BOARD OF STUDIES
NEW SOUTH WALES

2011

HIGHER SCHOOL CERTIFICATE
EXAMINATION

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
  Black pen is preferred
- Draw diagrams using pencil
- Board-approved calculators may be used
- A data sheet, formulae sheets and Periodic Table are provided at the back of this paper
- Write your Centre Number and Student Number at the top of pages 9, 13, 15, 19 and 21

Total marks – 100

Section I Pages 2–22

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

Section II Pages 23–30

25 marks

- 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.

---

1 What is the main cause of orbital decay of a satellite in low Earth orbit?

(A) Tidal effects of the Moon

(B) The Sun's gravitational field

(C) Friction between the atmosphere and the satellite

(D) The interaction of the solar wind with the satellite

2 A 60 kg object has a weight of 240 N on the surface of Planet X.

What is the acceleration due to gravity on the surface of Planet X?

(A) 0.25 m s^{-2}

(B) 4 m s^{-2}

(C) 250 m s^{-2}

(D) $14\,400 \text{ m s}^{-2}$

3 Metals have a crystal lattice structure.

What part of the metal's structure does the lattice represent?

(A) The number of Cooper pairs

(B) The location of the metal ions

(C) The position of the free electrons

(D) The energy gap below the conduction band

4 Why are insulators poor conductors of electricity?

(A) Insulators do not have a conduction band.

(B) The valence bands of insulators do not contain any electrons.

(C) Insulators have a large energy band gap and a full valence band.

(D) Insulators have a small energy band gap and a partly filled conduction band.

5 Which law best applies to the operation of an electrical transformer?

(A) Conservation of Mass

(B) Conservation of Energy

(C) Conservation of Charge

(D) Conservation of Momentum

6 Why is the back emf induced in a motor greater when the motor is rotating faster?

(A) A larger current is induced.

(B) It takes a greater emf to spin the motor.

(C) The rate of change of magnetic flux is greater.

(D) More magnetic field lines are being cut per rotation.

7 Two parallel plates are 2 mm apart and have a potential difference of 100 V between them. An electron is placed halfway between the plates.

What is the magnitude of the force on the electron?

(A) 8.0×10^{-18} N

(B) 1.6×10^{-17} N

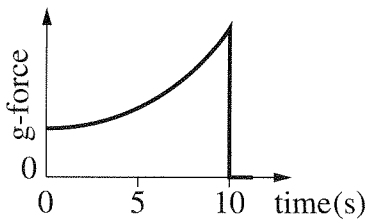
(C) 8.0×10^{-15} N

(D) 1.6×10^{-14} N

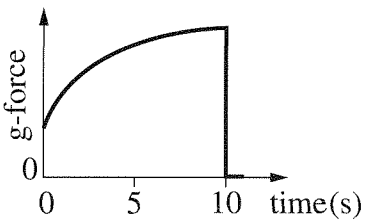
8 A rocket is launched. Its engine produces a constant thrust for the first 10 seconds and is then switched off.

Which graph best illustrates the g-force experienced by an astronaut in the rocket?

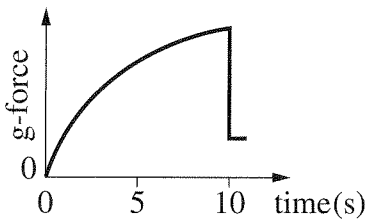
(A)



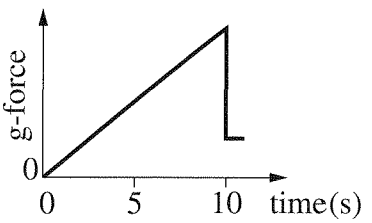
(B)



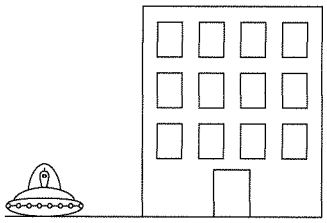
(C)



(D)



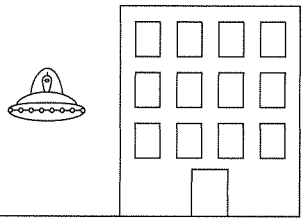
9 The diagram shows a stationary spacecraft next to a building, as seen by an observer across the street.



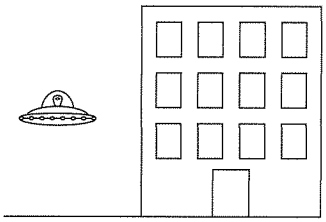
A short time later the spacecraft is observed to be travelling vertically upwards at 0.8c, relative to the building.

Which diagram best represents the appearance of the moving spacecraft, as seen by the observer?

