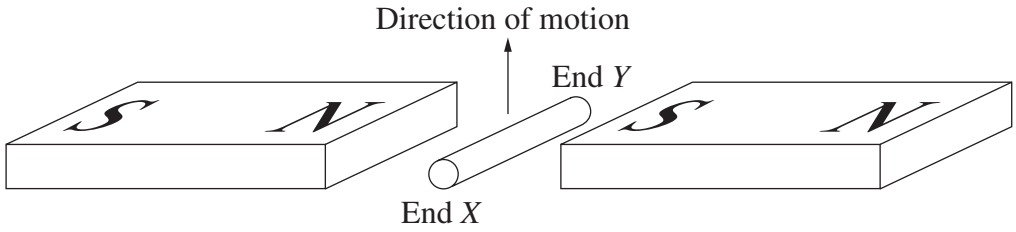
(b) When the metal rod is moved upwards through the magnetic field as shown in the diagram, an emf is induced between the two ends.



(i) Which end of the rod is negative? **1**

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(ii) Explain how the emf is produced in the rod. **3**

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(c) Explain how the principle of induction can be used to heat a conductor. **2**

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Centre Number

Section I – Part B (continued)

Student Number

Marks

Question 24 (8 marks)

In terms of band structures and relative electrical resistance, describe the differences between a conductor, an insulator and a semiconductor. **8**

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Marks

Question 25 (6 marks)

A pair of parallel metal plates, placed in a vacuum, are separated by a distance of 5.00×10^{-3} m and have a potential difference of 1000 V applied to them.

(a) Calculate the magnitude of the electric field strength between the plates. **1**

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(b) Calculate the magnitude of the electrostatic force acting on an electron between the plates. **1**

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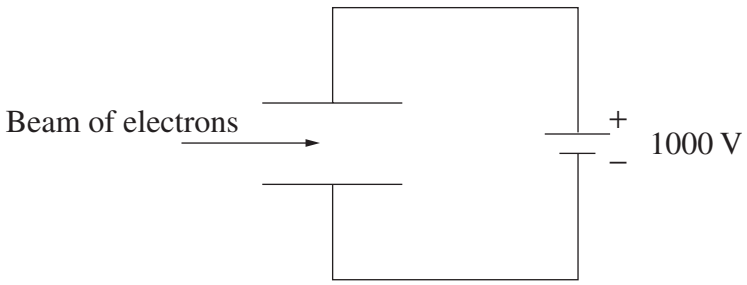
(c) A beam of electrons is fired with a velocity of 3.00×10^{6} m s^{-1} between the plates as shown. A magnetic field is applied between the plates, sufficient to cancel the force on the electron beam due to the electric field. **4**



Calculate the magnitude and direction of the magnetic field required between the plates to stop the deflection of the electron beam.

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Marks

Question 26 (3 marks)

Some materials become superconductors when cooled to extremely low temperatures. Identify THREE properties of superconductors. **3**

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Question 27 (4 marks)

There are two areas in which energy savings can be made by the use of superconductors. These are: **4**

- electricity generation and transmission;
- transportation.

Discuss how energy savings can be achieved in each of these two areas.

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Physics

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.

Marks

Question 28 — Geophysics (25 marks)

