BOARD OF STUDIES
NEW SOUTH WALES

2010

HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- A data sheet, formulae sheets and Periodic Table are provided at the back of this paper
- Write your Centre Number and Student Number at the top of pages 13, 15, 17, 21, 23 and 25

Total marks – 100

Section I Pages 2–25

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 21–32
- Allow about 1 hour and 40 minutes for this part

Section II Pages 27–36

25 marks

- Attempt ONE question from Questions 33–37
- 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 The International Space Station orbits Earth at an altitude of approximately 330 km. Another satellite, Meteosat, is in geostationary orbit at an altitude of 36 000 km.

Which of the following correctly compares the orbital velocity and orbital period of these satellites?

	International Space Station	*Meteosat*
(A)	Greater orbital velocity	Shorter orbital period
(B)	Lesser orbital velocity	Shorter orbital period
(C)	Greater orbital velocity	Longer orbital period
(D)	Lesser orbital velocity	Longer orbital period

2 Which of the following best describes Galileo's analysis of projectile motion?

(A) A projectile launched with a great enough velocity would escape Earth's gravity.

(B) A projectile would travel in a straight line until it ran out of momentum, then it would fall.

(C) A projectile launched from the equator towards the east with a great enough velocity would orbit Earth.

(D) A projectile would travel in a parabolic path because it has constant horizontal velocity and constant vertical acceleration.

3 A scientist at a particle accelerator laboratory observes the lifetime of a particular subatomic particle to be 1.0×10^{-6} s when it is travelling at 0.9999 c.

What would the lifetime of the particle be if it were stationary in the laboratory?

(A) 1.4×10^{-8} s

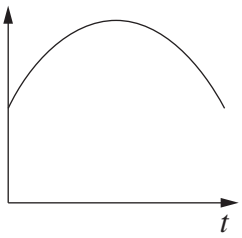
(B) 4.5×10^{-8} s

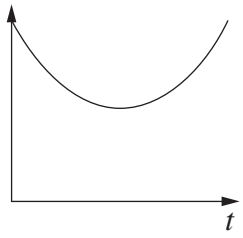
(C) 1.0×10^{-6} s

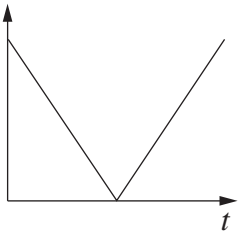
(D) 7.1×10^{-5} s

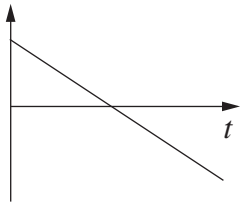
4 A ball was thrown upward at an angle of 45°. It landed at the same height as thrown.

Which graph best represents the kinetic energy of the ball during its time of flight?

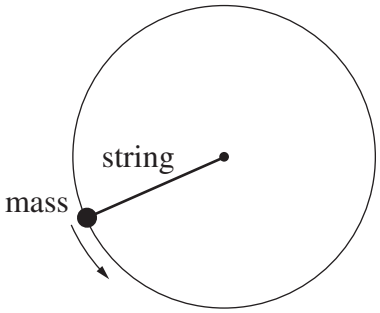
(A) 

(B) 

(C) 

(D) 

5 A 200 g mass is swung in a horizontal circle as shown. It completes 5 revolutions in 3 seconds. The circle has a 2 m diameter.



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Which of the following forces is closest to that required to keep the mass moving in this circle?

(A) 0.50 N

(B) 2.5 N

(C) 10 N

(D) 20 N

6 Which statement about the Michelson-Morley experiment is correct?

(A) It was a valid experiment because it tested the principle of relativity.

(B) It was a valid experiment because it took into account the known properties of light.

(C) It was an invalid experiment because it did not take into account the particle nature of light.

(D) It was an invalid experiment because the speed of Earth through the aether was not taken into account.

7 The acceleration due to gravity on the surface of Mercury is 3.6 $m\,s^{-2}$.

How much does a 2.0 kg brick weigh on Earth and on Mercury?

	Weight of brick on Earth	*Weight of brick on Mercury*
(A)	2.0 kg	2.0 kg
(B)	19.6 kg	7.2 kg
(C)	19.6 N	19.6 N
(D)	19.6 N	7.2 N

8 While drilling into a tough material, the DC motor in an electric drill is slowed significantly. This causes its coils to overheat.

Why do the coils overheat?

(A) The resistance of the coils increases significantly.

(B) The increased friction on the drill is converted to heat.

(C) The back emf decreases and so the current in the coils increases.

(D) The induced eddy currents increase and so more heat is produced.

9 Why is high voltage used to transmit electrical energy from power stations to users?

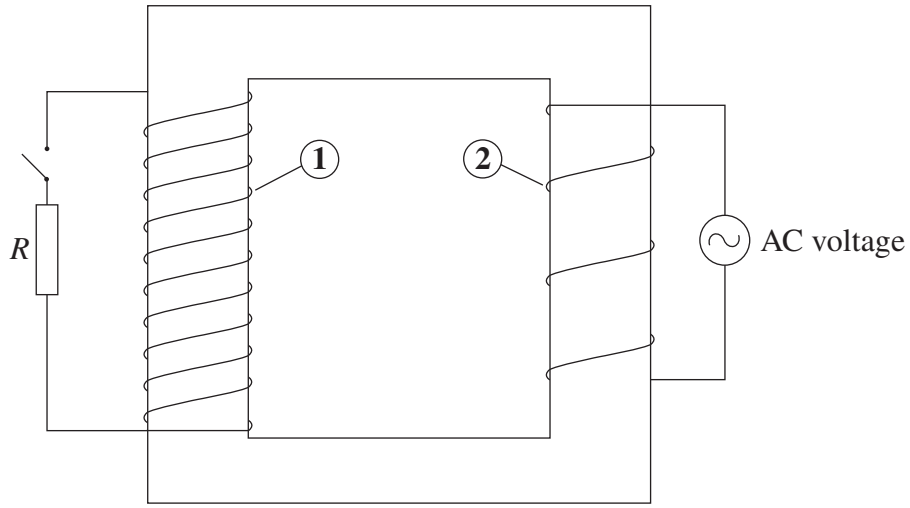
(A) It helps to protect the system from lightning strikes.