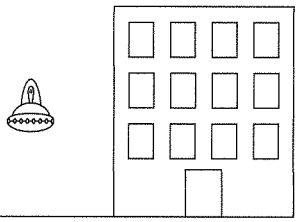
(A)



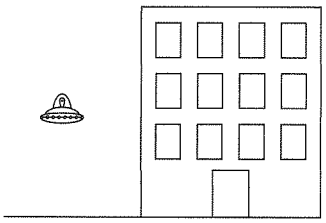
(B)



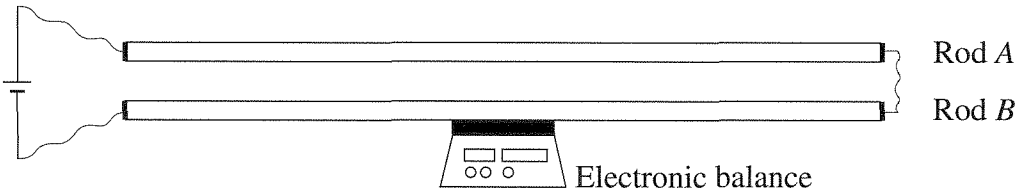
(C)



(D)



10 A student performed an experiment using two identical metal rods connected to a power supply. Rod *A* was placed at different distances from Rod *B*, and the measurements on the electronic balance were recorded.



Which is the independent variable?

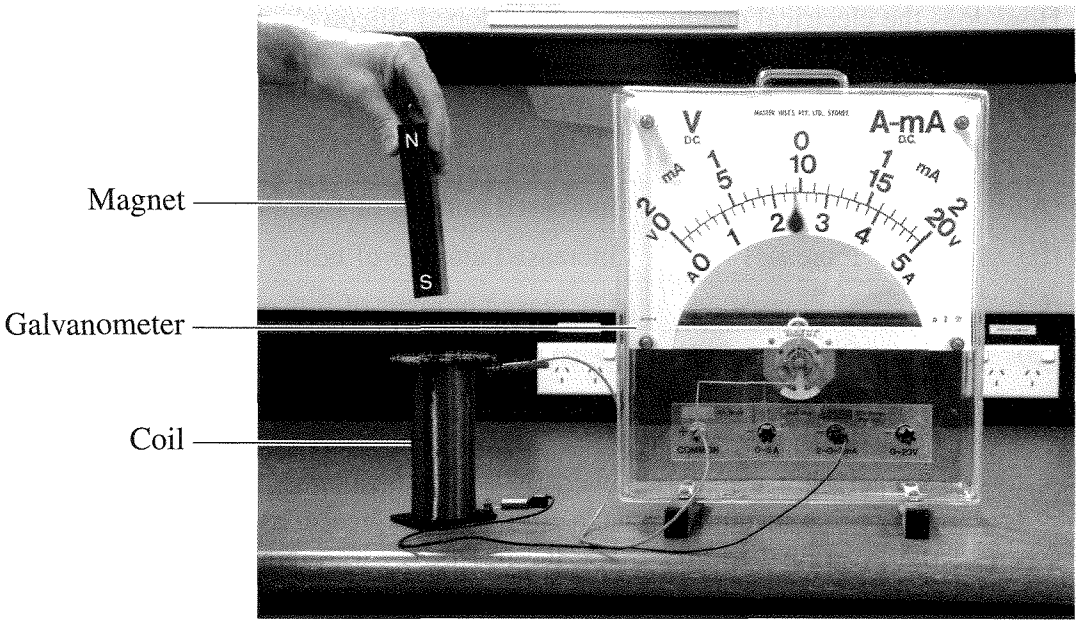
(A) The length of the rods

(B) The current in Rod *A*

(C) The mass recorded on the balance

(D) The distance between the two rods

11 A student set up the equipment shown to carry out a first-hand investigation.



What was the student investigating?

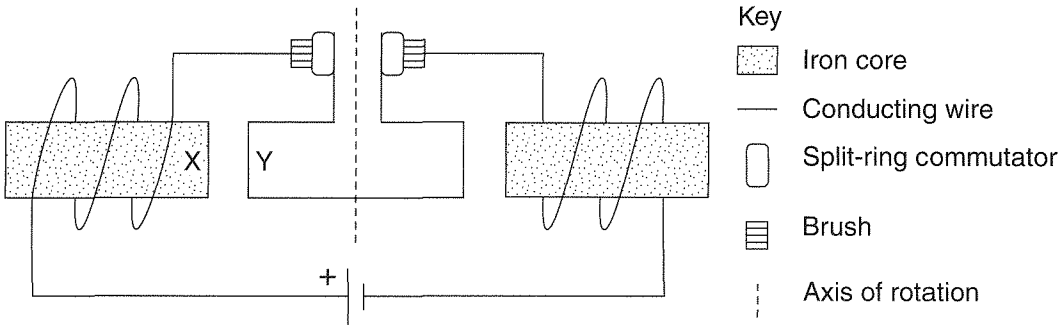
(A) Gravity

(B) The motor effect

(C) Magnetic levitation

(D) Electromagnetic induction

12 The diagram represents a DC electric motor.



What is the polarity of the magnetic pole at X, and the direction of the motion of wire Y?

