BOARD OF STUDIES
NEW SOUTH WALES

2013

HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
  Black pen is preferred
- 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, 19, 23 and 25

Total marks – 100

Section I Pages 2–27

75 marks

This section has two parts, Part A and Part B

Part A – 20 marks

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

Part B – 55 marks

- Attempt Questions 21–31
- Allow about 1 hour and 40 minutes for this part

Section II Pages 29–39

25 marks

- Attempt ONE question from Questions 32–36
- Allow about 45 minutes for this section

Section I
75 marks

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

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

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1 An investigation is designed to determine the size of the generated current when the strength of a magnet is varied.

Which is the independent variable for this investigation?

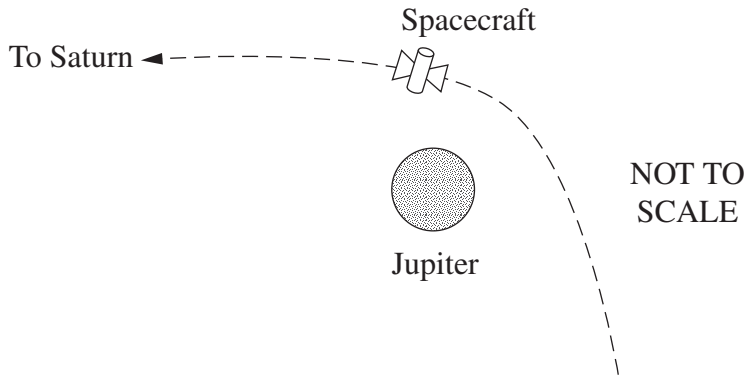
(A) Speed of the magnet

(B) Strength of the magnet

(C) Size of the generated current

(D) Distance between the coil and the magnet

2 This diagram shows the path of a spacecraft as it goes past Jupiter and heads towards Saturn.



Which effect influences the path of the spacecraft?

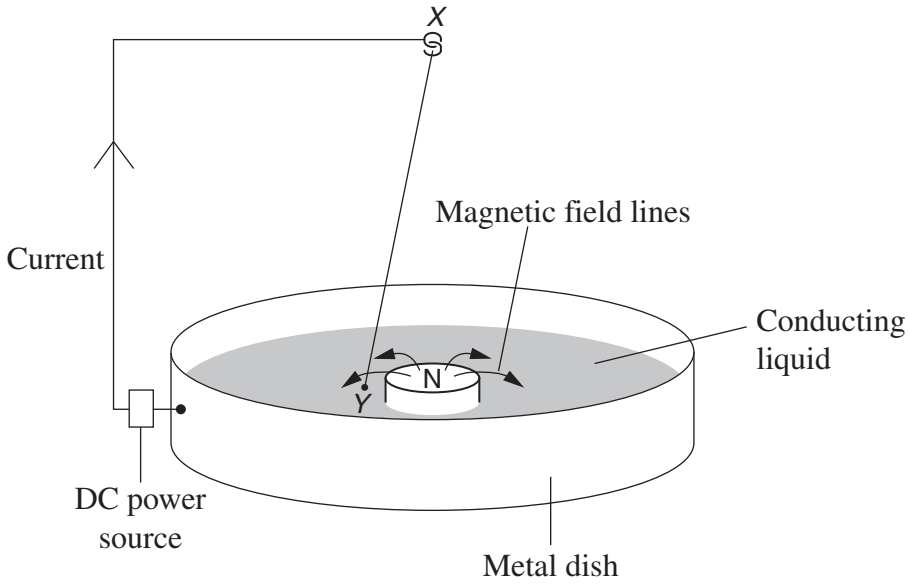
(A) Frictional

(B) Motor

(C) Photoelectric

(D) Slingshot

3 The diagram shows equipment attached to a battery.



In which direction will the wire *XY* move?

(A) Clockwise

(B) Anticlockwise

(C) Towards the magnet

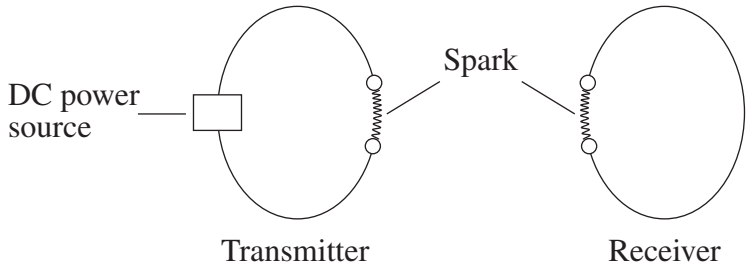
(D) Away from the magnet

4 Students performed an investigation to determine the initial velocity of a projectile.

Which row correctly identifies a hazard of this investigation and a related precaution?

	Hazard	*Safety precaution*
(A)	flying projectile	wearing safety glasses
(B)	range of projectile	measuring the range with a tape measure
(C)	enclosed shoes	limiting the range of the projectile
(D)	safety glasses	flying projectile

5 The diagram represents an experiment that was conducted by Hertz.



What was Hertz trying to investigate?

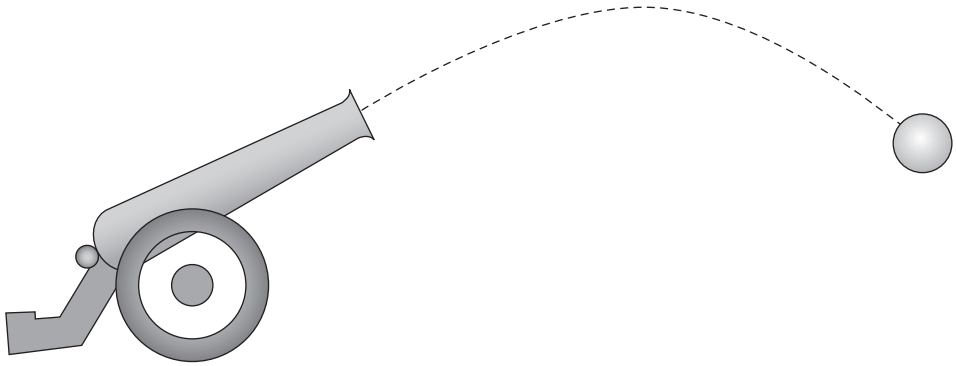
(A) Photoelectric effect

(B) Electrical induction

(C) Black body radiation

(D) Properties of radio waves

6 This diagram shows the path of a cannonball, fired from a cannon.



Which set of vectors represents the horizontal and vertical components of the cannonball's velocity along the path?

