BOARD OF STUDIES
NEW SOUTH WALES

2007

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 9, 13, 17, 19, 21 and 25

Total marks – 100

Section I Pages 2–26

75 marks

This section has two parts, Part A and Part B

Part A – 15 marks

- Attempt Questions 1–15
- Allow about 30 minutes for this part

Part B – 60 marks

- Attempt Questions 16–27
- Allow about 1 hour and 45 minutes for this part

Section II Pages 27–40

25 marks

- Attempt ONE question from Questions 28–32
- Allow about 45 minutes for this section

Section I
75 marks

Part A – 15 marks
Attempt Questions 1–15
Allow about 30 minutes for this part

Use the multiple-choice answer sheet for Questions 1–15.

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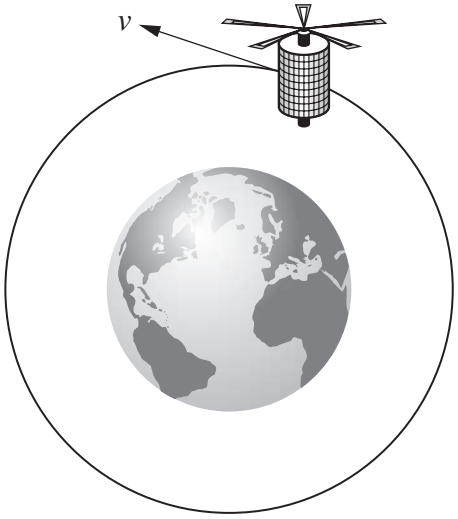
1 A satellite is in orbit around Earth with tangential velocity v as shown.



Which of the following describes the direction of the centripetal force acting on the satellite?

(A) Same direction as the gravitational force

(B) Opposite direction to the gravitational force

(C) Same direction as the tangential velocity

(D) Opposite direction to the tangential velocity

2 A spaceship sitting on its launch pad is measured to have a length L. This spaceship passes an outer planet at a speed of $0.95\,c$.

Which observations of the length of the spaceship are correct?

	Observer on the spaceship	*Observer on the planet*
(A)	No change	Shorter than L
(B)	No change	Greater than L
(C)	Shorter than L	No change
(D)	Greater than L	No change

3 The gravitational potential energy of a given mass is known at both Earth's surface and at a fixed distance above Earth.

What CANNOT be determined by comparing these two values of gravitational potential energy?

(A) The mass of Earth

(B) The speed of rotation of Earth

(C) The escape velocity of a satellite from Earth

(D) The work done in moving between the two points

4 The acceleration due to gravity on Earth's surface is g. Suppose the radius of Earth was reduced to a quarter of its present value while its mass remained the same.

What would be the new value of the acceleration due to gravity on the surface?

(A) $\frac{1}{16}\,g$

(B) $\frac{1}{4}\,g$

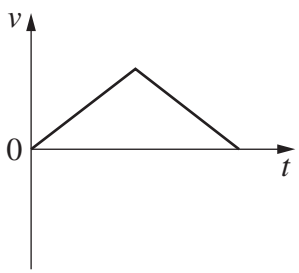
(C) $4\,g$

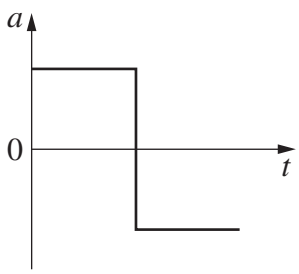
(D) $16\,g$

5 A cannon ball is fired vertically upward from a stationary boat.

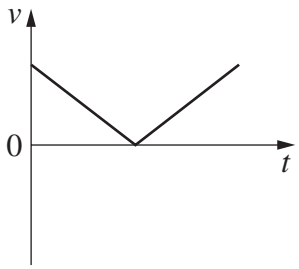
Which pair of graphs best describes the velocity, v, and acceleration, a, of the cannon ball as functions of time, t? Ignore air resistance.

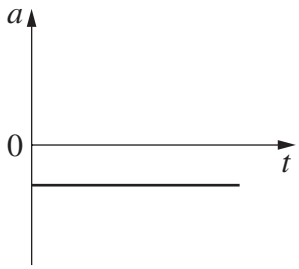
(A)



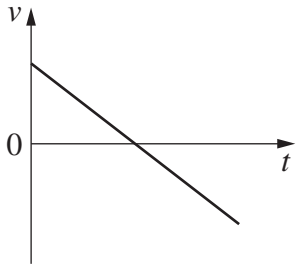


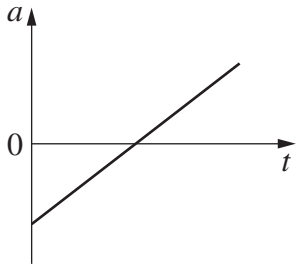
(B)



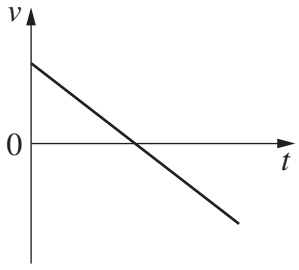


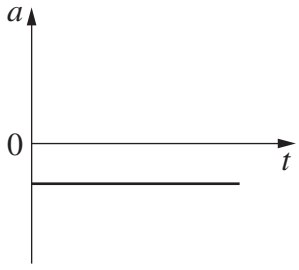
(C)



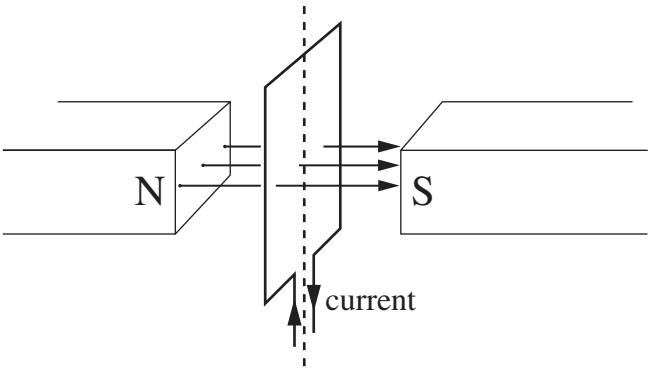


(D)





6 An electric motor is set up as shown.



When current is supplied the coil does not turn.

Which of the following is required for the coil to start turning?

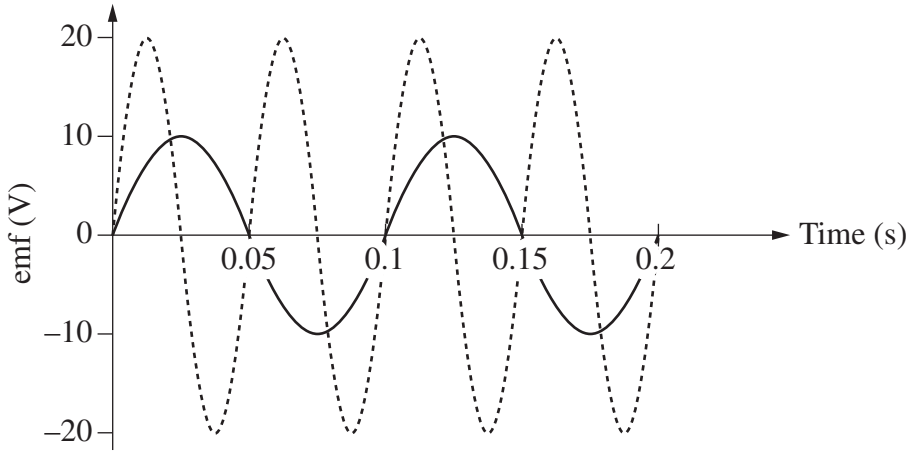
(A) The magnetic field must be increased.