(B) It allows the supporting structures to have smaller insulators.

(C) It minimises the effects of the electrical resistance of the wires.

(D) It ensures that, even with voltage losses, 240 V will still reach the user.

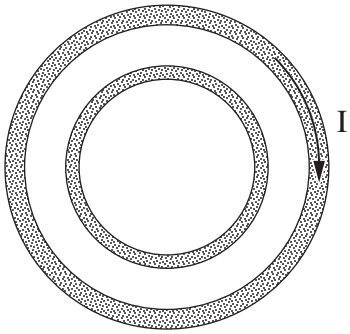
10 The diagram shows a model of a transformer in a circuit.



Which of the following correctly identifies Part 1 and Part 2 and the function of this transformer?

	Part 1	*Part 2*	*Function of transformer*
(A)	Primary coil	Secondary coil	Step-up
(B)	Secondary coil	Primary coil	Step-down
(C)	Primary coil	Secondary coil	Step-down
(D)	Secondary coil	Primary coil	Step-up

11 Two copper rings lie in the same plane as shown.



An increasing current flows clockwise around the outer ring.

What happens in the inner ring?

(A) A decreasing clockwise current flows.

(B) A decreasing anticlockwise current flows.

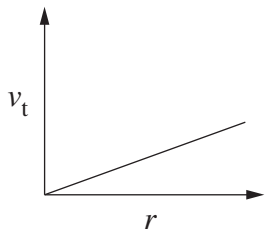
(C) An increasing clockwise current flows.

(D) An increasing anticlockwise current flows.

12 The terminal velocity (v_t) of a spherical object in Earth's atmosphere is proportional to the square root of its radius (r).

Which graph correctly shows this relationship?

(A)



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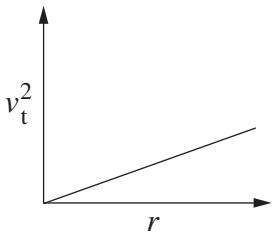

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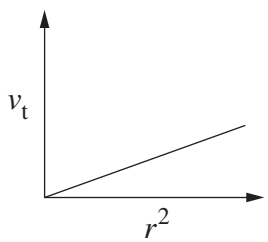

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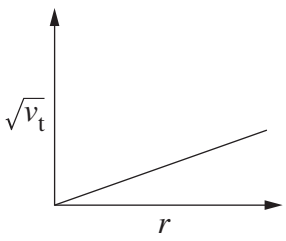


13 What was Max Planck's contribution to the development of quantum physics?

(A) He combined the quantised wave and particle models of light.

(B) He analysed the photoelectric effect and described light as quantised energy packets.

(C) He explained black body radiation and the photoelectric effect using quantised energy.

(D) He hypothesised that the radiation emitted and absorbed by the walls of a black body cavity is quantised.

14 Heinrich Hertz devised and performed an experiment to investigate electromagnetic waves. In this experiment he was able to determine the speed of the waves.

Which method was used to determine the speed?

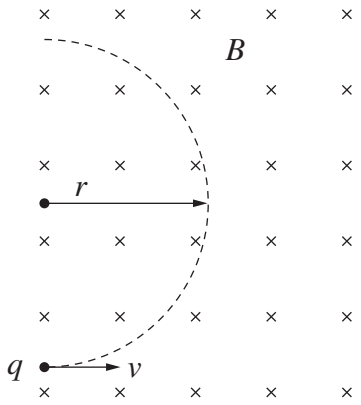
(A) Timing how long it took the wave to travel a known distance

(B) Producing a wave of known wavelength and using reflection to determine the frequency

(C) Producing a wave of known frequency and using interference to determine the wavelength

(D) Using an interference pattern to determine the distance travelled and time taken

15 A charged particle, q, enters a uniform magnetic field B at velocity v. The particle follows a circular path of radius r as shown.



If the magnitude of the magnetic field were doubled and the other variables were kept constant, what would the new radius be?

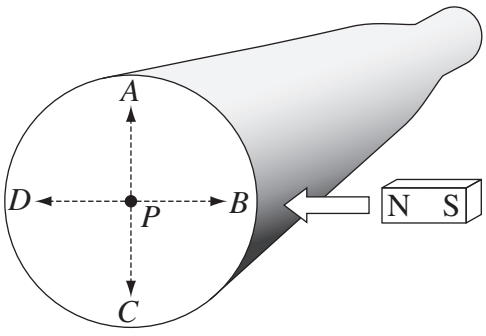
(A) $\frac{r}{4}$

(B) $\frac{r}{2}$

(C) $2r$

(D) $4r$

16 A cathode ray beam strikes the screen at point P, producing a bright spot. The north end of a magnet is brought towards the beam as shown.



Towards which point does the bright spot move?

(A) A

(B) B

(C) C

(D) D

17 JJ Thomson determined the charge/mass ratio of the electron by constructing a device which contained

(A) perpendicular magnetic fields.

(B) perpendicular electric fields.

(C) parallel electric and magnetic fields.

(D) perpendicular electric and magnetic fields.

18 What did William and Lawrence Bragg use X-rays to investigate?

(A) The speed of light

(B) The emission of photoelectrons

(C) The crystal structure of materials

(D) The charge to mass ratio of an electron

19 Why is pure copper a better electrical conductor than pure silicon?

(A) Electrons move through copper in pairs.