	Horizontal	*Vertical*
(A)	→ → → →	↓ ↓ ↓ ↓
(B)	→ → → →	↑ ↑ ↓ ↓
(C)	→ → → →	↑ ↑ ↓ ↓
(D)	→ → → →	↓ ↓ ↓ ↓

7 Eddy currents are a major source of energy loss in an iron core transformer.

What is one way to minimise this energy loss?

(A) Laminate the iron core with an insulator

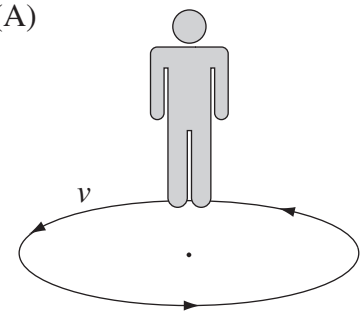
(B) Put fewer turns of wire in the primary coil

(C) Operate the transformer with a higher current

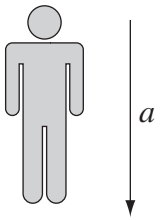
(D) Decrease the distance between the primary and secondary coils

8 Which of the diagrams best represents an example of an inertial frame of reference?

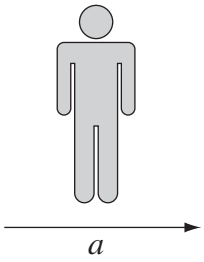
(A)



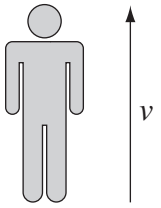
(B)



(C)



(D)



9 Three potentially hazardous conditions that can be experienced by astronauts in space are listed.

I Extreme heat
II Weightlessness
III Communication blackout

Which combination of these conditions is associated with safe re-entry of a manned spacecraft?

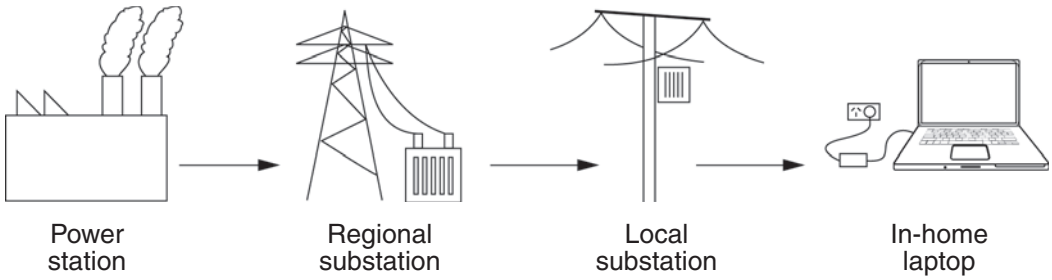
(A) I and II only

(B) I and III only

(C) II and III only

(D) I, II and III

10 The diagram represents the transfer of electrical energy from a power station to a laptop computer.



Which flow diagram shows the correct use of transformers in this transfer?

(A) Step-down → Step-up → Step-up → Step-down

(B) Step-down → Step-down → Step-up → Step-up

(C) Step-up → Step-down → Step-down → Step-down

(D) Step-up → Step-up → Step-down → Step-up

11 Why did the Braggs use X-rays to determine the crystal structure of metals?

(A) X-rays have a low frequency.

(B) X-rays have a short wavelength.

(C) X-rays can pass through metals.

(D) X-rays travel at the speed of light.

12 Why is a magnet able to hover above a superconductor that is below its critical temperature?

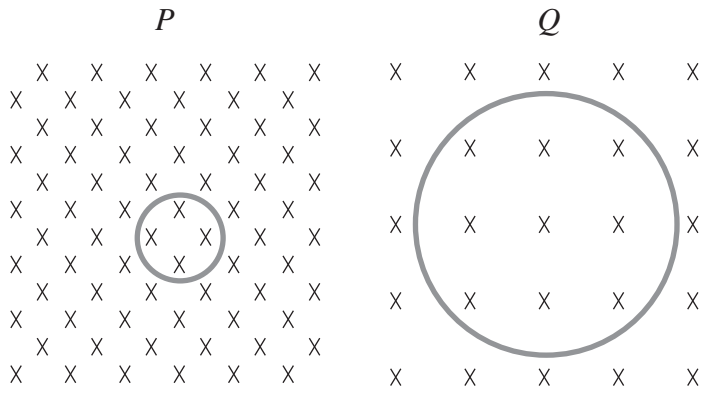
(A) The superconductor excludes magnetic flux.

(B) The superconductor loses conductive properties when placed in a magnetic field.

(C) The eddy current in the superconductor creates a potential difference between the magnet and the superconductor.

(D) The gravitational force on the magnet is balanced by the force created by the crystal lattice structure of the superconductor.

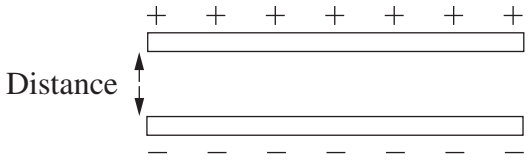
13 Different magnetic fields are passing through two copper rings, *P* and *Q*, as shown.



Which row of the table correctly identifies the ring with the greater magnetic flux and the ring with the greater magnetic flux density?

	Greater magnetic flux	*Greater magnetic flux density*
(A)	*P*	*P*
(B)	*Q*	*Q*
(C)	*P*	*Q*
(D)	*Q*	*P*

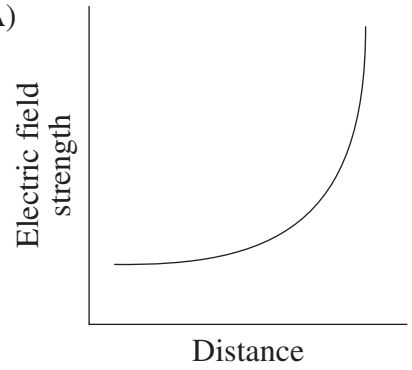
14 Two charged plates are initially separated by a distance as shown in the diagram.



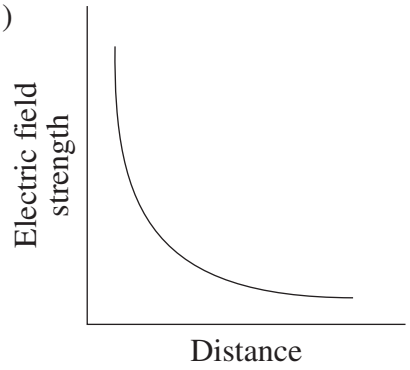
The potential difference between the plates remains constant.

Which of the graphs best represents the change in electric field strength as the distance between the two plates is increased?

