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HSC Trial Examination

Physics

This paper must be kept under strict security and may only be used on or after the morning of Monday 13 August, 2001, as specified in the NEAP Examination Timetable

General Instructions

Reading time 5 minutes

Working time 3 hours

Board-approved calculators may be used.

Write using blue or black pen.

Draw diagrams using pencil.

Examination structure

Section I Pages 2–19 Total marks 75

This section has two parts, Part A and Part B

Part A Total marks (15)
Attempt Questions 1–15.
Allow about 30 minutes for this part.

Part B Total marks (60)
Attempt Questions 16–30.
Allow about 1 hour and 45 minutes for this part

Section II Pages 20–28 Total marks 25

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

Section I

Total marks 75

Part A

Total marks 15
Attempt Questions 1–15.
Allow about 30 minutes for this part.

Use the multiple-choice answer sheet.
Select the alternative A, B, C, or D that best answers the question. Fill in the response oval completely.

Sample 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ● B ⊗ C ○ D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate this by writing the word *correct* and draw an arrow as follows:

correct ↙

A ⊗ B ⊗ C ○ D ○

1. Satellite communication systems must be very flexible to receive messages, respond with data and deal with difficulties. Which of the following statements is false?

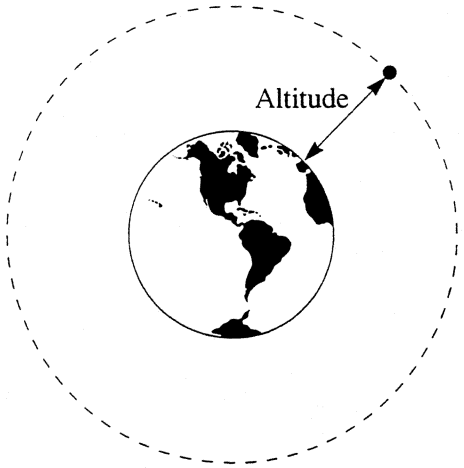
   (A) Communication with satellites and other space probes rely on electromagnetic radiation.

   (B) Sunspot activity can affect the Earth's magnetic field, which in turn can cause problems for communication with satellites.

   (C) Deep space telecommunications utilise very low radio frequencies to avoid communication problems.

   (D) Microwaves are the major carriers of data between Earth-based stations and satellites.

2. The Earth, whose radius is 6.38×10^6 m and mass is 5.98×10^{24} kg, has an artificial satellite, which orbits at a particular altitude. The mass of the satellite is 540 kg and has acceleration due to gravity at this altitude is 0.233 m s^{-2}.



   What is the altitude of this orbiting satellite?

   (A) 4.14×10^4 km

   (B) 4.14×10^7 km

   (C) 3.50×10^4 km

   (D) 3.50×10^7 km

3. Two moons *A* and *B* of the same planet orbit with radii of *r* and 2*r* respectively. If both moons have the same mass and equal velocity then the centripetal force acting on moon *B* would be

   (A) half as large as the centripetal force on moon *A*.

   (B) the same as the centripetal force on moon *A*.

   (C) twice as large as the centripetal force on moon *A*.

   (D) four times as large as the centripetal force on moon *A*.

4. A model rocket is launched from the Earth at an angle of 55° from the vertical with an initial velocity of 120 m s^{-1}. What is the projectile's speed 3.00 s later?

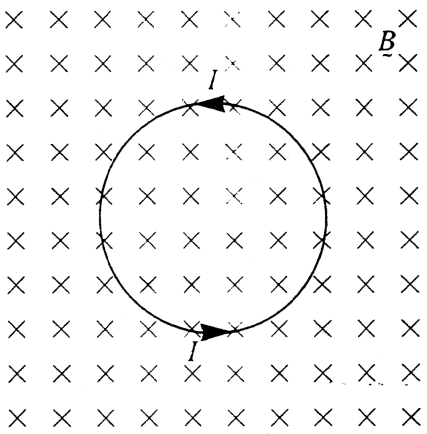
   (A) 68.8 m s^{-1}

   (B) 98.3 m s^{-1}

   (C) 106 m s^{-1}

   (D) 120 m s^{-1}

5. A circular coil of wire is placed into a region with a magnetic field directed into the page. as shown in the following diagram.



When a current I flows in the coil. the magnetic force acting on the coil will tend to cause it to

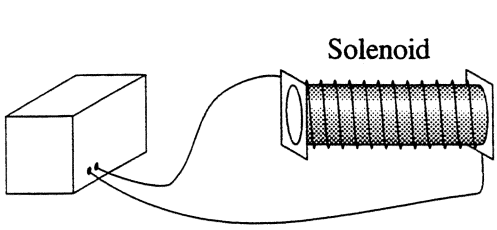
(A) expand.

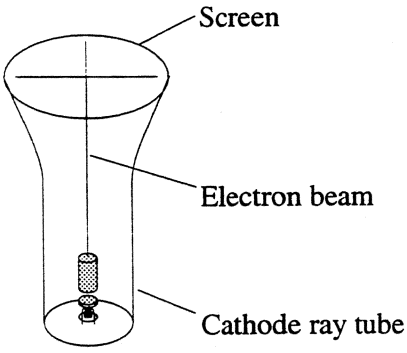
(B) contract.

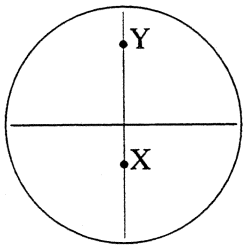
(C) move up the page.

(D) move down the page.

6. A screen is placed at the end of a cathode ray tube. An undeflected electron beam strikes the centre of the screen. When a solenoid carrying a current is placed beside the cathode ray tube, the electron beam strikes the screen at position X.







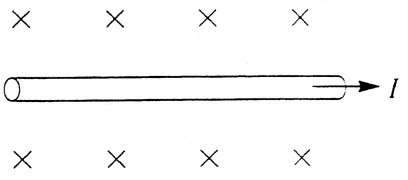
Screen at end of cathode ray tube

What changes to the magnitude and direction of the current in the solenoid would cause the electron beam to strike the screen at position Y?

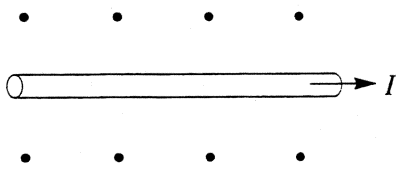
	Change to current magnitude	*Change to current direction*
(A)	Increases	Remains the same
(B)	Increases	Reverses
(C)	Decreases	Remains the same
(D)	Decreases	Reverses

7. A conductor carries a current I to the right. Which diagram shows the magnetic field created near the conductor?

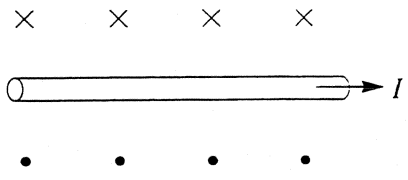
(A)



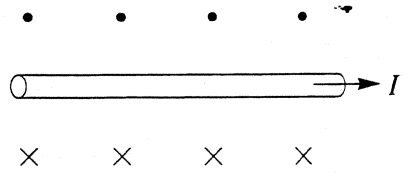
(B)



(C)



(D)



8. An aircraft with a large wingspan flies at a constant velocity perpendicular to the Earth's magnetic field. An emf is induced across the wings of the aircraft. Which statement is correct?

(A) A magnetic force between the wings and the Earth creates the emf.

(B) An electrostatic force between the wings and the Earth's magnetic field creates the emf.

(C) The relative motion between the wings and the Earth's magnetic field creates the emf.

(D) The relative motion between the wings and the Earth creates the emf.

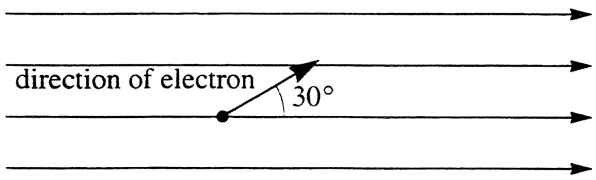
9. A transformer connected to a 240 V AC supply has 7,000 primary turns and 350 secondary turns. It delivers a secondary current of 2.4 A. Find the primary current and secondary voltage, assuming there are no energy losses.

