NSW Education Standards Authority

IMPORTANT:
This resource was developed to support a previous version of the syllabus. It may contain content that differs from the current syllabus.

2018 **HIGHER SCHOOL CERTIFICATE EXAMINATION**

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA 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 2–32)

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 33–43)

- 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

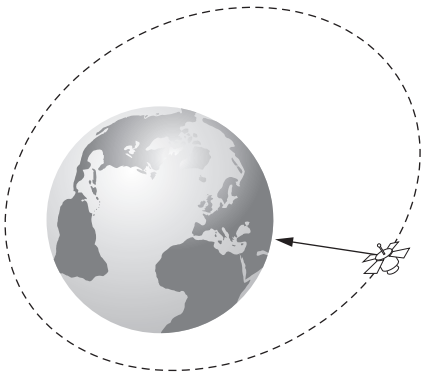
Use the multiple-choice answer sheet for Questions 1–20.

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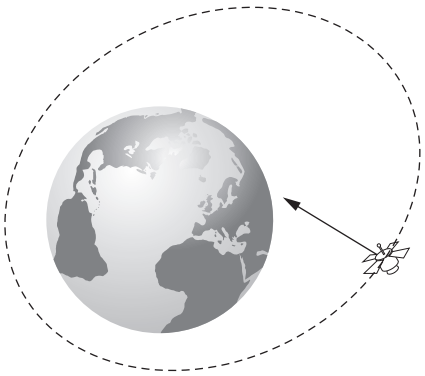
1 A satellite orbits Earth as shown.

Which diagram correctly shows the direction of the satellite's acceleration?

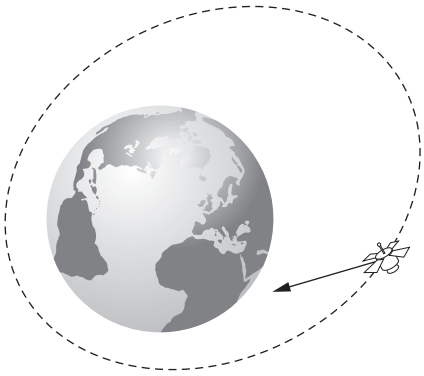
A.



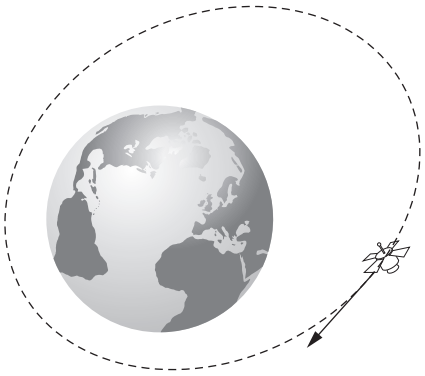
B.



C.

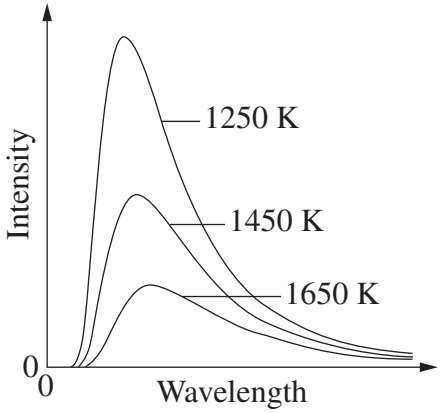


D.

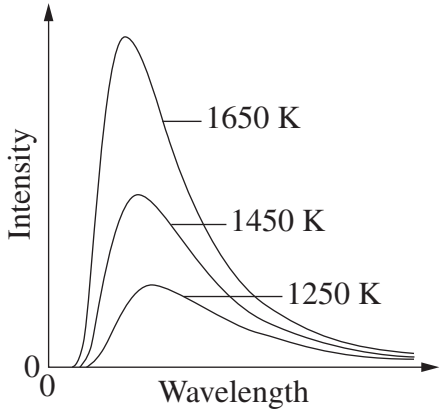


2 Which graph is consistent with predictions resulting from Planck's hypothesis regarding radiation from hot objects?

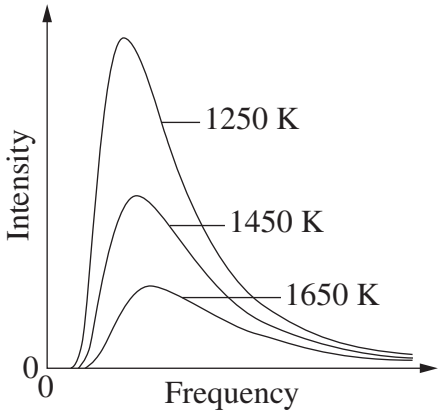
A.



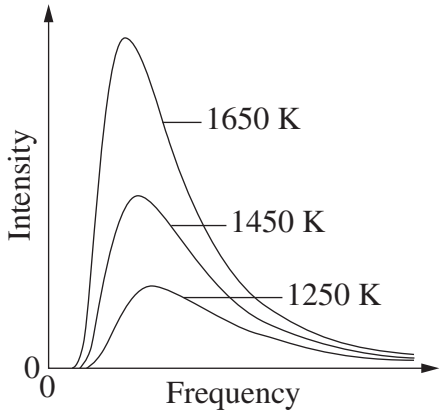
B.



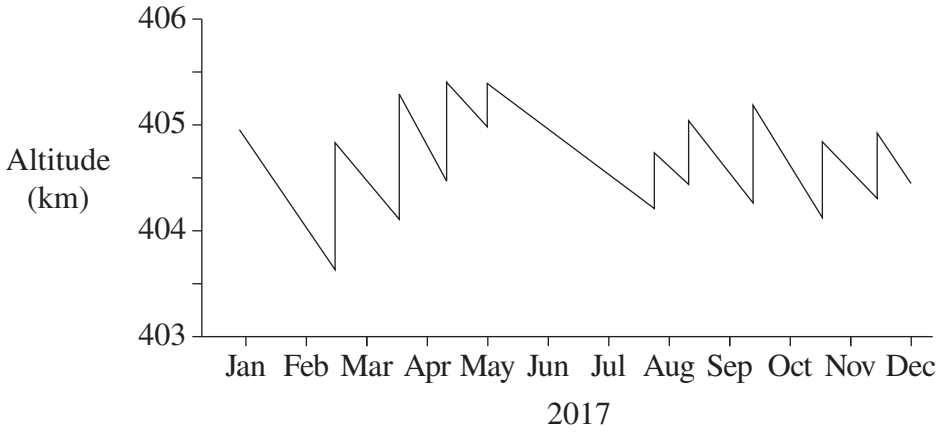
C.



D.



3 The graph shows the altitude of the International Space Station (ISS) during 2017.



The altitude can only be boosted by supply craft visiting the ISS.

Why does the altitude decrease in the times between height boosts?

A. Momentum of the ISS is being transferred to air molecules.

B. The moon's gravity changes the net force on the ISS as it orbits Earth.

C. The decrease in altitude makes it possible for a supply craft to reach the ISS.

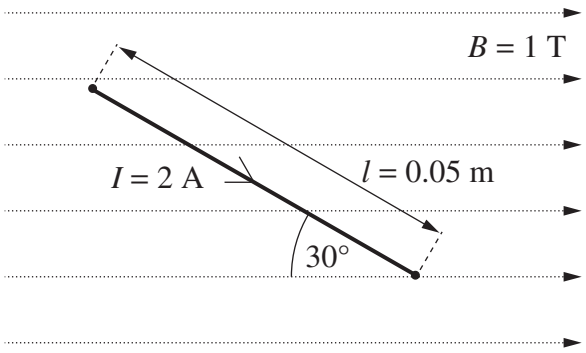
D. The total mass of the ISS changes with the deliveries from each supply craft.

4 A motor, battery and ammeter are connected in series. When the motor is turning at full speed, the ammeter has a reading of 0.1 A. While the motor is spinning, a person holds the shaft of the motor to stop it.

Which row of the table correctly identifies the change in the ammeter reading and an explanation for the change?