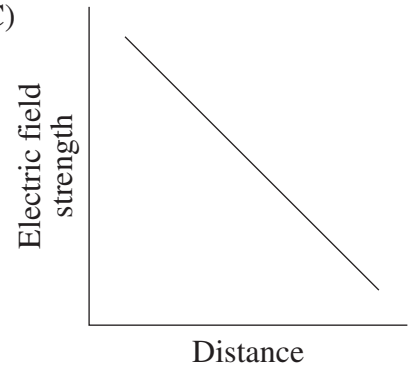
(A)



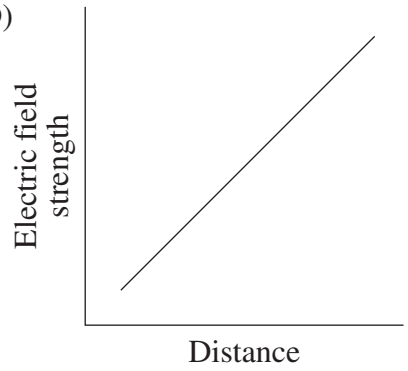
(B)



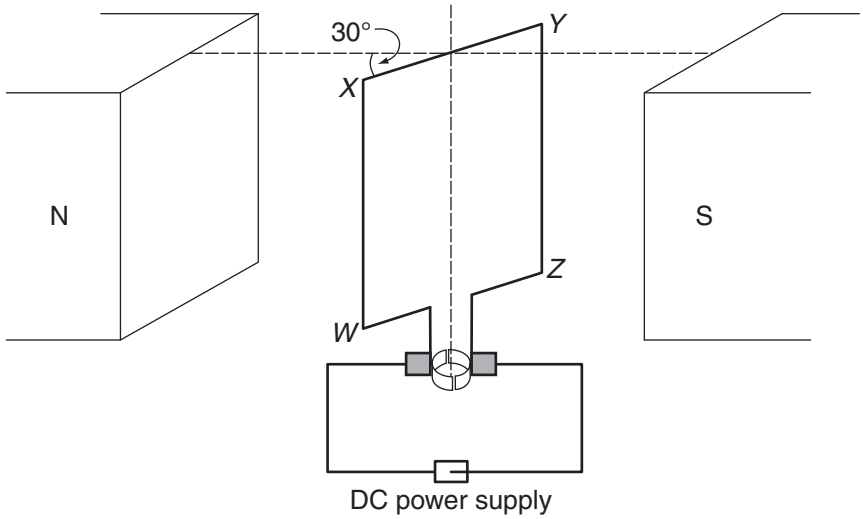
(C)



(D)



15 The diagram shows a single-loop motor.



The equations $\tau = nBIA\cos\theta$ and $F = BIl\sin\omega$ can be used to calculate the torque in the motor and the force on the length of wire WX respectively.

What angles are represented by θ and ω in the above equations?

	θ	ω
(A)	30°	90°
(B)	30°	30°
(C)	60°	90°
(D)	60°	30°

16 Which physical phenomenon allows current to flow through a metal wire?

(A) Holes can move through a wire.

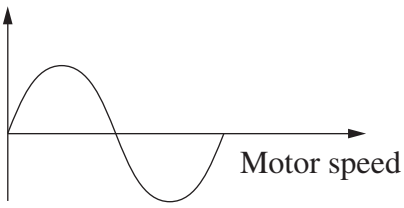
(B) Charged atoms can move through a wire.

(C) Electrons in a fully filled band can carry charge through a wire.

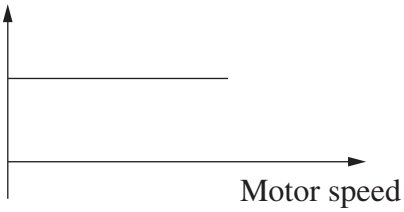
(D) Electrons in a partially filled band can carry charge through a wire.

17 Which graph best represents the change in torque for a DC motor, with a radial magnetic field, from start up to operating speed?

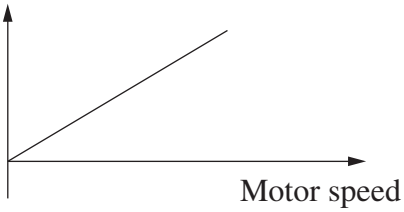
(A) Torque



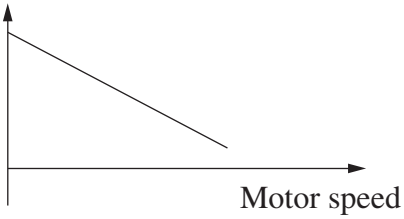
(B) Torque



(C) Torque



(D) Torque



18 Michelson and Morley conducted an experiment to measure the relative velocity of the Earth through the aether.

Why is the result of the experiment significant?

(A) The result supported Michelson and Morley's hypothesis.

(B) The result showed their hypothesis was incorrect because their investigation was not accurate enough.

(C) The failure to detect the expected relative velocity contributed to the development of special relativity.

(D) The successful verification of the expected relative velocity contributed to the development of special relativity.

19 A spaceship moves close to the speed of light, relative to a planet.

The rest-frame length of the spaceship can be determined by an observer who is

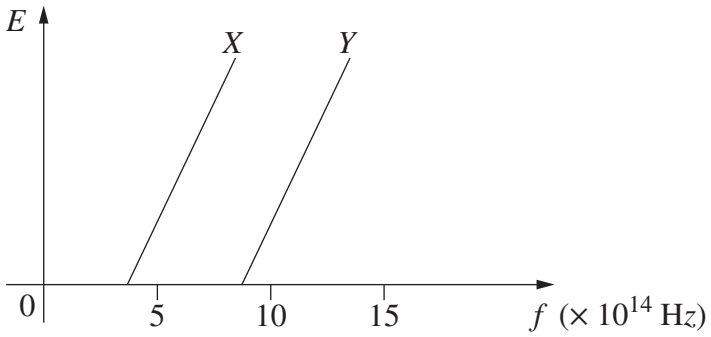
(A) on the spaceship measuring the time taken for light to travel between two points on the planet.

(B) on the planet measuring the time taken for light to travel from the front to the back of the spaceship.

(C) on the spaceship measuring the time taken for light to travel from the front to the back of the spaceship.

(D) on the planet measuring the difference in the arrival time of light from the front and the back of the spaceship.

20 The graph shows the maximum kinetic energy (E) with which photoelectrons are emitted as a function of frequency (f) for two different metals X and Y.



The metals are illuminated with light of wavelength 450 nm.

