NSW EDUCATION STANDARDS AUTHORITY

2017

HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A data sheet, formulae sheets and Periodic Table are provided at the back of this paper

Total marks: 100

Section I – 75 marks (pages 2–28)

This section has two parts, Part A and Part B

Part A – 20 marks

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

Part B – 55 marks

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

Section II – 25 marks (pages 29–39)

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

Section I
75 marks

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

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

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1 Who was the main advocate for the distribution of DC electricity to cities?

A. Edison

B. Faraday

C. Tesla

D. Westinghouse

2 Which of the following is an inertial frame of reference?

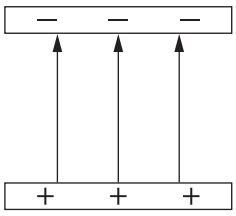
A. A rocket during launch

B. A train travelling at a constant velocity

C. A car turning a corner at a constant speed

D. A lift slowing down as it approaches the ground floor

3 Which of the following correctly shows the electric field between two parallel, charged plates?

A.


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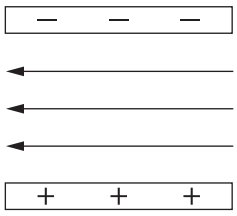

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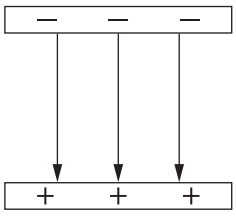
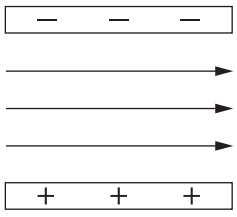


D.


4 An astronaut with a mass of 75 kg lands on Planet *X* where her weight is 630 N.

What is the acceleration due to gravity (in m s^{-2}) on Planet *X*?

A. 0.12

B. 8.4

C. 9.8

D. 735

5 An electric current flows in undoped silicon.

Which statement about this current is true?

A. The number of electrons moving exceeds the number of holes moving.

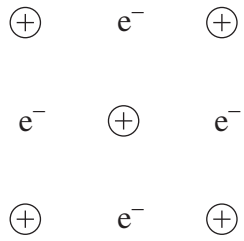
B. The number of holes moving exceeds the number of electrons moving.

C. Equal numbers of holes and electrons are moving in the same direction.

D. Equal numbers of holes and electrons are moving in opposite directions.

6 Which of the following best represents the structure of a metallic lattice?

A.



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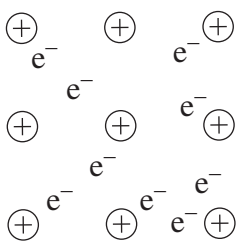

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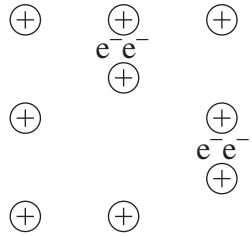

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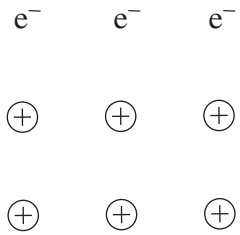


7 Which of the following is a correct statement about the Michelson–Morley experiment?

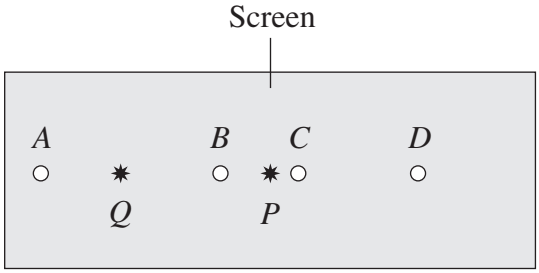
A. It proved the existence of the luminiferous aether.

B. It compared the speeds of light rays travelling along parallel paths.

C. It was invalid because the equipment was not sufficiently sensitive.

D. It was unable to detect the motion of Earth through the luminiferous aether.

8 An electron is fired in a vacuum towards a screen. With no electric field being applied, the electron hits the screen at *P*. A uniform electric field is turned on and another electron is fired towards the screen from the same location, at the same velocity, striking the screen at point *Q*.



With the electric field still turned on, a proton is fired towards the screen from the same starting point as the electrons and with the same velocity.

At what point does the proton strike the screen?

A. *A*

B. *B*

C. *C*

D. *D*

9 What does the Maltese cross apparatus demonstrate about cathode rays?

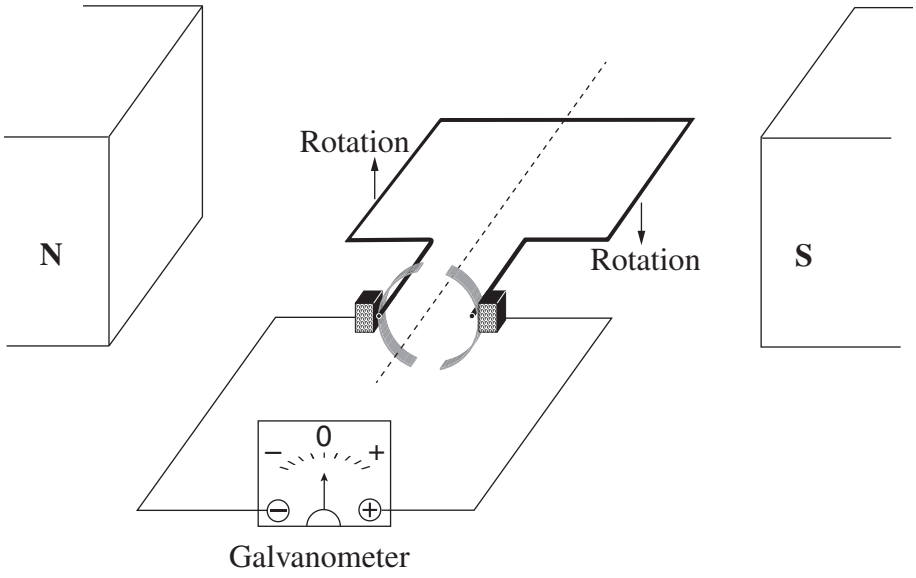
A. They travel in straight lines.

B. They consist of a beam of electrons.

C. They are absorbed by a metal surface.

D. They are not affected by magnetic fields.

10 The diagram shows a model of a generator connected to a galvanometer.

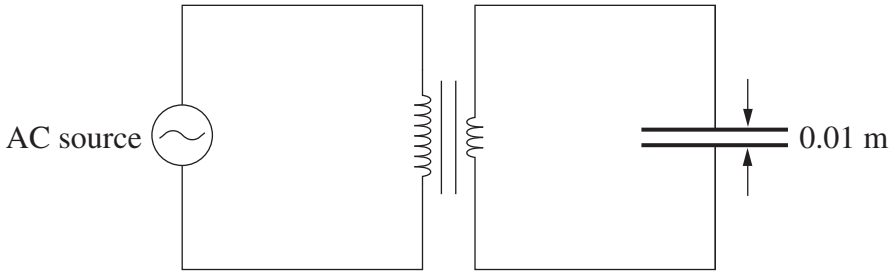


The loop is rotated continuously in a clockwise direction as viewed from the end nearest the galvanometer.