	Reading on ammeter	*Explanation*
A.	Decreases	Decrease in back emf
B.	Increases	Increase in back emf
C.	Decreases	Increase in back emf
D.	Increases	Decrease in back emf

5 The diagram shows a current-carrying conductor in a magnetic field.



What is the magnitude of the force on the conductor?

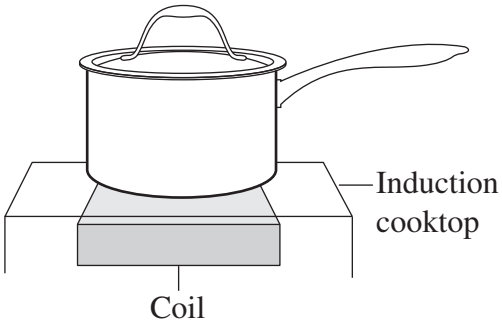
A. 0 N

B. 0.05 N

C. 0.09 N

D. 0.10 N

6 The diagram shows a saucepan of water on an induction cooktop.



Which row of the table correctly identifies a property of the material used to make the saucepan and the frequency of the changing magnetic field produced by the coil?

	Property of saucepan	*Frequency*
A.	Insulator	High (50 kHz)
B.	Conductor	High (50 kHz)
C.	Insulator	Low (50 Hz)
D.	Conductor	Low (50 Hz)

7 A planet *X* has twice the mass and twice the radius of Earth.

What is the magnitude of the gravitational acceleration close to the surface of planet *X*?

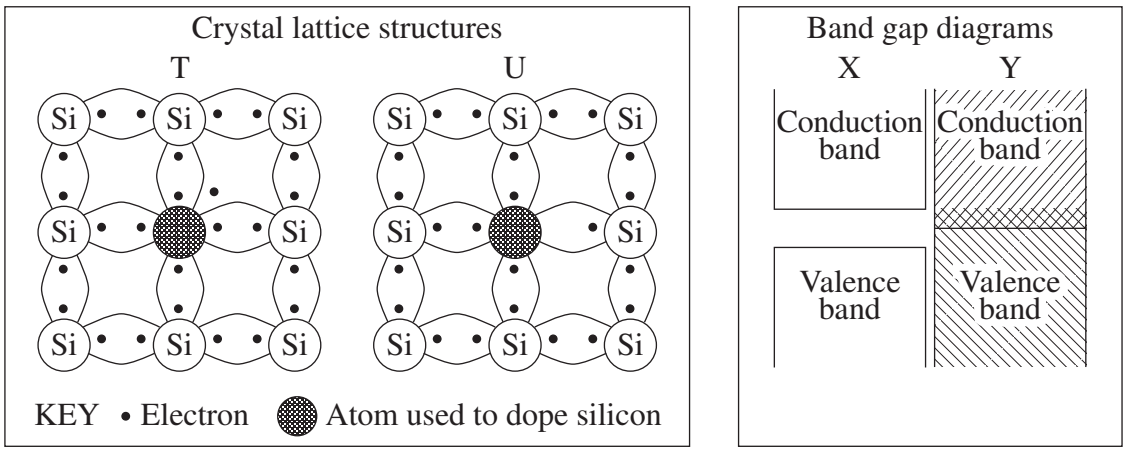
A. $\frac{1}{2}g$

B. $1\,g$

C. $2\,g$

D. $4\,g$

8 Crystal lattice structures for two types of doped semiconductors and band gap diagrams for two types of materials are shown.



Which row of the table correctly matches the type of doped semiconductor with its crystal lattice structure and band gap diagram?

	Type of semiconductor	*Crystal lattice structure*	*Band gap diagram*
A.	*n*-type	U	X
B.	*n*-type	T	Y
C.	*p*-type	T	Y
D.	*p*-type	U	X

9 A hypothetical journey to a distant star might be accomplished in an astronaut's life span by travelling at relativistic speeds.

What is the key concept which underpins such a hypothetical journey?

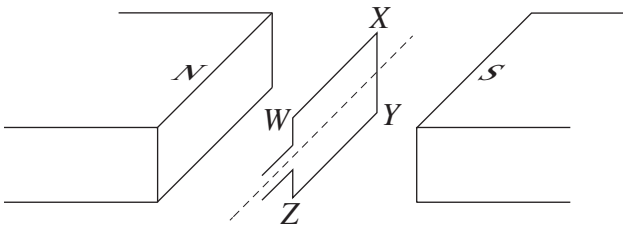
A. From the frame of reference of the spacecraft making the journey, the distance to the star is less.

B. Clocks on the spacecraft run slower and hence the rate at which fuel is used for the journey is decreased.

C. Relativistic effects on the spacecraft reduce its mass, making it possible to accelerate to the speeds needed for such a journey.

D. The relativistic increase in the mass of the fuel on board makes it possible to complete a longer journey with less fuel.

10 The diagram shows some parts of a simple DC motor.



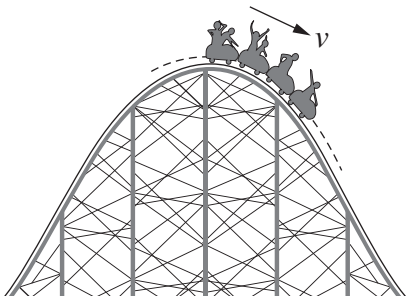
Which row of the table correctly describes the direction of force acting on side *WX* and the direction of torque this produces on the coil?

	Direction of force acting on WX	*Direction of torque produced on the coil by the force acting on WX*
A.	Remains constant	Remains constant
B.	Remains constant	Reverses every 180°
C.	Reverses every 180°	Remains constant
D.	Reverses every 180°	Reverses every 180°

11 During the launch of a space vehicle from Earth, an astronaut feels an increased downward *g* force.

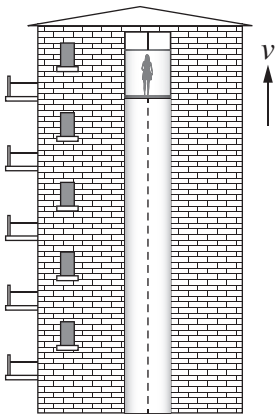
In which of the following situations would a person also feel an increased downward *g* force?

A.



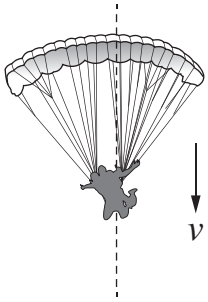
Roller-coaster speeding up

B.



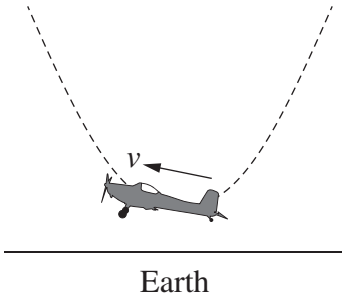
Lift slowing down

C.



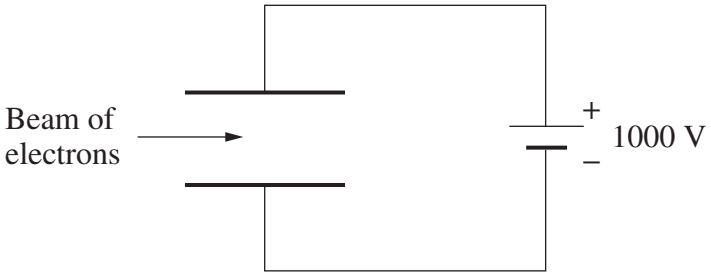
Parachute falling at a constant velocity

D.



Plane pulling out of a dive

12 The diagram shows electrons travelling in a vacuum at 2×10^6 m s^{-1} between two charged metal plates 1×10^{-3} m apart.



A magnetic field is to be applied to make the electrons continue to travel in a straight line.

What is the magnitude and direction of the magnetic field that is to be applied?