	Primary current	*Secondary voltage*
(A)	0.12 A	12 V
(B)	0.12 A	4800 V
(C)	48 A	12 V
(D)	48 A	4800 V

10. A electrician drills a hole into a wall using an electric drill. As he makes the hole, friction on the end of the drill causes the armature of the motor within the drill to slow down. How will the back emf and the current through the armature change as the drill slows down?

	Back emf	*Current*
(A)	Increase	Increase
(B)	Increase	Decrease
(C)	Decrease	Increase
(D)	Decrease	Decrease

11. An electron crosses the magnetic field at an angle of 30° as shown in the diagram below. The magnetic field has a strength of 0.25 T and the electron has a velocity of 3.0×10^6 m s^{-1}.



The magnitude of the magnetic force on this electron at the instant shown is

(A) 6.8×10^{-25} N

(B) 6.0×10^{-14} N

(C) 1.2×10^{-13} N

(D) 1.3×10^{-1} N

12. Cathode ray tubes were involved in the discovery of

(A) superconductors.

(B) semiconductors.

(C) black body radiation.

(D) electrons.

13. Electrons passing through copper wire under the influence of an electric field tend to gain almost no kinetic energy. This is because

(A) they are gaining electrical energy.

(B) they collide with copper ions.

(C) they gain mass.

(D) copper is not a superconductor.

14. A photon of light with a wavelength of 530 nm has an energy of

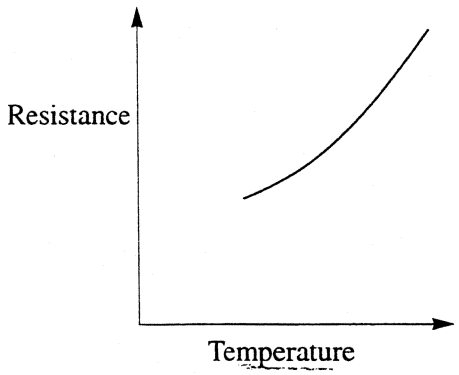
(A) 3.75×10^{-28} J.

(B) 3.75×10^{-19} J.

(C) 8.5×10^{-26} J.

(D) 1.8×10^{2} J.

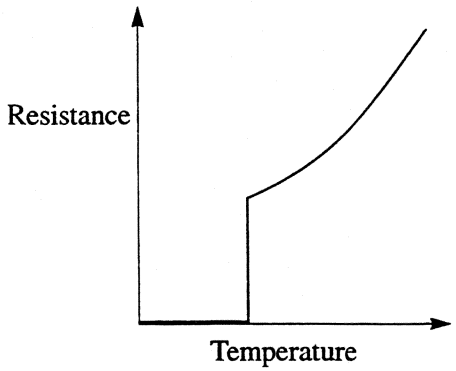
15. It was well known at the beginning of the twentieth century that the resistance of mercury decreases as temperature decreases, as shown in the graph below.



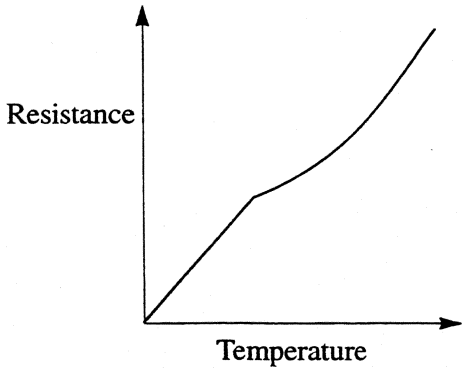
However it was discovered that at very low temperatures this line is no longer smooth.

The best representation for the resistance versus temperature of mercury as it approaches absolute zero is

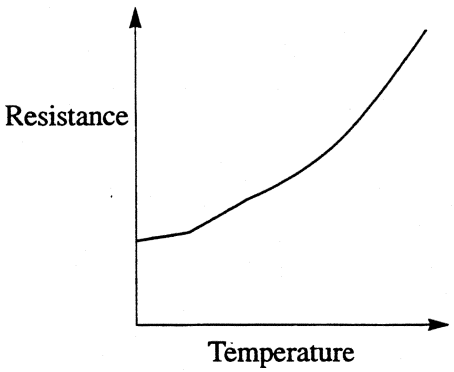
(A)



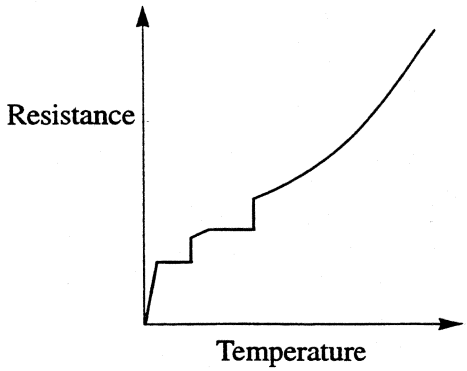
(B)



(C)



(D)



Part B

Total marks 60
Attempt Questions 16–30.
Allow about 1 hour and 45 minutes for this part.

Answer Part B questions in the spaces provided.
Show all relevant working in questions that require calculations.

Marks

Question 16 (5 marks)

Near the surface of the planet Mars, when a 4.0 kg rock is dropped from rest, it reaches a speed of 7.5 m s^{-1} in 2.0 s.

(a) What is the acceleration due to gravity near the surface of Mars? **2**

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(b) The planet Mars has an average radius of 3.4×10^6 m. What is the mass of Mars? **3**

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Question 17 (4 marks)

Sputnik I, Earth's first artificial satellite, had an orbital period of 5,760 seconds, while Australia's first *AUSSAT* satellite launched in 1985 had an orbital period of 24 hours, giving it a geosynchronous orbit.

(a) What was the average orbital radius of *Sputnik's* orbit? **2**

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(b) Discuss the advantages that *AUSSAT's* geosynchronous orbit has over *Sputnik's* orbit. **2**

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Question 18 (7 marks)

Marks

The theory of relativity discusses the physical consequences of the absence of a universal frame of reference. The special theory of relativity, published in 1905 by Albert Einstein, is concerned with problems involving inertial frames of reference. Its fundamental principles, however, caused apparent discrepancies in measurements.

(a) What are inertial frames of reference? **1**

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(b) State TWO fundamental principles upon which the special theory of relativity is based. **2**

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(c) State TWO apparent discrepancies caused by these fundamental principles and outline how Einstein was able to explain them. **4**

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Marks

Question 19 (4 marks)

Humans have not travelled widely in space, but there have been a significant number of deep space probes sent to investigate our solar system and beyond.

(a) State one reason as to why humans have not travelled widely within our solar system. 1

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(b) Deep space probes have utilised a fuel-efficient method known widely as the **sling-shot** effect. 3

Describe how this effect works, stating clearly the basic physical principle upon which it operates.

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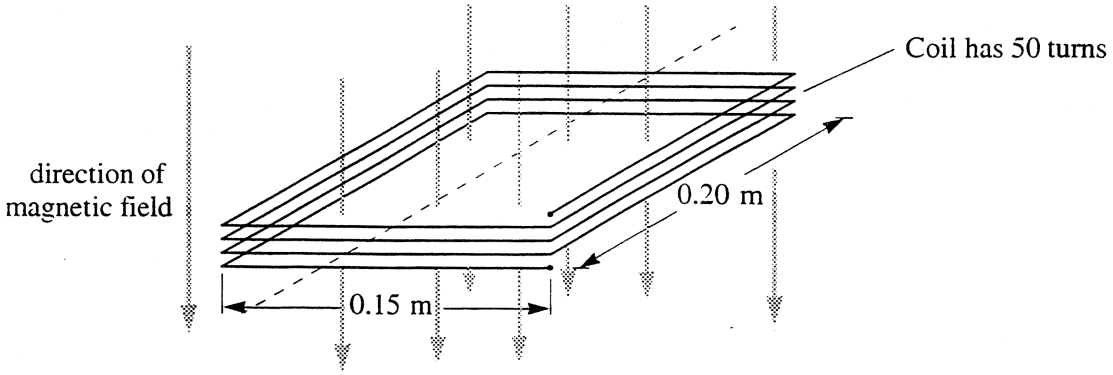
Marks

Question 20 (4 marks)

A coil with 50 turns and dimensions of 0.15 m by 0.20 m can pivot about an axis as shown in the diagram below. Its plane is initially perpendicular to a magnetic field whose flux density is 0.60 T.