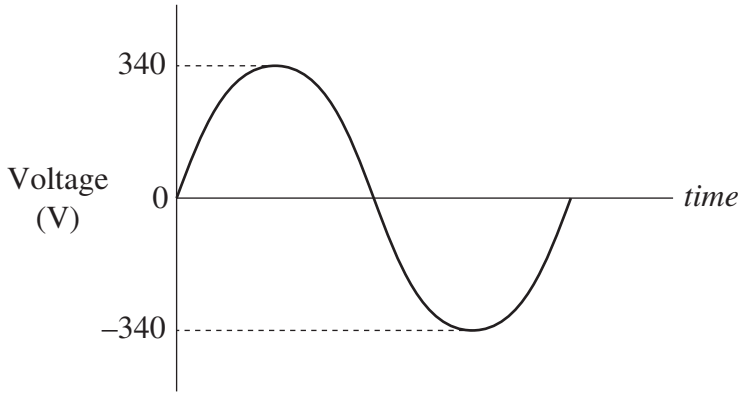
Which row of the table correctly identifies the type of generator and the movement of the needle of the galvanometer?

	Type of generator	*Movement of the needle*
A.	DC	Swings between 0 and +
B.	AC	Swings between – and 0
C.	DC	Swings between + and –
D.	AC	Swings between – and +

11 An AC source is connected to a transformer having a primary winding of 900 turns. Connected to the secondary winding of 450 turns is a pair of parallel plates 0.01 m apart.



The AC input is shown in the graph.



What is the maximum field strength (in V m^{-1}) produced between the plates?

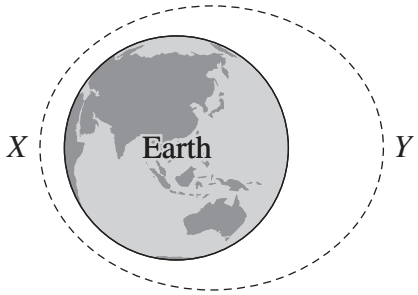
A. 1.7

B. 6.8

C. 1.7×10^4

D. 6.8×10^4

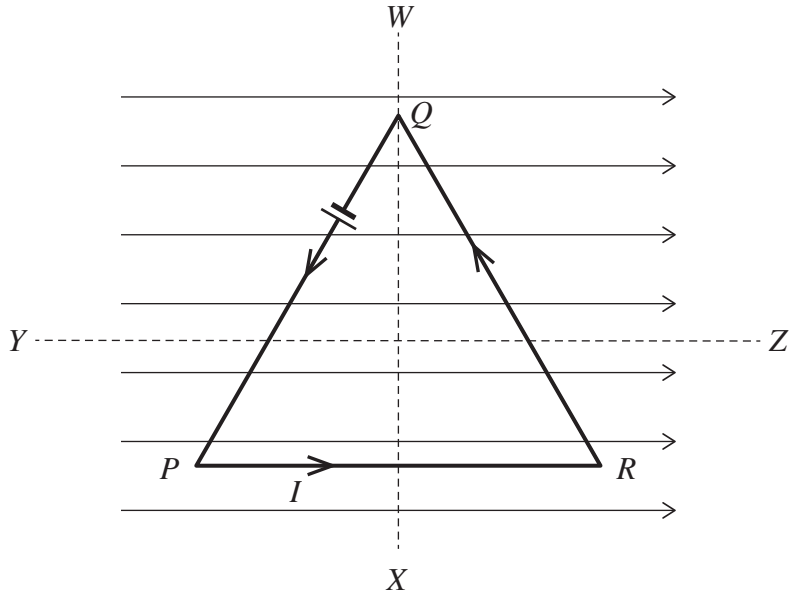
12 A satellite orbits Earth with an elliptical orbit that passes through positions *X* and *Y*.



Which row of the table correctly identifies the position at which the satellite has greater kinetic energy and the position at which it has greater potential energy?

	Greater kinetic energy	*Greater potential energy*
A.	*X*	*X*
B.	*X*	*Y*
C.	*Y*	*X*
D.	*Y*	*Y*

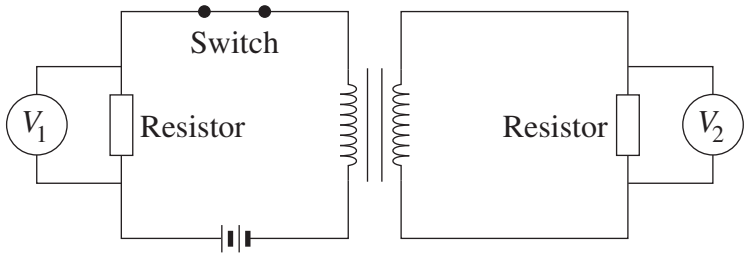
13 A triangular piece of wire is placed in a magnetic field as shown.



When current *I* is supplied as shown, how does the wire move?

	Axis of rotation	*Direction of movement*
A.	*YZ*	*Q* into page
B.	*YZ*	*Q* out of page
C.	*WX*	*R* into page
D.	*WX*	*R* out of page

14 The diagram shows a DC circuit containing a transformer.

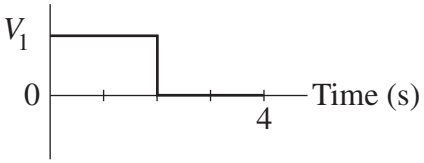


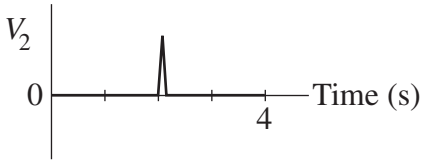
The potential differences V_1 and V_2 are measured continuously for 4 s. The switch is initially closed.

At $t = 2$ s, the switch is opened.

Which pair of graphs shows how the potential differences V_1 and V_2 vary with time over the 4-second interval?

A.





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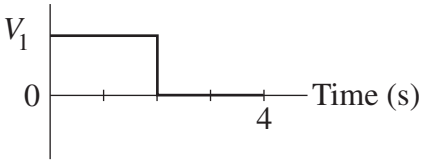

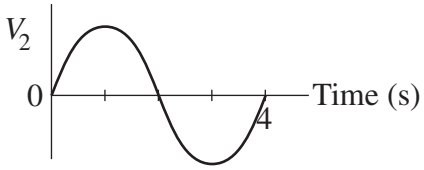

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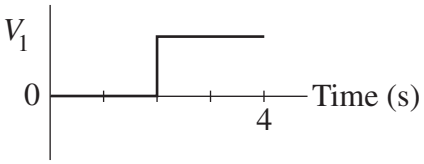