(a) (i) Describe Earth's current magnetic field. **2**

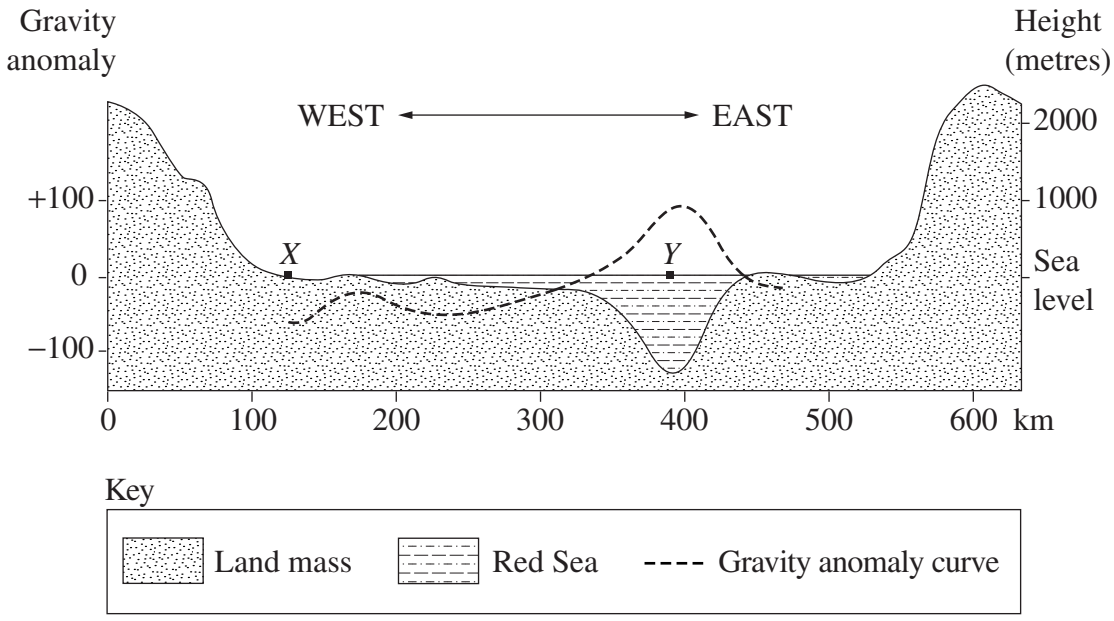
(ii) The diagram represents the magnetic anomalies of the oceanic crust located near the island of Iceland in the mid-Atlantic. **4**

Mid-ocean ridge

Explain the origin of the pattern of magnetic anomalies on either side of the mid-ocean ridge.

(b) (i) Recount the steps involved in gravity data reduction. **2**

(ii) The diagram shows the surface height and gravity anomaly curve in a region near the Red Sea.



(1) Propose reasons for the difference in the gravity anomaly at the locations marked *X* and *Y*. **2**

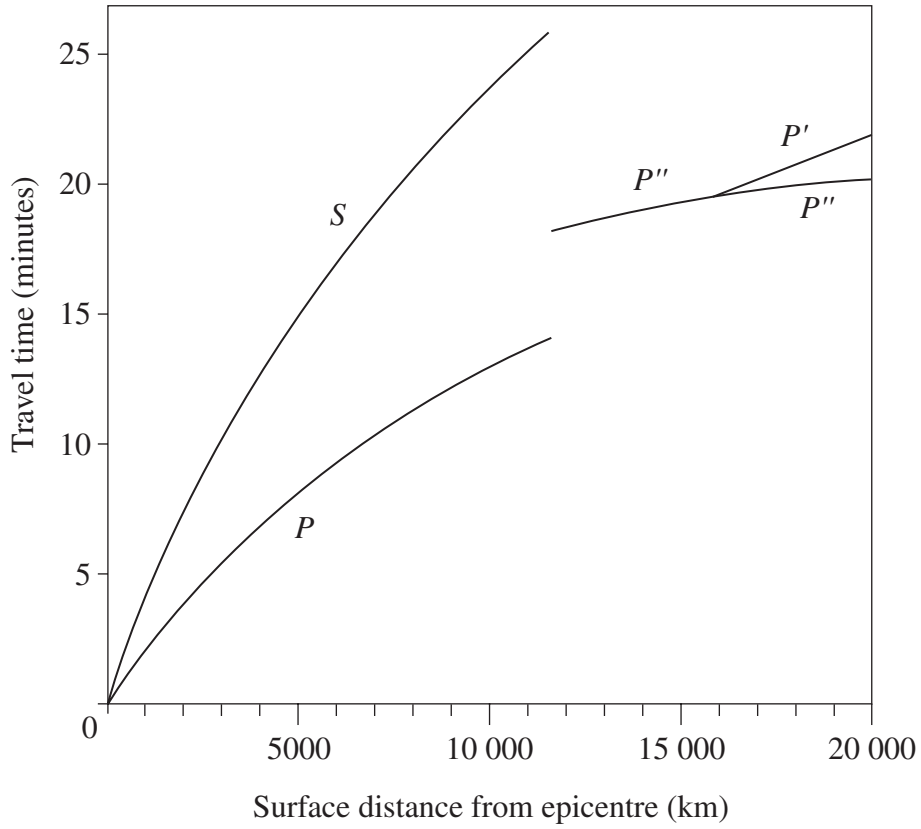
(2) Predict the likely variation in orbital path for a satellite moving from West to East across the region shown in the diagram. **2**

Question 28 continues on page 29

Marks

Question 28 (continued)

(c) The graph shows the travel time for *P* waves and *S* waves at different surface distances from an earthquake epicentre.