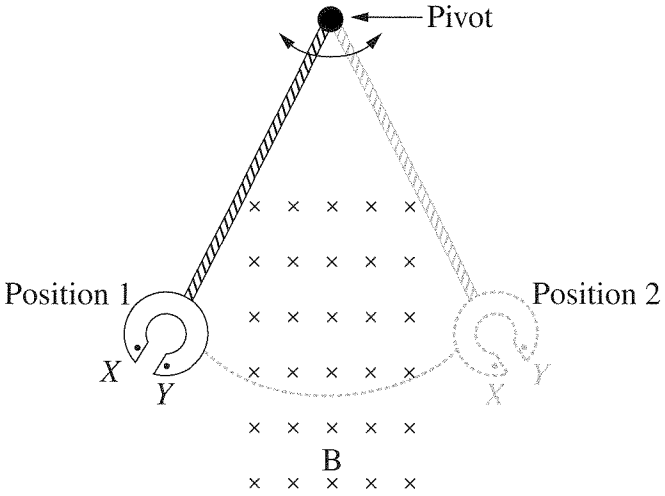
	Polarity of magnetic pole at X	*Direction of motion of wire Y*
(A)	South	Into the page
(B)	South	Out of the page
(C)	North	Into the page
(D)	North	Out of the page

13 A sample of pure silicon is doped with arsenic.

How does the electrical conductivity of the doped silicon change, and for what reason?

	Change in electrical conductivity	*Reason*
(A)	Increases	Increased number of free electrons
(B)	Increases	Increased number of holes
(C)	Decreases	Decreased number of free electrons
(D)	Decreases	Decreased number of holes

14 A heavy copper split ring is attached by a light insulating rod to a pivot to form a pendulum. A region of uniform magnetic field B is present as shown. As the pendulum swings from Position 1 to Position 2, the induced emf in the ring is measured between points *X* and *Y*.



Which graph best represents the measured emf during the time that the pendulum swings from Position 1 to Position 2?

(A) 

(B) 

(C) 

(D) 

15 A marble rolls off a 1.0 m high horizontal table with an initial velocity of 4.0 m s^{-1}.

How long will it take the marble to hit the floor?

(A) 0.20 s

(B) 0.25 s

(C) 0.45 s

(D) 3.20 s

16 A satellite is orbiting a planet at a constant speed.

Which of the following statements is correct?

(A) The satellite is not accelerating.

(B) The orbit of the satellite has a fixed radius.

(C) Fuel must be used to supply a constant thrust to the satellite.

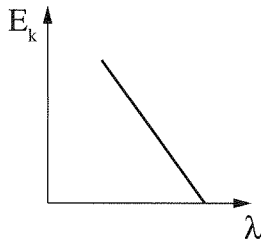
(D) The centripetal force on the satellite is balanced by the gravitational force.

17 When photons with energy E strike a metal surface, electrons may be emitted.

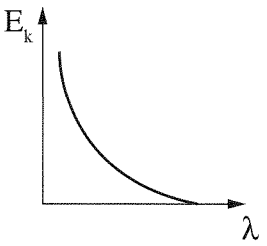
The maximum kinetic energy (E_k) of the electrons is given by $E_k = E - W$ where W is a constant for the metal.

Which of the following graphs shows the relationship between the maximum kinetic energy of these electrons (E_k) and the wavelength of the photons (λ)?

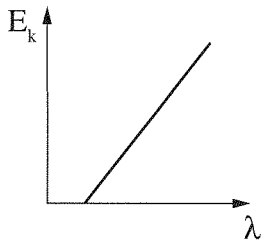
(A)



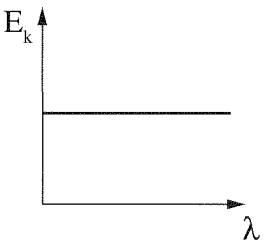
(B)



(C)



(D)



18 An electric motor is constructed using a square coil and a uniform magnetic field of strength 0.45 T. The coil has 3 turns and sides of 10 cm. A current of 0.5 A flows through the coil.

What is the maximum torque experienced by the coil as it rotates?

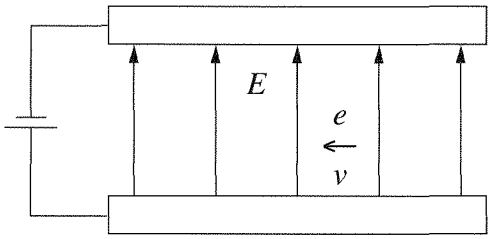
(A) 2.25×10^{-3} Nm

(B) 6.75×10^{-3} Nm

(C) 22.5 Nm

(D) 67.5 Nm

19 An electron, e, travelling with a velocity, v, passes through an electric field, E, between two parallel plates.



What is the direction of the force that this electric field exerts on the electron?

(A) ↑

(B) ↖

(C) ↙

(D) ↓

20 A satellite, initially in a low Earth orbit, is moved to a new orbit where its gravitational potential energy is half its initial value.

What is the gravitational force experienced by the satellite in its new orbit?

(A) Half the initial force

(B) Twice the initial force

(C) Four times the initial force

(D) One quarter the initial force

Physics

Centre Number

Student Number

Section I (continued)

Part B – 55 marks
Attempt Questions 21–30
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.