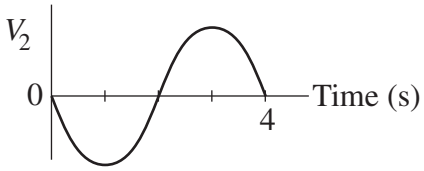

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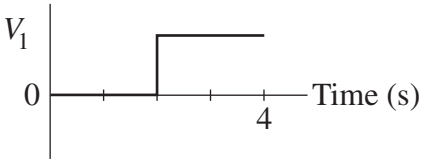
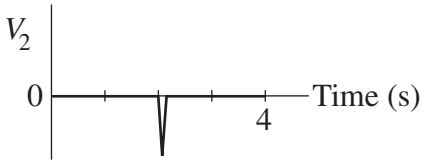
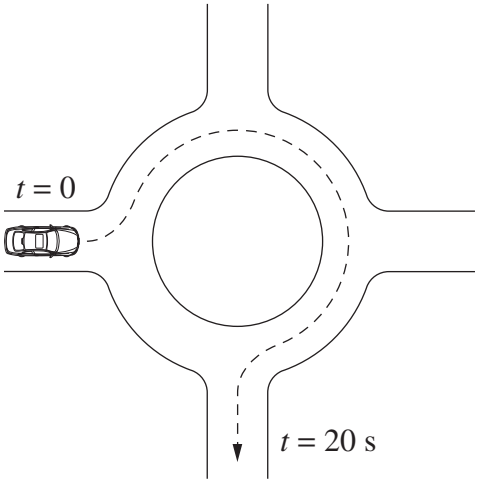
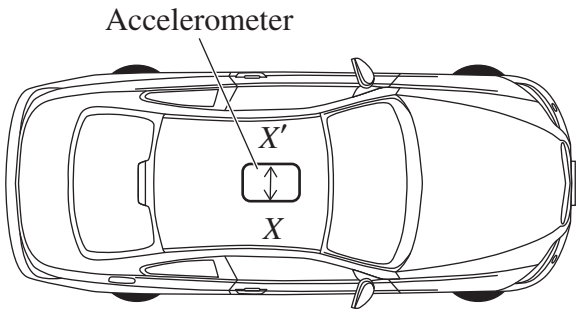




15 A car travelling at a constant speed follows the path shown.

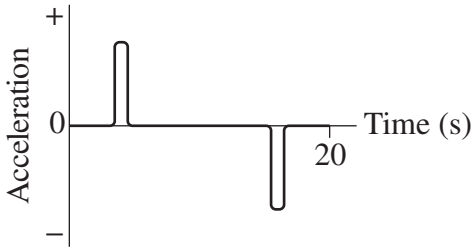




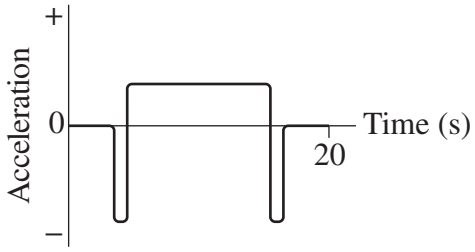
An accelerometer that measures acceleration along the X–X' direction is fixed in the car.

Which graph shows the measurements recorded by the accelerometer over the 20-second interval?

A.



B.



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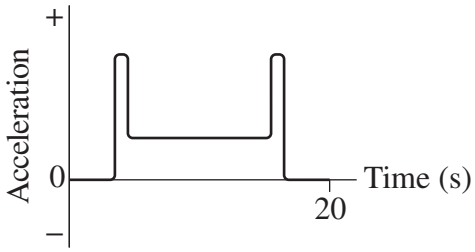
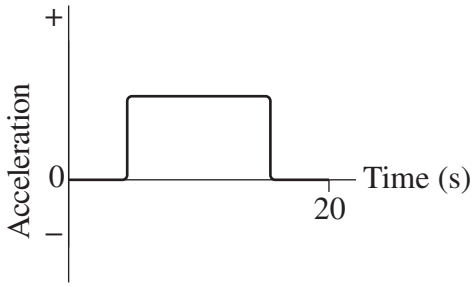


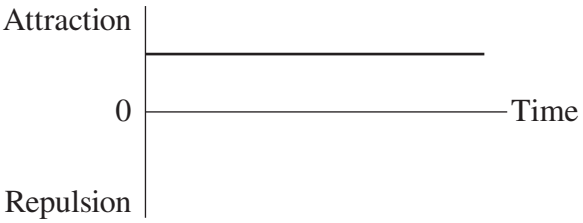
D.



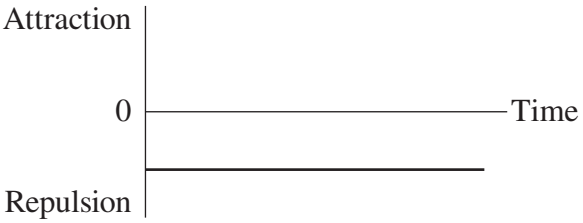
16 An AC supply is connected to a light bulb by two long parallel conductors as shown.

Which graph shows the variation over time of the magnetic force between the two conductors?

A.



B.



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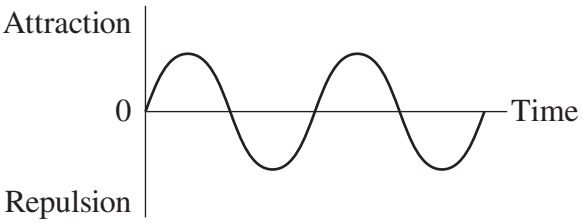

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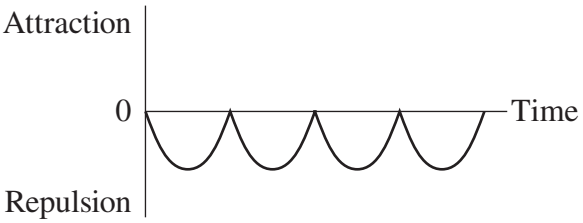
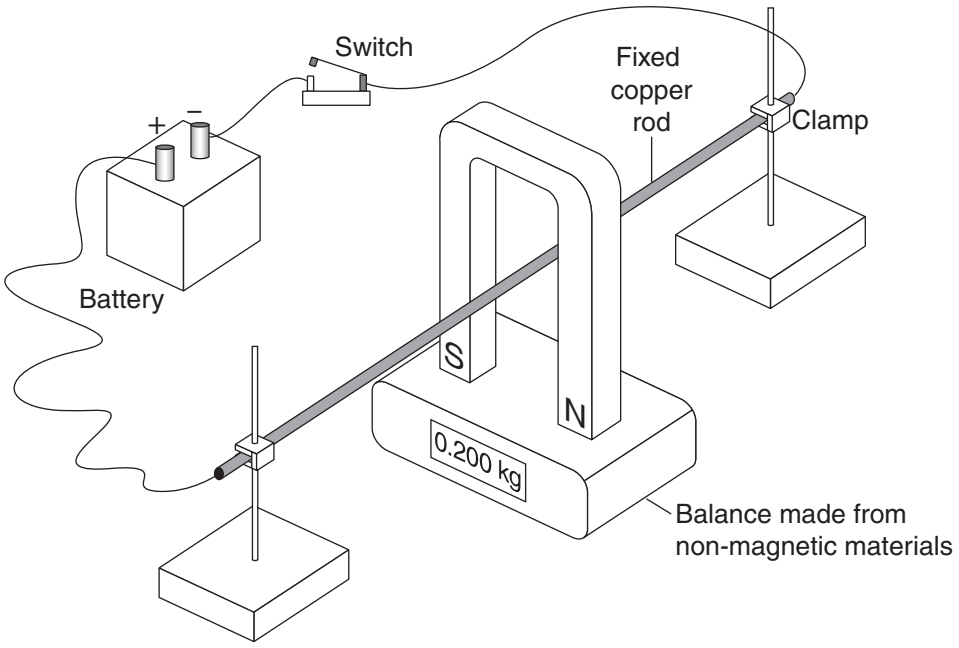


17 A magnet rests on an electronic balance. A rigid copper rod runs horizontally through the magnet, at right angles to the magnetic field. The rod is anchored so that it cannot move.