(i) Contrast the properties of *P* waves and *S* waves. **2**

(ii) Account for the absence of *S* waves at distances greater than 11 000 km from the earthquake epicentre. **2**

(iii) Identify how this graph supports the existence of a solid inner core of Earth. **2**

(d) Assess the application and advantages of TWO geophysical methods in mineral exploration. **7**

End of Question 28

Marks

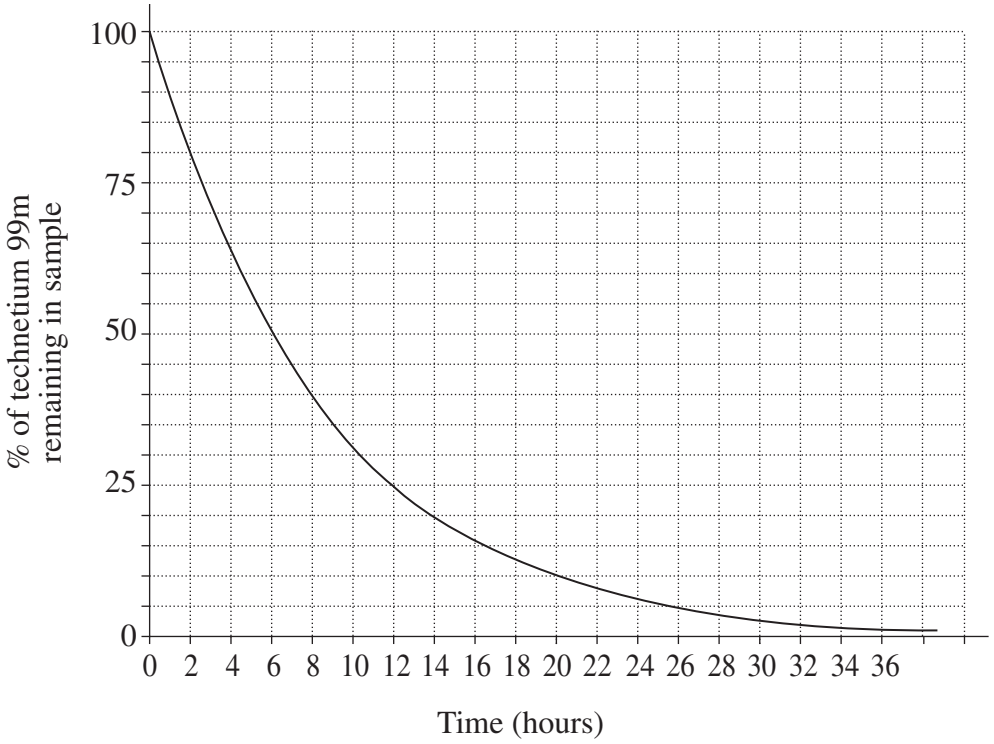
Question 29 — Medical Physics (25 marks)

(a) (i) Briefly describe how an endoscope works. **2**

(ii) Explain how a computed axial tomography (CAT) scan is produced. **4**

(b) Technetium 99m is an artificial isotope which is frequently used to obtain a scan of the human body.

(i) Using the graph, determine the half life of technetium 99m. **1**



(ii) A patient is given an injection containing 6.0×10^{-18} kg of technetium 99m. The scan is taken four hours after the injection. **2**

How much technetium 99m remains undecayed when the scan is taken? (Give your answer in kilograms.)

(iii) Propose reasons why scans are best taken between two and five hours after injection of this radioisotope. **3**

Question 29 continues on page 31

Question 29 (continued)

(c) The diagrams shown are an MRI of the human upper arm, an X-ray of a human hand and a CAT scan of the human pelvis (hip bone) as seen in cross-section from above.

MRI of human upper arm
Procedure time: 30–60 minutes

X-ray of human hand
Procedure time: 5 minutes

CAT scan of human pelvis (hipbone)

Procedure time: 40 minutes

(i) Identify TWO advantages of MRI scans over CAT scans. **2**

(ii) A patient is brought into a hospital out-patients ward complaining of a severe headache. He explains that he hit his head while playing football. The doctor thinks that the patient may be suffering from a fractured skull. **2**

Explain why the doctor would order an X-ray to confirm the diagnosis of a fractured skull.