(B) The direction of the current must be reversed.

(C) The magnitude of the current must be increased.

(D) The starting position of the coil must be changed.

7 In the graph shown, the solid curve shows how the emf produced by a simple generator varies with time. The dashed curve is the output from the same generator after a modification has been made to the generator.



Which modification was made to produce the result shown?

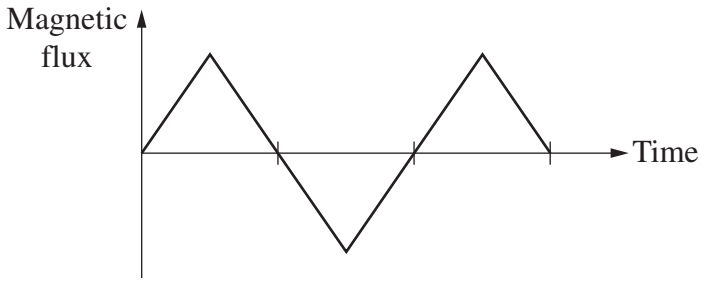
(A) The area of the coil was doubled.

(B) A split-ring commutator was added.

(C) The speed of rotation of the coil was doubled.

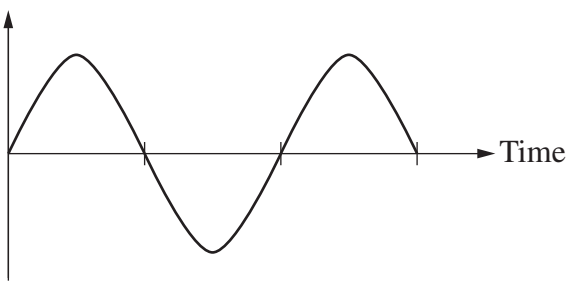
(D) The number of turns in the coil was quadrupled.

8 The variation in magnetic flux through a coil is shown below.

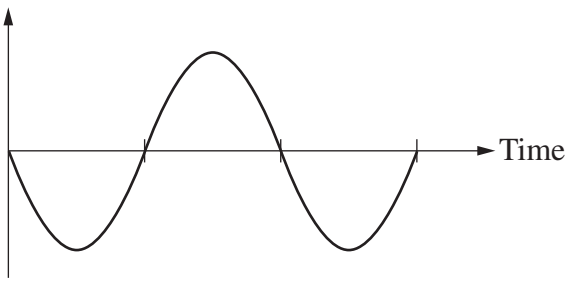


Which graph best represents the corresponding induced emf in the coil?

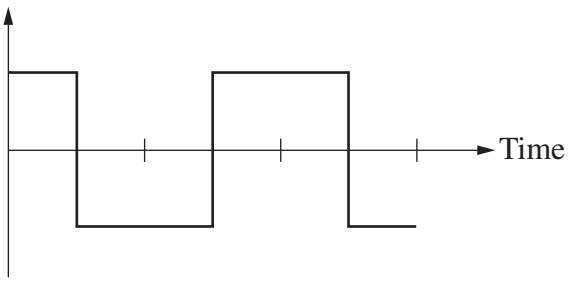
(A)



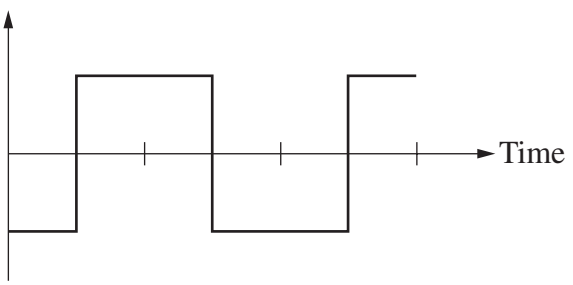
(B)



(C)



(D)



9 A stationary exercise bike has a solid metal wheel that is rotated by a chain connected to the pedals. An array of strong permanent magnets provides a magnetic field close to the face of the wheel.

The exercise level can be selected from 1 (easy) to 6 (hard) using a control panel.

When level 6 is selected, which of the following statements is correct?

(A) The current supplied to the bike is a minimum.

(B) The magnetic field at the wheel is a minimum.

(C) The induced current in the wheel is a maximum.

(D) The distance between the magnets and the wheel is a maximum.

10 What is the wave property that enabled Hertz to calculate the velocity of radiowaves and compare it to the velocity of light?

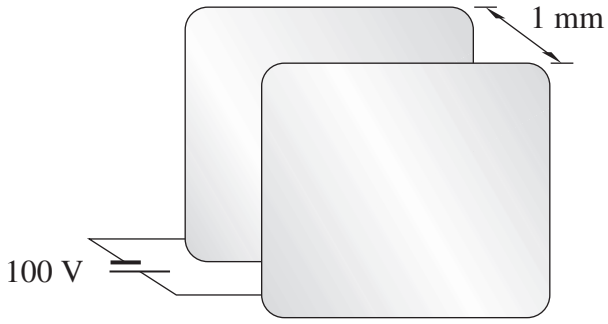
(A) Interference

(B) Polarisation

(C) Reflection

(D) Refraction

11 Two parallel metal plates are 1 mm apart. A potential difference of 100 V is applied as shown.



What is the magnitude of the uniform electric field between the plates?

(A) 10^{-3} V m^{-1}

(B) 10^{-1} V m^{-1}

(C) 10^{2} V m^{-1}

(D) 10^{5} V m^{-1}

12 The Bragg experiment used X-rays to investigate crystal structure.

Which statement best describes the results of this experiment?

(A) X-rays are scattered from a crystal and form an interference pattern.

(B) X-rays penetrate a crystal and form an interference pattern behind it.

(C) X-rays are absorbed and re-emitted equally in all directions by a crystal.

(D) X-rays absorbed by a crystal produce minima and those reflected produce maxima.

13 An electron is moving near a long straight wire. When a current is applied to the wire the electron experiences a force in the same direction as the current flow in the wire.

What was the electron's initial direction of motion?

(A) Parallel to the current direction

(B) Opposite to the current direction

(C) Towards the wire and perpendicular to it

(D) Away from the wire and perpendicular to it

14 Which of the following is a property of a silicon *p*-type semiconductor?

(A) It is positively charged.

(B) It has fewer holes than pure silicon.

(C) It can be produced by doping the silicon with boron.

(D) It can be produced by doping the silicon with phosphorus.

15 What CANNOT be calculated using the principle of conservation of energy?

(A) The energy of a proton at rest

(B) The production of back emf in a motor

(C) Voltage transformation in an ideal transformer

(D) The escape velocity of an object from the gravitational field of a planet

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Physics

Centre Number

Student Number

Section I (continued)

Part B – 60 marks
Attempt Questions 16–27
Allow about 1 hour and 45 minutes for this part

Answer the questions in the spaces provided.