(B) Silicon contains fewer free electrons than copper.

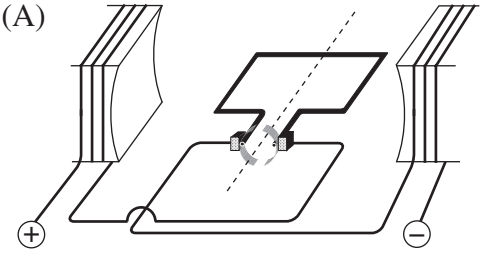
(C) Copper has a conduction band and silicon does not.

(D) Copper atoms contain more electrons than silicon atoms.

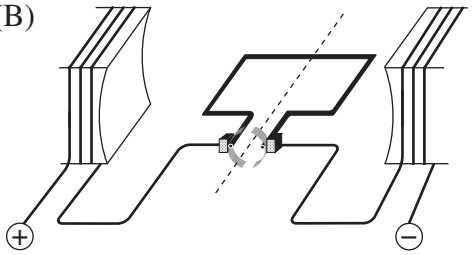
20 The diagrams show possible ways to connect the coils and rotor of a DC motor to a DC power supply.

In which circuit will the rotor turn in a clockwise direction?

(A)



(B)



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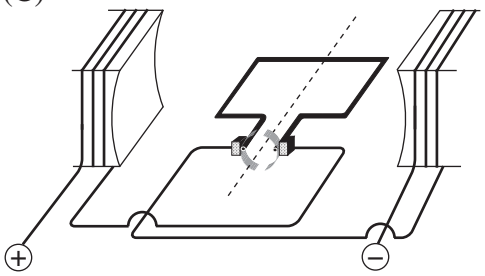
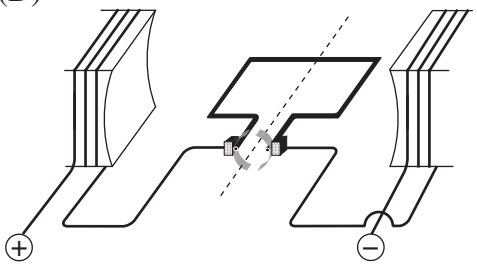


(D)



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Physics

Centre Number

Student Number

Section I (continued)

Part B – 55 marks
Attempt Questions 21–32
Allow about 1 hour and 40 minutes for this part

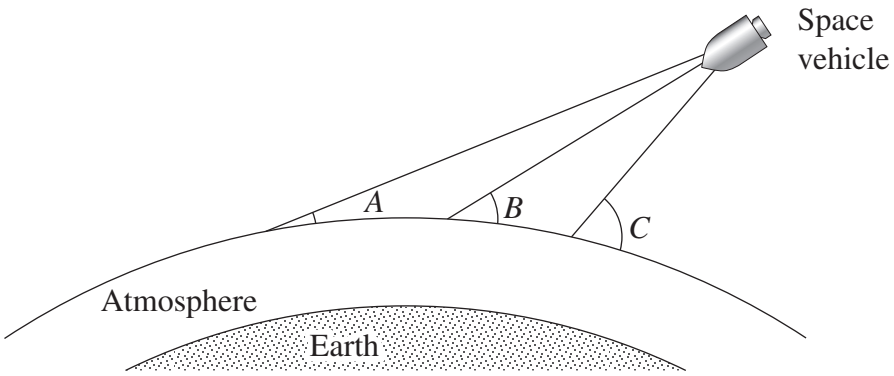
Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Show all relevant working in questions involving calculations.

Question 21 (2 marks)

The optimum angle for safe re-entry of a space vehicle into Earth's atmosphere is angle *B*. **2**

Outline consequences of the space vehicle entering the atmosphere at angle *A* AND angle *C*.



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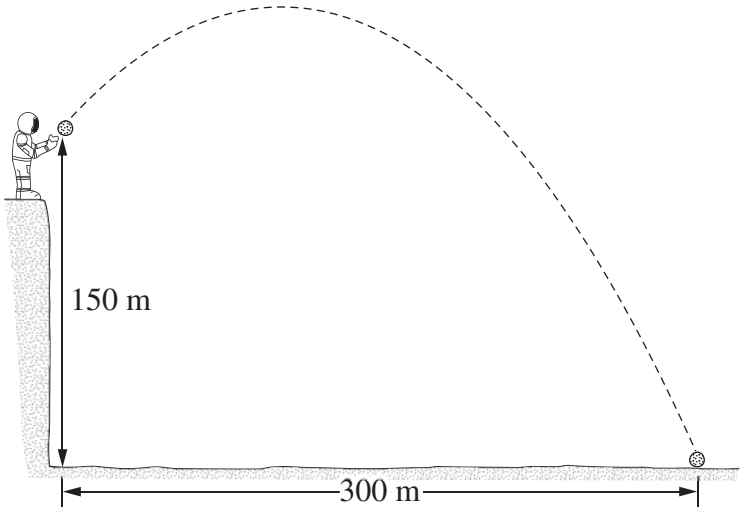
Question 22 (5 marks)

An astronaut on the Moon throws a stone from the top of a cliff. The stone hits the ground below 21.0 seconds later. The acceleration due to gravity on the moon is 1.6 ms^{-2}.