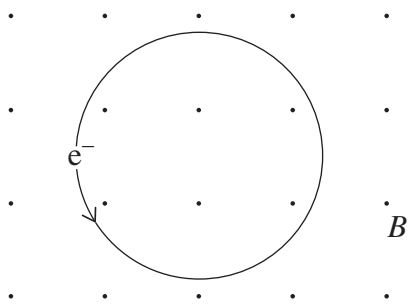
A. 5×10^{-1} T into the page

B. 5×10^{-1} T out of the page

C. 1×10^{6} T into the page

D. 1×10^{6} T out of the page

13 An electron moves in a circular path with radius r in a magnetic field as shown.



If the speed of the electron is increased, which row of the table correctly shows the effects of this change?

	Force on electron	*Radius of path*
A.	Increases	Decreases
B.	Increases	Increases
C.	Decreases	Decreases
D.	Decreases	Increases

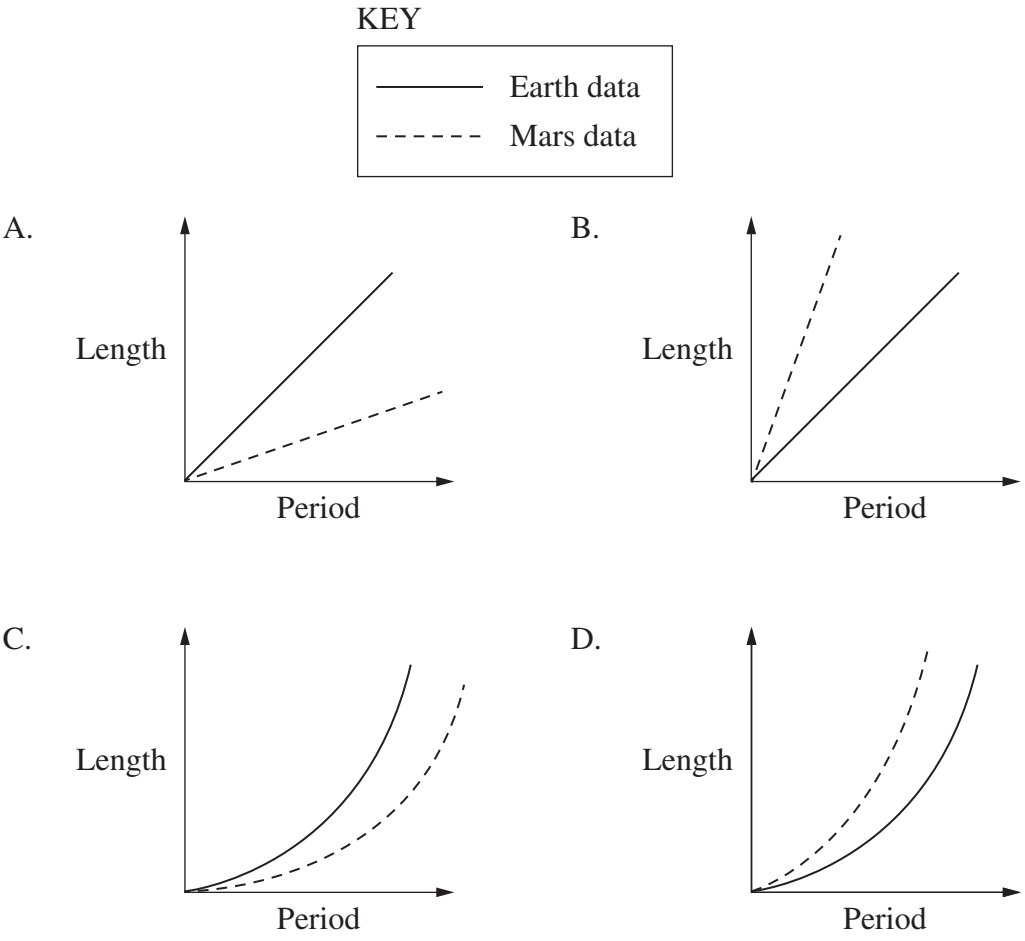
14 A pendulum can be used to determine the acceleration due to gravity using the relationship

$$T = 2\pi\sqrt{\frac{l}{g}}$$

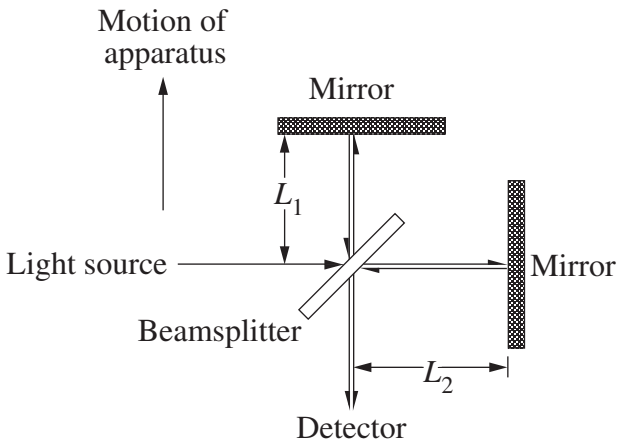
where T is the period and l is the length of the pendulum.

The acceleration due to gravity on the surface of Mars is less than that on Earth.

Which graph relates the variables for the pendulum correctly for both planets?



15 The diagram shows a simplified model of the Michelson–Morley experiment. It can be assumed that distances L_1 and L_2 are equal without affecting the outcome.



The times taken for the light to travel in both directions along the lengths L_1 and L_2 are t_1 and t_2 respectively.

What was Michelson attempting to demonstrate in this experiment?

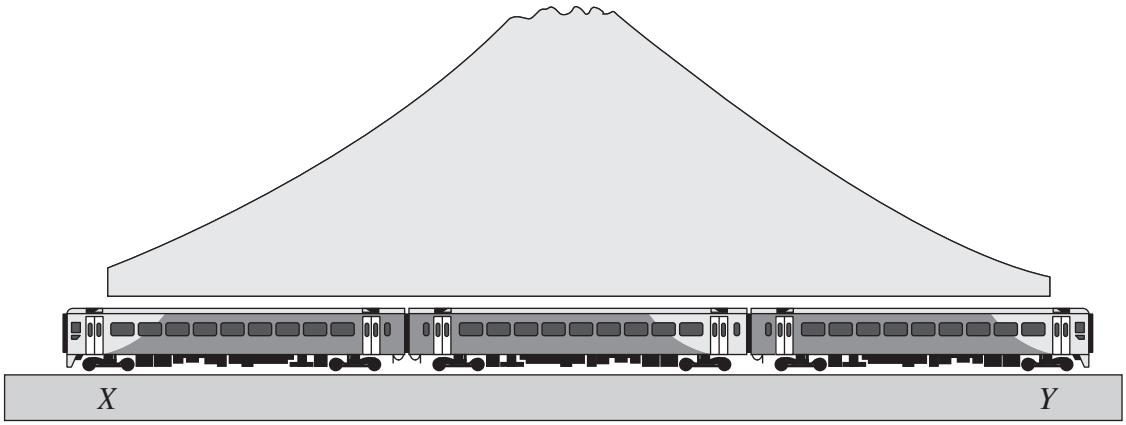
A. The relativistic contraction of L_1 would cause t_1 to be less than t_2.

B. The ether is carried through space with Earth, which would cause t_1 to be equal to t_2.

C. The times t_1 and t_2 would be the same because the velocity of the apparatus was much less than the speed of light.

D. The motion of the apparatus resulting from Earth's orbital motion around the sun would cause t_1 to be greater than t_2.

16 When a train is at rest in a tunnel, the train is slightly longer than the tunnel.



In a thought experiment, the train is travelling from left to right fast enough relative to the tunnel that its length contracts and it fits inside the tunnel.

An observer on the ground sets up two cameras, at *X* and *Y*, to take photos at exactly the same time. The photos show that both ends of the train are inside the tunnel.

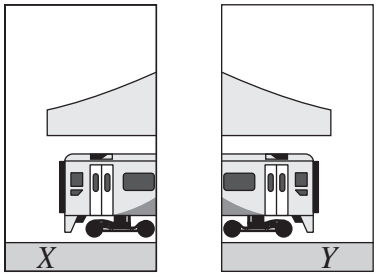


Photo 1 Photo 2

A passenger travelling on the train at its centre can see both ends of the tunnel and is later shown the photos.