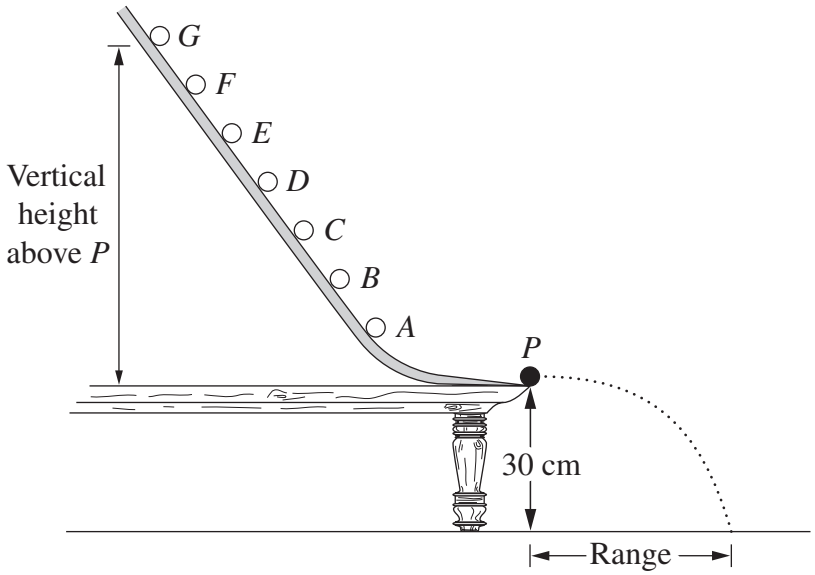
Show all relevant working in questions involving calculations.

Question 16 (5 marks)

Please turn over

Question 16 (5 marks)

A group of students conducted an investigation in which ball bearings were released from various points on a ramp. The ball bearings rolled down the ramp to the edge of a table at point *P* as shown. Their ranges were measured.



The results are shown in the table.

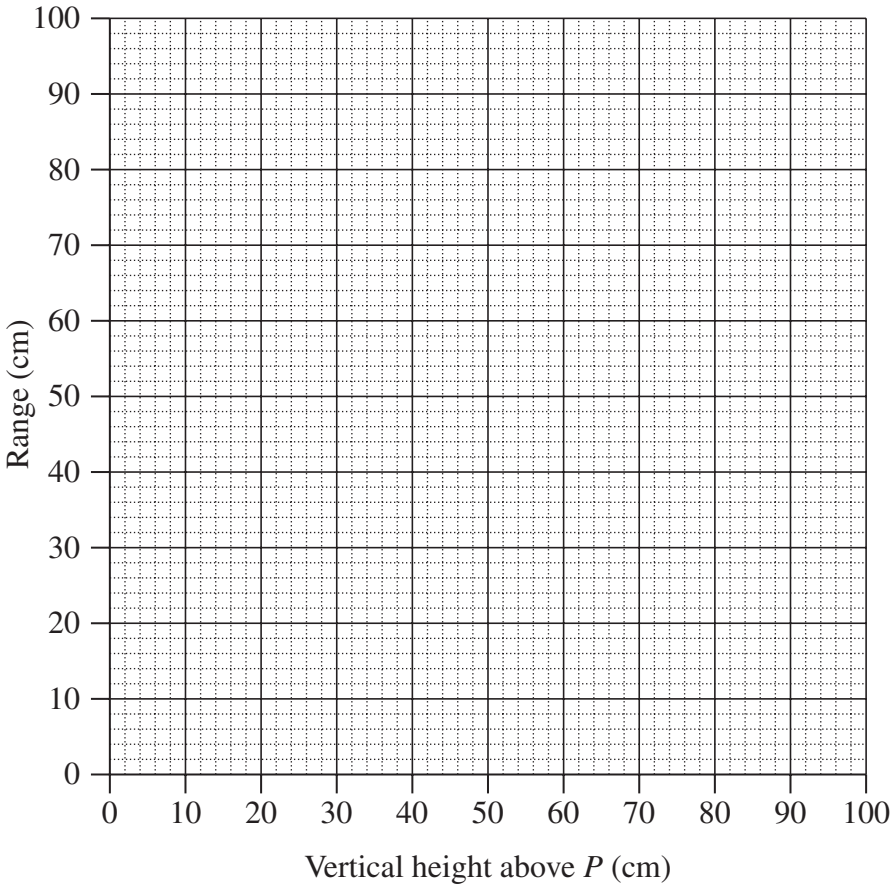
Point of release	*Vertical height above P* (cm)	*Range* (cm)
A	10	32
B	20	44
C	30	58
D	40	66
E	50	76
F	60	82
G	70	87

Question 16 continues on page 11

Marks

Question 16 (continued)

(a) Plot the data from the table and draw a curve of best fit. **2**



(b) (i) Using your graph, predict the range of a ball bearing released from a height of 80 cm above point *P*. **1**

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(ii) Calculate the horizontal velocity of the ball bearing released from a height of 80 cm above point *P*. **2**

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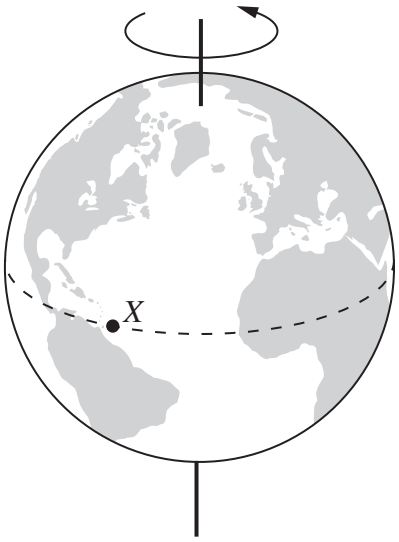
End of Question 16

Marks

Question 17 (4 marks)

The diagram shows the position X on Earth's surface from which a satellite is to be launched into a geostationary orbit.



(a) On the diagram, draw an arrow to show the direction of launch from X, and justify your choice. **1**

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(b) Given that the radius of Earth is 6.38×10^6 m, calculate the height of the satellite above Earth's surface. **3**

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Marks

Question 18 (7 marks)

(a) How has our understanding of time been influenced by the discovery of the constancy of the speed of light? **2**

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(b) A piece of radioactive material of mass 2.5 kilogram undergoes radioactive decay. How much energy is released if 10 grams of this mass are converted to energy during the decay process? **2**

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(c) A mass is moving in an inertial frame of reference at a velocity v relative to a stationary observer. The observer measures an apparent mass increase of 0.37%. **3**

Calculate the value of v in m s^{-1}.