(a) Calculate the horizontal component of the stone's initial velocity. Show your working. **1**

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(b) Calculate the vertical component of the stone's initial velocity. Show your working. **2**

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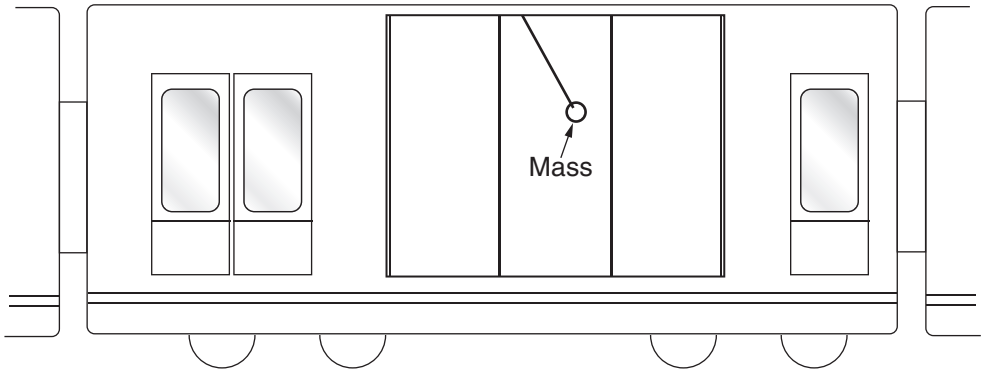
(c) On the diagram, sketch the path that the stone would follow if the acceleration due to gravity was higher. The initial velocity is the same. **2**

Question 23 (5 marks)

A train is travelling on a straight horizontal track. A student on the train attaches a mass on a string to the ceiling of the train. The student observes that the mass remains stationary in the position shown.



(a) Why does the mass hang with the string at an angle to the vertical? **2**

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(b) The string then breaks and the mass falls. **3**

Indicate the path of the mass on the diagram above. Explain why the mass has taken this path.

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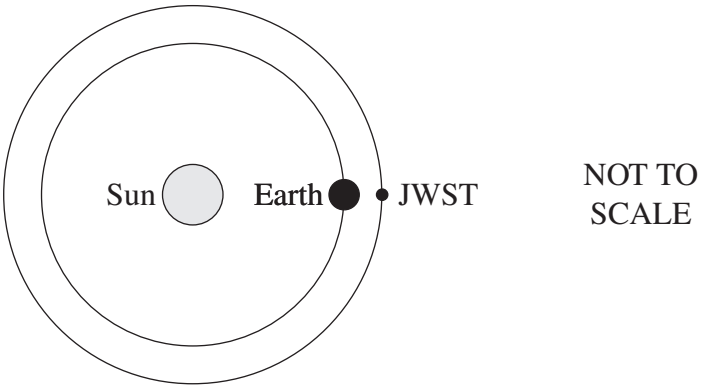
Question 24 (3 marks)

In 2014 the James Webb Space Telescope (JWST) will be placed in orbit around the Sun. Earth and the JWST will follow the orbits shown, with identical orbital periods. This appears to contradict Kepler's law of periods. **3**



Why is it possible for the JWST to orbit the Sun with the same orbital period as Earth? In your answer, refer to Kepler's law of periods.

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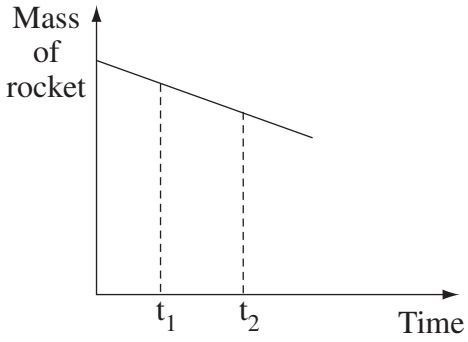
Question 25 (4 marks)

The mass of a rocket decreases during launch as it burns fuel, as shown in the graph. The rocket engine produces a constant upward force on the rocket.



(a) How does the law of conservation of momentum apply to the motion of the rocket? **2**

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(b) Why do the g-forces on an astronaut in the rocket differ at times t_1 and t_2? **2**

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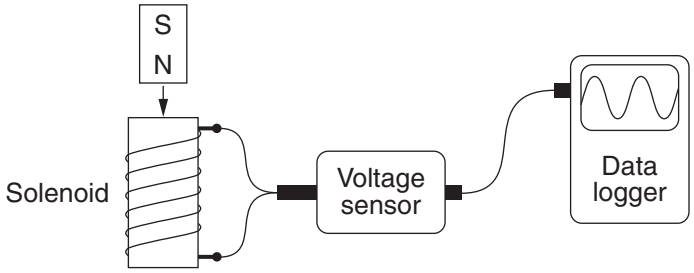
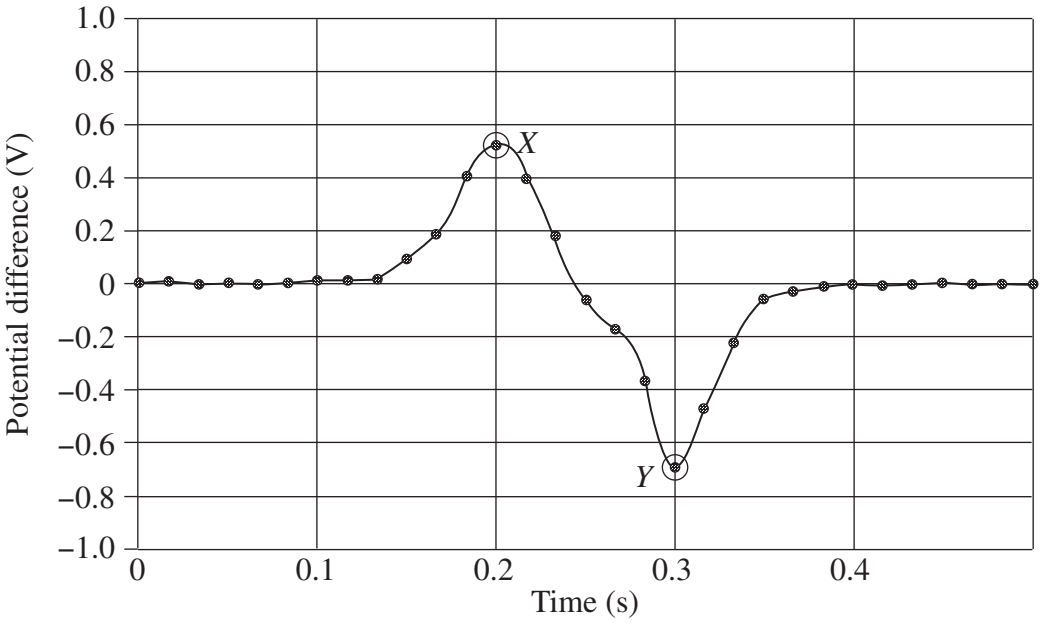
Question 26 (5 marks)

A bar magnet is dropped through the centre of a solenoid connected to a data logger as shown.