From the point of view of the passenger, what is observed and what can be deduced about the photos?

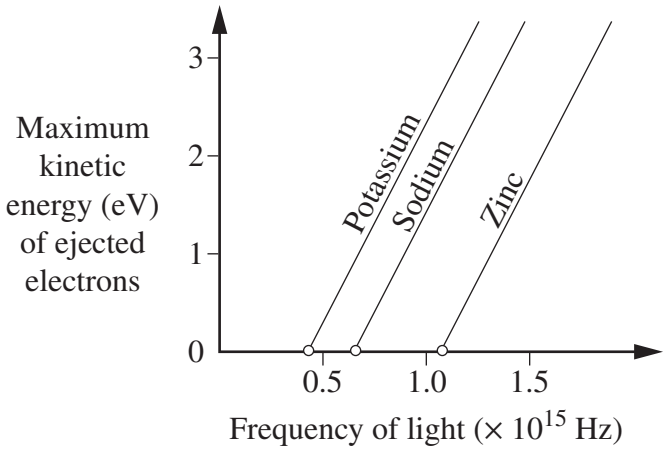
A. The tunnel's length contracts so the train does not fit, and photo 2 is taken before photo 1.

B. The tunnel's length contracts so the train does not fit, and photos 1 and 2 are taken at the same time.

C. The tunnel appears to expand due to length contraction of the train, allowing it to fit in the tunnel, and photo 1 is taken before photo 2.

D. The tunnel appears to expand due to length contraction of the train, allowing it to fit in the tunnel, and photos 1 and 2 are taken at the same time.

17 The graph shows the maximum kinetic energy of electrons ejected from different metals as a function of the frequency of the incident light.



What can be deduced from this graph?

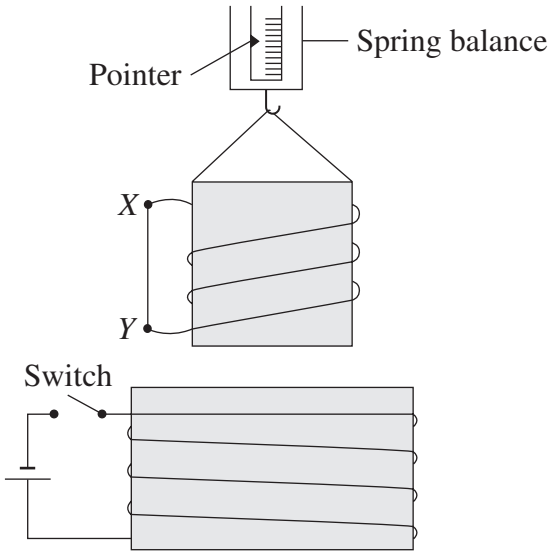
A. The maximum kinetic energy of ejected electrons is proportional to the number of photons incident on the metal surface.

B. More photons are required to cause an electron to be ejected from zinc than from potassium.

C. Any photon that can eject an electron from the surface of zinc must also be able to cause an electron to be ejected from potassium.

D. For any given frequency that causes electrons to be ejected from all three metals, the number of electrons ejected is always greatest for potassium.

18 An experiment is set up as shown.

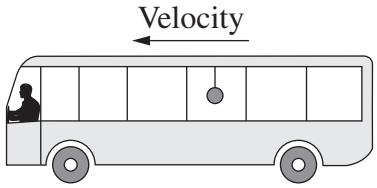


When the switch is closed, the reading on the spring balance changes immediately, then returns to the initial reading.

Which row of the table correctly shows the direction of the current through the straight conductor *XY* and the direction in which the pointer on the spring balance initially moves?

	Direction of current through the straight conductor	*Direction in which the pointer initially moves*
A.	From *X* to *Y*	Down
B.	From *X* to *Y*	Up
C.	From *Y* to *X*	Down
D.	From *Y* to *X*	Up

19 A mass was hanging from the roof of a bus that was travelling forward on a horizontal road at a constant velocity.



The string holding the mass was cut. At the same instant, the bus driver applied the brakes, causing the bus to slow down at a rate of 3 m s^{-2}.

To an observer outside the bus, the mass follows a parabolic trajectory.

Which statement correctly describes the resulting motion of the mass observed from within the frame of reference of the moving bus?

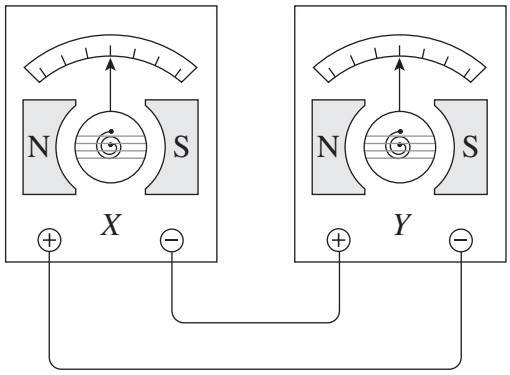
A. The mass travelled in a straight line vertically downwards.

B. The mass travelled in a straight line downwards and towards the front of the bus.

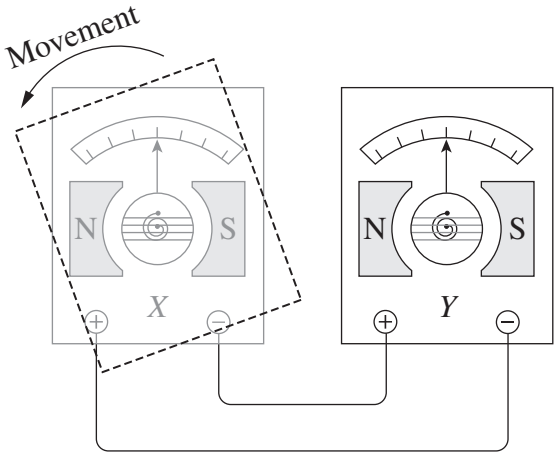
C. The mass travelled in a parabolic path downwards and towards the back of the bus.

D. The mass travelled in a parabolic path downwards and towards the front of the bus.

20 Two identical galvanometers *X* and *Y* were connected as shown and placed on a desk.



The meter *X* was then picked up and rotated suddenly anticlockwise to the position shown by the dotted outline, while the meter *Y* remained stationary on the desk.



When this action is carried out, the pointers on both meters move relative to the scales on the meters.

Which row of the table correctly identifies the movement of the pointer on *Y* and the reason for its behaviour?

	Movement of pointer	*Reason*
A.	Towards right	The movement of *X* produces a current that flows into the opposite terminal of *Y*.
B.	Towards right	According to Lenz's law the effect produced must oppose the cause of the flux.
C.	Towards left	*Y* behaves as a motor with the current flowing through it from right to left.
D.	Towards left	For every force, there is an equal and opposite force.

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2018 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.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Please turn over

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Question 21 (4 marks)

(a) Compare the force of gravity exerted on the moon by Earth with the force of gravity exerted on Earth by the moon. **2**

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(b) The acceleration due to gravity on the moon is $1.6\ m\ s^{-2}$ and on Earth it is $9.8\ m\ s^{-2}$. Quantitatively compare the mass and weight of a 70 kg person on the moon and on Earth. **2**

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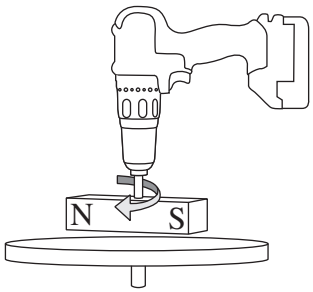
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Question 22 (6 marks)

(a) A drill spins a magnet above a non-magnetic metal disc which is free to rotate. **3**



Explain the effect of the rotating magnet on the disc.

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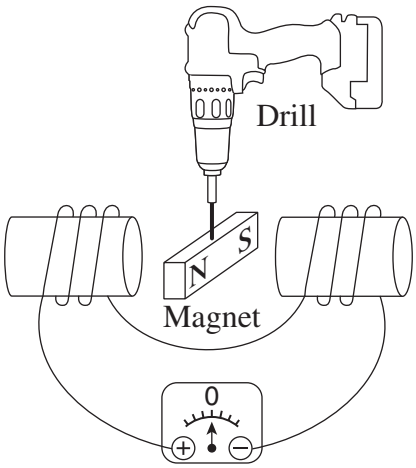
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Question 22 continues on page 21

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(b) The diagram shows a magnet attached to an electric drill so that it can be rotated between two coils connected to a voltmeter. **3**



The drill starts from rest and gradually speeds up, reaching its full speed after three revolutions.