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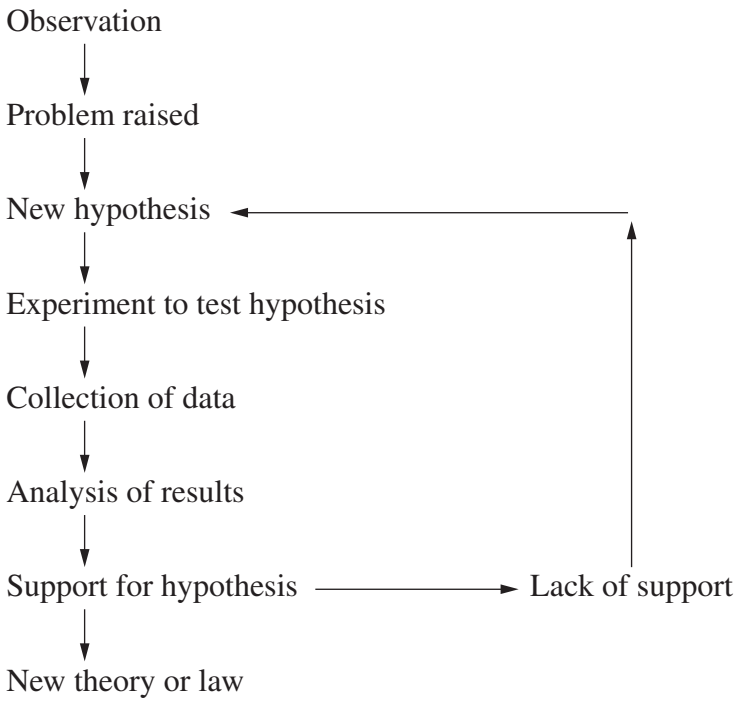
Question 19 (6 marks)

This flowchart represents one model of scientific method used to show the relationship between theory and the evidence supporting it.



Question 19 continues on page 15

Marks

Question 19 (continued)

Analyse Einstein's Theory of Special Relativity and the evidence supporting it as an application of this model of scientific method. **6**

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End of Question 19

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Marks

Question 20 (4 marks)

Assess the effects of the development of AC generators on today's society and the environment. **4**

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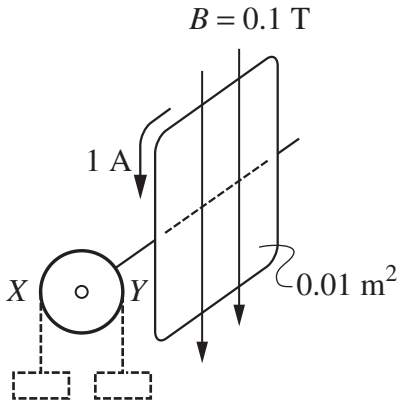
Marks

Question 21 (5 marks)

A simple motor consists of a flat rectangular coil with n turns in a magnetic field B as shown.



The coil has an area of 0.01 m^2 and carries a current of 1 A. The motor drives a pulley of diameter 20 cm, and weights can be hung from either side of the pulley at point X or point Y.

(a) In order to prevent rotation, should a weight be hung at point X or at point Y? Justify your answer. **1**

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(b) What is the magnitude of the torque provided by a mass of 0.2 kg suspended from either point X or point Y? **2**

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(c) If the motor is just stopped by a mass of 0.2 kg, how many turns does the coil have? **2**

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Centre Number

Section I – Part B (continued)

Student Number

Marks

Question 22 (4 marks)

Explain why solid state devices have largely replaced thermionic devices. **4**

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Please turn over

Marks

Question 23 (4 marks)

(a) The table shows the critical temperature T_c at which some materials become superconducting. **1**

Year discovered	*Material*	T_c (K)	T_c (°C)
1941	Niobium nitride	16	–257
1987	$YBa_2Cu_3O_7$(YBCO)	92	–185
1993	$HgBa_2Ca_2Cu_3O_7$	133	–140

With reference to the table, identify what scientists working in the area of superconductivity are trying to achieve.

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(b) Describe what happens to one property of superconductors near the critical temperature. **1**

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(c) Explain why magnetic levitation occurs in superconducting materials. **2**

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Question 24 (3 marks)

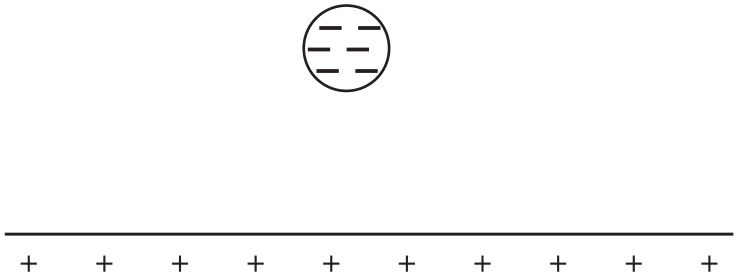
Please turn over

Marks

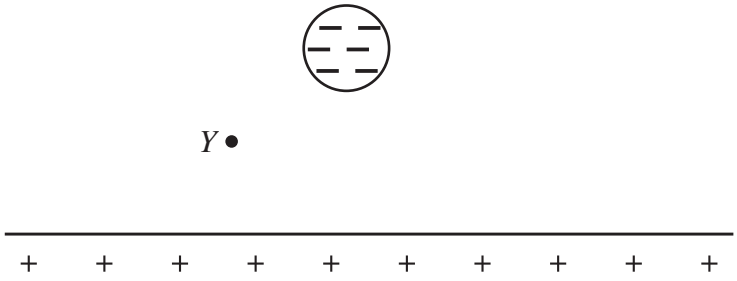
Question 24 (continued)

(a) A negatively charged cylinder is fixed in position near a positively charged plate as shown in the cross-section. **1**

Sketch the electric field lines between the cylinder and the plate on the cross-section diagram.



(b) A tiny particle of mass 10^{-30} kg and charge $+6 \times 10^{-12}$ C is released at point Y as shown on the diagram. The particle initially accelerates at 7.0×10^{21} m s^{-2}. **2**



Calculate the electric field intensity at Y.

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Marks

Question 25 (4 marks)

A student claims that a DC generator is an 'electric motor in reverse'. **4**

Analyse this claim with reference to the structure and function of a simple DC generator and an electric motor.

Include diagrams in your answer.

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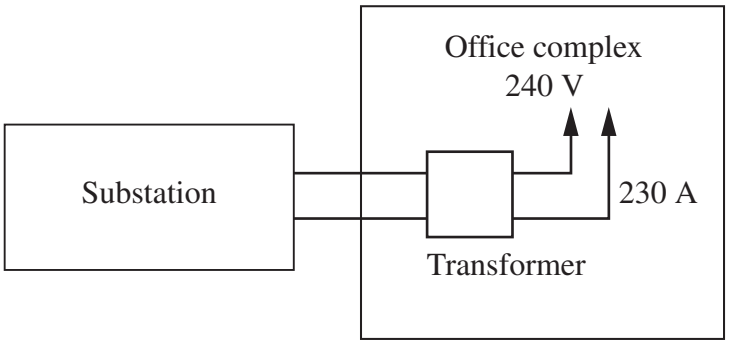
Marks

Question 26 (6 marks)

An electricity substation delivers a current of 10 A at a voltage of 6 kV to an office complex. The office complex uses a transformer to provide a current of 230 A at a voltage of 240 V.



(a) Explain why AC is preferable to DC as an input current for transformers. **2**

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(b) Outline possible causes of energy loss in the transformer. **2**

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(c) Calculate the energy lost by the transformer in eight hours. **2**

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Marks

Question 27 (8 marks)

(a) Scientists tried to explain observations of black-body radiation using classical wave theory and then quantum theory. **3**

How does quantum theory satisfactorily explain black-body radiation?