What would be the effect of doubling the intensity of this light without changing the wavelength?

(A) For metal X, the number of photoelectrons emitted would not change but the maximum kinetic energy would increase.

(B) For metal X, the number of photoelectrons emitted would increase but the maximum kinetic energy would remain unchanged.

(C) For both metals X and Y, the number of photoelectrons emitted would not change but the maximum kinetic energy would increase.

(D) For both metals X and Y, the number of photoelectrons emitted would increase but the maximum kinetic energy would remain unchanged.

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Physics

Centre Number

Student Number

Section I (continued)

Part B – 55 marks
Attempt Questions 21–31
Allow about 1 hour and 40 minutes for this part

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

Show all relevant working in questions involving calculations.

Question 21 (4 marks)

During the course you studied one of the following scientists who has contributed to the development of space exploration:

- Tsiolkovsky
- Oberth
- Goddard
- Esnault-Pelterie
- O'Neill
- von Braun

Name of scientist studied: .....

(a) Outline ONE contribution made by the named scientist to the development of space exploration. **2**

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(b) Outline how to ensure that secondary sources of information about the scientist are reliable. **2**

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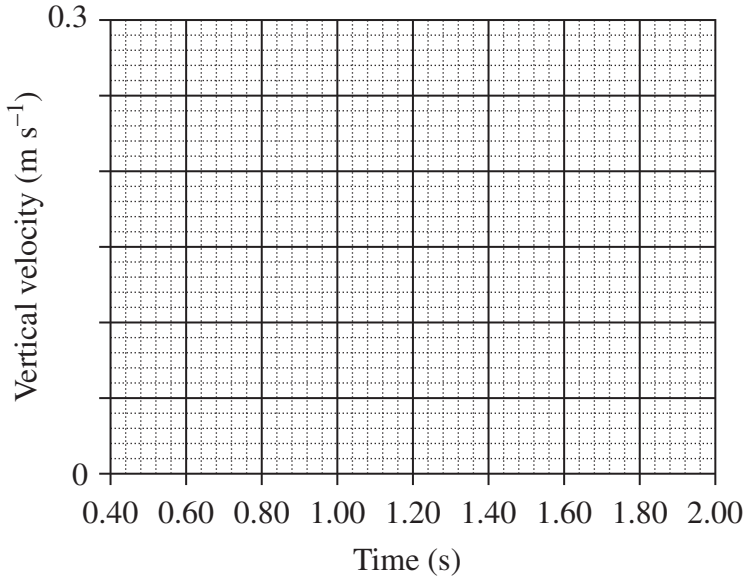
Question 22 (3 marks)

This set of data was obtained from a motion investigation to determine the acceleration due to gravity on a planet other than Earth. **3**

Time (s)	Vertical velocity (m s^{-1})
0.60	0.02
1.00	0.09
1.20	0.12
1.40	0.17
1.80	0.23

Plot the data from the table, and then calculate the acceleration.



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Question 23 (5 marks)

A planet orbits the star, Pollux, at a distance of 1.64 astronomical units (AU). It takes 590 Earth days to complete one orbit.

(a) Why does the mass of the planet play NO role in determining its orbital speed around Pollux? **2**

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(b) A satellite orbits Pollux with a period of 365 Earth days. **3**

How far is the satellite from Pollux in astronomical units (AU)?

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Centre Number

Student Number

Section I – Part B (continued)

Question 24 (5 marks)

With the aid of a diagram, explain how a photocell works. **5**

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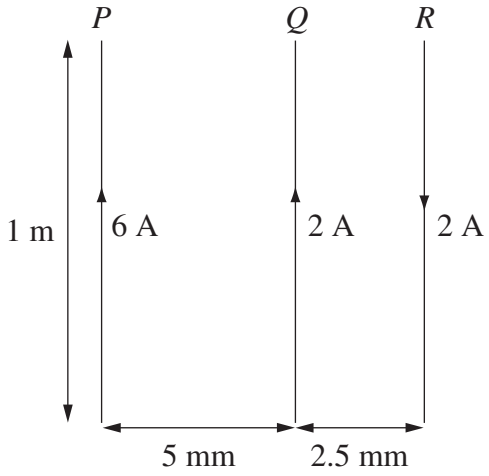
Question 25 (4 marks)

P, *Q* and *R* are straight current-carrying conductors.

Conductors *P* and *R* are fixed and unable to move. Conductor *Q* is free to move.



(a) In which direction will the conductor *Q* move as a result of the current flow in *P* and *R*? **1**

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(b) Calculate the magnitude of the force experienced by *Q* as a result of the currents through *P* and *R*. **3**

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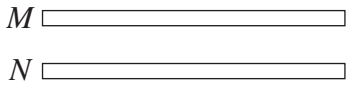
Question 26 (5 marks)

An electric field is produced between two charged parallel plates, *M* and *N*.



(a) The plates, *M* and *N*, are 1.0 cm apart and have an electric field of 15 V m^{-1}. **2**

Calculate the potential difference between the plates.

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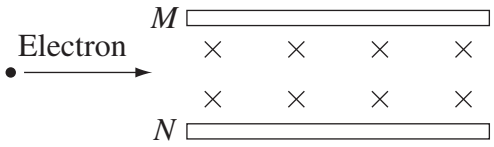
(b) The potential difference is now changed and a magnetic field of 0.5 T is placed perpendicular to the plates, as shown in the diagram below. **3**



Determine the magnitude and direction of the electric field required to allow the electron to travel through undeflected, if the electron is moving at 1×10^4 m s^{-1}.