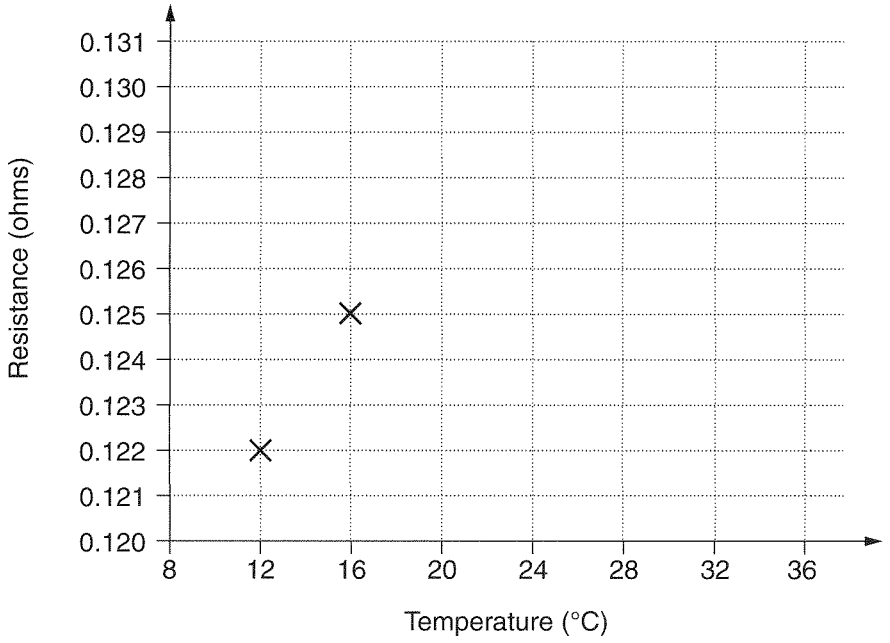
Question 21 (5 marks)

Please turn over

Question 21 (5 marks)

The electrical resistance, R, of a piece of wire was measured at different temperatures, T. Near room temperature, the resistance of the wire can be modelled by the equation $R = mT + b$.

Temperature (°C)	*Resistance (ohms)*
12	0.122
16	0.125
32	0.129
36	0.131



(a) Plot the TWO remaining data points on the graph provided. Draw a line of best fit on the graph and use it to estimate the electrical resistance of the wire at 24°C. **3**

.....

(b) Assess the validity of using the data from this experiment to estimate the electrical resistance at –100°C. **2**

.....

.....

.....

.....

Question 22 (5 marks)

(a) What was the purpose of the experiment that Michelson and Morley conducted in 1887? **1**

.....

.....

(b) Draw a labelled diagram that outlines how the experiment was performed. **4**

BLANK PAGE

Question 23 (7 marks)

A rocket launches a satellite into an orbit 350 km above Earth's surface. The weight of the satellite is 14.0 kN at launch, and is 12.6 kN when in orbit.

(Radius of Earth = 6380 km, mass of Earth = 5.97×10^{24} kg)

(a) Why does the weight of the satellite change? **1**

.....

(b) Calculate the orbital velocity of this satellite. **2**

.....

.....

.....

.....

.....

(c) Explain TWO effects that a reduction in altitude would have on the motion of this satellite. **4**

.....

.....

.....

.....

.....

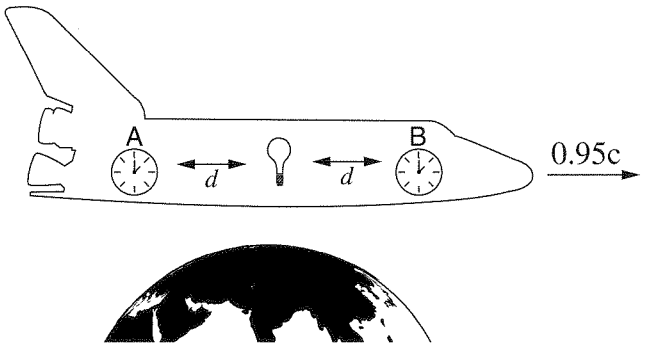
.....

.....

.....

Question 24 (4 marks)

Consider the following 'thought experiment'. **4**
A scientist on board a spaceship wishes to synchronise two clocks. To achieve this, beams of light from a source placed midway between the clocks activate photocells, turning on both clocks.



The scientist observes the synchronisation of the clocks as the rocket flies past Earth at 0.95c. A person on Earth observes that the clocks are not synchronised. Account for these observations.

.....

.....

.....

.....

.....

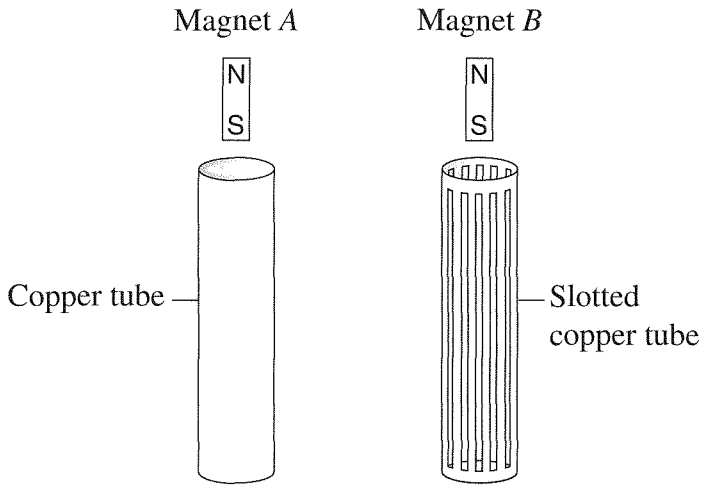
.....