Which expression can be used to calculate the balance reading when the switch is closed?

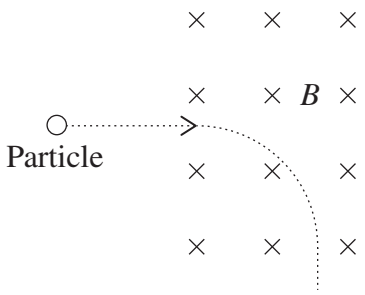
A. $0.200 \text{ kg} + BIl$

B. $0.200 \text{ kg} + \dfrac{BIl}{9.8}$

C. $0.200 \text{ kg} - BIl$

D. $0.200 \text{ kg} - \dfrac{BIl}{9.8}$

18 A particle of mass m and charge q travelling at velocity v enters a magnetic field of magnitude B and follows the path shown.

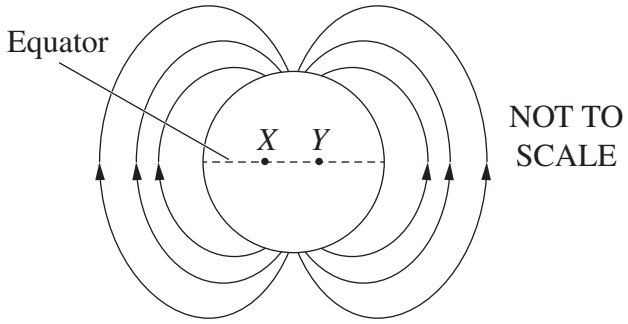


A second particle enters a magnetic field of magnitude $2B$ with a velocity of $\frac{1}{2}v$ and follows an identical path.

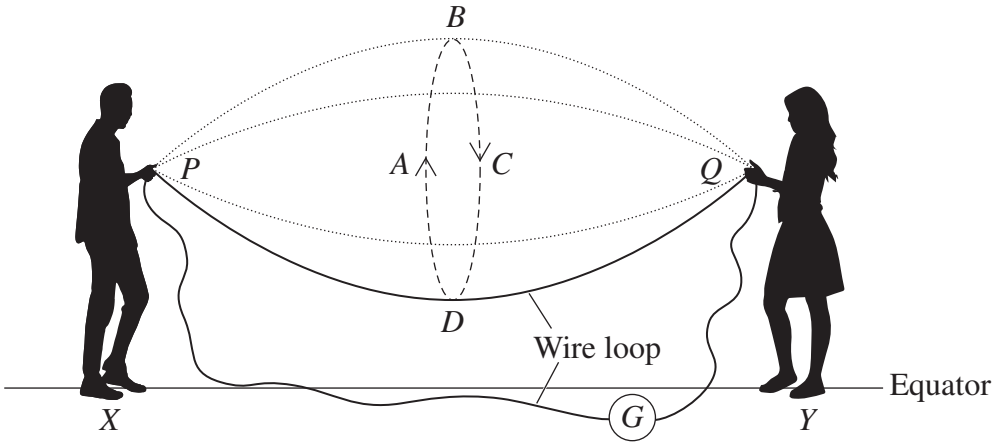
What is the mass and charge of the second particle?

	Mass	*Charge*
A.	m	q
B.	$\frac{1}{2}m$	$2q$
C.	$4m$	q
D.	m	$\frac{1}{2}q$

19 Earth's magnetic field is shown in the following diagram.



Two students standing a few metres apart on the equator at points *X* and *Y*, where Earth's magnetic field is parallel to the ground, hold a loop of copper wire between them. Part of the loop is rotated like a skipping rope as shown, while the other part remains motionless on the ground.



At what point during the rotation of the wire does the maximum current flow in a direction from *P* to *Q* through the moving part of the wire?

A. *A*

B. *B*

C. *C*

D. *D*

20 The length of a spaceship is measured by an observer to be 3.57 m as the spaceship passes with a velocity of 0.7c.

At what velocity would the spaceship be moving relative to the observer if its measured length was 2.5 m?

A. 0.490c

B. 0.707c

C. 0.714c

D. 0.866c

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2017 | HIGHER SCHOOL CERTIFICATE EXAMINATION

Centre Number

Student Number

Physics

Section I Part B
Answer Booklet

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

Instructions

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

Please turn over

Question 21 (5 marks)

A laser emits light of wavelength 550 nm.

(a) Calculate the frequency of this light. **2**

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(b) The electrons in a specific metal must absorb a minimum of 5×10^{-19} J in order to be ejected from its surface. **3**

Explain why electrons will not be ejected from this metal when photons of wavelength 550 nm strike its surface. Support your answer with relevant calculations.

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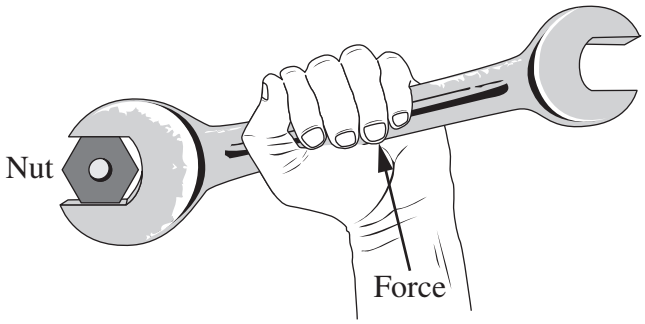
Question 22 (5 marks)

(a) A torque is applied to a nut, using a wrench, as shown. **2**



Suggest TWO ways that the applied torque could be increased.

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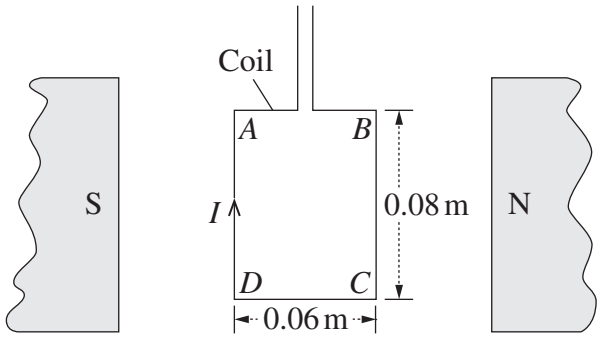
(b) A coil consisting of 15 turns is placed in a uniform 0.2 T magnetic field between two magnets. A current of 7.0 amperes flows in the direction shown. **3**



Calculate the magnitude and direction of the torque produced by the side *BC* of the 15-turn coil.

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Question 23 (5 marks)

Using examples from special relativity, explain how theories in science are validated in different ways. **5**

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Question 24 (5 marks)

The escape velocity from a planet is given by $v = \sqrt{\frac{2GM}{r}}$.