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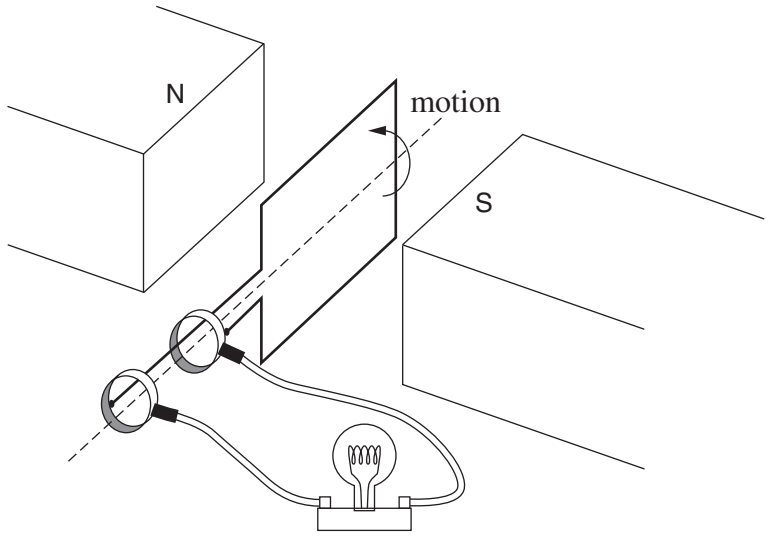
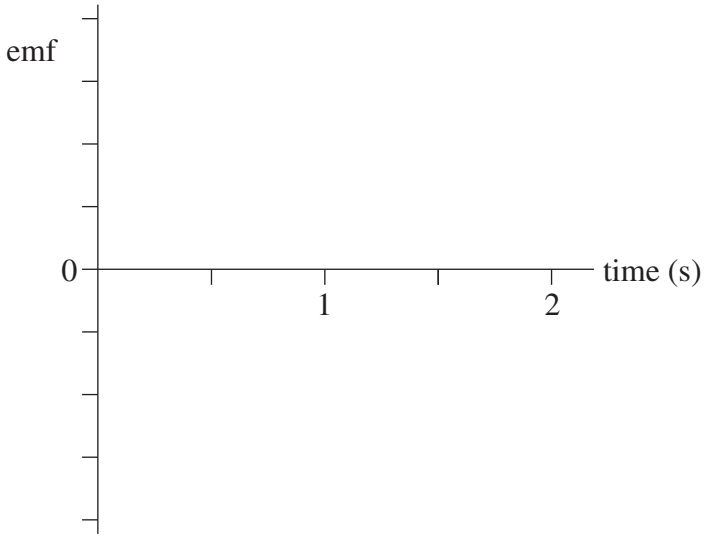
Question 27 (7 marks)

(a) A generator starts at the position shown and is rotated by one revolution in the first second. It is then rotated by two revolutions in the next second. **3**



Sketch a graph on the axes showing the electromotive force (emf) produced by this generator for these two seconds.



Question 27 continues on page 21

(b) An electric motor can be used to propel a vehicle. The electric motor can be made to operate as a generator when the vehicle is moving. This will have a braking effect on the vehicle. **4**

Explain the physics principles involved in the propelling and braking of this vehicle.

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End of Question 27

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Centre Number

Student Number

Section I – Part B (continued)

Question 28 (6 marks)

Assess Einstein's contribution to quantum theory. **6**

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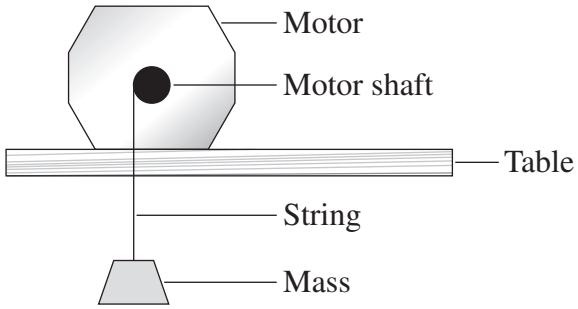
Question 29 (5 marks)

A 0.05 kg mass is lifted at a constant speed by a DC motor. The motor has a coil of 100 turns in a 0.1 T magnetic field. The area of the coil is 0.0012 m^2. The motor shaft has a radius of 0.004 m.



(a) Determine the force needed to lift the mass. **2**

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(b) Calculate the minimum current required in the coil to lift the mass. **3**

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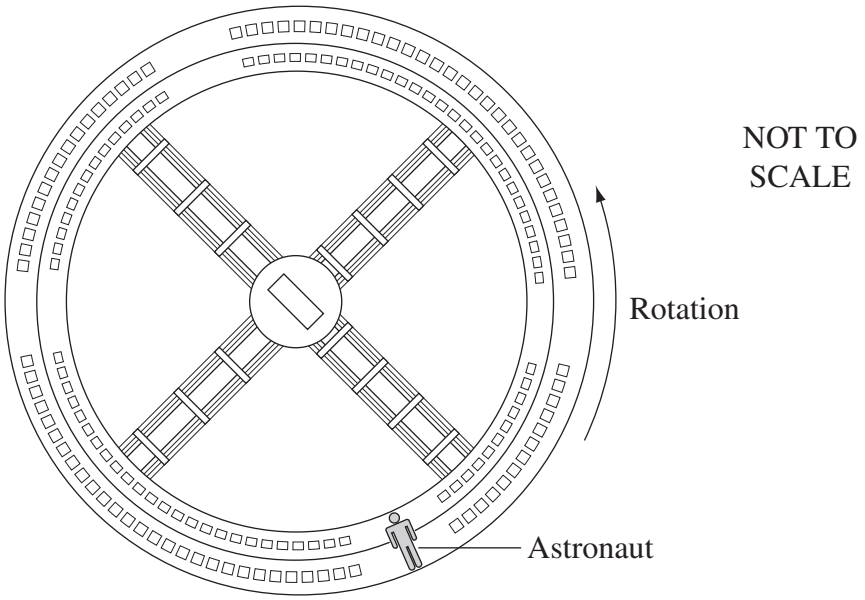
Question 30 (4 marks)

The diagram shows a futuristic space station designed to simulate gravity in a weightless environment.



(a) Explain how rotating the space station simulates gravity for the astronaut. **2**

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Question 30 continues on page 26

Question 30 (continued)

(b) Calculate the rotational speed that a space station with a diameter of 550 m would need for astronauts to experience 1 g of acceleration. **2**

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End of Question 30

Question 31 (7 marks)

Explain how changing the electrical properties of materials has led to the development of new technologies which can benefit society. **7**

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Physics

Section II

25 marks
Attempt ONE question from Questions 32–36
Allow about 45 minutes for this section

For Question 32
- answer parts (a)–(c) of the question in Section II Answer Booklet 1.
- answer parts (d)–(f) of the question in Section II Answer Booklet 2.

Extra writing booklets are available.

For Questions 33, 34 and 36
- answer parts (a)–(d) of the question in Section II Answer Booklet 1.
- answer parts (e)–(f) of the question in Section II Answer Booklet 2.

Extra writing booklets are available.

For Question 35
- answer parts (a)–(c) of the question in Section II Answer Booklet 1.
- answer parts (d)–(e) of the question in Section II Answer Booklet 2.

Extra writing booklets are available.

Show all relevant working in questions involving calculations.