.....

.....

Question 25 (4 marks)

Identical magnets *A* and *B* are suspended above vertical copper tubes as shown in the diagram. **4**



The magnets are dropped at the same time. Each magnet falls straight through its tube without touching the tube walls.

Which magnet leaves its tube first and why?

.....

.....

.....

.....

.....

.....

.....

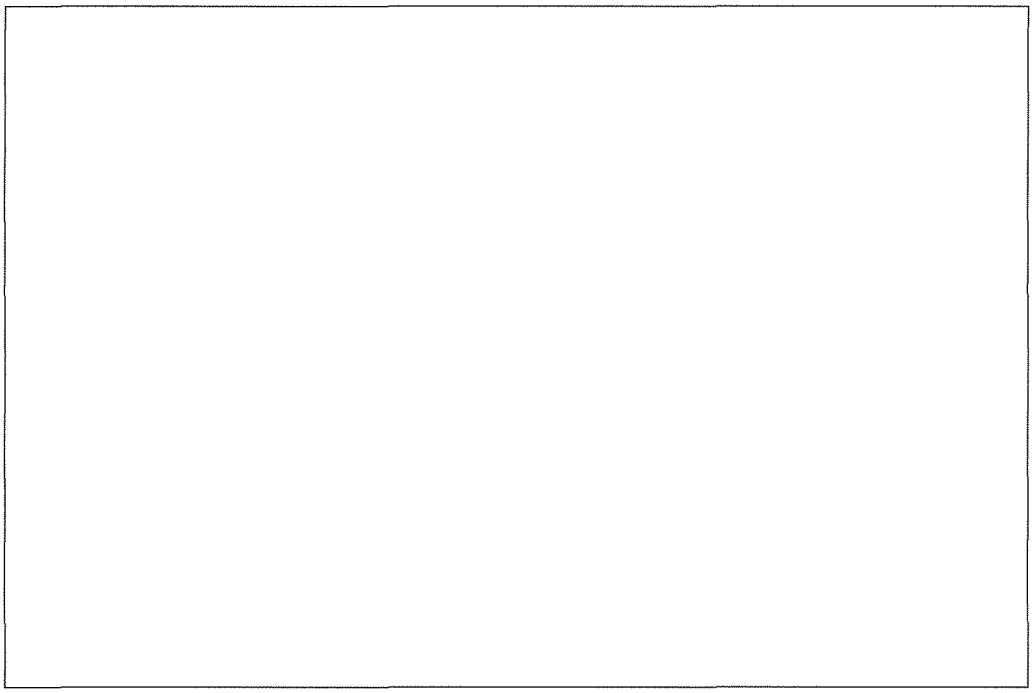
.....

.....

.....

Question 26 (9 marks)

(a) Use a flowchart to show how electrical energy is transferred from a power station to its point of use. **3**



Question 26 continues on page 17

Question 26 (continued)

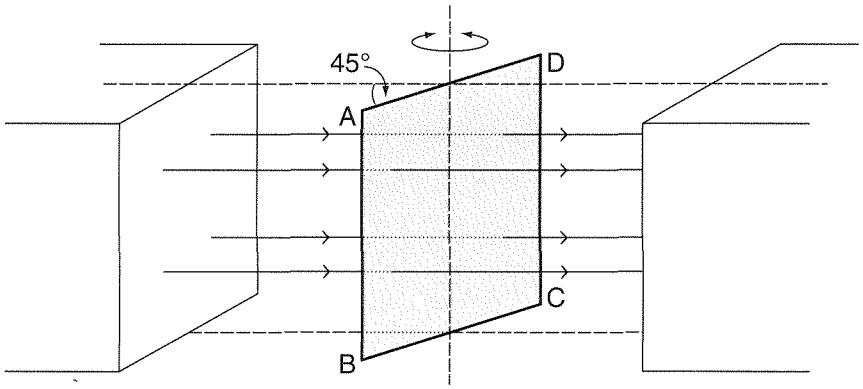
(b) Discuss the effects on the environment of the development of AC generators. **6**

End of Question 26

BLANK PAGE

Question 27 (4 marks)

A single turn coil is positioned in a region of uniform magnetic field with a strength of 0.2 T. The plane of the coil is at 45° to the magnetic field. The coil is a square with 5 cm sides, and carries a current of 10.0 A.



(a) Calculate the magnitude of the force on side AB. **2**

.....

.....

.....

(b) Explain why the net force produced by the magnetic field on the coil is zero. **2**

.....

.....

.....

Question 28 (6 marks)

(a) How could a student test the hypothesis that cathode rays are streams of particles? In your answer refer to the results that would be observed. **3**

.....

.....

.....

.....

.....

.....

.....

(b) How is an electron beam produced in an electron gun? **3**

.....