The data are recorded in the graph as shown.



(a) Why is the magnitude of the potential difference at *Y* greater than at *X*? **2**

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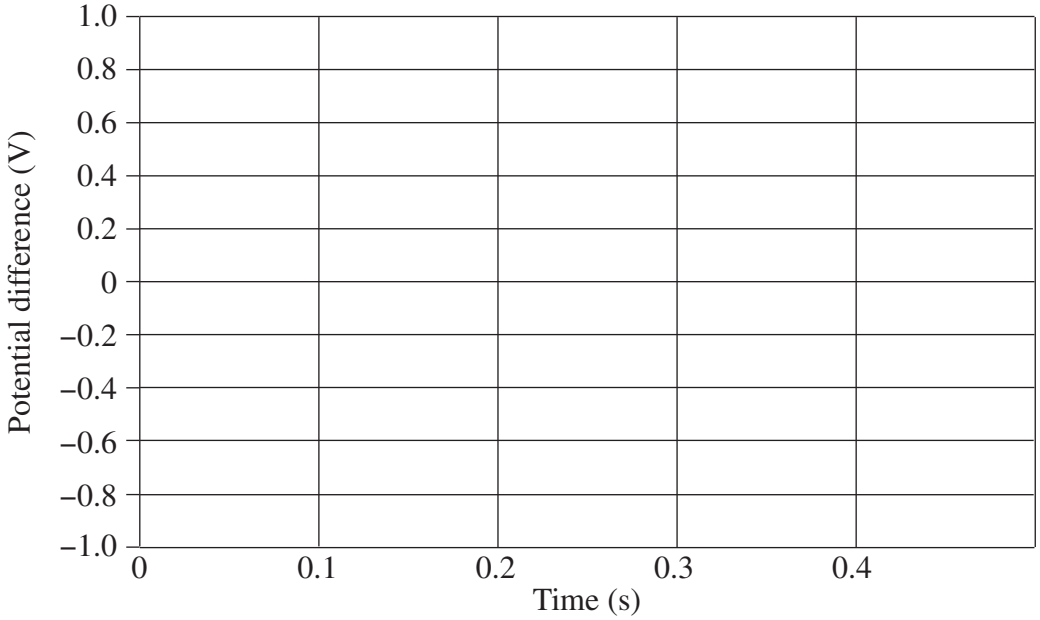
Question 26 continues on page 19

Question 26 (continued)

(b) The magnet is dropped again with two changes being made. **3**

1. It is dropped from a greater height.
2. The south pole of the magnet is pointing down.

Sketch a graph that represents the most likely outcome of this new experiment.



End of Question 26

Question 27 (6 marks)

Magnetic resonance imaging is a current technology that uses superconductors. Identify two OTHER technologies that use superconductors. Evaluate the impact of these technologies on society and the environment. **6**

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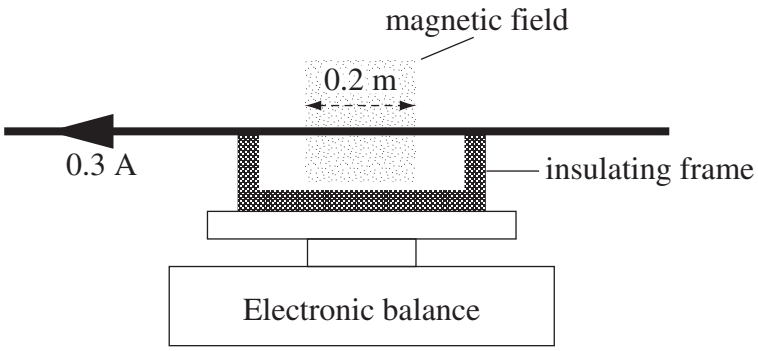
Question 28 (4 marks)

A copper rod is placed on a wooden frame, which is placed on an electronic balance. A length of 0.2 m of the rod passes at right angles to a horizontal magnetic field. **4**



When a current of 0.3 A is passed through the rod, the reading on the balance increases by 7.5×10^{-4} kg.

What is the strength and direction of the magnetic field?

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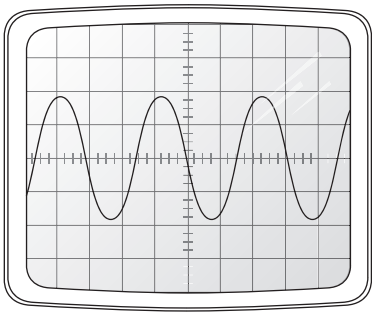
Question 29 (3 marks)

Two sets of plates deflect an electron beam in a cathode ray oscilloscope to produce the trace on the screen as shown. **3**



Explain how the deflection plates produce this pattern.

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Question 30 (5 marks)

Pure germanium can be doped by adding small amounts of boron.