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(b) Describe Hertz's observation of the photoelectric effect. **2**

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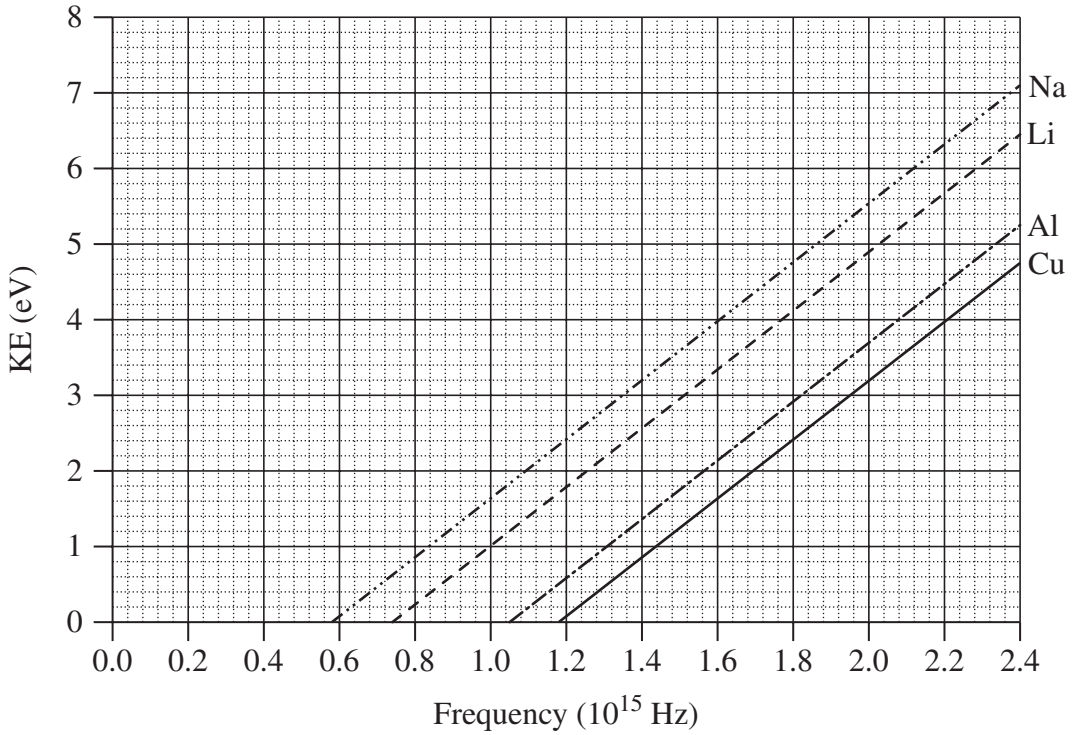
Question 27 continues on page 26

Marks

Question 27 (continued)

(c) An experiment was conducted in which light of different frequencies was shone onto the surfaces of four different metals. Electrons were found to be emitted and their kinetic energies were measured. The graph shows the results.



(i) Calculate the gradient of the sodium (Na) graph. Show your working. **2**

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(ii) Each of the graphs has the same gradient. What is the significance of this observation? **1**

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End of Question 27

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Physics

Section II

25 marks
Attempt ONE question from Questions 28–32
Allow about 45 minutes for this section

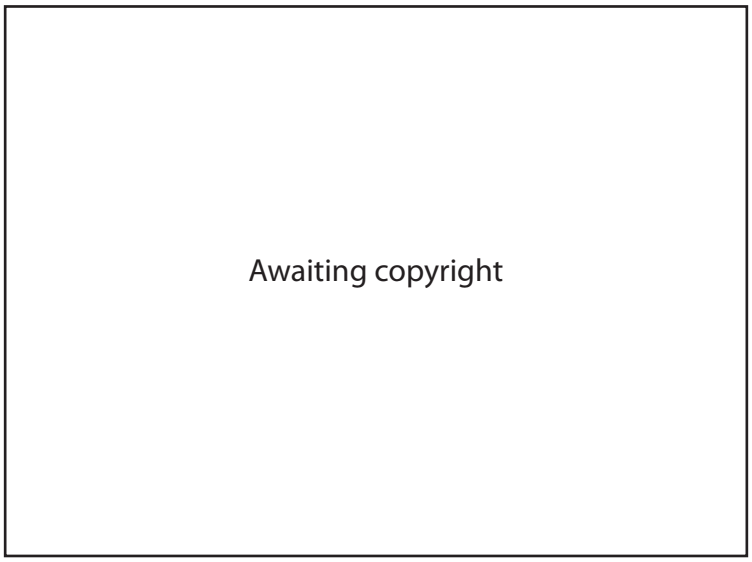
Answer the question in a writing booklet. Extra writing booklets are available.

Show all relevant working in questions involving calculations.

Marks

Question 28 — Geophysics (25 marks)

(a) (i) The graph shows the velocity of *P* and *S* waves at different depths in the Earth. **3**



Describe the rigidity and density of rocks at different depths in the Earth and relate this to the velocity of both *P* and *S* waves.

(ii) The velocity of *S* waves through rock is given by the formula **2**

$$v_s = \sqrt{\frac{\mu}{\rho}} \quad \text{where} \quad \mu = \text{rigidity}, \quad \rho = \text{density}.$$

Two rocks, *A* and *B*, are compared. Both have the same rigidity but rock *A* has twice the density of rock *B*. If the velocity of *S* waves in rock *B* is 7 km s^{-1}, calculate the velocity of *S* waves in rock *A*.

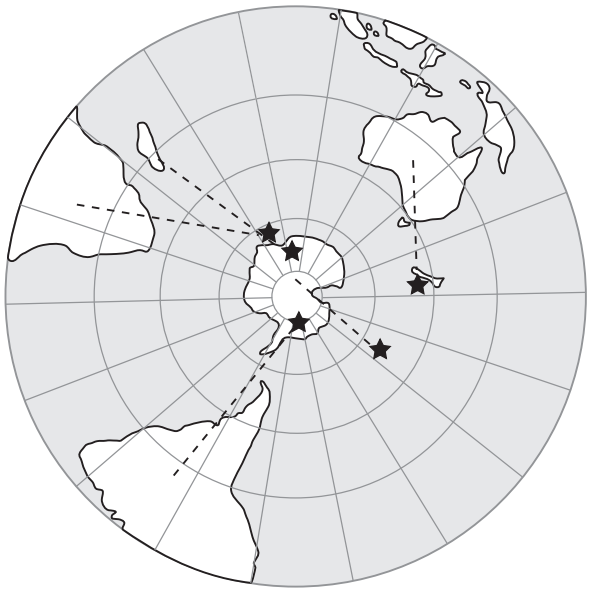
Question 28 continues on page 29

Question 28 (continued)

(b) (i) In your study of Geophysics you performed an investigation that models the variation of the inclination of Earth's magnetic field with latitude. **2**

Describe how you modelled the variation and the results obtained.

(ii) The map below shows the positions of the south magnetic pole about 200 million years ago as measured from each of five present day land masses. The positions of the south magnetic pole are shown as ★ on the map. **4**



Explain how these south magnetic pole positions were determined and how they provide evidence for continental drift.