(a) The radius of Mars is 3.39×10^6 m and its mass is 6.39×10^{23} kg. **2**

Calculate the escape velocity from the surface of Mars.

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(b) Using the law of conservation of energy, show that the escape velocity of an object is independent of its mass. **3**

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Question 25 (7 marks)

(a) Outline the contribution of the Braggs to the scientific understanding of materials. **2**

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(b) Explain how doping pure silicon with boron changes its electrical properties. **2**

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(c) Outline reasons why superconductors are used on board maglev trains. **3**

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Question 26 (6 marks)

(a) Outline consequences of a crewed spacecraft re-entering Earth's atmosphere at an angle greater than 10°. **2**

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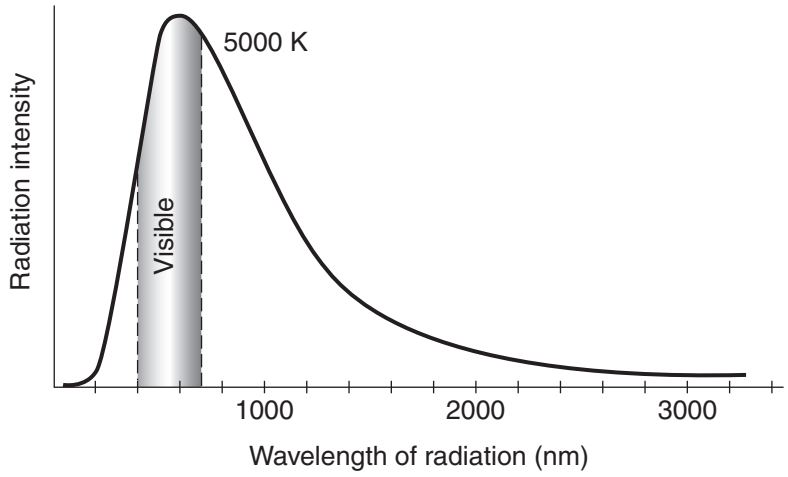
(b) When the 100 tonne space shuttle re-entered Earth's atmosphere from its orbit, the gases compressed in front of the decelerating shuttle reached a temperature of 5000 K. **4**

The graph shows the intensity of radiation emitted by gases at 5000 K.



Relate the information in the graph to the energy changes required for the shuttle to make a safe landing.

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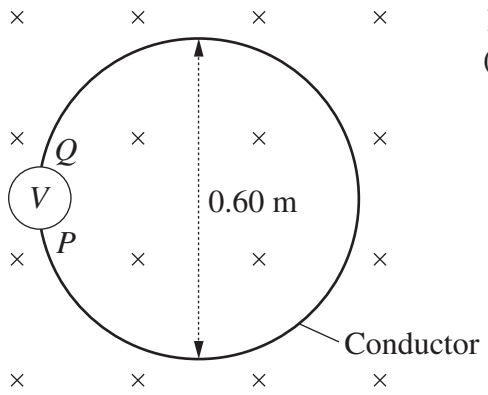
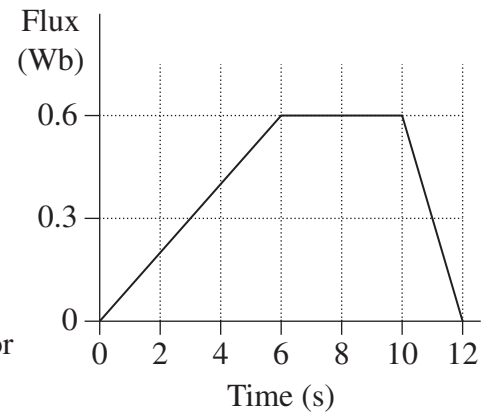
Question 27 (5 marks)

The diagram shows an electric circuit in a magnetic field directed into the page. The graph shows how the flux through the conductive loop changes over a period of 12 seconds.





(a) Calculate the maximum magnetic field strength within the stationary loop during the 12-second interval. **2**

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(b) Calculate the maximum voltage generated in the circuit by the changing flux. In your answer, indicate the polarity of the terminals *P* and *Q* when this occurs. **3**

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Question 28 (6 marks)

Contrast the design of transformers and magnetic braking systems in terms of the effects that eddy currents have in these devices. **6**

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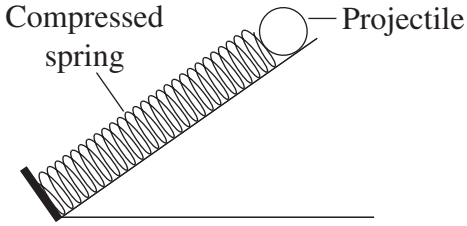
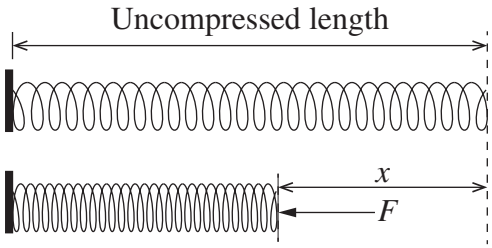
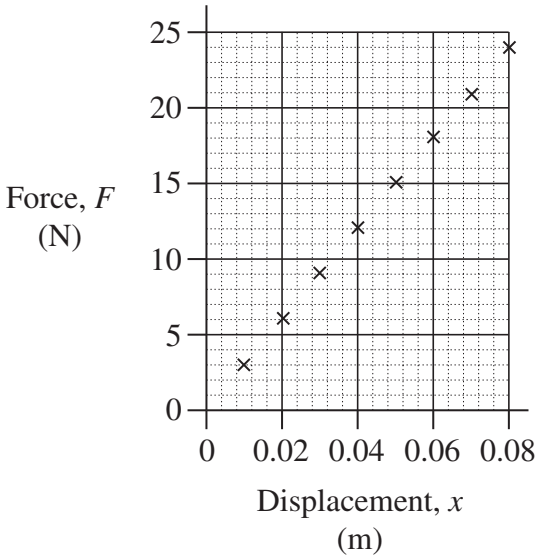
Question 29 (7 marks)

A spring is used to construct a device to launch a projectile. The force (F) required to compress the spring is measured as a function of the displacement (x) by which the spring is compressed.





The potential energy stored in the compressed spring can be calculated from $E_p = \frac{1}{2}kx^2$, where k is the gradient of the force–displacement graph shown.



Question 29 continues on page 27

Question 29 (continued)

(a) A projectile of mass 0.04 kg is launched using this device with the spring compressed by 0.08 m. Calculate the launch velocity. **4**

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(b) Calculate the range of a projectile launched by this device from ground level at an angle of 60° to the horizontal with a velocity of 10 m s^{-1}. **3**

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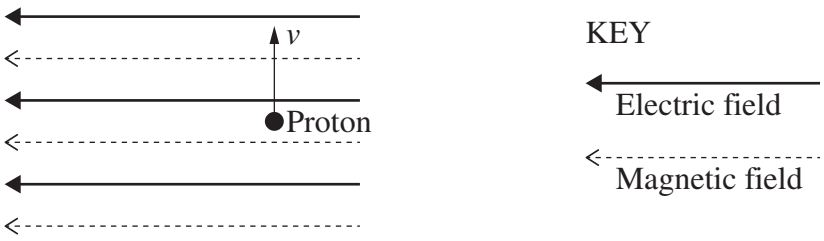
End of Question 29

Question 30 (4 marks)

In a thought experiment, a proton is travelling at a constant velocity in a vacuum with no field present. An electric field and a magnetic field are then turned on at the same time. **4**

The fields are uniform in magnitude and direction and can be considered to extend infinitely. The velocity of the proton at the instant the fields were turned on is perpendicular to the fields.