(a) The coil is attached to a supply which delivers a current of 3.0 A. What is the value of the torque that will act on the coil when lying perpendicular to the magnetic field? Account for this value. **2**

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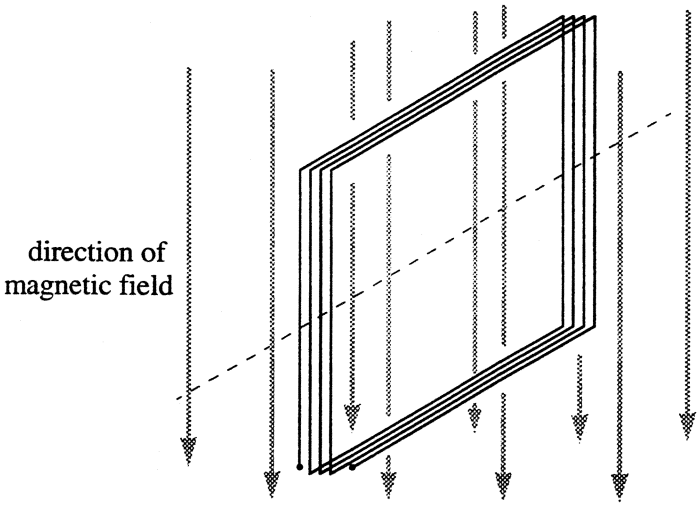
(b) The coil is disconnected from the supply and rotated through 90° so that its plane is now parallel to the magnetic field. **2**



Explain how this rotation creates an emf between the ends of the coil.

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Marks

Question 23 (2 marks)

In a particular electric motor, wires carrying currents of 4.0 A are aligned perpendicular to a magnetic field of flux density 1.2 T. 2

Determine the force on each centimetre section of the wire.

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Question 24 (5 marks)

(a) Explain, using a diagram, how a galvanometer utilises the motor effect for its operation. 3

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(b) Contrast the operation of a galvanometer with that of a simple generator. 2

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Question 21 (2 marks)

Marks

Two long conductors, which are lying parallel to each other, carry currents in an easterly direction. If the currents are respectively of 2.0 A and 4.0 A, and both wires are separated by a distance of 10 mm, calculate the magnitude of the force acting on a 2.0 m section of the wires. **2**

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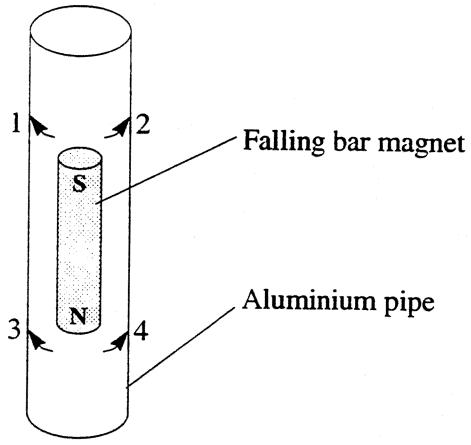
Question 22 (4 marks)

A bar magnet falls through a section of aluminium pipe as shown below. As it falls electric currents are created in the pipe immediately above and below the falling magnet.



(a) Show clearly by using the numbers shown in the above diagram the direction in which these currents flow. **2**

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(b) Explain how these currents are created. **2**

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Marks

Question 25 (3 marks)

Transmission of electrical energy is usually accomplished by alternating currents operating at high voltage. 3

Outline why AC is the preferred current form for the transmission of electrical energy and why high voltage is used.

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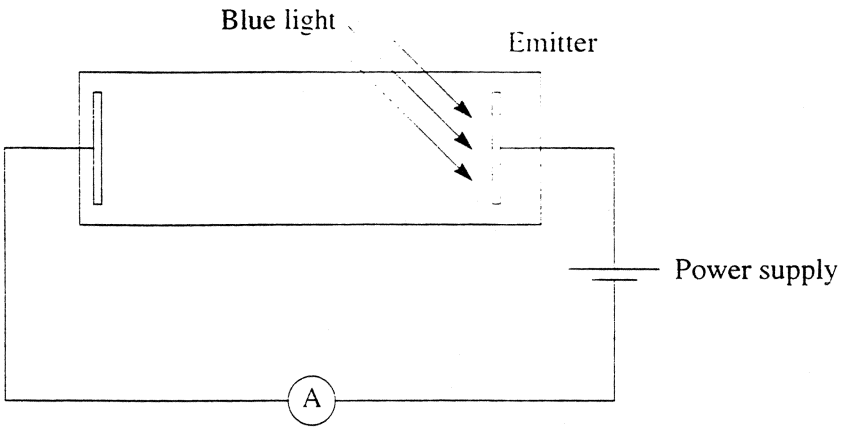
Marks

Question 26 (6 marks)

An evacuated tube is set up as shown below to demonstrate the photoelectric effect.



(a) Describe what happens to the atoms on the surface of the emitter when blue light hits it. **1**

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(b) What happens to the reading on the ammeter when the voltage on the power supply is increased? Explain why this is so. **2**

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(c) If the blue light is removed and replaced with an infrared light, predict what would happen to the reading observed on the ammeter. **1**

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(d) Explain what your answer in (c) tells us about the nature of light. **2**

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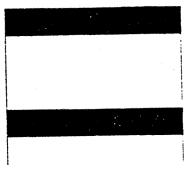
Marks

Question 27 (4 marks)

For atoms in a crystal we can consider the electrons to be in energy bands rather than in distinct levels.



(a) Using sketches and words compare the band structures for an insulator and a conductor. 2

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(b) Outline an example of how semiconductors have had a significant impact on our world. 2

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Question 28 (3 marks)

William and Lawrence Bragg developed the Bragg Spectrometer.

(a) State what part of the electromagnetic spectrum it uses. 1

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(b) State what specifically their device was used to study and why visible light was no use in their spectrometer. 2

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Question 29 (3 marks) **Marks**

Clarify the difference in behaviour of electrons when they flow in a metal at room temperature and when they flow in a superconductor below its critical temperature. **3**

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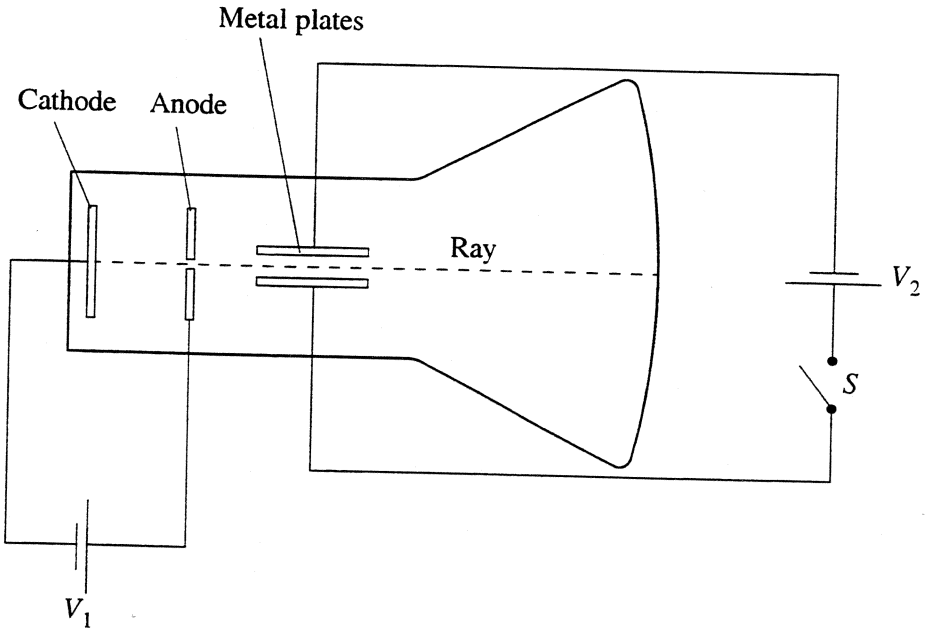
Question 30 (5 marks)

The following diagram shows the path of a cathode ray in an evacuated glass tube when switch S is open.



(a) Describe what will happen to the path of this ray if the switch S is now closed. **1**

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(b) If V_2 remains constant, and the voltage at V_1 is doubled, describe what will now happen to the beam. **1**

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Marks

Question 30 (continued)

(c) Thomson's famous experiment used a cathode ray tube like the one above, but it had one important addition. State what it was. **1**

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(d) Explain how Thomson's experiment led to an important breakthrough in science. **2**

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Section II

Total 25 Marks
Attempt ONE question from Questions 31–35.
Allow about 45 minutes for this section.
Answer the question in a writing booklet. Extra writing booklets are available.