(iii) The patient, now diagnosed with a fractured skull, complains of other symptoms that may indicate that he is suffering from brain damage. **2**

Suggest ONE additional scan which may be required to confirm this diagnosis. Justify your choice.

(d) Assess the impact of medical applications based on ultrasound and the magnetic field of particles within the body on modern society. **7**

End of Question 29

Marks

Question 30 — Astrophysics (25 marks)

(a) (i) The star Algol is an eclipsing binary as viewed from Earth. **2**

Describe the observations made by astronomers to identify a star as an eclipsing binary.

(ii) Binary stars are important in determining stellar masses. **4**

Explain how the total mass of a binary star system can be calculated.

(b) The table gives information about various nearby stars.

Star	*Distance* (parsecs)	*Apparent visual magnitude*	*Colour Index*
Proxima Centauri	1.29	11.01	1.90
Barnard's Star	1.82	9.54	1.74
Lalande 21185	2.55	7.49	1.51
Ross 154	2.97	10.37	1.75

(i) Which star from the table is the most blue in colour? **1**

(ii) Calculate how much brighter Ross 154 is than Proxima Centauri when viewed from Earth. **2**

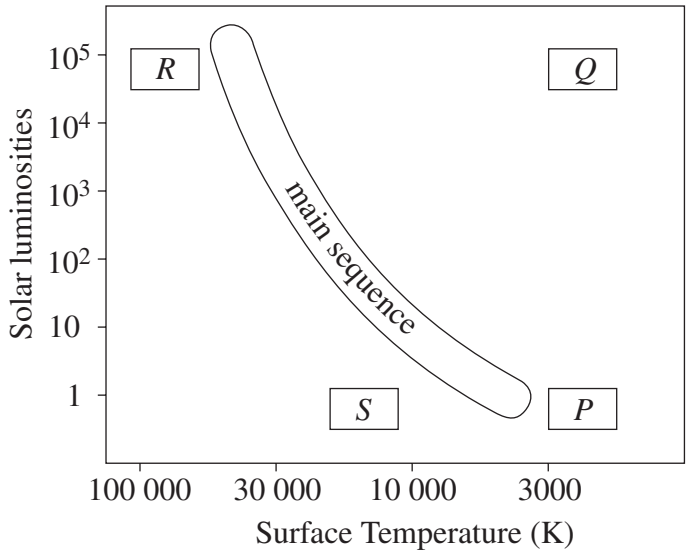
(iii) Sketch a labelled diagram indicating the information required to use the trigonometric parallax method to determine the distance to Barnard's Star. **3**

Question 30 continues on page 33

Marks

Question 30 (continued)

(c) An H-R diagram can be used to show the evolutionary track of stars.



(i) Select the position *P*, *Q*, *R* or *S* on the H-R diagram in which white dwarfs would be found. Justify your choice. **2**

(ii) A white dwarf is considered to be in a stable condition. Explain why a white dwarf does not continue to shrink in size. **2**

(iii) Describe ONE nuclear reaction taking place in a star located on the main sequence. **2**

(d) Discuss how the development of adaptive optics and at least one other development have improved resolution and sensitivity of ground based astronomy. **7**