Analyse the motion of the proton after the fields have been turned on.

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Physics

Section II

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

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

Show all relevant working in questions involving calculations.

Pages

Question 31 Geophysics 30–31

Question 32 Medical Physics 32

Question 33 Astrophysics 33–34

Question 34 From Quanta to Quarks 35–36

Question 35 The Age of Silicon 37–39

Question 31 — Geophysics (25 marks)

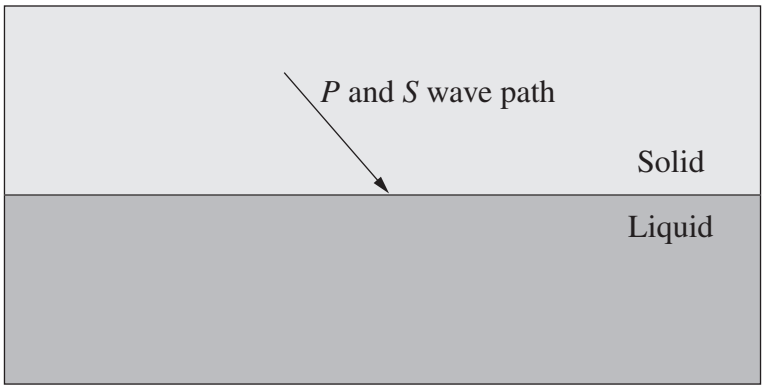
Answer parts (a), (b) and (c) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) (i) Give TWO reasons why the scientific community was initially reluctant to accept the idea that Earth's plates are moving. **2**

(ii) How do features associated with the magnetic properties of the oceanic crust support the theory of plate tectonics? **3**

(b) (i) *P* waves and *S* waves are travelling through the same medium. Contrast the movement of particles associated with these waves. **2**

(ii) Describe the behaviour of the *P* waves and *S* waves when they reach the boundary shown in the diagram. **3**



(c) Describe TWO different methods that can be used to calculate the mass of Earth. In your answer, refer to the relevant equations. **4**

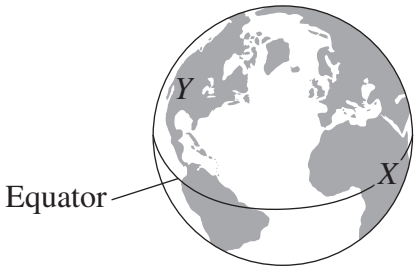
Question 31 continues on page 31

Question 31 (continued)

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

(d) (i) Outline how one type of gravimeter works. **2**

(ii) The diagram shows features of two locations, *X* and *Y*, which affect gravity measurements taken at those locations. **3**



KEY

X 200 m mountain

Y 5000 m mountain

Justify the use of data reduction when conducting gravity surveys at *X* and *Y*.

(e) Compare the information obtained about Earth's interior from natural vibrations and vibrations caused by human activity. In your answer, refer to the processes used to obtain the data. **6**

End of Question 31

Question 32 — Medical Physics (25 marks)

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

(a) (i) In an endoscope, how do the arrangements of fibres in coherent and incoherent bundles differ? **2**

(ii) Explain how light is used to create an endoscopic image. **3**

(b) (i) Describe how ultrasound can be used to measure ONE property of bone. **2**

(ii) B scans typically use ultrasound waves of frequency 20 MHz whereas sector scans typically use ultrasound waves of frequency 3.5 MHz. Account for the use of different frequencies in terms of the purposes of these scans. **3**

(c) Explain how the application of a radio frequency wave changes the behaviour of nuclei with net spin in a strong, external magnetic field. **4**

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

(d) (i) Describe ONE way in which X-ray radiation for medical imaging is produced. **2**

(ii) Why is a CAT scan image superior to a plain X-ray image? **3**

(e) Functional imaging techniques allow assessment of the way the body is working, rather than providing detailed information about its structure. **6**

Relate the processes used to produce functional medical images to their benefits. Include examples in your answer.

Question 33 — Astrophysics (25 marks)

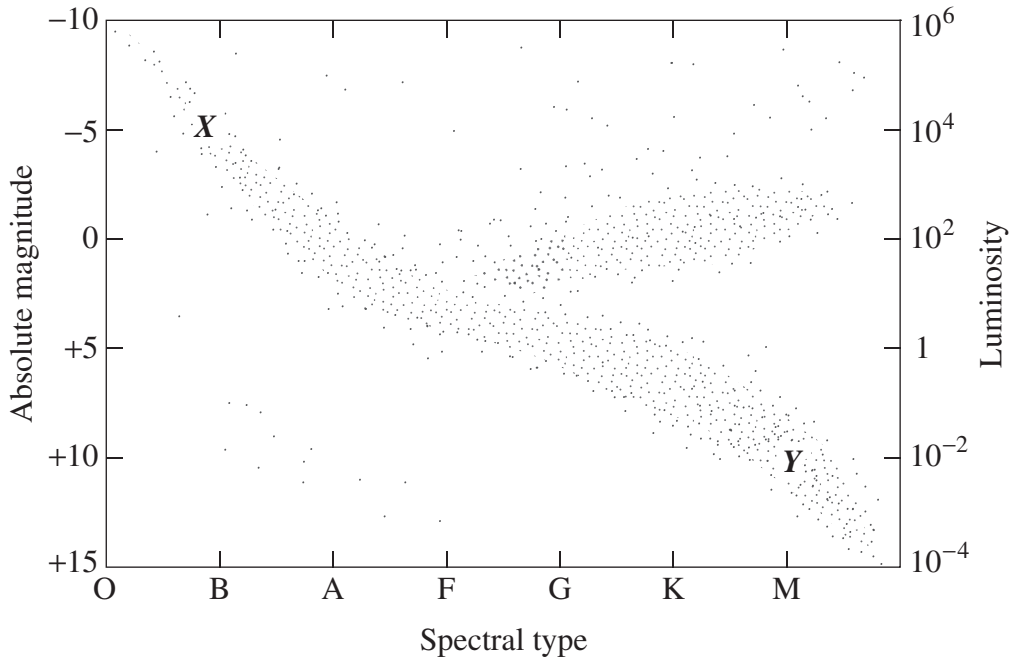
Answer parts (a), (b) and (c) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) (i) Why do space-based optical telescopes provide more information than similar sized Earth-based optical telescopes? **2**

(ii) Two stars, *P* and *Q*, have apparent magnitudes of 10.3 and 8.5. **3**

Use the brightness ratio to compare the brightness of these two stars.

(b) (i) The diagram shows the positions of stars *X* and *Y* on a H–R diagram. **2**



Outline the differences in the spectra of stars *X* and *Y*.