(c) Remote sensing by satellites has added greatly to our ability to understand Earth. **7**

Analyse how the introduction of satellites has contributed to TWO areas of knowledge of Earth that were previously inaccessible.

Question 28 continues on page 30

Question 28 (continued)

(d) Seismograms are shown for a nuclear test and an earthquake.

Ack: Lawrence Livermore National Laboratory

(i) By using features of the seismograms, compare the nature of the energy release during a nuclear test and an earthquake. **3**

(ii) What information do seismograms provide about nuclear tests? **2**

(iii) Describe how seismogram studies are used in either natural hazard reduction or mineral exploration. **2**

End of Question 28

Marks

Question 29 — Medical Physics (25 marks)

(a) Ultrasound imaging depends on the fact that different materials have different acoustic impedances. The density and acoustic impedance of fat and muscle are shown.

	Density (kg m^{-3})	*Acoustic impedance* (kg m^{-2} s^{-1} $\times$ 10^6)
Fat	9.25×10^2	1.38
Muscle	1.073×10^3	1.70

(i) Calculate the fraction of ultrasound intensity that is transmitted as it passes from fat into muscle. **2**

(ii) Explain how a piezoelectric crystal can act as both a source and detector of ultrasonic waves. **3**

(b) (i) In your study of Medical Physics you performed an investigation to identify the function of the components of MRI equipment. The following information is from the *Australian Twin Registry Newsletter*, 2006.

> **MRI: How does it work?**
> Unlike conventional radiography Computed Tomography (CT) scans, which make use of potentially harmful X-rays passing through a patient to generate images, MRI is based on the magnetic properties of atoms within the tissue. A powerful magnet generates a magnetic field roughly 10,000 times stronger than the Earth's. A very small percentage of hydrogen atoms within the body will line up with this field. Radio waves are passed through the person's body then "bounce back" depending on how many lined up atoms they meet. The subtle differences in how the radio waves bounce back provide the information needed to construct the image.
>
> Australian Twin Registry

Assess the information provided in this article in terms of its scientific accuracy. **4**

(ii) Why is ultrasound imaging NOT used for investigating the function and structure of the brain? **2**

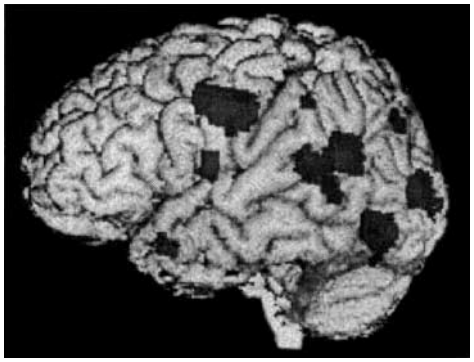
Question 29 continues on page 32

Question 29 (continued)

(c) Assess the effects on the lives of individuals and the wider community of the production and use of X-rays, CAT scans and MRI. **7**

(d) (i) Compare the advantages and disadvantages of CAT and PET scans in investigating the structure and function of the brain with reference to the images shown. **3**

Image A



Dark areas show abnormal brain activity function.

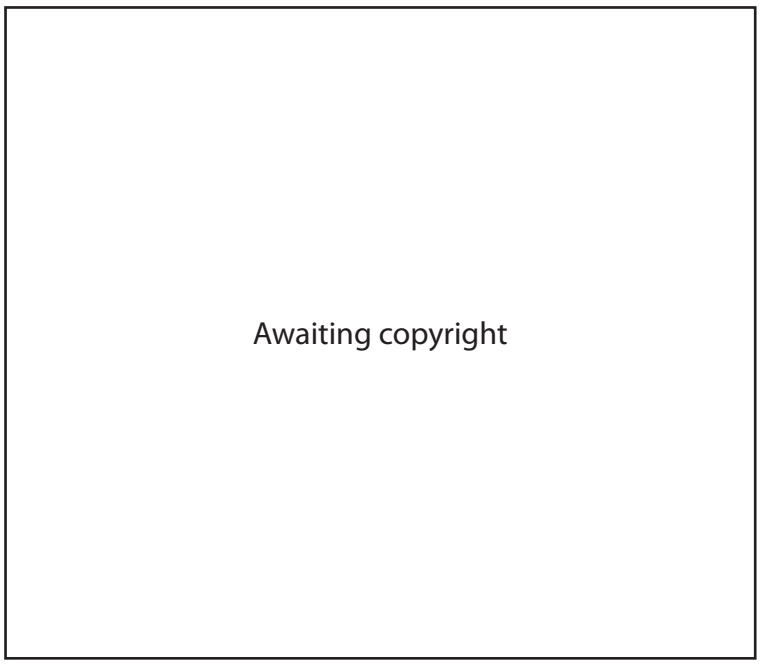
Image B

White area shows the result of a stroke.

Question 29 continues on page 33

Question 29 (continued)

Osteoporosis is a degenerative disease in which there is a gradual loss of minerals in the bone. This leads to decreased bone strength and an increased chance of bone fractures.



(ii) With reference to the images shown, compare TWO imaging techniques which can be used to diagnose osteoporosis. **4**

End of Question 29

Marks

Question 30 — Astrophysics (25 marks)

(a) (i) Describe how the existence of a binary star may be deduced. **2**

(ii) The distance from the Sun to Earth is 1 astronomical unit (1 AU). The apparent magnitude of the Sun, when viewed from Earth, is –26.5. Calculate the apparent magnitude of the Sun when viewed from Saturn, a distance of 10 AU from the Sun. **3**

(b) (i) In your study of Astrophysics you performed a first-hand investigation to demonstrate ONE characteristic of a star that can be deduced by observing the light received from it. **2**

Describe your investigation and the results obtained.

(ii) Explain how TWO other characteristics or properties of a star can be deduced by observing the light received from the star. **4**

(c) Evaluate the ways that TWO technologies used in modern astrophysics have changed scientific understanding of celestial objects. **7**

(d) The table shows some characteristics of selected stars.

Star	*Apparent magnitude*	*Absolute magnitude*	*Spectral class*
Sun	–26.5	+4.7	G2
Sirius A	–1.51	+1.4	A1
Betelgeuse	+0.41	–5.6	M2
Arcturus	+0.00	–0.3	K2
Vega	+0.04	+0.5	A0

(i) Which star is the most distant from Earth? Justify your answer. **1**

(ii) Sketch in your writing booklet a Hertzsprung-Russell diagram showing the positions of the stars in the table. Identify the position of the Main Sequence on your diagram. **3**

(iii) Compare the physical properties, nuclear reactions and relative stages of stellar evolution of the stars Sirius A and Arcturus. **3**

Marks

Question 31 — From Quanta to Quarks (25 marks)

(a) The Bohr model of the atom describes a nucleus with electron shells surrounding it.

(i) Calculate the wavelength of the electromagnetic radiation required to remove an electron from the second shell of a hydrogen atom. **2**

(ii) Outline atomic spectral features that cannot be completely explained by the Rutherford-Bohr model. **3**

(b) In your study of Quanta to Quarks you have performed an investigation to observe radiation emitted from a nucleus using a Wilson Cloud Chamber or a similar detection device.