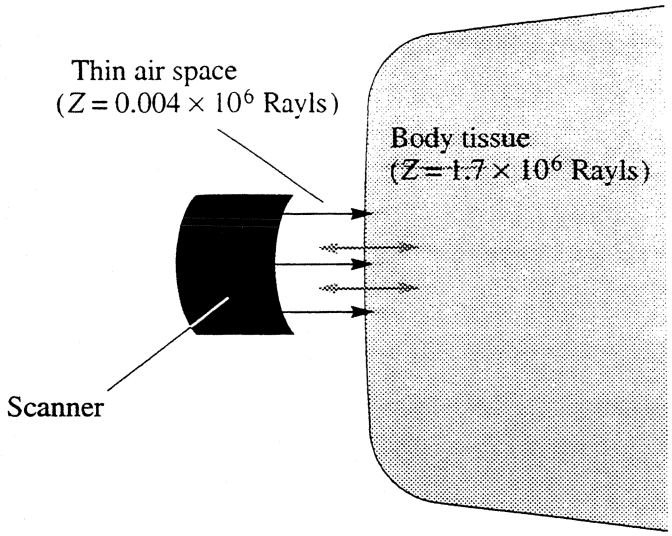
Marks

Question 32 — Medical Physics (25 marks)

(a) Ultrasound imaging depends on variations of the acoustic impedance of different body tissues.

(i) Define the term 'acoustic impedance'. **1**

(ii) Determine the percentage of the incident intensity of an ultrasound wave which is reflected by body tissue, as shown below. **2**



(iii) Explain why the ultrasound waves reflected in (ii) above are a problem and outline how the intensity of these reflected waves are significantly reduced in clinical use. **3**

(iv) Summarise the procedure used to obtain a sector scan and explain how the 2-dimensional image is formed. **2**

(b) (i) Describe the production of X-rays in a modern X-ray tube. **2**

(ii) Compare the processes employed in computerised axial tomography (CAT or CT scans) with the production of a radiograph. **2**

(iii) Outline the advantages associated with the use of computerised axial tomography in comparison with conventional X-ray radiography. **1**

(c) PET (positron emission tomography) and MRI (magnetic resonance imaging) are two of the latest, most sophisticated methods of diagnostic imaging. Compare and contrast these methods in terms of image formation. **6**

(d) Advances in technology, developed from our understanding of the electromagnetic spectrum, have enabled the development of sophisticated tools, which analyse and interpret body structures and functions through diagnostic imaging. **6**

Assess the impact of the development of modern methods of diagnostic imaging on society.

Question 34 — From Quanta to Quarks (25 marks) **Marks**

(a) When hydrogen gas is placed into an excited state, it emits light at a number of specific wavelengths. Hydrogen's spectrum can be examined to show that in the visible region it includes a number of lines that come closer together at shorter wavelengths.

(i) Using the equation **2**

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

calculate the wavelength of visible light emitted for hydrogen gas when $n_i = 3$.

(ii) What energy would be associated with each photon emitted at this wavelength? **2**

(b) In an attempt to explain his model of the atom, Neils Bohr abandoned some of the ideas of classical physics. In doing so, he was able to clearly explain the emission and absorption spectra of hydrogen, but his model of the atom still had several inadequacies.

(i) How did Neils Bohr relate the concept of emission spectra to the development of atomic theory? **2**

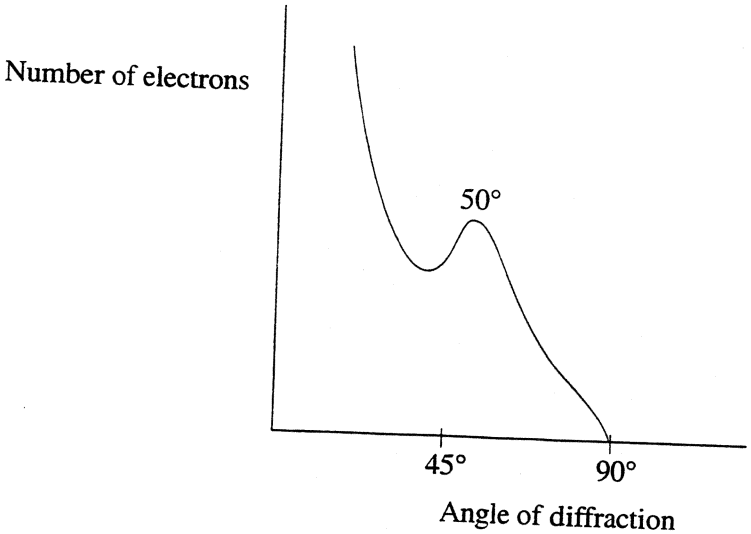
(ii) Explain one of the inadequacies of the Bohr model of the atom. **1**

(c) Louis de Broglie proposed that any moving particle could be associated with certain wave properties.

(i) Calculate the wavelength of an electron travelling with a speed of 1.4×10^6 m s^{-1}. **2**

(ii) Davisson and Germer were able to support de Broglie by demonstrating experimentally that streams of electrons are diffracted when they are scattered from crystals. **4**

In one of their experiments involving electrons of the specific energy of 8.6×10^{-18} J they obtained a graph shown below.



Discuss the significance of the peak at 50°.

Marks

Question 34 (Continued)

(d) The electron microscope is an important application of the wave characteristics of electrons. The resolving power of an electron microscope is related directly to the wavelength of the electrons.

(i) Contrast the resolving power of an electron microscope with that of a light microscope. 2

(ii) Explain, using diagrams, how a magnetic lens operates to focus a beam of electrons. 2

(e) A student tested three radioactive sources labelled A, B and C and recorded his results in a table.

Sample	*Effect when placed in perpendicular electric field*	*Observation of tracks in a cloud chamber*	*Effect of shielding detected by a Geiger counter*
A	Deflected towards positive plate	Possible evidence of thin tracks	Counts stopped by 5 mm of aluminium
B	Undeflected	No tracks visible	Counts reduced to about 50% by 100 mm of lead
C	Deflected away from positive plate	Thick straight tracks clearly seen	Counts stopped by 0.5 mm of paper

The three samples are known to be α, β and γ sources.

(i) Identify the samples A and C. 1

(ii) Explain how you were able to identify sample A. 2

(f) Consider the following reaction when nitrogen-14 is bombarded by an α (^4_2He) particle.

$$^{14}_{7}\text{N} + ^{4}_{2}\text{He} \rightarrow ^{17}_{8}\text{O} + ^{1}_{1}\text{H}$$

Atomic rest masses: $m(^1_1\text{H}) = 1.007825\ \mu$

$m(^4_2\text{He}) = 4.002603\ \mu$

$m(^{14}_7\text{N}) = 14.003074\ \mu$

$m(^{17}_8\text{O}) = 16.999131\ \mu$

Calculate the difference in binding energy between the reactants and the products. 3

(g) According to the quark model proposed by Gell-Mann and Zweig, hadrons (such as protons and neutrons) are made from a combination of fundamental particles called quarks.