(ii) Describe a process which can be used to obtain the spectrum of an individual star. **3**

(c) A star has a negative colour index. **4**

Explain how the colour index is determined and how it can be used to deduce information about this star.

Question 33 continues on page 34

Question 33 (continued)

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

(d) (i) Use a labelled H–R diagram to show the areas in which stars would be plotted for a typical open cluster and a typical globular cluster. **2**

(ii) Outline the differences between the stars in an open cluster and a globular cluster. **3**

(e) Explain how gravitational forces affect star deaths for a range of solar masses. **6**

End of Question 33

Question 34 — From Quanta to Quarks (25 marks)

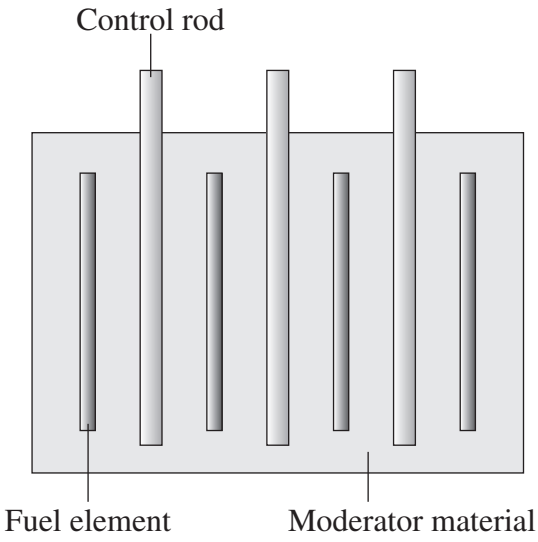
Answer parts (a), (b) and (c) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) (i) State the composition of the He-3 nucleus in terms of fundamental particles. **2**

(ii) Outline features of the strong nuclear force. **3**

(b) (i) Distinguish between the processes of nuclear fission and transmutation. **2**

(ii) The diagram shows some components of a nuclear reactor. **3**

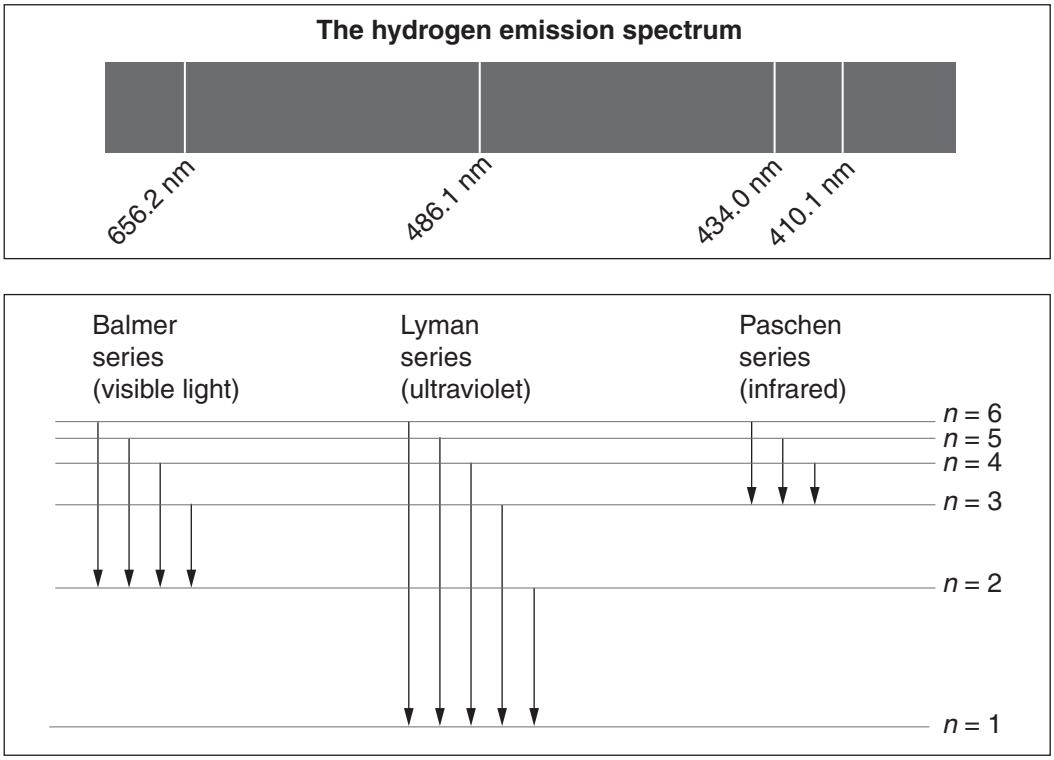


Explain how the labelled components work together to produce a controlled nuclear reaction.

Question 34 continues on page 36

Question 34 (continued)

(c) The diagrams show features of the hydrogen emission spectrum. **4**



With reference to Bohr's postulates, explain how the line at 434.0 nm in the hydrogen emission spectrum is produced. Support your answer with calculations.

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

(d) (i) How were the stable electron orbits in the Bohr model of the atom incompatible with a prediction of classical physics? **2**

(ii) How did de Broglie, and Davisson and Germer contribute to the modification of the Bohr model of the atom? **3**

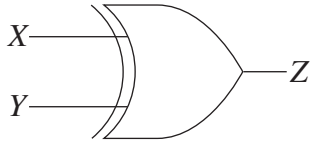
(e) Explain how the properties of protons and neutrons contribute to their uses as tools for investigating matter. **6**

End of Question 34

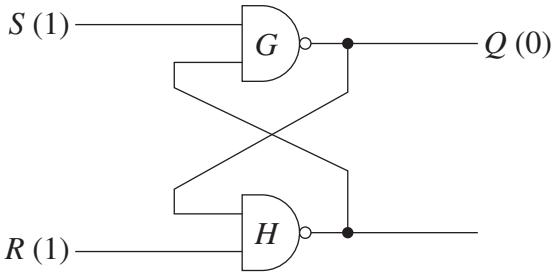
Question 35 — The Age of Silicon (25 marks)

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

(a) (i) The diagram shows a logic gate with two inputs. Construct a truth table for this logic gate. **2**



(ii) The logic circuit shown can be used to store data. The *Q* output is in the '0' state. The *R* and *S* inputs are in the '1' state. **3**

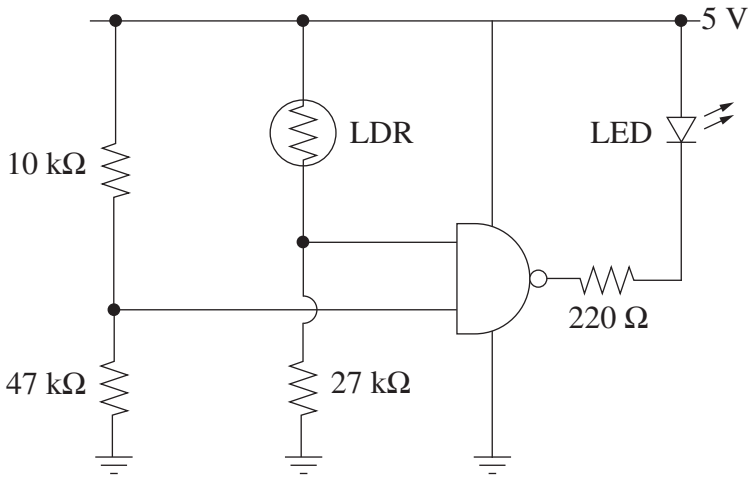


Show that the state of *Q* remains the same unless the *S* input state is changed to the '0' state.