End of Question 30

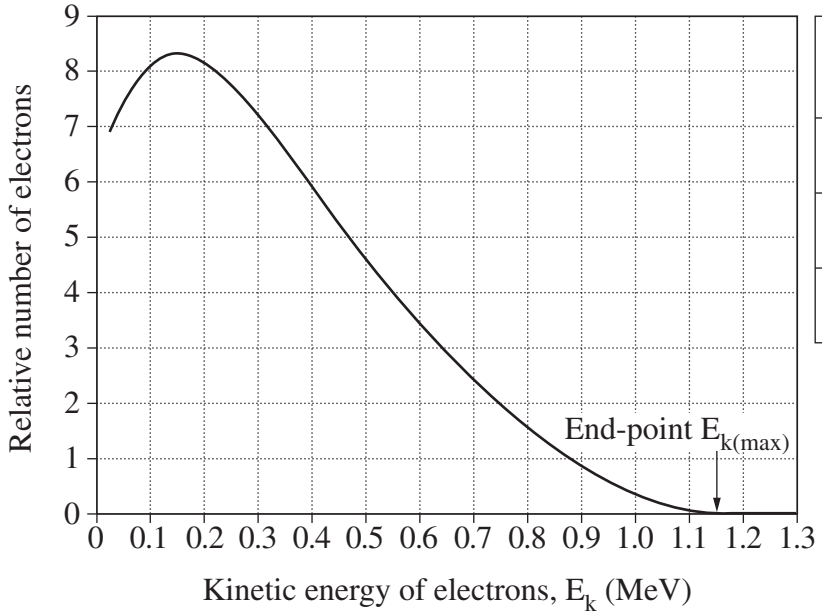
Marks

Question 31 — From Quanta to Quarks (25 marks)

(a) (i) Describe Davisson and Germer's experiment that confirmed the de Broglie hypothesis of wave-particle duality. **2**

(ii) Explain the stability of the electron orbits in the Bohr atom, using de Broglie's hypothesis. **4**

(b) The diagram shows the kinetic energy distribution of the electrons emitted in the β-decay of $^{210}_{83}$Bi into $^{210}_{84}$Po. The energy released during β-decay depends on the mass defect in the transmutation, as it does in nuclear fission.



Nucleus or particle	*Mass* (amu)
^{210}Bi	209.938 57
^{210}Po	209.936 78
e	0.000 55

(i) Identify the scientist who suggested that the existence of the neutrino relates to the need to account for the energy distribution of electrons emitted in β-decay. **1**

(ii) Use the data to calculate the mass defect in the β-decay of $^{210}_{83}$Bi. (Assume that the neutrino is a massless particle.) **2**

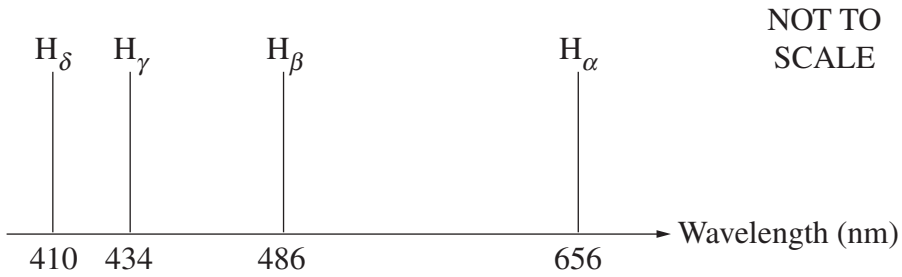
(iii) Account for the energy distribution of electrons emitted in this β-decay. **3**

Question 31 continues on page 35

Marks

Question 31 (continued)

(c) The diagram represents the four spectral lines in the visible region of the hydrogen spectrum known as the Balmer Series.



(i) Explain how the Balmer Series provides strong experimental evidence in support of Bohr's model of the hydrogen atom. **3**

(ii) Calculate the wavelength of the next line in the Balmer Series. **3**

(d) Discuss how neutron scattering and ONE other process have been used to increase our understanding of the structure of matter. **7**