Describe how the quark model differentiates between a proton and a neutron by their combination of different quarks. 2

Formulae

$$c = f\lambda$$

$$\text{Intensity} \propto \frac{1}{d^2}$$

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

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

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

$$P = VI$$

$$\text{Energy} = VIt$$

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

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

$$\sum F = ma$$

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

$$p = mv$$

$$\Delta p = Ft$$

$$F = \frac{Gm_1m_2}{r^2}$$

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

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

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

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

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

$$F = BIl\sin\theta$$

$$\frac{F}{l} = k\frac{I_1I_2}{d}$$

$$\tau = Fd$$

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

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

$$E_p = \frac{Gm_1m_2}{r}$$

Formulae

$$v = u + at$$

$$v_x^2 = u_x^2$$

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

$$\Delta x = u_x t$$

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

$$\frac{s}{t} = \frac{u+v}{2}$$

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

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

$$F = qvB\sin\theta$$

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

$$E = hf$$

$$Z = \rho v$$

$$\frac{I_r}{I_o} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$$

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

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

$$\text{Amplifier gain} = \frac{V_{out}}{V_{in}}$$

$$A_o = \frac{V_o}{V_+ - V_-}$$

Numerical values of several constants

Charge on the 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 (in vacuo), c	3.00×10^8 m s^{-1}
Magnetic force constant, $\left(k \equiv \frac{\mu_0}{2\pi}\right)$	2×10^{-7} N A^{-2}
Universal gravitation constant, G	6.67×10^{-11} N m^2 kg^{-2}
Mass of Earth	6.0×10^{24} kg
Planck's constant, h	6.626×10^{-34} J s
Rydberg's constant, R_H	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}

PERIODIC TABLE

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 Phosphorous	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** 65.39 Zinc	31 **Ga** 69.72 Gallium	32 **Ge** 72.61 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** [98.91] 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 Lanthanides	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** [210.0] Polonium	85 **At** [210.0] Astatine	86 **Rn** [222.0] Radon
87 **Fr** [223.0] Francium	88 **Ra** [226.0] Radium	89–103 Actinides	104 **Rf** [261.1] Rutherfordium	105 **Db** [262.1] Dubnium	106 **Sg** [263.1] Seaborgium	107 **Bh** [264.1] Bohrium	108 **Hs** [265.1] Hassium	109 **Mt** [268] Meitnerium	110 **Uun** — Ununnilium	111 **Uuu** — Unununium	112 **Uub** — Ununbium	113	114 **Uuq** – Ununquadium	115	116 **Uuh** – Ununhexium	117	118 **Uuo** – Ununoctium

KEY

Atomic number
Atomic mass
79 **Au** 197.0 Gold
Symbol of element
Name of element

57 **La** 138.9 Lanthanum	58 **Ce** 140.1 Cerium	59 **Pr** 140.9 Praseodymium	60 **Nd** 144.2 Neodymium	61 **Pm** [146.9] 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
89 **Ac** [227.0] Actinium	90 **Th** 232.0 Thorium	91 **Pa** 231.0 Protactinium	92 **U** 238.0 Uranium	93 **Np** [237.0] Neptunium	94 **Pu** [239.1] Plutonium	95 **Am** [241.1] Americium	96 **Cm** [244.1] Curium	97 **Bk** [249.1] Berkelium	98 **Cf** [252.1] Californium	99 **Es** [252.1] Einsteinium	100 **Fm** [257.1] Fermium	101 **Md** [258.1] Mendelevium	102 **No** [259.1] Nobelium	103 **Lr** [262.1] Lawrencium

Where the atomic wieghts are not known, the relative atomic mass of the most common radioactive isotope is shown in brackets.
The atomic weights of Np and Tc are given for the isotopes ^{237}Np and ^{99}Tc.

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Physics

Solutions and suggested marking scheme

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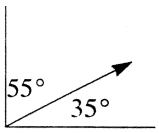
Section I

Part A

Answer and explanation	Outcomes assessed
Question 1 C Communication in space does rely on electromagnetic radiation in the form of radio or microwave transmissions. Sunspot activity can affect communication. However deep space telecommunications utilise high radio frequencies to avoid communication problems. Therefore option C is the incorrect statement.	H4 H9
Question 2 C The distance, r, from the centre of mass to the satellite must be calculated as $r = \left(\frac{Gm}{g}\right)^{-1/2}$ $= \left(\frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{0.233}\right)^{-1/2}$ $= 4.13 \times 10^{7}$ m Altitude = distance (r) – radius $= 4.13 \times 10^{7} - 6.38 \times 10^{6}$ $= 3.5 \times 10^{7}$ m $= 3.5 \times 10^{4}$ km	H6 H14
Question 3 A The centripetal force acting is given by the expression $F = \frac{mv^2}{r}$, i.e. $F \propto \frac{1}{r}$ As r changes to $2r$, the force on Moon B is only half as large as the force on Moon A.	H2 H6
Question 4 C Note angle from horizontal is 35° Initial vertical velocity is $120\sin 35° = 98.3\text{m s}^{-1}$ Horizontal velocity is $120\cos 35°$ (This does not change, as there is no acceleration in the horizontal direction)  After 3.00 s, the vertical velocity $= 120\sin 35° - (9.8 \times 3)$ $= 39.4\text{m s}^{-1}$ Speed is combined components value: $= \sqrt{98.3^2 + 39.4^2}$ $= 106\text{ m s}^{-1}$	H2 H9 H14
Question 5 B When a current flows in the coil it has its own magnetic field. The coil's magnetic field and the external magnetic field will interact. The coil's magnetic field as given by the right hand grasp rule is out of the inside the loop and into the page outside of the loop. The stronger magnetic field outside of the loop causes the loop to contract.	H9

Part A (Continued)

Answer and explanation	Outcomes assessed
Question 6 B The beam is deflected down from the central position to position X due to the solenoid's magnetic field. Hence to achieve position Y which is further from the central position and on the opposite side from X, the magnitude of the current must increase and the direction of the current must reverse.	H9
Question 7 D A current-carrying conductor has a magnetic field around it. The direction of the magnetic field is given by the right hand grip rule. When the current flows to the right, the magnetic field is out of the page above the conductor and into the page below the conductor.	H7
Question 8 C The relative motion between a conductor (the wings) and a magnetic field (here the Earth's magnetic field) creates the emf (by Faraday's law).	H7
Question 9 A $\frac{V_p}{V_s} = \frac{n_p}{n_s}$ where $V_p = 240$ V, $I_s = 2.4$ A, $n_p = 7000$ turns and $n_s = 350$ V $\therefore V_s = \frac{V_p \times n_s}{n_p}$ $= \frac{240 \times 350}{7000}$ $= 12$ V $V_p I_p = V_s I_s$ and $I_s = 2.4$ A $\therefore I_p = \frac{V_s I_s}{V_p}$ $= \frac{2.4 \times 12}{240}$ $= 0.12$ A	H9 H14
Question 10 C As the drill slows down, the back emf will reduce, since the rate of emf is proportional to the rate of change of flux. As the back emf is reduced, the current flowing through the drill must therefore increase.	H7 H9
Question 11 B $F = qvB\sin\theta$ $= 1.6 \times 10^{-19} \times 3 \times 10^6 \times 0.25 \sin 30°$ $= 6.0 \times 10^{-14}$ N	H9
Question 12 D Cathode rays led to discovery of charge to mass ratio of electrons, which led to the discovery of electrons.	H9
Question 13 B Electrons collide with the copper ions and lose their kinetic energy.	H7

Part A (Continued)

Answer and explanation	Outcomes assessed
Question 14 B $E = hf$ $= \frac{hc}{\lambda}$ $= \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{530 \times 10^{-9}}$ $= 3.75 \times 10^{-19}$ J	H10
Question 15 A At the transition temperature the resistance drops to very close to zero.	H10

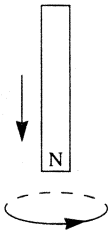
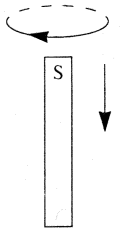
Part B

Sample answer	Outcomes and marking guide
Question 16	
(a) $v = u + at$ $\therefore a = \frac{v-u}{t}$ $= \frac{7.5-0}{4}$ $= 3.75 \text{ m s}^{-2}$	H6 H9 H14 • One mark for correctly writing and transposing the formula • One mark for correct magnitude of the acceleration 2
(b) $g = \frac{GM}{r^2}$ $\therefore M = \frac{gr^2}{G}$ $= \frac{3.75 \times (3.4 \times 10^6)^2}{6.67 \times 10^{-11}}$ $= 6.5 \times 10^{23} \text{kg}$	H6 H9 H14 • One mark for correctly writing and transposing the formula • One mark for correct substitution of values • One mark for correct mass. 3
Question 17	•
(a) $\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$ $\therefore r^3 = \frac{GMT^2}{4\pi^2}$ $r = \sqrt[3]{\frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times 5760^2}{4\pi^2}}$ $= \sqrt[3]{3.35 \times 10^{20}} = 6.95 \times 10^6 \text{ m}$	H7 H14 • One mark for correctly writing and transposing the formula • One mark for the correct radius 2
(b) A geosynchronous satellite can have signals bounced off it to different parts of the world, so Aussat can be used as a means of communication or as part of a regional weather tracking system. If the satellite is also geostationary, it can remain over the same point on the Earth's surface. Sputnik, because of its much faster orbital period, could not be used for communications nor to relay information.	H4 H13 • A discussion listing features of each type of orbits and clearly explaining their comparative usefulness . . . . . 2 • A response which mentions a feature of the each type of orbits 1