		Pages
Question 32	Geophysics	30–31
Question 33	Medical Physics	32–33
Question 34	Astrophysics	34–35
Question 35	From Quanta to Quarks	36
Question 36	The Age of Silicon	37–39

Question 32 — Geophysics (25 marks)

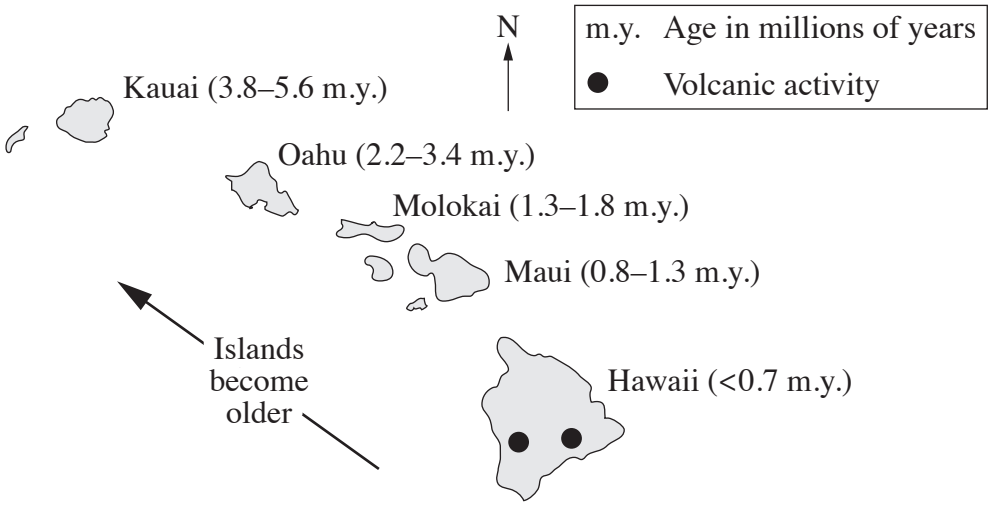
Answer parts (a)–(c) in Section II Answer Booklet 1.

(a) Describe how ONE piece of geophysics equipment detects seismic waves. **3**

(b) (i) Describe a procedure that could be followed to determine the density of rock types. **3**

(ii) How could the reliability of the results of part (b) (i) be determined? **2**

(c) The diagram shows the age and position of each island in the Hawaiian island chain.



(i) Explain the volcanic activity on the island of Hawaii. **2**

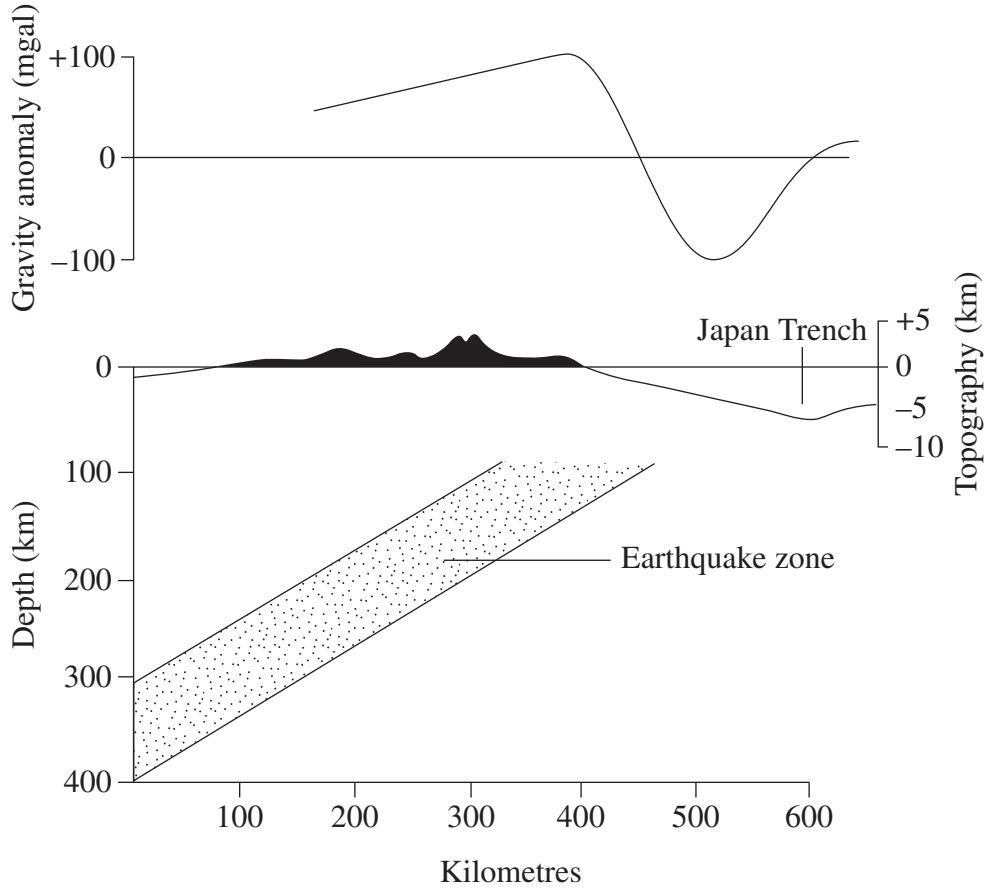
(ii) Explain how the formation of the Hawaiian island chain can be used as evidence for the theory of plate tectonics. **3**

Question 32 continues on page 31

Question 32 (continued)

Answer parts (d)–(f) in Section II Answer Booklet 2.

(d) The graphs show the observed gravity anomaly across the Japan Trench and its relationship to topography. The earthquake zone is dipping away from the trench. **3**



Explain the significance of the shape of the gravity anomaly line with reference to the graphs.

(e) The Earth has a radius of 6357 km through the poles. Show how the acceleration due to gravity at the North Pole can be determined. **3**

(f) Discuss the effectiveness of using geophysical methods in mineral exploration and environmental monitoring. **6**

End of Question 32

Question 33 — Medical Physics (25 marks)

Answer parts (a)–(d) in Section II Answer Booklet 1.

(a) Outline differences between X-ray images and CAT scans. **3**

(b) Outline a first-hand investigation to demonstrate the transfer of light by optical fibres. **2**

(c) Explain how an endoscope can be used to obtain tissue samples of internal organs. **3**

(d) (i) How is the orientation of the magnetic axis of a hydrogen nucleus affected by the application of a strong magnetic field during an MRI scan? **2**

(ii) Explain the difference in the relaxation time of hydrogen in water and the relaxation time of hydrogen in other molecules. **3**

Question 33 continues on page 33

Question 33 (continued)

Answer parts (e)–(f) in Section II Answer Booklet 2.