(a) Is the doped germanium an n-type or a p-type semiconductor? Justify your answer. **2**

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(b) Explain how the addition of boron alters the electrical conductivity of germanium. **3**

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Question 31 (5 marks)

(a) What is the energy of a photon having a wavelength of 1000 nm? **2**

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(b) Explain why light having a wavelength longer than a certain value does not produce an electric current in a photocell. **3**

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Question 32 (8 marks)

Two significant problems that will affect a manned spaceflight to Mars are: **8**

- the changes in gravitational energy
- protecting the space vehicle from high-speed electrically charged particles from the Sun.

Use your understanding of physics to analyse each of these problems.

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Physics

Section II

25 marks
Attempt ONE question from Questions 33–37
Allow about 45 minutes for this section

Answer the first parts of the question in a writing booklet. Answer the rest of the parts in a SEPARATE writing booklet. Extra writing booklets are available.

Show all relevant working in questions involving calculations.

Question 33 — Geophysics (25 marks)

Answer parts (a)–(b) in a writing booklet.

(a) (i) List THREE properties of earth materials studied in geophysics. **1**

(ii) Observations of the period of a pendulum on a ship show variations with location. **3**

Explain how these observations could be used to deduce information about the shape of Earth. Your answer must include a description of the shape of Earth.

(iii) The period of a pendulum is $T = 2\pi\sqrt{\frac{l}{g}}$. **2**

The period of a particular pendulum is measured at one location as 2.00 seconds. When measured at a second location the period is 2.05 seconds.

Determine the ratio of the strength of the gravitational field at the first location to that at the second location.

(b) How are gravity measurements used to obtain information about the structure of Earth? **6**

Question 33 continues on page 29

Question 33 (continued)

Answer parts (c)–(d) in a SEPARATE writing booklet.

(c) Seismic waves provide information about the larger scale structure of Earth.

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

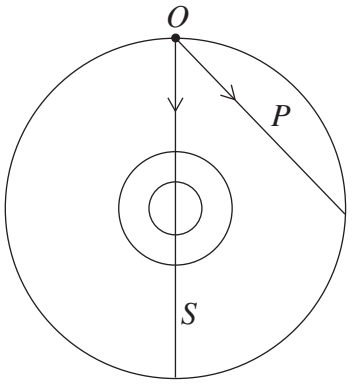
(ii) The speed of P waves is given by $v_P = \sqrt{\dfrac{K + \dfrac{4\mu}{3}}{\rho}}$. **3**

The speed of S waves is given by $v_S = \sqrt{\dfrac{\mu}{\rho}}$.

- K, μ and ρ are all positive quantities
- ρ increases with depth
- μ, which is zero for a liquid, increases with depth at a faster rate than ρ

From this information about S and P waves, deduce how their velocities vary with depth.

(iii) In what way are the paths of the S and P waves shown below incorrect? **2**



(d) There is current acceptance of the idea that the continents have moved relative to each other. **6**

Why was there initial reluctance to accept this idea, and what evidence led to its acceptance?

End of Question 33

Question 34 — Medical Physics (25 marks)

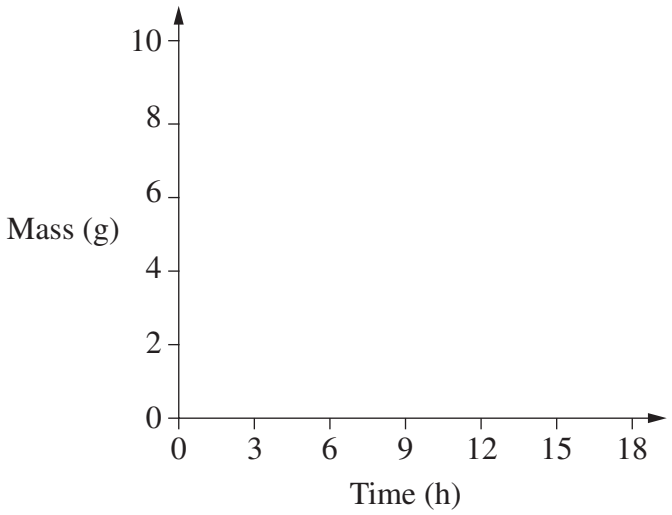
Answer parts (a)–(c) in a writing booklet.

(a) Describe how an X-ray image of the bones in the hand is produced. **3**

(b) (i) What is ONE advantage and ONE disadvantage of using a radioisotope with a 6 hour half-life for medical imaging? **2**

(ii) The half-life of Tc–99m is 6 hours. **2**

Copy the following set of axes into your writing booklet, and draw a graph to show how the mass of a 10 g sample of Tc–99m changes over 18 hours.



(c) (i) Why is hydrogen the most commonly targeted element in the magnetic resonance imaging process? **2**

(ii) Describe how energy from the radio frequency oscillator of a magnetic resonance imaging machine interacts with hydrogen to obtain information about the inside of the body. **3**

Question 34 continues on page 31

Question 34 (continued)

Answer parts (d)–(e) in a SEPARATE writing booklet.

(d) (i) The acoustic impedance of air is 400 kg m^{-2} s^{-1}. **3**

Tissue	*Density* (kg m^{-3})	*Velocity of sound* (m s^{-1})
Muscle	1076	1580
Bone	1912	4080
Brain	1025	1540

Calculate the intensity of the reflected ultrasound at the interface between chest muscle and air as a proportion of the incident intensity.

(ii) Describe how the Doppler effect is used in ultrasound imaging and outline information that a Doppler ultrasound scan can provide about blood flow in the heart. **4**

(e) A cancer specialist has access to ultrasound, CAT and PET scanners. **6**

Which of these technologies is the most appropriate to detect a 3 mm brain tumour? Justify your choice.

End of Question 34

Question 35 — Astrophysics (25 marks)

Answer parts (a)–(b) in a writing booklet.