.....

.....

.....

.....

.....

.....

Question 29 (5 marks)

(a) Calculate the number of photons, $\lambda = 450$ nm, which are required to transfer 1.0×10^{-3} J of energy. **3**

.....

.....

.....

.....

.....

.....

.....

(b) A 1 W beam of light transfers 1 J per second from one point to another. **2**

With reference to the particle model of light, contrast a 1 W beam of red light and a 1 W beam of blue light.

.....

.....

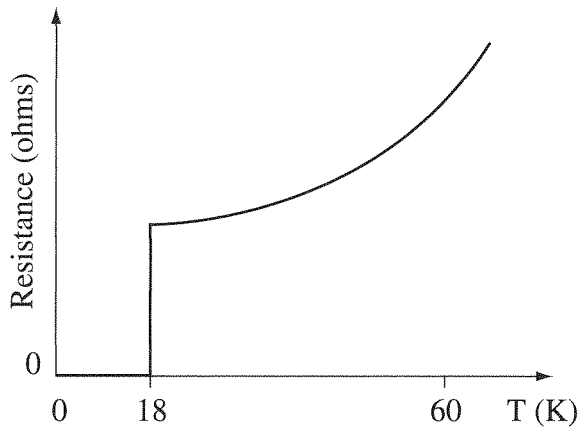
.....

.....

.....

Question 30 (6 marks)

The graph shows the relationship between the resistance of a metal alloy sample and its temperature.



(a) Why is the resistance of the sample higher at 60 K than at 30 K? **2**

.....

.....

.....

.....

(b) Use BCS theory to explain why the resistance of the sample is zero at temperatures below 18 K. **4**

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Physics

Section II

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

Answer the parts of the question as indicated in Section II Answer Booklet 1 and Section II Answer Booklet 2.
Extra writing booklets are available.

Show all relevant working in questions involving calculations.

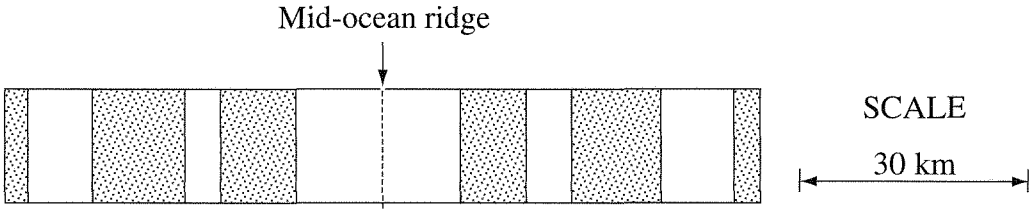
Question 31 — Geophysics (25 marks)

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

(a) Describe how geophysicists have reduced the risks from a natural hazard. In your answer, refer to a specific natural hazard and the instruments used to monitor it. **3**

(b) (i) How is the rate of sea-floor spreading determined from magnetic anomaly measurements? **3**

(ii) The diagram represents the magnetic anomalies of the oceanic crust in a particular region where the rate of sea-floor spreading is 30 km per million years. **2**



Use this information to construct a graph of magnetic field polarity vs time.

(c) (i) Describe a first-hand investigation that demonstrates the relationship between the nature of a surface and the radiation reflected from it. **4**

(ii) How can remote sensing techniques be used to monitor the regrowth of vegetation in regions affected by bushfire? **2**

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

(d) (i) Explain why measurements of the gravitational field strength taken on Earth's surface at two different latitudes result in different values. **2**

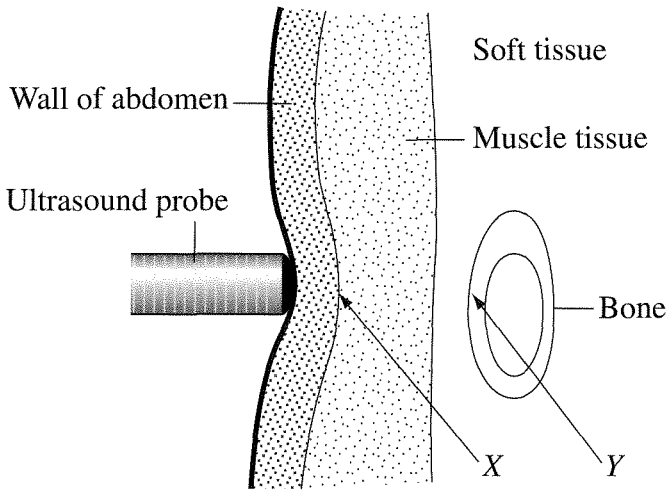
(ii) Explain how resource exploration has been aided by the use of gravity methods. **3**

(e) Explain how seismic methods and a knowledge of wave properties have increased our understanding of the structure of Earth. **6**

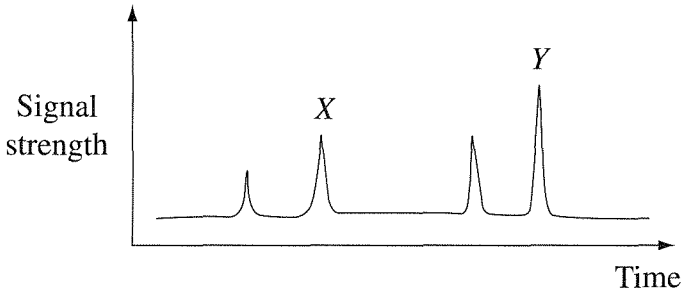
Question 32 — Medical Physics (25 marks)

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

An ultrasound probe fires a pulse of ultrasound into the abdomen as shown in the diagram.