Sketch a graph showing the induced emf across the coils during the time that it takes the magnet to reach its full speed.



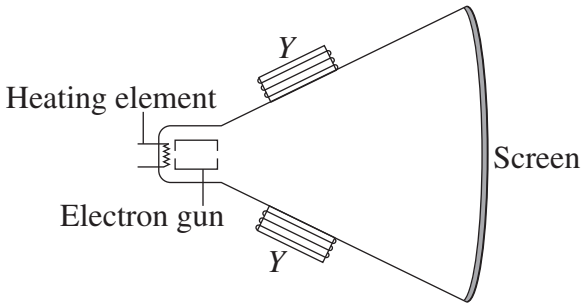
End of Question 22

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Question 23 (5 marks)

The diagram shows a cathode ray tube in a television.



(a) Outline energy changes associated with the electrons passing through the gun, and when they strike the screen. **2**

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(b) Explain the role of the components labelled *Y* in forming an image on the screen. **3**

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Question 24 (5 marks)

(a) Outline TWO features of high-voltage transmission lines that contribute to the safe transmission of electricity. **2**

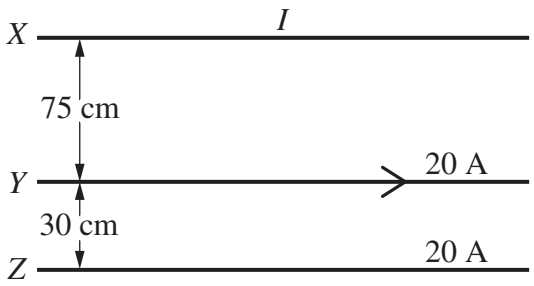
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(b) Three parallel wires *X*, *Y* and *Z* all carry electric currents. A force of attraction is produced between *Y* and *Z*. There is zero net force on *Y*. **3**



What is the magnitude and direction of the current in *X*?

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Question 25 (6 marks)

(a) State ONE benefit and ONE limitation of the use of superconductors in the transmission of electricity through power grids. **2**

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(b) Contrast features of electrical conduction in a pure metal at room temperature with electrical conduction in a pure metallic superconductor below its critical temperature. **4**

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Question 26 (4 marks)

Outline the similarities and differences between the effects of electric fields and gravitational fields on matter. In your answer, refer to the definitions of these fields. **4**

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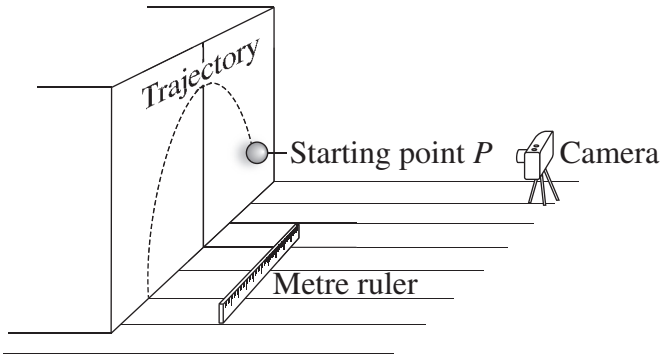
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Question 27 (6 marks)

(a) The diagram shows a camera and a ruler set up to obtain data about a projectile's motion along the trajectory shown. The entire trajectory is visible through the camera. **3**



Identify ONE of the errors in this set-up and describe the effect of this error on the results.

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Question 27 continues on page 27

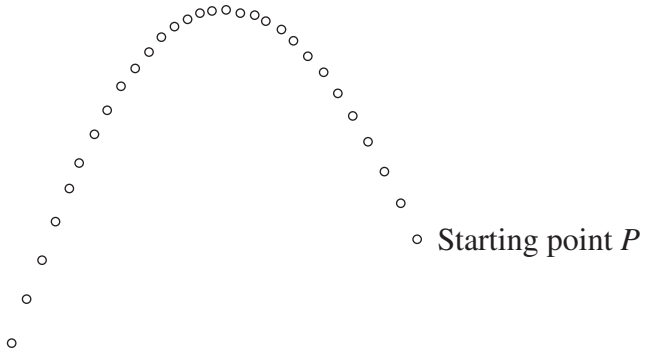
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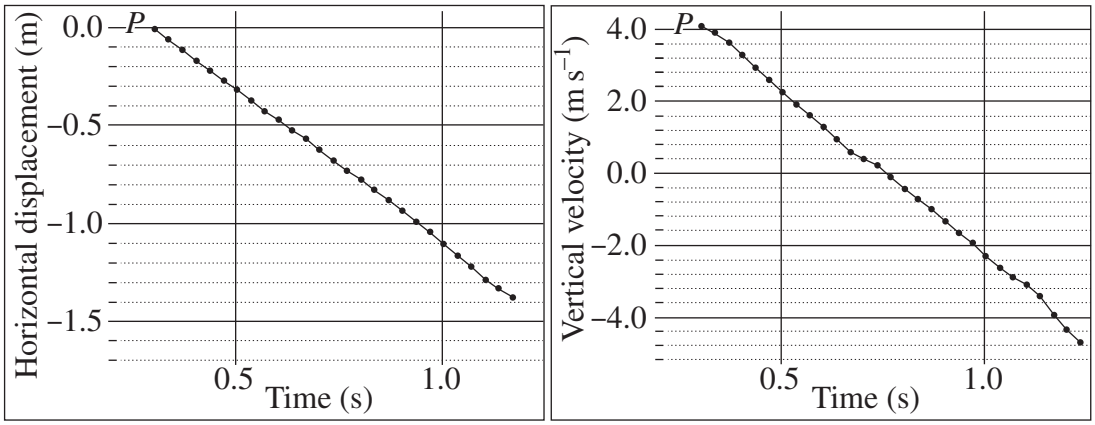
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(b) An experiment was set up based on the method described in part (a), but conducted so that the data obtained were valid. **3**

The image shows the trajectory of the ball.



The graphs show data from this experiment.



Using the graphs, describe the velocity and acceleration of the ball quantitatively and qualitatively.

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End of Question 27

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Question 28 (5 marks)

The radius of the moon is 1740 km. The moon's mass is 7.35×10^{22} kg. In this question, ignore the moon's rotational and orbital motion.

A 20 kg mass is launched vertically from the moon's surface at a velocity of 1200 m s^{-1}.

(a) Show that the change in potential energy of the mass in moving from the surface to an altitude of 500 km is 1.26×10^7 J. **2**

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(b) Calculate the velocity of the 20 kg mass at an altitude of 500 km. **3**

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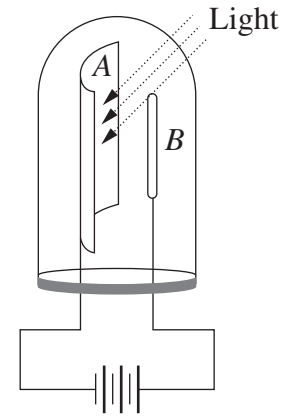
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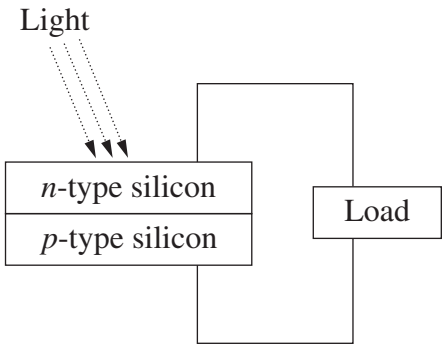
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Question 29 (8 marks)

The diagram shows two different cells.