(e) (i) How is the Doppler effect used in ultrasonics to investigate blood flow characteristics? **3**

(ii) Outline TWO technologies that are required for an ultrasound scan. **3**

(f) The data set gives information about a variety of radioactive isotopes, some of which can be used in diagnostic tools for medicine. **6**

Radioactive isotope	*Radiation emitted*	*Half life*
Fluorine-18	β^+	109.77 minutes
Strontium-90	β	28.8 years
Carbon-14	β	5730 years
Technetium-99m	γ	6 hours
Cobalt-60	γ	5.27 years

Using the information in the table, justify which radioactive isotopes are suitable for use in diagnostic imaging techniques.

End of Question 33

Question 34 — Astrophysics (25 marks)

Answer parts (a)–(d) in Section II Answer Booklet 1.

(a) Describe an investigation that can be used to show why it is desirable in terms of sensitivity for a telescope to have a larger diameter lens. **3**

(b) Matar is a star in the same spectral class as the Sun, yet it has four times the mass of the Sun.

(i) Draw a labelled Hertzsprung–Russell (H–R) diagram, and mark the position of Matar on the diagram with an X. **3**

(ii) Contrast the physical properties, other than mass, of Matar and the Sun. **2**

(c) Describe the dominant nuclear reaction in an A2 main sequence star. **3**

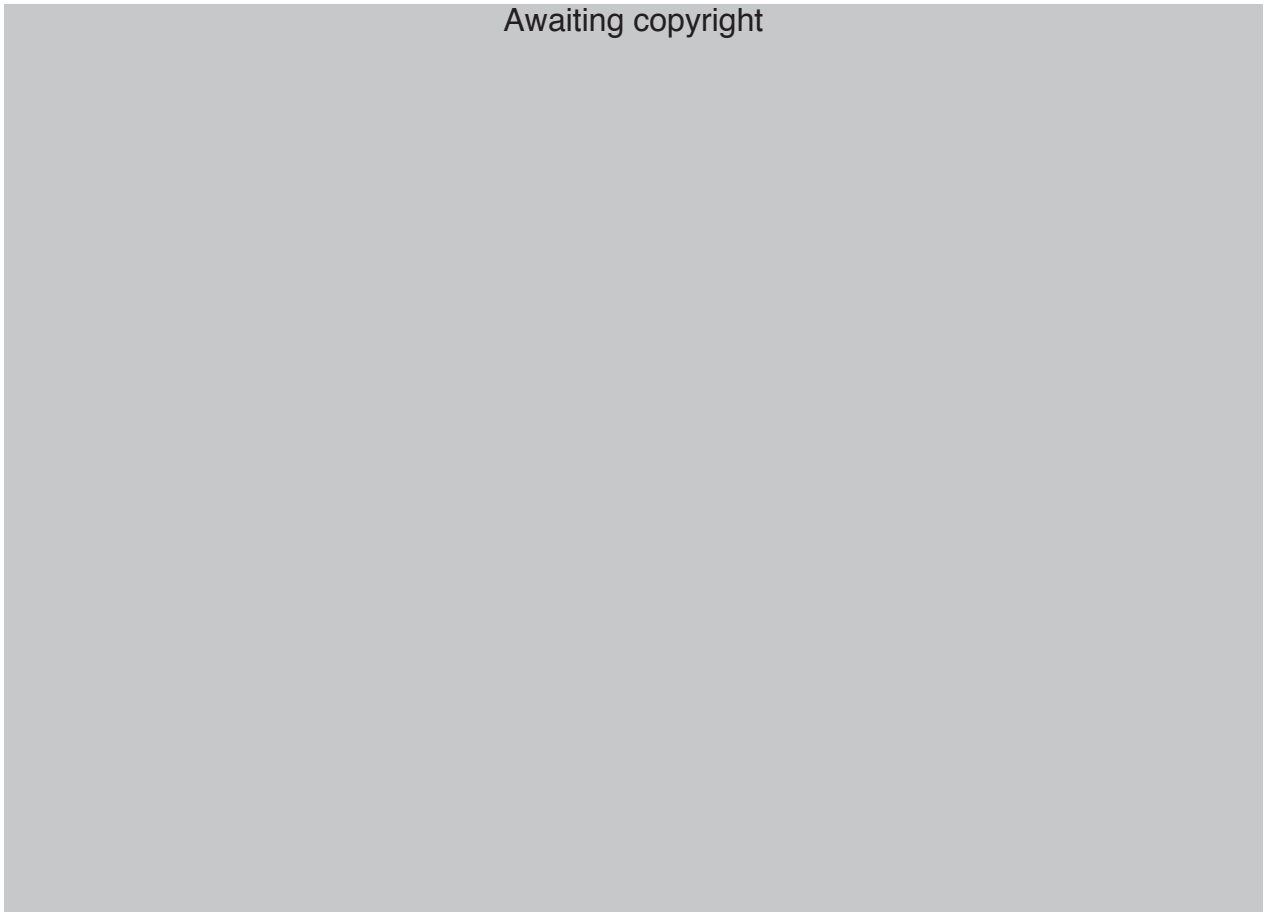
(d) Describe the transition process of a G2 main sequence star, such as the Sun, evolving into a red giant. **3**

Question 34 continues on page 35

Question 34 (continued)

Answer parts (e)–(f) in Section II Answer Booklet 2.

(e) The graphs give information that could be used to calculate the distance from Earth to a Type 1 Cepheid Variable.



(i) The star is claimed to be approximately 1260 parsecs from Earth. **3**

Show how this claim is supported or refuted by the information in the graphs.

(ii) State an advantage and a disadvantage of using the graphs above to calculate the distance to a star. **2**

(f) How is light analysed, using physics principles, in order to determine the standard properties for the main sequence stars of Spectral Class A shown in this table? **6**

Spectral Class	Effective Temperature (K)	Colour	$Mass/Mass_{Sun}$	$Luminosity/Luminosity_{Sun}$
A	7500 – 10000	White	2.0 – 3.0	8 – 55

Acknowledgement: CSIRO

End of Question 34

Question 35 — From Quanta to Quarks (25 marks)

Answer parts (a)–(c) in Section II Answer Booklet 1.

(a) (i) Outline the key features of the Rutherford model of the atom. **2**

(ii) Explain how the Bohr model of the atom overcomes an identified limitation of the Rutherford model of the atom. **3**

(b) This equation describes a nuclear reaction.