(i) Describe how you carried out your investigation. **2**

(ii) Isotopes can be used in medicine, agriculture and engineering. **4**

Choose TWO of these areas and nominate a different isotope for use in each area.

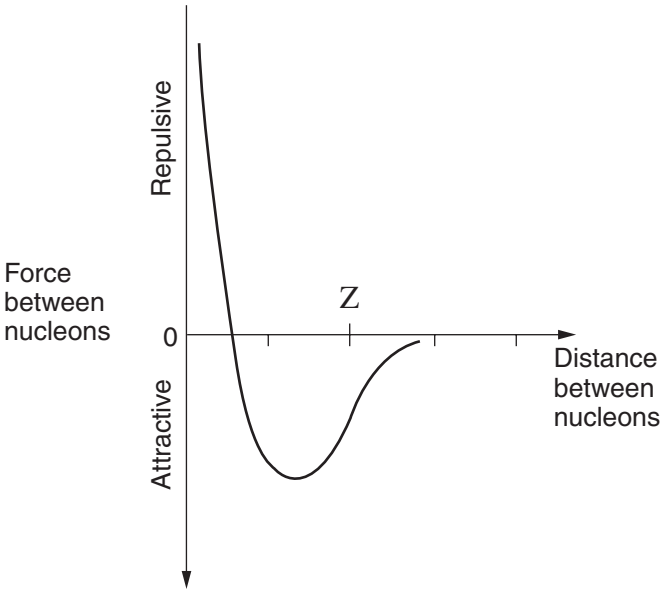
For each isotope, explain how the properties of the isotope are related to its use.

(c) Analyse how de Broglie's proposal and supporting experimental evidence led to the move from classical physics to quantum physics. **7**

Question 31 continues on page 36

Question 31 (continued)

(d) (i) The graph shows the force between nucleons as a function of the distance between them. **2**

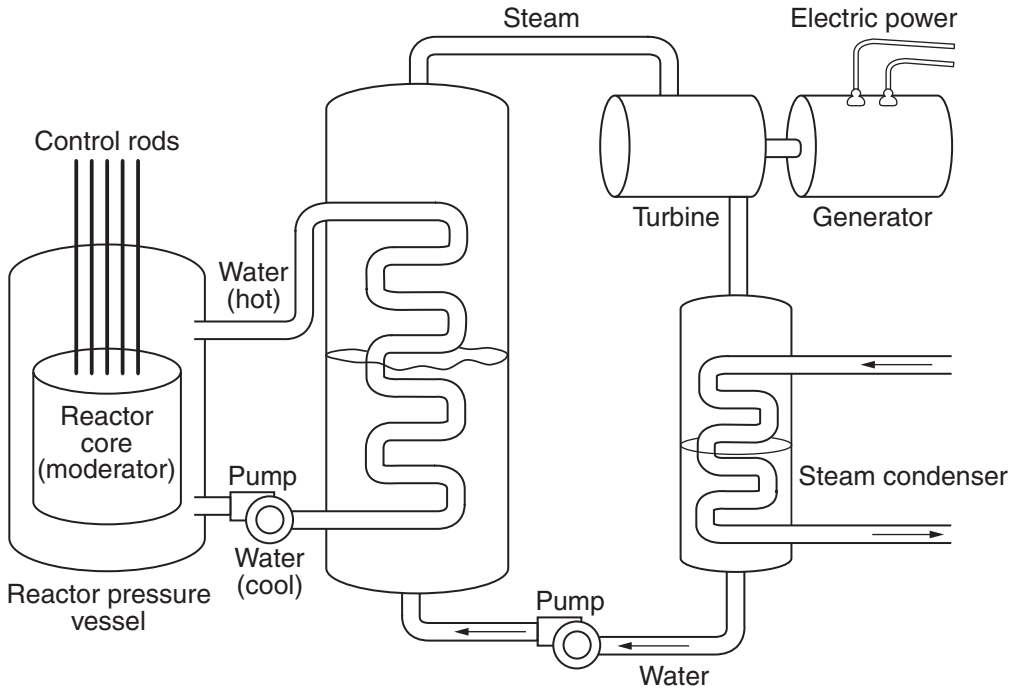


Explain what would happen if two nucleons were separated by the distance indicated as Z on the graph.

Question 31 continues on page 37

Question 31 (continued)

The figure shows the basic features of a nuclear fission reactor.



(ii) Which part of a nuclear reactor regulates the rate of fission reaction taking place? Justify your answer. **2**

(iii) Neutron beams can be extracted from nuclear reactors. **3**

Describe how the neutrons can be used as a probe for investigating the properties of matter.

End of Question 31

Marks

Question 32 — The Age of Silicon (25 marks)

(a) Consider the logic expression $C = \left(\overline{A} + \overline{B}\right)\left(A + B\right)$.

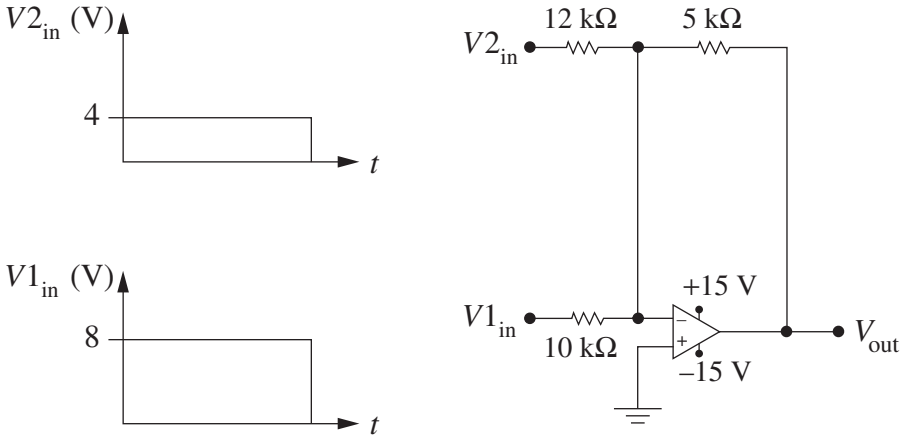
(i) Using standard symbols, draw a labelled logic diagram in your writing booklet corresponding to this expression. **2**

(ii) Develop a truth table for *C*. **3**

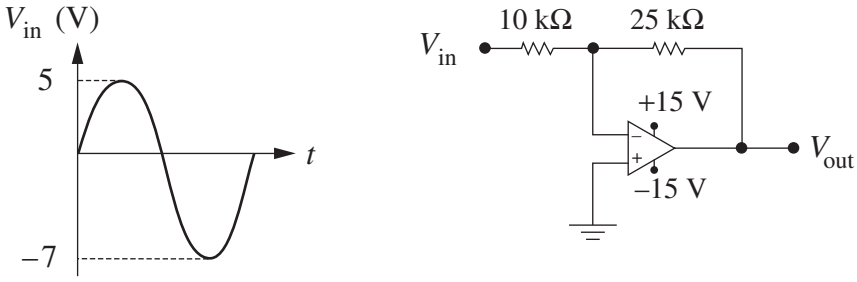
(b) In your study of the Age of Silicon you have investigated operational amplifiers. The two operational amplifier circuits shown below have the indicated waveforms applied at their inputs.