(a) (i) The Japanese radio telescope HALCA was placed in an elliptical orbit which took it as far as 21 000 km from Earth. It took measurements simultaneously with ground-based radio telescopes. **3**

Explain the benefit that the HALCA telescope gives radio astronomers.

(ii) SOFIA is an infrared telescope. It is operated from high-altitude aircraft. Give TWO reasons for the greater validity of data from this telescope, compared to ground-based observations. **2**

(b) Properties of stars, including their surface temperature and chemical composition, can be measured by using their spectra.

(i) Identify other properties of stars which can be determined from their spectra. **2**

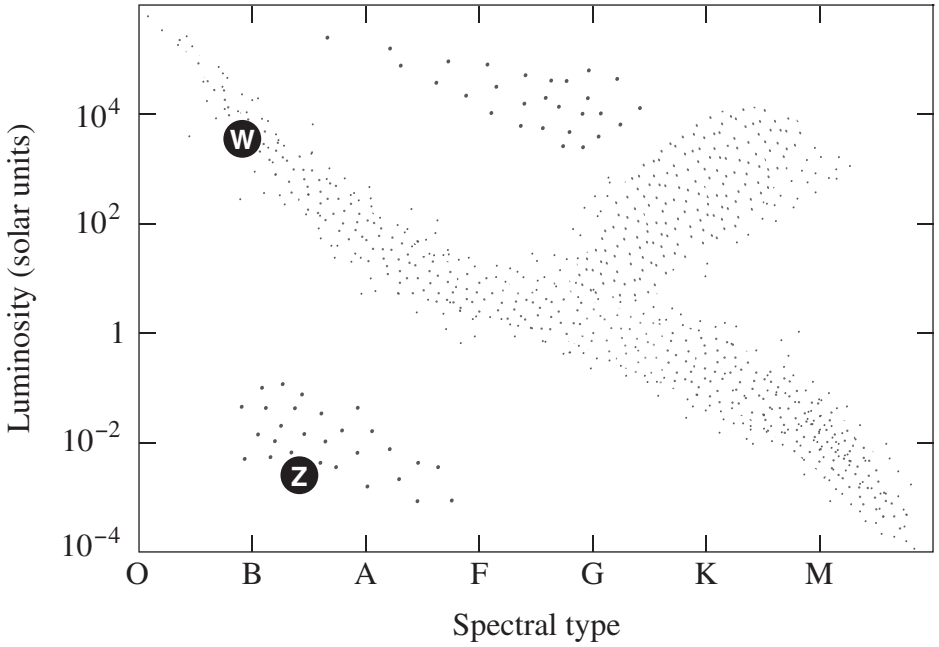
(ii) Explain how surface temperatures and chemical compositions of stars can be determined from their spectra. **5**

Question 35 continues on page 33

Question 35 (continued)

Answer parts (c)–(d) in a SEPARATE writing booklet.

(c) Hertzsprung-Russell diagrams can be used to deduce the properties of stars.



(i) Identify the type of stars found in region Z on the above diagram. **1**

(ii) Describe the relationship between the masses of main sequence stars and their luminosities AND lifetimes. **2**

(iii) Contrast the energy production processes of stars in regions W and Z. **2**

(iv) Copy the axes from the above Hertzsprung-Russell diagram into your writing booklet. Sketch a Hertzsprung-Russell diagram for the stars in an ancient globular cluster on these axes. **2**

(d) Identify THREE advances in measurement technologies, and describe how they have improved our understanding of celestial objects. **6**

End of Question 35

Question 36 — From Quanta to Quarks (25 marks)

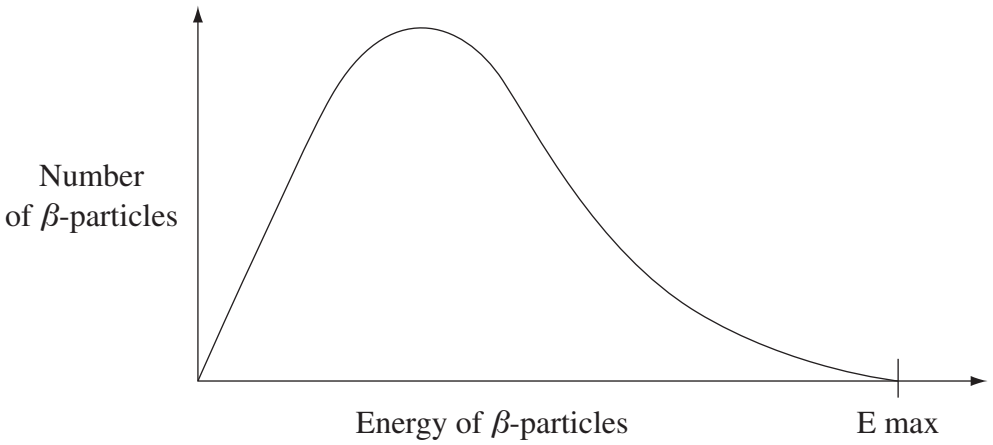
Answer parts (a)–(d) in a writing booklet.

(a) Outline the relationship between Bohr's atomic model and Planck's equation $E = hf$. **3**

(b) Calculate the wavelength of a photon which is emitted when an electron in a hydrogen atom moves from energy level n = 4 to n = 2. **2**

(c) How did Louis de Broglie explain the stability of electron orbits in hydrogen atoms? **3**

(d)



How did Pauli account for the distribution of energies in the β-decay curve? **2**

Answer parts (e)–(g) in a SEPARATE writing booklet.