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{141}_{56}\text{Ba} + {}^{92}_{36}\text{Kr} + 3\,{}^{1}_{0}\text{n}$$

Particle	Mass (amu)
$^{235}_{92}$U	235.0439
$^{141}_{56}$Ba	140.9144
$^{92}_{36}$Kr	91.9263
$^{1}_{0}$n	1.008 665

(i) Use the data above to calculate the energy released in this reaction. **3**

(ii) Apply Einstein's idea of the equivalence of mass and energy to explain the production of energy in the reaction above. **2**

(c) Pauli is said to have 'suggested' the existence of the neutrino. **4**

Explain why the neutrino was 'suggested' but not discovered by Pauli.

Answer parts (d)–(e) in Section II Answer Booklet 2.

(d) (i) Identify the fundamental forces proposed by the standard model of the atom. **2**

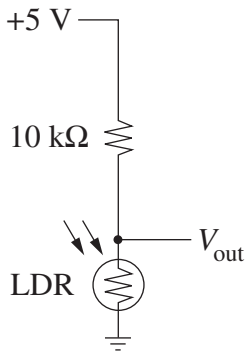
(ii) Explain how the stability of atomic nuclei is maintained. **3**

(e) How did de Broglie use existing concepts and ideas to come up with new interpretations that have increased our understanding of the structure of matter? **6**

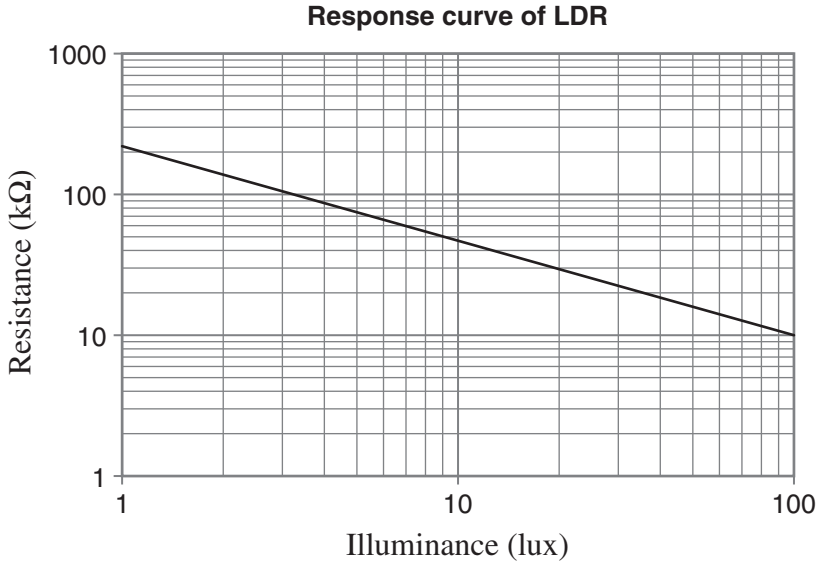
Question 36 — The Age of Silicon (25 marks)

Answer parts (a)–(d) in Section II Answer Booklet 1.

(a) This circuit shows how a light-dependent resistor (LDR) can be used to control a voltage output. **3**



The response curve of the LDR in the circuit is shown.



What would the voltage V_{out} be when the light intensity at the LDR is 20 lux?

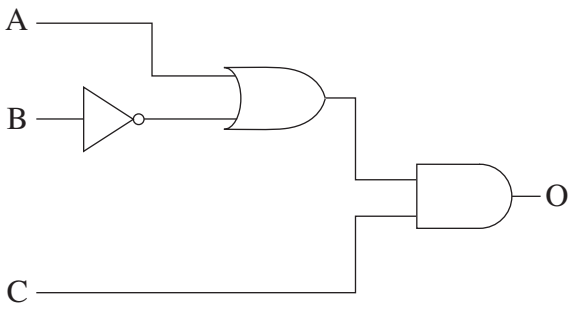
Question 36 continues on page 38

Question 36 (continued)

(b) Describe the role of a LDR in a camera. **3**

(c) Explain how input and output transducers can be used to control the temperature in a room. **4**

(d) For the logic circuit, construct a truth table showing the output, O, for all possible combinations of inputs A, B and C. **3**



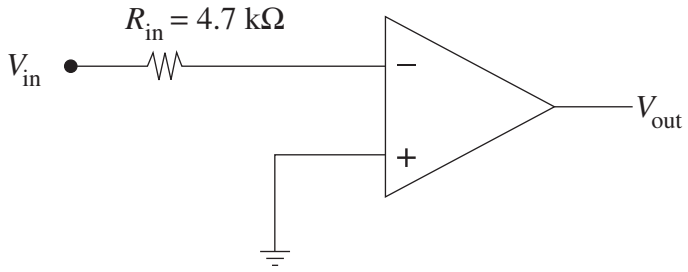
Question 36 continues on page 39

Question 36 (continued)

Answer parts (e)–(f) in Section II Answer Booklet 2.

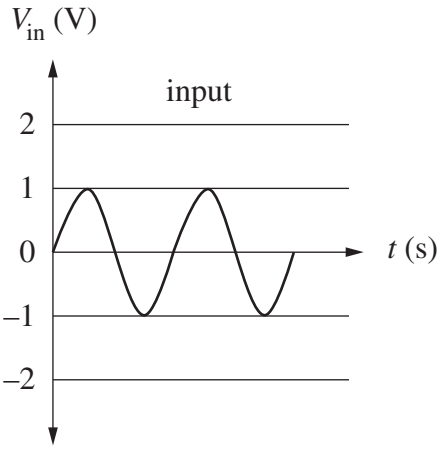
(e) (i) Describe an ideal operational amplifier. **2**

(ii) The diagram shows an operational amplifier. **2**



Reproduce this diagram in your writing booklet and modify it to perform as an inverting amplifier with a gain of 2.

(iii) The diagram shows an input waveform V_{in} for an inverting amplifier with a gain of 2. **2**



Sketch the output waveform V_{out} in your writing booklet.

(f) Assess how the development of electronics since the invention of the transistor has met the increasing computing needs of society. **6**

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

$v = f\lambda$

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

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

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

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

$P = VI$

Energy $= VIt$

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

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

$\Sigma F = ma$

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

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

$W = Fs$

$p = mv$

Impulse $= Ft$

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

$F = mg$

$v_x^2 = u_x^2$

$v = u + at$

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

$\Delta x = u_x t$

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

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

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

$E = mc^2$

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

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

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

FORMULAE SHEET

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

$$F = BIl\sin\theta$$

$$\tau = Fd$$

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

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

$$F = qvB\sin\theta$$

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

$$E = hf$$

$$c = f\lambda$$

$$Z = \rho v$$

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

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

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

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

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

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

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

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

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

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium						

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

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

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

Standard atomic weights are abridged to four significant figures.

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

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