Vacuum photocell



Solar cell

(a) How does light contribute to the flow of current in each of these two cells? **4**

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(b) Explain how ONE advance in scientific understanding and ONE advance in technology have led to the use of semiconductors. **4**

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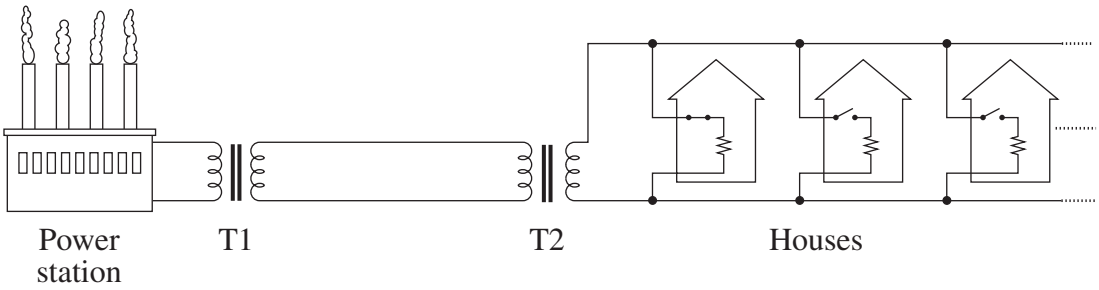
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Question 30 (6 marks)

The diagram shows a model of a system used to distribute energy from a power station through transmission lines and transformers to houses. **6**



During the evening peak period there is an increase in the number of electrical appliances being turned on in houses.

Explain the effects of this increased demand on the components of the system, with reference to voltage, current and energy.

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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 34

Question 32 Medical Physics 35–36

Question 33 Astrophysics 37–38

Question 34 From Quanta to Quarks 39–40

Question 35 The Age of Silicon 41–43

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) Seismic methods are used to investigate physical properties of Earth. Identify TWO other methods used by geophysicists. **2**

(ii) How does a geophysical method, other than a seismic method, provide information about physical properties of Earth? **3**

(b) In November 2017, a new polar-orbiting weather satellite NOAA–20 was placed in orbit. Its orbital period is 100 minutes and it orbits Earth at an altitude of 870 km. The average radius of Earth is 6370 km.

(i) Explain ONE feature of NOAA–20's orbit that will make it better for monitoring climate than a geostationary satellite. **2**

(ii) Calculate the mass of Earth using the information provided about NOAA–20's orbit. The answer is different to that shown on the data sheet provided. **3**

(c) Explain how both Richer and Newton independently used data obtained from experiments using pendulums to determine the shape of Earth. **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) How are seismic data used to provide a model of Earth's core? Support your answer with a diagram. **4**

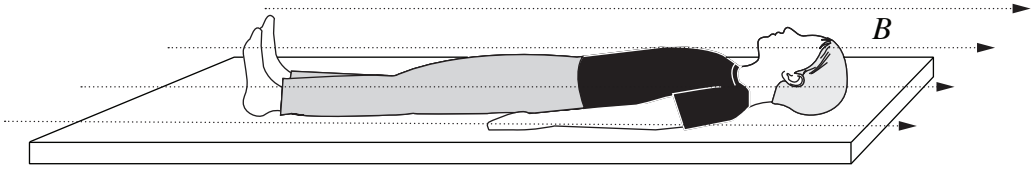
(e) Explain the role of palaeomagnetic data in providing evidence that supports the theory of plate tectonics. **7**

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.

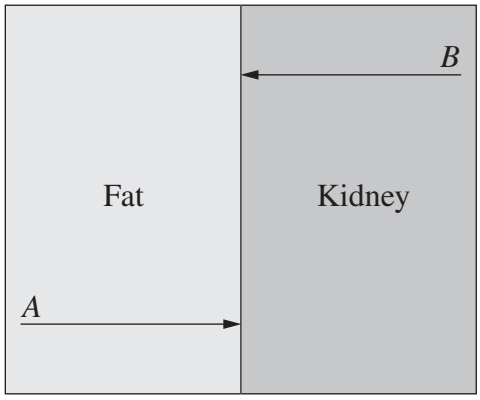
(a) (i) Identify TWO specific uses of magnetic resonance imaging (MRI). **2**

(ii) The diagram shows a person in the magnetic field within an MRI machine. **3**



Describe the effects of the application of the strong magnetic field, B, on hydrogen nuclei in the person's body.

(b) The diagram represents fat and kidney tissues inside a human body. The acoustic impedances of these tissues are not the same.



(i) Ultrasound waves A and B have the same frequency. **2**

Compare the behaviour of ultrasound waves A and B at the fat–kidney boundary.

(ii) The density of kidney tissue is $1050\ \text{kg m}^{-3}$ and the velocity of ultrasound waves in kidney tissue is $1560\ \text{m s}^{-1}$. At the fat–kidney boundary, the intensity of the reflected ultrasound is 1.0 % of that of the incident ultrasound. **3**

Calculate the acoustic impedance of fat tissue.

Question 32 continues on page 36

Question 32 (continued)

(c) Iodine-124 is a radioactive element. The equation for its decay is shown. The symbol e^+ is sometimes shown as β^+. **4**

$$^{124}I \rightarrow {}^{124}Te + e^+$$

The following is a decay table for iodine-124.

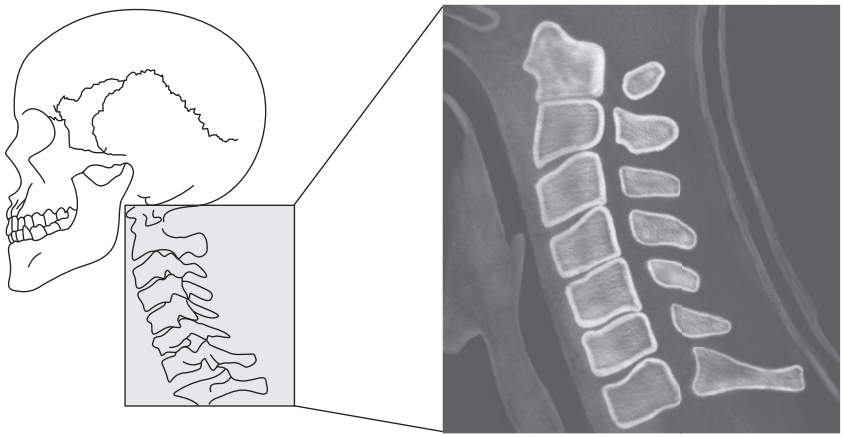
Time (h)	0	20	40	60	80	100	120	140
Proportion remaining	1.000	0.871	0.758	0.661	0.575	0.501	0.436	0.355

Justify the use of iodine-124 as a medical diagnostic tool. Support your answer quantitatively.

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) Explain how the Doppler effect is used for medical imaging. **4**

(e) The following image of the bones in a person's neck was produced using computed axial tomography (CAT). **7**



Compare both the production and benefits of this CAT image with a conventional X-ray image of the same part of the person's body.

End of Question 32

Question 33 — Astrophysics (25 marks)

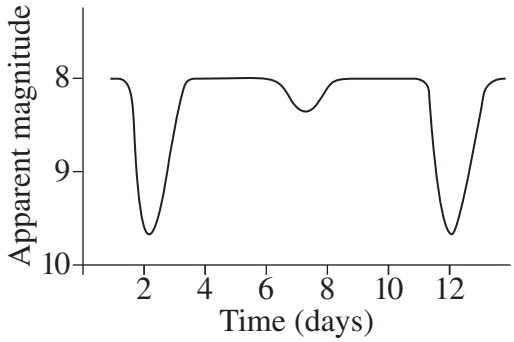
Answer parts (a), (b) and (c) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) (i) Define the parsec with the aid of a diagram. **2**

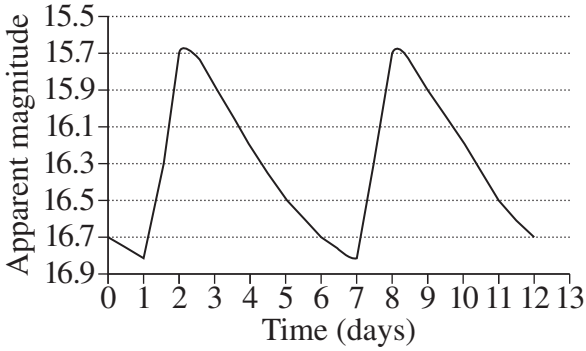
(ii) Outline TWO limitations of using ground-based instruments to make trigonometric parallax measurements. **3**

(b) The diagrams show light curves of two variable stars.