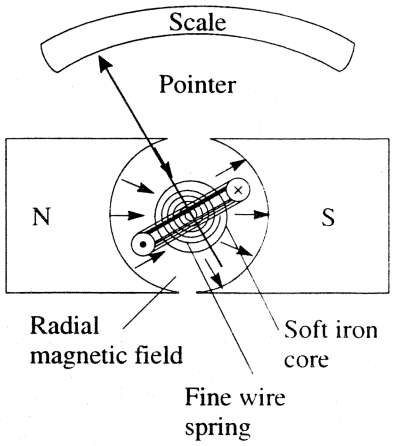
Part B (Continued)

	Sample answer	Outcomes and marking guide
Question 18		
(a)	Inertial frames of reference are those that are moving with constant velocity or at rest. In these frames Newton's law of inertia holds.	H6 H13 • A correct definition of the term 1
(b)	The special theory of relativity is based on the assumptions that the laws of physics are the same in all inertial frames of reference and that the speed of light is the same for all observers, regardless of their state of motion.	H1 H2 H13 • A correct account of two principles. . . . . 2 • A correct account of one principle. 1
(c)	If the speed of light is to be a constant then time and length must be relative concepts, i.e. time and length must change as velocity increases. Einstein explained that the factor by which time dilates and length contracts as a result of relative motion is given by the expression $\sqrt{1-\frac{v^2}{c^2}}$. He conducted thought experiments to help understand and explain his theory of special relativity and these consequences.	H2 H6 H13 • A clear statement of two apparent discrepancies and outline of Einstein's explanation of them . . . . . 3–4 • A statement of one apparent discrepancy and a basic account of time dilation or of Einstein's use of thought experiments . . . 2 • A response which states that time or length are relative and mentions time dilation . . 1
Question 19		
(a)	Man has not travelled widely in space because • distances in space are considerable to reach any significant destination. • costs of launch and to provide fuel and supplies are extremely large. • time factor too large to reach destination at presently attainable velocities.	H1 H4 H13 • One reason 1
(b)	When a spacecraft approaches a larger body such as a planet, its incoming speed (although accelerated, due to the planet's gravitational attraction and by Newton's third law the planet will experience a force slowing it down) and its outgoing speed are the same relative to the planet, but they are changed in direction. However relative to the Sun its speed will have increased since the spacecraft acquires angular momentum from the planet. At the same time the planet loses a similar amount of angular momentum (law of conservation of angular momentum). This increase in speed relative to the Sun is known as the sling-shot effect.	H6 H7 H9 H13 • A clear, correct explanation of the sling-shot effect . . . . . 3 • A mostly correct explanation of the sling-shot effect. . . . . 2 • A response which mentions changes in angular momentum 1
Question 20		
(a)	torque $= nBIA\cos\theta$, where θ is the angle between the direction of the magnetic flux density and the normal to the surface. Here, $\theta = 90°$ and so the torque is zero.	H9 H14 • One mark for realising the angle is 90° • One mark for the correct torque. 2
(b)	As the conductor rotates through the magnetic field, B, there is a change of magnetic flux threading the coil. By Faraday's law, an emf is induced which is proportional to the rate of change of the magnetic flux.	H7 H9 H13 • A clear explanation which refers to change in magnetic flux through the coil and gives a correct statement of Faraday's law . . . . . 2 • A response which refers to change of magnetic flux and mentions Faraday's law1

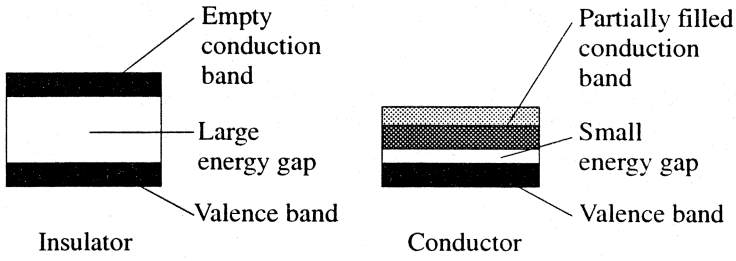
Part B (Continued)

Sample answer	Outcomes and marking guide
Question 21	
$F = \frac{kI_1I_2l}{d}$ $= \frac{2.0 \times 10^{7} \times 2.0 \times 4.0 \times 2}{0.01}$ $= 3.2 \times 10^{-4}$ N	H9 H14 • One mark for correctly writing and substituting into the formula • One mark for the correct magnitude of the force 2
Question 22	
(a) Above the magnet the current will flow from 2 to 1 and below the magnet the current will flow from 3 to 4.	H7 H14 • Correct statement of the direction of current flow above and below the magnet . . . . . 2 • Correct statement of the direction of current flow either above or below the magnet . . 1
(b) The relative motion between the falling magnet and the aluminium pipe conductor produces a change in magnetic flux. This changing magnetic flux induces an emf in the pipe. This in turn (according to Lenz's law) produces an opposing force acting against the motion of the falling magnet. Causes an anticlockwise current in the loop below magnet  Causes a clockwise current in the loop above magnet  	H9 H13 H14 • A correct explanation referring to induced emf caused by changing magnetic flux and which refers to Lenz's law . . . . . 2 • A response which refers to induced emf in the pipe. 1
Question 23	
$F = BIl\sin\theta$ Here $\theta = 90°$, so $F = 1.2 \times 4.0 \times 0.01 \times 1$ $= 0.048$ $= 4.8 \times 10^{-2}$ N	H7 H9 H14 • One mark for correctly writing and substituting into the formula • One mark for the correct magnitude of the force 2

Part B (Continued)

Sample answer	Outcomes and marking guide
Question 24	
(a) The galvanometer operates as a moving coil meter. When a current flows in the conducting coil, it creates its own magnetic field. This magnetic field interacts with the external magnetic field provided by the magnet. The forces involved create a torque which rotates the coil. A hairspring is provided to offer a restoring torque and to bring the coil to rest. This action can be calibrated to give a reading on a scale, such that the current is proportional to the angle of rotation ($I \propto \theta$).  	H7 H9 H13 • A detailed, correct explanation of the galvanometer with a correct labelled diagram ..... 3 • An explanation of the galvanometer and a mostly correct diagram ..... 2 • An explanation of the galvanometer OR • A mostly correct diagram 1
(b) The main differences are between the inputs and outputs of the two instruments. A galvanometer creates motion when supplied with electrical energy. It uses the motor effect (i.e. produces a force and hence a torque) when a current is supplied. A generator creates electricity when supplied with motion. It uses mechanical action i.e. forces to create an electric current.	H4 H13 • A correct statement of the differences between galvanometer and generator.... 2 • A response which correctly states some properties of either galvanometer or generator relevant to the comparison.... 1
Question 25	
AC is used in preference to DC for transmission because • AC power is easily generated in large quantities. • AC power is cheaper to generate than DC power. • AC power enables lower energy loss during transmission due to the alternating nature of the current. • ✓ AC power is easily transformed. • ✓ AC power is safer than DC power for humans. • ✓ AC power is suitable for devices such as clocks and motors that require precise timing. • AC voltage varies sinusoidally with time	H3 H4 H9 H13 • An outline which includes at least three relevant points ..... 3 • An outline including two relevant points. 2 • A response which includes one relevant point..... 1

Part B (Continued)

Sample answer	Outcomes and marking guide
Question 26	
(a) The metal emits electrons.	H10 • A correct answer 1
(b) The current will decrease. Electrons which are emitted will be repelled from the negative terminal.	H10 • A correct answer and explanation . . . . . 2 • A correct answer OR • A correct explanation. 1
(c) Probably no electrons will be emitted. It depends on the threshold frequency of the emitter metal.	H7 • A correct answer 1
(d) Light is made of photons. The higher the frequency, the higher the energy of each photon.	H10 • An explanation of the photon nature of light and the relationship between frequency (or wavelength) and photon energy. . . . . 2 • A response which mentions a relationship between frequency and energy. 1
Question 27	
(a) Insulators have a much greater energy gap than do conductors. This allows electrons to easily move in conductors but not in insulators.  	H10 • A correct comparison of the band structures including a diagram showing relative energy band and gap sizes of insulators and conductors. . . . . 2 • A response which mentions the greater energy gap of insulators OR • A response including a graphical depiction of the relative energy band or gap sizes of insulators and conductors. 1
(b) Semiconductors have led to the development of transistors, which in turn led to the development of powerful computers. The impact of computers is seen in many areas, including the increased wealth of countries that can develop computer systems and use them to control their financial and information systems.	H4 • A clear explanation of the impact of semiconductors on the world. . . . . 2 • A response which refers to some applications of semiconductors 1
Question 28	
(a) The Bragg spectrometer uses X rays.	H10 • A correct answer 1
(b) The spectrometer was used to study the structure of crystal lattices. Visible light is too large in wavelength to diffract around the spacing between the crystal planes. Much shorter wavelength radiation is required.	H2 • One mark for the identification of the use of the spectrometer • One mark for the explanation that visible light has too high a wavelength 2