Analysis of the reflected sound produced the following scan.



(a) (i) Identify the type of scan and the information that can be obtained from it. **2**

(ii) The peaks X and Y correspond to the ultrasound reflected from the muscle tissue and bone respectively. Explain why the signal strength at Y is greater than at X. **2**

(iii) The acoustic impedance of the abdomen wall adjacent to the muscle is 1.56×10^6 kg m^{-2} s^{-1}. If muscle tissue has a density of 1.04×10^3 kg m^{-3} and an acoustic velocity of 1580 m s^{-1}, calculate the percentage of the incident ultrasound pulse that is reflected at boundary X. **3**

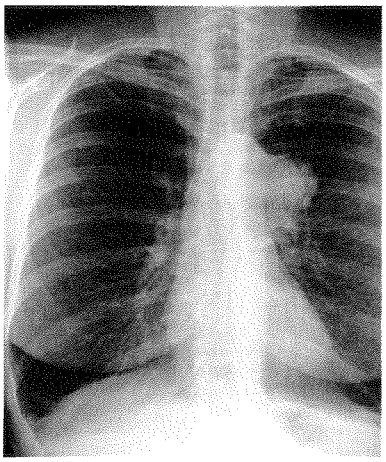
Question 32 continues on page 26

Question 32 (continued)

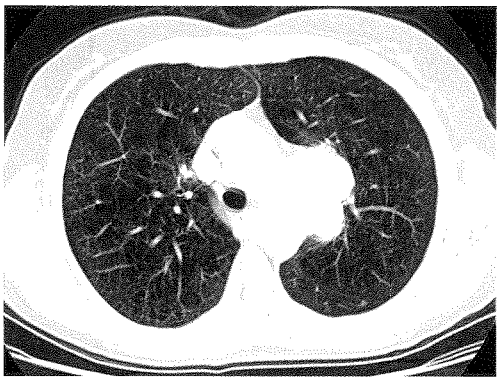
(b) (i) Explain how X-rays are produced in an X-ray tube. **3**

(ii) The photographs *A* and *B* show scans of the same part of the body. **3**

A



B



Compare the information provided by the two scans.

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

(c) Explain why MRI is an effective tool for diagnosing brain tumours. **3**

(d) With reference to coherent and incoherent bundles of fibres, explain how an endoscope is used to observe internal organs. **3**

(e) *An increased understanding of the properties of radioactive isotopes has been important in the development of medical technologies used to analyse bodily processes.* **6**

Justify this statement.

End of Question 32

Question 33 — Astrophysics (25 marks)

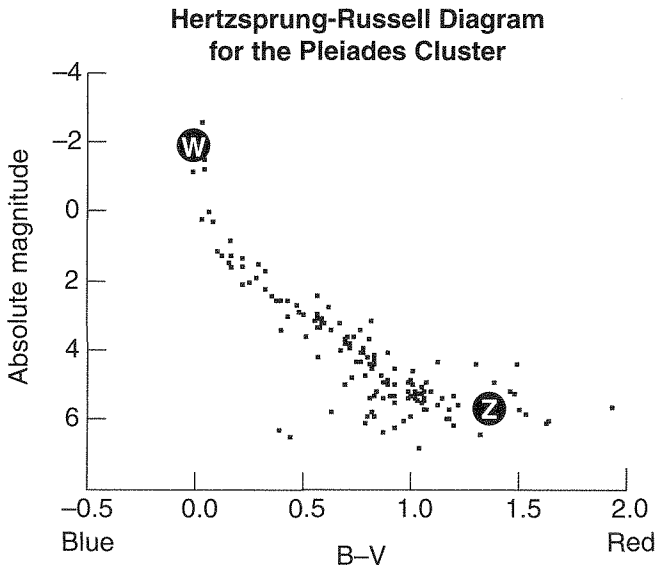
Answer parts (a)–(b) in Section II Answer Booklet 1.

(a) (i) Using a diagram, define the term *parsec*. **2**

(ii) Why was the resolution of Galileo's telescope more important for his observations than its sensitivity? **3**

(iii) Describe ONE technology that has improved the resolution of telescopes. **2**

(b)



(i) Compare the nuclear processes in a star found at W to a star found at Z on the Hertzsprung-Russell diagram. **3**

(ii) In 2008, the distance to the Pleiades cluster was determined as 135 pc. Calculate the apparent magnitude of a star at W. **2**

(iii) Calculate the relative brightness of a star found at W to a star found at Z. **2**

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

(c) Using a Cepheid and one other named example, explain the difference between intrinsic and extrinsic variable stars. **4**

(d) *Spectroscopy is an important tool in obtaining information about stars, but it is a much more powerful tool when combined with photometry.* **7**

Justify this statement.