Question 35 continues on page 38

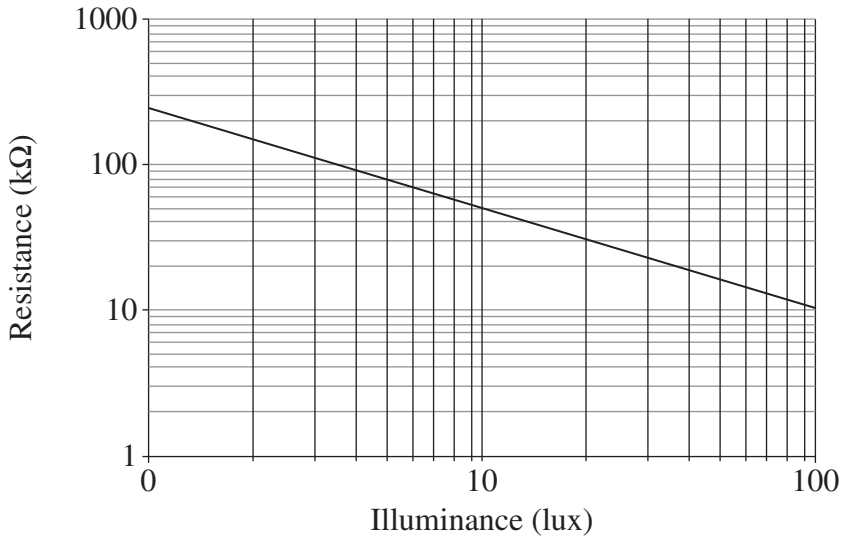
Question 35 (continued)

(b) The diagram shows a circuit incorporating a light dependent resistor (LDR).



(i) Use a sketch to show how the output of this circuit could be modified to operate a 12-volt fan. **2**

(ii) This graph shows how the resistance of the LDR changes with illuminance. **3**



For an input logic level to be high, the voltage must be greater than 2 V.

What is the minimum illuminance required to turn on the LED? Support your answer with calculations.

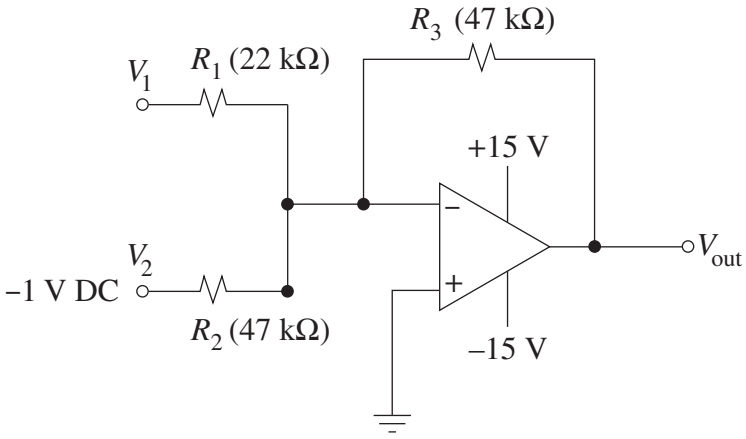
(c) Contrast open-loop gain amplifiers and closed-loop gain amplifiers in terms of their function and circuit construction. **4**

Question 35 continues on page 39

Question 35 (continued)

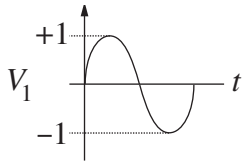
Answer parts (d) and (e) of the question on pages 6–8 of the Section II Writing Booklet. Start each part of the question on a new page.

(d) The diagram shows an operational amplifier connected to two input signals V_1 and V_2.



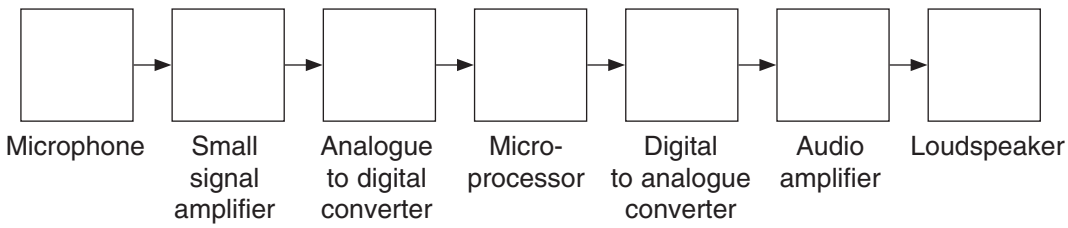
(i) Determine the formula relating inputs V_1 and V_2 to V_{out}. **2**

(ii) The input to V_1 is shown by the graph. **3**



Draw a voltage–time graph showing the voltage at V_{out}.

(e) The block diagram shows the essential components of a digital signal processing system. **6**



With reference to the diagram provided, explain why both analogue and digital circuits are used in audio systems.

End of paper

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Physics

DATA SHEET

Charge on electron, q_e	-1.602×10^{-19} C
Mass of electron, m_e	9.109×10^{-31} kg
Mass of neutron, m_n	1.675×10^{-27} kg
Mass of proton, m_p	1.673×10^{-27} kg
Speed of sound in air	340 m s^{-1}
Earth's gravitational acceleration, g	9.8 m s^{-2}
Speed of light, c	3.00×10^8 m s^{-1}
Magnetic force constant, $\left(k \equiv \frac{\mu_0}{2\pi}\right)$	2.0×10^{-7} N A^{-2}
Universal gravitational constant, G	6.67×10^{-11} N m^2 kg^{-2}
Mass of Earth	6.0×10^{24} kg
Planck constant, h	6.626×10^{-34} J s
Rydberg constant, R (hydrogen)	1.097×10^7 m^{-1}
Atomic mass unit, u	1.661×10^{-27} kg 931.5 MeV/c^2
1 eV	1.602×10^{-19} J
Density of water, ρ	1.00×10^3 kg m^{-3}
Specific heat capacity of water	4.18×10^3 J kg^{-1} K^{-1}

FORMULAE SHEET

$$v = f\lambda$$

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

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

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

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

$$P = VI$$

$$\text{Energy} = VIt$$

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

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

$$\Sigma F = ma$$

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

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

$$W = Fs$$

$$p = mv$$

$$\text{Impulse} = Ft$$

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

$$F = mg$$

$$v_x^2 = u_x^2$$

$$v = u + at$$

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

$$\Delta x = u_x t$$

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

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

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

$$E = mc^2$$

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

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

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

FORMULAE SHEET

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

$$F = BIl\sin\theta$$

$$\tau = Fd$$

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

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

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

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

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

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

$$F = qvB\sin\theta$$

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

$$E = hf$$

$$c = f\lambda$$

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

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

$$Z = \rho v$$

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

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

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

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

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

Standard atomic weights are abridged to four significant figures.

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

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).

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