Part B (Continued)

Sample answer	Outcomes and marking guide
Question 29	
In a metal, the electrons move in a zigzag path, colliding with the vibrating ions and rebounding but gradually drifting under the influence of the electric field towards the positive end of the wire. In the superconducting state, the BCS theory suggests that electrons in metals pair and pass by the ions which barely vibrate at all. As the first electron passes it distorts the lattice structure slightly causing the ions to move closer and then attract the second electron to follow the path of the first.	H10 • One mark for mentioning electrons moving through the lattice. • One mark for showing clear understanding of electron movement in ordinary conductor and some discussion of superconductor nuclei vibrating less. • One mark clearly outlining electron pairing process or similar. 3
Question 30	
(a) The ray will bend down the page towards the bottom of the tube.	H9 • A correct answer 1
(b) The beam will still bend towards the bottom of the page, but its curve will be less pronounced.	H9 • A correct answer 1
(c) Thomson used coils to act as electromagnets at the front and back of the tube.	H2 • A correct answer 1
(d) By balancing the electric and magnetic fields, Thomson was able to measure the charge to mass ratio for cathode rays. This led to the discovery that cathode rays were tiny particles which are now called electrons. The discovery of electrons was a significant discovery in science.	H3 • A clear explanation of the result of the experiment and its further implications . . 2 • A response which states that Thomson discovered electrons (or similar) 1

Section II

Question 31 Geophysics

		Sample answer	Outcomes and marking guide
(a)	(i)	B	H8 • A correct answer 1
	(ii)	In S waves, the particles move at right angles to the motion of travel of the energy. In liquids the particles are not bonded together in the same way as they are in solids. The atoms are free to slide past each other without much resistance. The sideways movement of one particle will not cause the next particle along to vibrate as well because they are not bonded together. In solids, the particles are bonded into place and the movement of one particle in a sideways direction will pull the neighbouring atoms causing them to move sideways too. This enables this kind of distortion to be carried along a solid but not a liquid.	H8 H14 • A clear explanation stating the transverse nature of S waves and explaining why they cannot travel through a liquid in terms of bonding of particles . . . . . 2 • A response which refers to the transverse nature of S waves 1
	(iii)	PP waves are P waves that have reflected from the surface of the Earth. They are significant because tracing the paths of PP rays helps to determine how the mantle's density varies with depth.	H8 H14 • A clear description of PP waves as reflecting from the Earth's surface and explanation of their significance . . . . . 2 • A response which mentions reflection from the Earth's surface 1
	(iv)	Looking at the seismograph, the P wave arrives at 10.02 p.m. S wave arrives at 10.09 p.m. This is a 7 minute difference. Using the next graph a 7 minute difference between arrival times of S and P appears at 4500 km.	H8 H11 H14 • An answer in the range 4200–4800 km with a correct explanation of the method used 2 • An answer in the range 4200–4800 km OR • A correct explanation of the method used 1
(b)		To find ore bodies, you can use measurements of gravitational field strengths on the surface, because a low density ore body will alter the field strength. However there are other factors that may alter the measurements and they need to be accounted for, because their effect may be greater than that of the ore body. This process is called gravity reduction. Three examples are • Reduction due to altitude: The height above sea level has an effect on gravitational field strength. • Reduction due to the topography: Nearby hills will decrease gravitational field strength. • Reduction due to the latitude: The Earth is flattened at the poles and so the distance to the centre and therefore the gravitational field strength depends on latitude.	H9 H12 • A clear response which refers to the measurement of gravitational field strength in finding ore bodies, and which explains what gravity reduction is, why it is needed, and gives three examples. . . . . 4–5 • A response which defines gravity reduction and gives at least one correct example. 2–3 • A response which includes a basic description of gravity reduction OR • A response which mentions gravitational field strength and gives at least one example 1

Question 31 Geophysics (Continued)

	Sample answer	Outcomes and marking guide
(c)	Satellites have enabled geophysicists to make significant advances in their understanding of the changes on the surface and in the atmosphere of the earth. Using satellites, laser beam reflection has enabled data relating to the position and movement of the Earth's crustal plates to be measured with great accuracy. This has greatly increased the understanding of plate movement and also could lead to better predictions of earthquakes. Satellites have enabled the large-scale collection of gravitational data which has led to better understanding of the structures beneath the Earth's surface. Satellites can now collect large amounts of data on the contents of the Earth's atmosphere on a daily basis and on a global scale. This will lead to better understanding of the Earth's atmosphere and the factors that are causing it to change. Satellites can measure the land use and vegetation on the surface of the Earth, which may lead to better understanding of how to prevent problems relating to poor land use management.	H1 H4 H9 H14 • A response which states a variety of significant uses and clearly explains their impacts. . . . . 4 • A response which includes two examples and with some linking of data collection to their impacts. . . . . 3 • A response which states some examples of the types of data collection from satellites . . . . . 2 • A response which mentions any example of the use of satellites that relates to geophysics 1
(d)	$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$ $\frac{7000000^3}{(15 \times 60 \times 60)^2} = \frac{6.67 \times 10^{-11} M}{4\pi^2}$ $M = 7 \times 10^{22}\text{kg}$	H9 • One mark for use of the formula • One mark for correct substitution of values • One mark for the correct mass. 3
(e)	Sample answer relating to nuclear test ban treaties: In the study of seismology, geophysicists have been able to determine the strength, depth and location of any earthquake activity. They have also been able to tell the difference between a natural earthquake and the detonation of a nuclear device. By measuring seismic activity constantly all over the globe, it is possible for geophysicists to supply their political leaders with unequivocal evidence when a country contravenes test ban regulations. The size of a device and its location are easily pinpointed. This is compared to the information that the particular country has given to the scientific community and political action can be taken if a contravention has occurred.	H4 H16 • A response which gives a clear description of examples of the role of the geophysicist in the chosen example . . . . . 3–4 • A response which states examples but does not clearly state a role . . . . . 2 • A response which gives at least one example
(f)	A study of the conductivity of the ground, using either conductivity or electromagnetic measurements, could lead to the location of the pipe. Ground penetrating radar could also be used. This uses the reflection of radio waves from an antennae to a receiver. For a single field, the pipe could be detected using a hand held GPR system.	H11 • Two correctly described geophysical investigations . . . . . 2 • One correctly described geophysical investigation. 1