End of Question 31

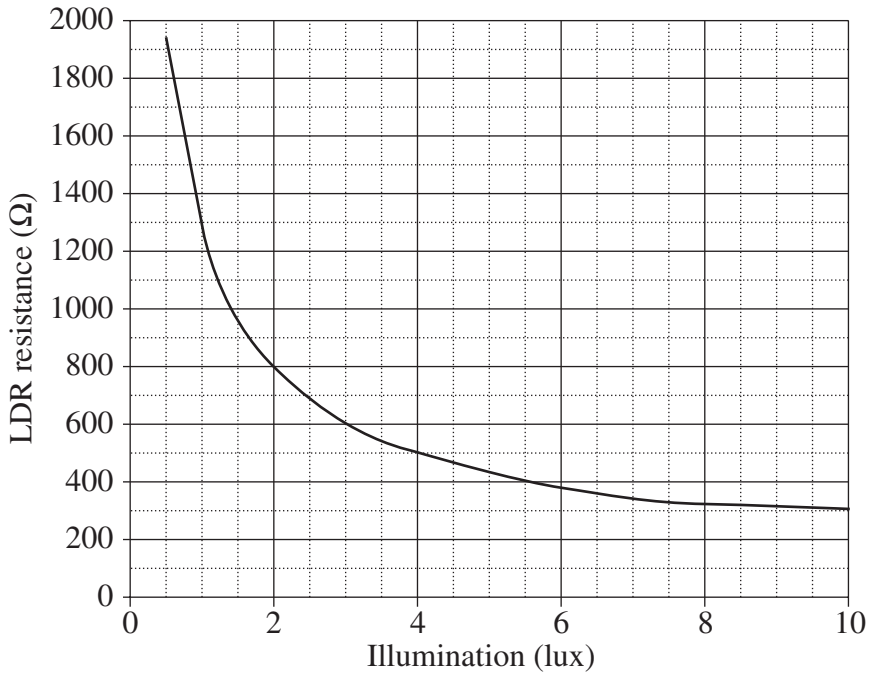
Marks

Question 32 — The Age of Silicon (25 marks)

(a) (i) Describe the structure of an LED. **2**

(ii) Explain why, in some applications, it is preferable to use an LED rather than an ordinary light source. **4**

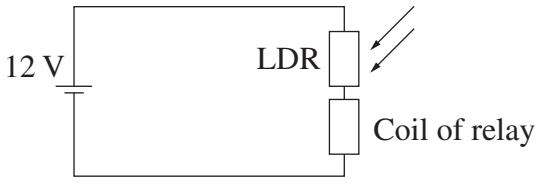
(b) (i) The diagram shows how the resistance of a light-dependent resistor (LDR) depends on the intensity of the light falling on it (illumination).



(1) Describe qualitatively how the resistance of this LDR changes as the illumination increases. **1**

(2) What is the resistance of this LDR when the intensity of light falling on it is 4 lux? **1**

(ii) This LDR is connected in series with the coil of a relay to a 12 volt power supply as shown. **4**



This relay switches on when the current through the coil reaches 4.8 mA. When connected in this circuit, the relay switches on when the illumination on the LDR is 2 lux.

Calculate the resistance of the coil of the relay.

Question 32 continues on page 37

Question 32 (continued)

(c) The table gives the output voltage of an amplifier as a function of the input voltage.

Input voltage (microvolt)	*Output voltage* (volt)
–300	8.0
–250	8.0
–200	8.0
–150	6.0
–100	4.0
–50	2.0
0	0.0
50	–2.0
100	–4.0
150	–6.0
200	–8.0
250	–8.0
300	–8.0

(i) Describe the properties of an ideal amplifier. **2**

(ii) Calculate the gain of this amplifier. **2**

(iii) Propose why this amplifier is not suitable for input signals that vary from −250 microvolt to +250 microvolt. **2**

(d) Early computers used thermionic devices. Later computers used transistors and today computers use integrated circuits. Discuss the impact and limitations of these developments. **7**

End of paper

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DATA SHEET

Charge on the electron, q_e	-1.602×10^{-19} C
Mass of electron, m_e	9.109×10^{-31} kg
Mass of neutron, m_n	1.675×10^{-27} kg
Mass of proton, m_p	1.673×10^{-27} kg
Speed of sound in air	340 m s^{-1}
Earth's gravitational acceleration, g	9.8 m s^{-2}
Speed of light, c	3.00×10^8 m s^{-1}
Magnetic force constant, $\left(k \equiv \frac{\mu_0}{2\pi}\right)$	2.0×10^{-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

$$c = f\lambda$$

$$\text{Intensity} \propto \frac{1}{d^2}$$

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

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

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

$$P = VI$$

$$\text{Energy} = VIt$$

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

where r = displacement

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

$$\Sigma F = ma$$

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

$$p = mv$$

$$\Delta p = Ft$$

$$F = -\frac{Gm_1m_2}{r^2}$$

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

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

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

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

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

$$F = BIl\sin\theta$$

$$\frac{F}{l} = k\frac{I_1I_2}{d}$$

$$\tau = Fd$$

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

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

FORMULAE SHEET

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

$$v = u + at$$

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

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

$$\Delta x = u_x t$$

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

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

$$l_v = l_{\mathrm{o}}\sqrt{1-\frac{v^2}{c^2}}$$

$$t_v = \frac{t_{\mathrm{o}}}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$F = qvB\sin\theta$$

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

$$E = hf$$

$$Z = \rho v$$

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

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

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

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

$$A_{\mathrm{o}} = \frac{V_{\mathrm{o}}}{V_+ - V_-}$$

PERIODIC TABLE OF THE ELEMENTS

KEY

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

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 — Ununbium	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.