In each case, copy the input waveforms into your writing booklet, and on the same axes sketch the output produced by the circuit. Show all relevant calculations.

(i) **3**



(ii) **3**



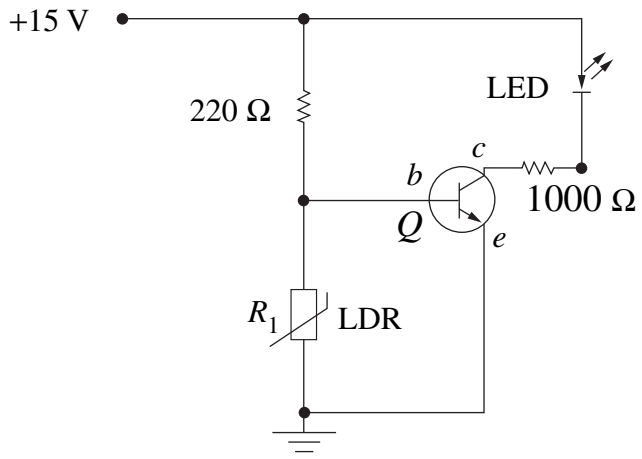
Question 32 continues on page 39

Question 32 (continued)

(c) Analyse how developments in the semiconductor industry could help to reduce energy consumption. **7**

(d) (i) Electronic circuits may use both input and output transducers. Explain the difference between these types of transducer, using an example of each. **3**

(ii) The circuit below is used to illuminate an alarm clock display. **2**



R_1 is a light-dependent resistor (LDR) and Q is a transistor with b, c and e as its base, collector and emitter terminals, respectively.

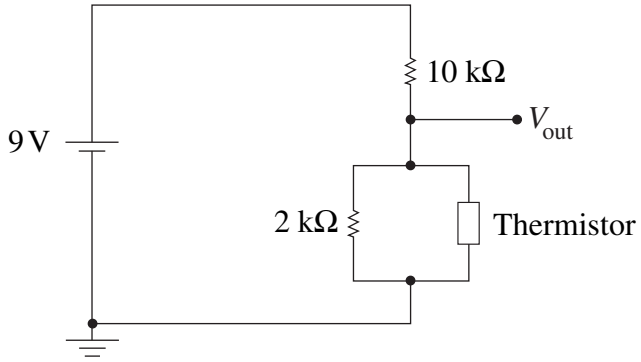
It is found that when the voltage at the base (ie across R_1) is below 0.7 V, the transistor is OFF, preventing current from flowing in the LED. If the base voltage is 0.7 V or more, the transistor is ON, causing 10 mA to flow through the LED.

Calculate the value of R_1 at the instant when the transistor switches on.

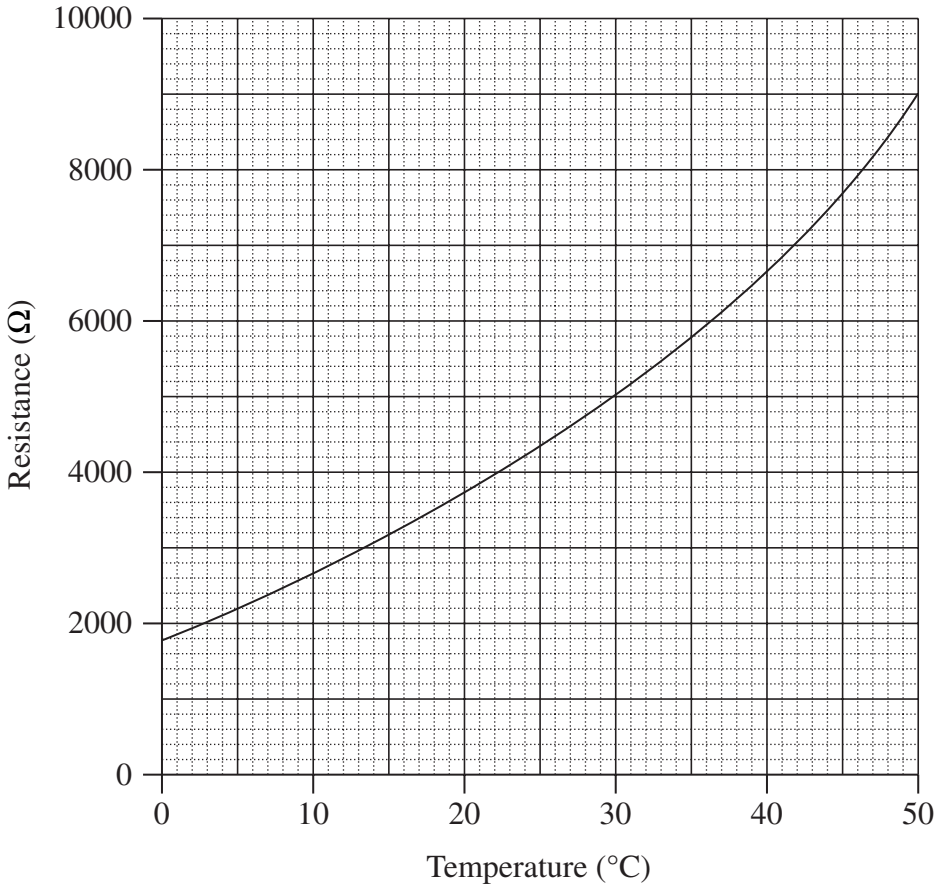
Question 32 continues on page 40

Question 32 (continued)

(iii) A thermistor is used to construct a thermometer circuit as shown. **2**



The thermistor's resistance as a function of temperature is plotted below.



At a certain temperature the output voltage V_{out} is found to be 1.2 V.

What is the temperature of the environment in which the thermometer circuit is located?

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

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

$$F = BIl\sin\theta$$

$$\tau = Fd$$

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

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

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

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

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

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

$$F = qvB\sin\theta$$

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

$$E = hf$$

$$c = f\lambda$$

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

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

$$Z = \rho v$$

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

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

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

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number — Symbol of element — Name of element

Atomic Weight

Example: 79 Au 197.0 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 65.41 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 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc [97.91] Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.8 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po [209.0] Polonium	85 At [210.0] Astatine	86 Rn [222.0] Radon
87 Fr [223] Francium	88 Ra [226] Radium	89–103 Actinoids	104 Rf [261] Rutherfordium	105 Db [262] Dubnium	106 Sg [266] Seaborgium	107 Bh [264] Bohrium	108 Hs [277] Hassium	109 Mt [268] Meitnerium	110 Ds [271] Darmstadtium	111 Rg [272] Roentgenium							

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm [145] Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.0 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac [227] Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np [237] Neptunium	94 Pu [244] Plutonium	95 Am [243] Americium	96 Cm [247] Curium	97 Bk [247] Berkelium	98 Cf [251] Californium	99 Es [252] Einsteinium	100 Fm [257] Fermium	101 Md [258] Mendelevium	102 No [259] Nobelium	103 Lr [262] Lawrencium

For elements that have no stable or long-lived nuclides, the mass number of the nuclide with the longest confirmed half-life is listed between square brackets.

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (October 2005 version) is the principal source of data. Some data may have been modified.