Graph A – Light curve of a binary star

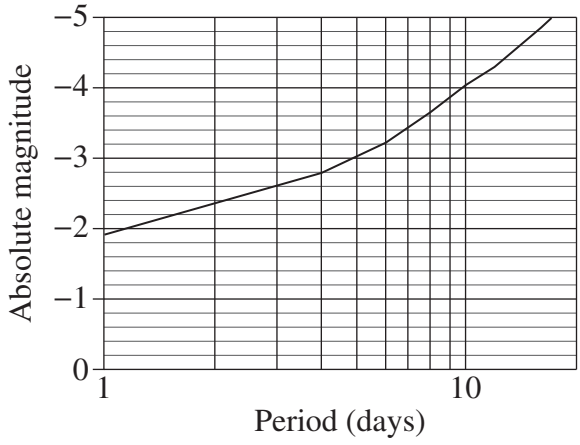


Graph B – Light curve of a Type I Cepheid variable star



(i) Contrast the reasons for the variation in brightness of these two stars. **2**

(ii) A period–luminosity graph for Type I Cepheid variable stars is shown. **3**



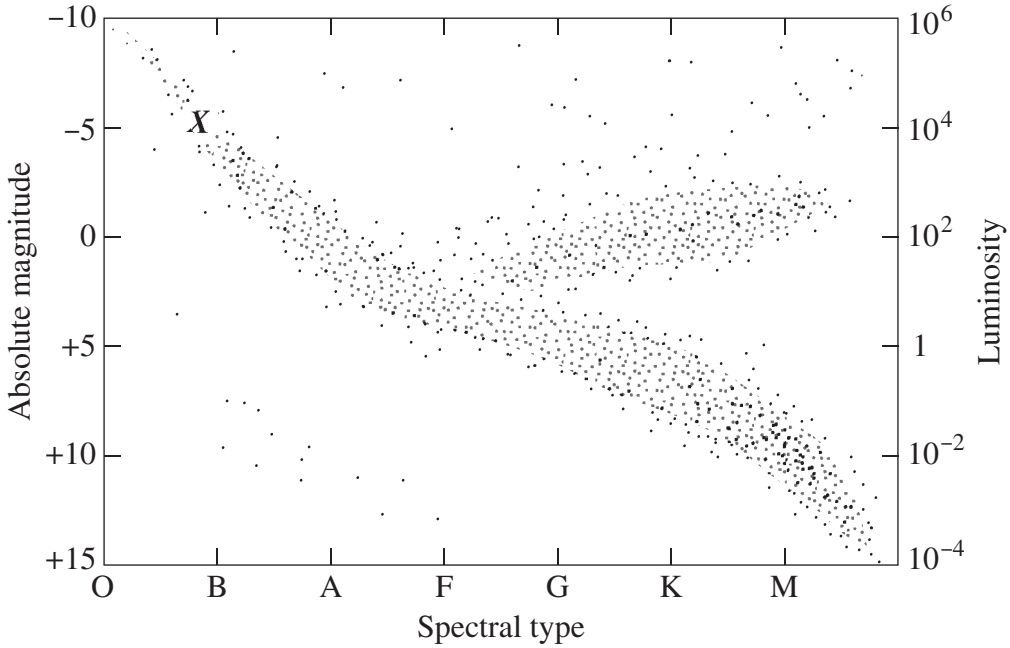
The average apparent magnitude of the Type I Cepheid variable star shown in Graph B is 16.3.

Calculate the distance of this Type I Cepheid variable star from Earth.

Question 33 continues on page 38

Question 33 (continued)

(c) A H–R diagram is shown. Star *X* is a main sequence star of 12 solar masses. **4**



Describe how star *X* will change physically and chemically as it continues to evolve.

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) Explain how measurements made using photoelectric technologies have increased the understanding of celestial objects beyond that provided using photographic methods. **4**

(e) Explain how black body spectra, emission spectra and absorption spectra are used to analyse the surface temperature and chemical composition of stars. In your answer, refer to observations that can be made in a school laboratory. **7**

End of Question 33

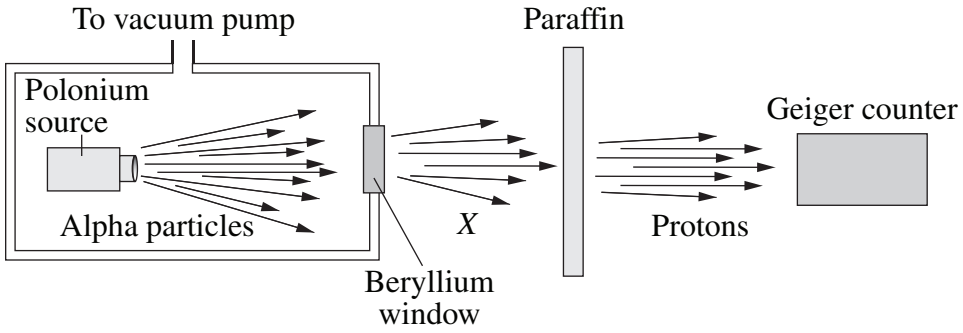
Question 34 — From Quanta to Quarks (25 marks)

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) Identify TWO limitations of the Bohr model of the atom. **2**

(ii) How does the Bohr model of the atom account for the emission spectrum of hydrogen? **3**

(b) (i) The diagram shows apparatus used to investigate subatomic particles. **2**



How did Chadwick use a law of physics to identify a property of *X*?

(ii) The following is a nuclear reaction that produces a neutron. **3**

$$^{4}_{2}\alpha + {}^{9}_{4}\text{Be} \rightarrow {}^{12}_{6}\text{C} + {}^{1}_{0}\text{n}$$

The table shows the masses of the particles in the reaction.

Particle	*Mass* (*u*)
$^{4}_{2}\alpha$	4.0012
$^{9}_{4}\text{Be}$	9.0122
$^{12}_{6}\text{C}$	12.0000
$^{1}_{0}\text{n}$	1.0087

Using the data from the table, calculate the energy released in this reaction. State your answer in joules.

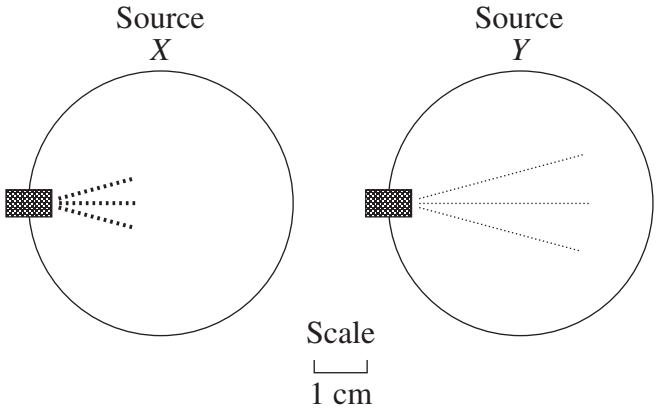
(c) How did Pauli infer the existence and properties of a new particle from measurements of the energies of beta particles? Support your answer with a graph. **4**

Question 34 continues on page 40

Question 34 (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) Radioactive sources, *X* and *Y*, producing two different types of radiation were placed in identical Wilson cloud chambers. The diagram shows the trails produced by each. **4**



Describe the changes in the nuclei of *X* and *Y* which have produced these trails.