(e) (i) James Chadwick discovered the neutron in 1932. How did Chadwick apply conservation laws? **3**

(ii) Outline how the properties of neutrons make them useful in scattering experiments. **2**

(f) Account for the existence of stable isotopes, referring to the forces which act within the atomic nucleus. **3**

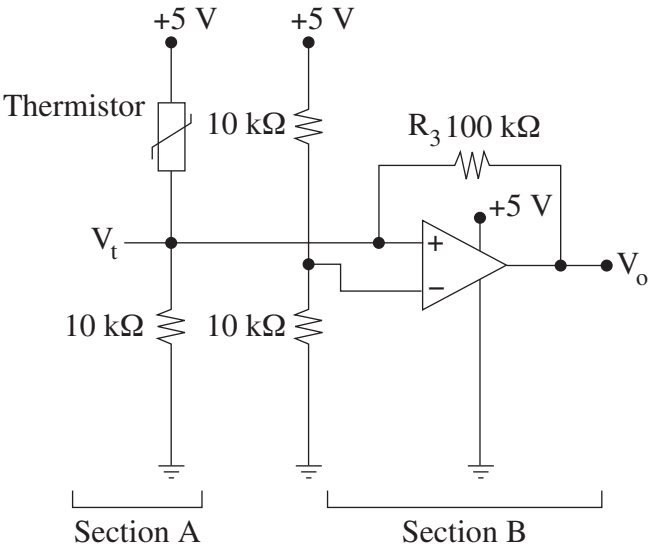
(g) 'Important fundamental discoveries in physics often lead to applications which have a significant effect on society.' **7**

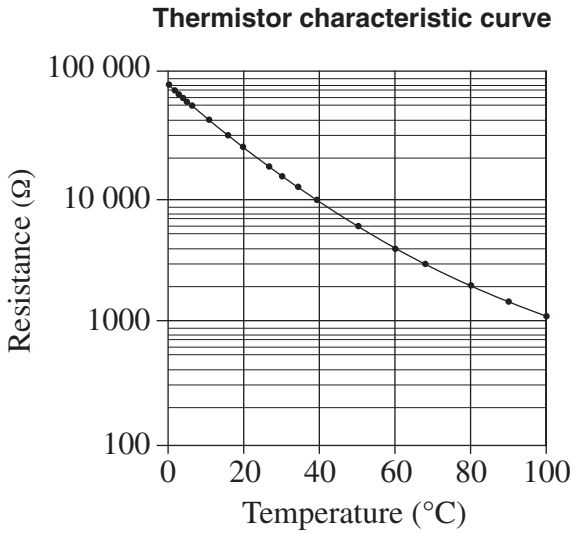
Evaluate this statement, with reference to the contributions of Rutherford, Einstein and Fermi to the development of the atomic bomb.

Question 37 — The Age of Silicon (25 marks)

Answer parts (a)–(b) in a writing booklet.

(a) A circuit and a graph of a thermistor characteristic curve are shown.





(i) What is the function of the circuit in Section A? **1**

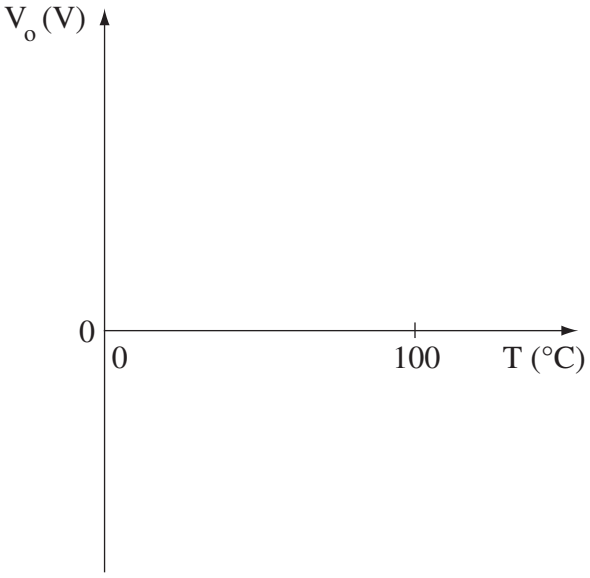
(ii) Ignoring the rest of the circuit, what is the value of V_t at 60°C? **2**

(iii) Explain the function of the circuit in Section B. In your answer, include an explanation of the function of resistor R_3. **4**

Question 37 continues on page 36

Question 37 (continued)

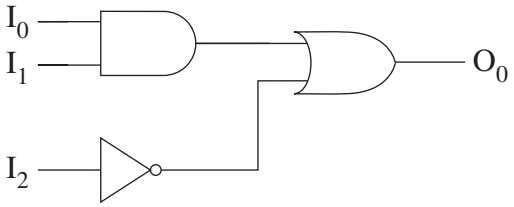
(iv) Copy the following axes into your writing booklet, and draw a graph of the output voltage versus temperature, as temperature increases from 0°C to 100°C. **3**



(b) Outline the construction and operation of a relay. Include diagrams in your answer. **4**

Answer parts (c)–(e) in a SEPARATE writing booklet.

(c) In your writing booklet, draw a truth table for the following logic circuit. **3**



(d) (i) What is the function of an input transducer? **1**

(ii) What type of transducer is an LED? **1**

(e) Analyse the effect of the rapid development of integrated circuits on 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

$$v = f\lambda$$

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

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

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

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

$$P = VI$$

$$\text{Energy} = VIt$$

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

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

$$\Sigma F = ma$$

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

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

$$W = Fs$$

$$p = mv$$

$$\text{Impulse} = Ft$$

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

$$F = mg$$

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

$$v = u + at$$

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

$$\Delta x = u_x t$$

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

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

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

$$E = mc^2$$

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

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

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

FORMULAE SHEET

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

$$F = BIl\sin\theta$$

$$\tau = Fd$$

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

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

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

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

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

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

$$F = qvB\sin\theta$$

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

$$E = hf$$

$$c = f\lambda$$

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

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

$$Z = \rho v$$

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

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

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

PERIODIC TABLE OF THE ELEMENTS