Question 34 — From Quanta to Quarks (25 marks)

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

(a) Name a radioisotope used in agriculture and describe its use. **2**

(b) (i) Explain how the reaction rate in a nuclear reactor can be increased or decreased. **4**

(ii) $^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{140}_{56}\text{Ba} + {}^{92}_{36}\text{Kr} + 4\,{}^{1}_{0}\text{n}$ **2**

Explain why energy is released in this reaction.

(c) Copy and complete in your booklet the following table comparing forces in the atomic nucleus. **3**

Forces in atomic nucleus

	Gravitational	*Electrostatic*	*Strong*
Strength	Low		
Direction	Attractive		
Range	Infinite		

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

(d) A cricket ball has a mass of 156 g and a velocity of 20 m s^{-1}. Calculate its de Broglie wavelength. **2**

(e) Identify the types and number of quarks and leptons in a tritium ($^{3}_{1}\text{H}$) atom. **2**

(f) Outline the main contributions of Heisenberg and Pauli to the development of atomic theory. **4**

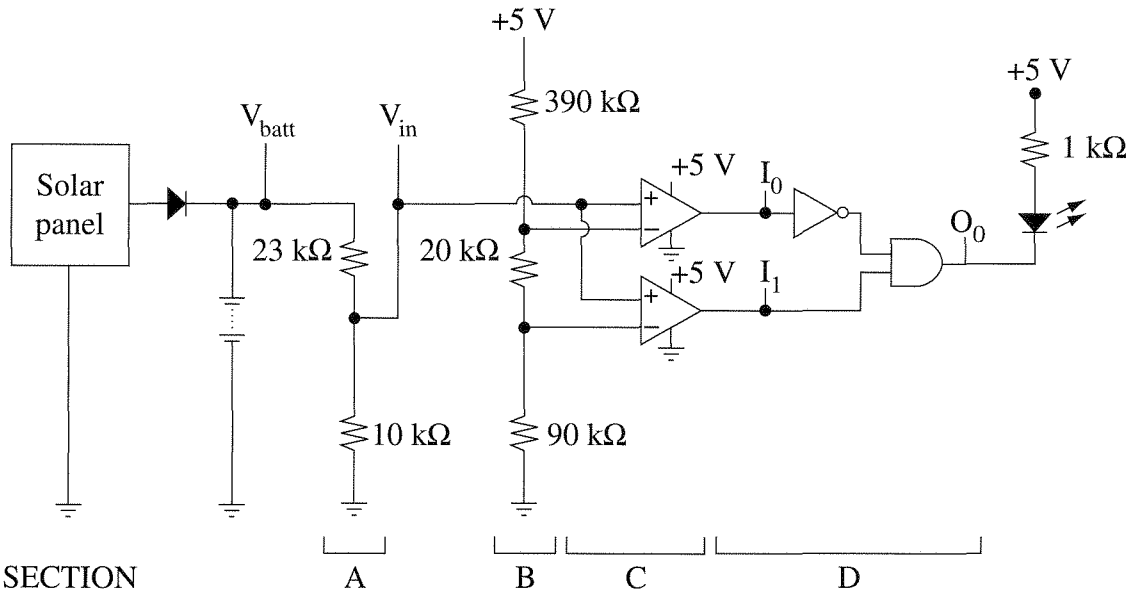
(g) *Mathematical models, validated by experimental evidence, have improved our understanding of the atom.* **6**

Justify this statement, focusing on the models developed by Bohr and de Broglie.

Question 35 — The Age of Silicon (25 marks)

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

A circuit for a solar battery charger is shown.



(a) Construct a truth table for the logic circuit contained in Section D. **3**

(b) Explain whether the operational amplifiers in Section C of the circuit are used in an open loop or closed loop configuration. **2**

(c) Determine the formula relating V_{batt} to V_{in}. **2**

(d) Calculate the range of voltages for V_{batt} for which the LED indicator lights up. **3**

Question 35 continues on page 30

Question 35 (continued)

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

(e) (i) Using a labelled diagram, describe the construction of an LED. **3**

(ii) Identify ONE advantage and ONE disadvantage of using LEDs for household lighting. **2**

(f) What properties of silica make it a suitable material for use in optical fibres? **3**

(g) The semiconductor integrated circuit industry is rapidly approaching fundamental physics limitations for the design of integrated circuits for computers. **7**

Explain what these limitations are and why this will require a reconceptualisation of the way computers are designed.

End of paper

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

$$v = f\lambda$$

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

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

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

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

$$P = VI$$

$$\text{Energy} = VIt$$

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

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

$$\Sigma F = ma$$

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

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

$$W = Fs$$

$$p = mv$$

$$\text{Impulse} = Ft$$

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

$$F = mg$$

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

$$v = u + at$$

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

$$\Delta x = u_x t$$

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

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

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

$$E = mc^2$$

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

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

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

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

KEY

Atomic Number
Symbol
Standard Atomic Weight
Name

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 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium						

Lanthanoids

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

Actinoids

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

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

Standard atomic weights are abridged to four significant figures.

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

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