(e) Using the standard model, analyse the roles of both forces and particles in the current understanding of the atom. **7**

End of Question 34

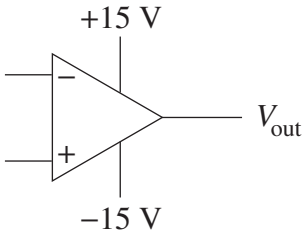
Question 35 — The Age of Silicon (25 marks)

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) Outline TWO differences between an electric circuit and an electronic circuit. **2**

(ii) How do the properties of silica make it an ideal material for use in electronic communication? **3**

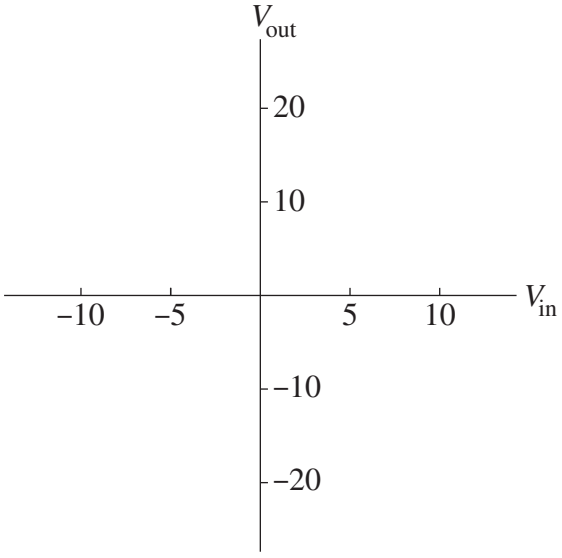
(b) The diagram shows an operational amplifier connected to a power supply.



This operational amplifier is used to make an inverting amplifier by adding an input resistor of 27 kΩ and a feedback resistor of 82 kΩ.

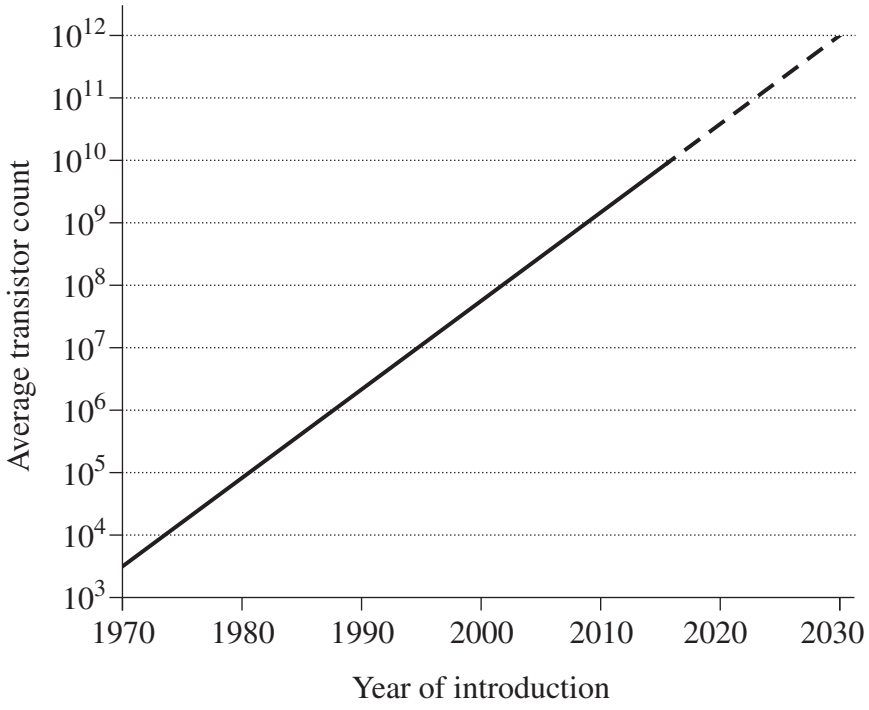
(i) In your answer booklet, draw the inverting amplifier described. **2**

(ii) Copy the axes shown into your answer booklet. Draw a graph showing the transfer characteristics of this inverting amplifier for the input range of −10 V to +10 V. **3**



Question 35 continues on page 42

(c) The graph shows the average number of transistors incorporated into integrated circuit chips from 1970 to 2015. **4**



Relate information in the graph to the evolution of computer technology.

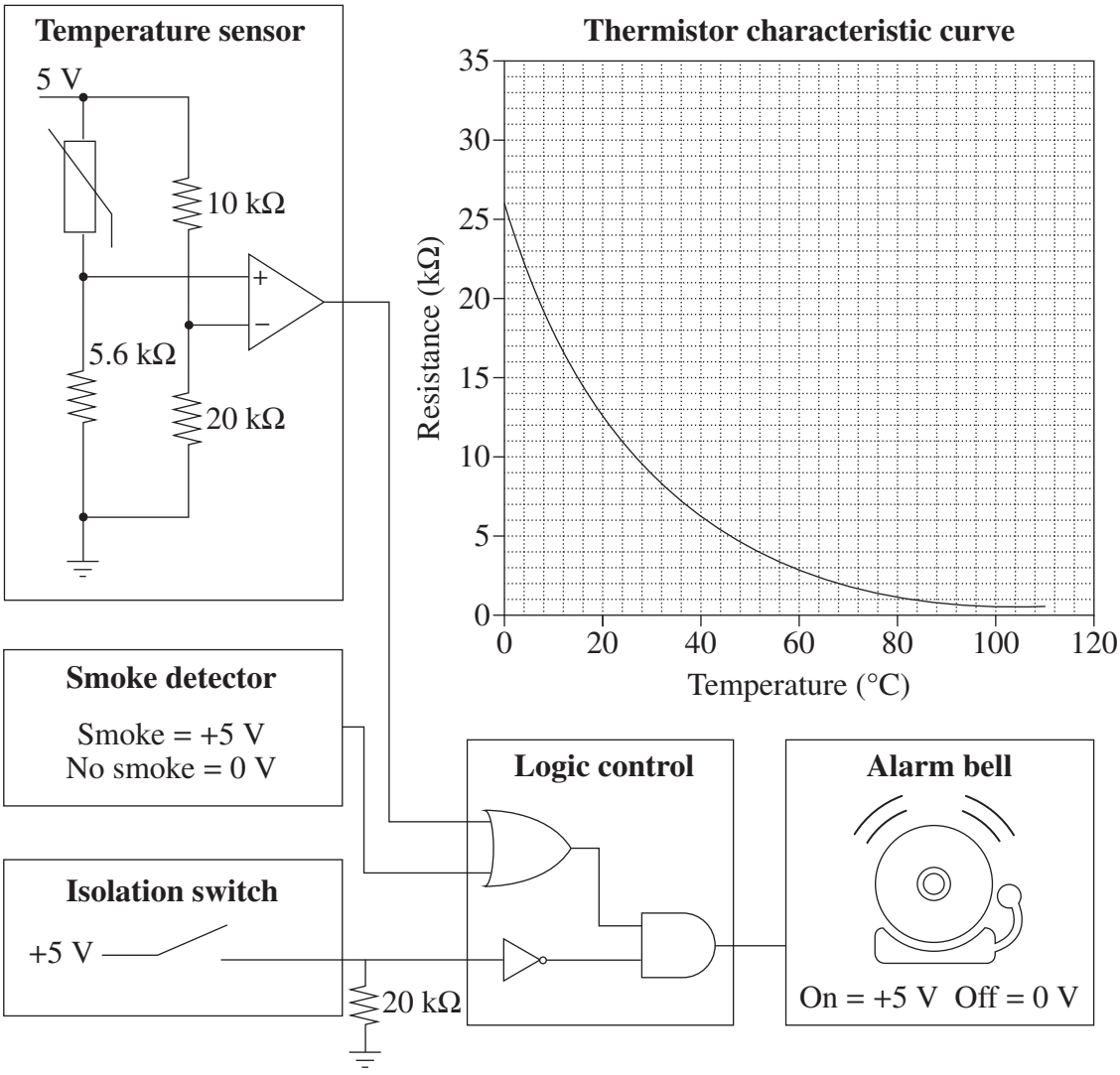
Question 35 continues on page 43

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) Explain how an electronic circuit can use a relay to switch high-power devices. In your answer, refer to the roles of the components of the relay. **4**

(e) The diagrams show a circuit and the characteristic curve of the thermistor used. **7**



Explain the operation of this circuit. Support your answer with a truth table and data from the thermistor characteristic curve.

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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.