Question 32 Medical Physics

		Sample answer	Outcomes and marking guide
(a)	(i)	Acoustic impedance is a measure of the resistance to the transmission of a wave by the medium through which it is being transmitted.	H8 • A correct definition 1
	(ii)	$\frac{I_r}{I_o} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$ $I_r = 100 \times \frac{(1.7 \times 10^6 - 0.004 \times 10^6)^2}{(1.7 \times 10^6 + 0.004 \times 10^6)^2}$ $= 99\%$	H8 • One mark for correctly writing and substituting into the formula • One mark for correct value of I_r 2
	(iii)	If 99% of the incident ultrasound waves are reflected before entering the tissue, then only 1% can be used to generate an image. This is insufficient. A coupling gel is applied to the region of the body to be scanned. This produces an air free contact between the transducer and the skin. The acoustic impedance of the coupling gel is matched to the acoustic impedance of the skin. This reduces the intensity of the reflected waves to nearly zero.	H8 H10 H13 • A response which clearly describes the nature of the problem and clearly explains the use of coupling gel and its acoustic impedance properties . . . . . 3 • A response which describes the nature of the problem and mentions the use of coupling gel. . . . . 2 • A response which gives a basic description of the problem OR • A response which mentions the use of coupling gel. 1
	(iv)	The ultrasound beam is directed through a range of small angles. This can be done by • Tilting/rocking the transducer head (old technology) • The beam is mechanically adjusted to exit the transducer through the predetermined angle range • The scan head consists of an array of very small transducer elements. The phase between each element is delayed to produce a sweep. This is called a phased array. The reflected pulses are stored point by point and then integrated to form a 2D image by an oscilloscope or computer.	H8 H13 • A response which clearly describes a method of obtaining a range of beam angles and refers to the use of a computer or oscilloscope to integrate the data . . . . . 2 • A response which mentions that a range of ultrasound beam angles are obtained in order to generate an image OR • A response which mentions the use of a computer or oscilloscope in forming an image 1
(b)	(i)	A large potential difference is applied between the electrodes of an evacuated tube. The cathode (negative) is heated by passing an electric current through it. This results in electrons being emitted and accelerated by the potential difference towards the target anode (i.e. a beam). Most of the energy transferred to the target is dissipated as thermal (heat) energy, however, some of the energy causes the emission of X-rays. The X-rays are produced by the rearrangement of the electrons within the atoms of the target metal (characteristic peaks) and the deflection (causing deceleration) of electrons within the electric field of the target atoms (bremsstrahlung).	H9 H10 H13 • A response which correctly describes relevant physical features of the X-ray tube (large potential difference, evacuated tube, use of tungsten target anode) and describes the processes behind the emission of X-rays from the anode. . . . . 2 • A response which correctly describes relevant physical features of the X-ray tube OR • A response which gives some detail of how X-rays are produced at the target anode . . 1

Question 32 Medical Physics (Continued)

	Sample answer	Outcomes and marking guide
(ii)	A radiographic image is produced by passing an X-ray beam through a patient and onto a photographic plate. Differences in beam intensity due to attenuation by different body tissues, such as bone and lungs, result in variations in exposure, which forms a corresponding 2D image. A CAT scanner also uses X-rays, but it produces many thin X-ray beams, which pass through the patient and into a detector (one of an array) which records the intensity of the beam. Both X-ray tube and the detector array are mounted on a gantry, which rotates, recording intensities at regular angular intervals. The intensity data is converted into many 2D images by a computer, which represent 'slices' through the patient. The combination of these slices can be used to produce a 3D image.	H9 H10 H12 • A response which correctly relates relevant similar and different features of the two processes . . . . . 2 • A response which correctly refers to some relevant features of the two processes but which does not refer to similarities and differences 1
(iii)	The production of a 3D image and increased differentiation between body tissues due to a greater range of shades of grey result in an improved diagnostic capability of CAT/CT scans.	H10 H12 H14 • A response which correctly relates a relevant advantage 1
(c)	In PET, a positron-emitting radioisotope is produced in a cyclotron and introduced into the patient. The pair annihilation of each positron with an electron from the patient's tissues releases gamma rays in opposite directions. These gamma rays are detected by two crystal scintillation detectors and photomultiplier tubes mounted opposite one another on rotating gantries, and a low resolution image is produced. MRI makes use of the magnetic properties of hydrogen nuclei. A large cylindrical magnet, with saddle coils which produce horizontal and vertical field gradients, surrounds the patient. When subjected to radio frequency pulses in this strong magnetic field, the magnetic field of the hydrogen atoms in the patient's tissues realign. The time taken to realign (relaxation time) is measured by a RF detector. Hydrogen atoms which are bonded to different molecules show different realignment times, and so structures which have different characteristics (for example different water content) will result in different intensity areas on the relatively high resolution MRI scan which is produced. While MRI yields higher resolution scans, one advantage of PET is that it can give information on the activity and hence function of tissues, as well as the structure that is revealed by MRI.	H9 H10 H13 H14 • A response which gives an accurate description of the equipment required to obtain the scans, some detail of the physical processes employed (e.g. reference to coincidental gamma rays for PET and Larmor frequencies relaxation times) and a comparison of the usefulness of the imaging techniques in terms of image resolution versus organ functionality . . . . . 5–6 • A response which gives an accurate description of the equipment required to obtain the scans and a comparison of the resolution of the obtained images . . . . . 3–4 • A response which states that PET employs radioisotopes and MRI uses a strong magnetic field and radio frequency waves, and which gives a basic outline of how both are used to produce a computer image of internal organs, tissues and structures . . 1–2

Question 32 Medical Physics (Continued)

Sample answer	Outcomes and marking guide
(d) Points which may be included in the student's response: • The use of techniques such as conventional X-ray radiography, CAT, PET and MRI allows for diagnoses which might otherwise require exploratory surgery. • The use of diagnostic imaging, whether in individual cases or in widespread screening programs, allows for the earlier detection of cancers and other diseases, which may result in changes in demographics as mortality rates of some diseases falls. • Specific case data and statistical data obtained from the widespread use of diagnostic imaging techniques can be of use to epidemiologists and medical researchers as they study diseases. • As the use of expensive diagnostic imaging technologies becomes more widespread, the average cost of using a given technique might be expected to fall, but the overall cost of healthcare to individuals and to society could be expected to rise. • The increasing use of techniques that involve ionising EM and other forms of radiation is accompanied by the risk of increased radiation exposure to health workers and the wider community, and the need for greater safety measures.	H4 H9 H13 H14 H16 • A response which clearly evaluates the impact of diagnostic imaging on the practice of modern medicine, evaluates its effect on society and predicts the effect of the global expansion of these techniques . . . . . 5–6 • A response which discusses the benefits of several of the non-invasive diagnostic imaging techniques compared with surgical diagnostic techniques, and which relates a technique to the early correct diagnosis and successful treatment of a common disease, which has a major impact on society . . . . . 3–4 • A response which names at least one of the diagnostic imaging techniques employing the electromagnetic spectrum (X-rays, CAT scans, PET, MRI) and which includes a description of the types of the scans obtained (where correctly applicable to the named techniques above) 1–2

Question 33 Astrophysics

		Sample answer	Outcomes and marking guide
(a)	(i)	Adaptive optics is used to make adjustments for the changing of density of the Earth's atmosphere. These satellites will be above the Earth's atmosphere and so it is not necessary.	H10 • A clear statement of the purpose of adaptive optics and explanation of why adaptive optics is not necessary in this case . . . . . 2 • A statement of the purpose of adaptive optics OR • An explanation of why adaptive optics is not necessary 1
	(ii)	The four satellites are to be used as an interferometer. The spread of these satellites increases the effective size of the telescope, in terms of its resolution, to 3 kilometres.	H3 • A clear statement of how the principles of interferometry would result in very high resolution imaging. . . . . 2 • A response which mentions interferometry or which refers to the high resolution of the images that would be produced. 1
	(iii)	The resolution would decrease as the base line would be smaller and so the angle between the distant star and each telescope will be decreased.	H10 • A correct statement that resolution would decrease and a clear explanation . . . . . 2 • A correct statement that resolution would decrease. 1
	(iv)	Examples: • The **Hubble space telescope**'s five cameras and spectrometers for near infrared, visible and ultraviolet radiation have given astronomers high resolution images of the solar system's planets and other objects as well as useful image and spectrum data on stars, nebulae and faint galaxies. • **Hipparcos** has been used to generate a highly accurate database of the position and apparent motion of stars. • **Chandra** provides high resolution images of X-ray sources such as pulsars and black holes, allowing scientists greater understanding of these high energy phenomena.	H2 • A clear description of the contribution of a correctly named astronomical satellite . . . . . 2 • One correctly named astronomical satellite or a relevant contribution. 1
(b)	(i)	The apparent magnitude of stars is measured through two filters, a visual filter and a blue filter. The colour index for each star is found by subtracting its visual apparent magnitude from its blue magnitude (B – V).	H10 • A response which clearly explains the use of blue and visible light filters to measure apparent magnitude and which gives a statement of or formula for colour index . 3 • A response which mentions the use of blue and visible filters and gives the formula for colour index. . . . . 2 • A response which mentions the use of two filters and refers to apparent magnitude OR • which gives the formula for colour index . 1

Question 33 Astrophysics (Continued)

	Sample answer	Outcomes and marking guide
(ii)	X has a much hotter surface than Y. X is probably white or blue whereas Y is probably red in colour.	H7 • A statement of the difference in surface temperature or colour of X and Y 1
(iii)	$m = 12$, $M = 2$ (reading from graph). $M = m - 5\log\frac{d}{10}$ $2 = 12 - 5\log\frac{d}{10}$ $\therefore d = 1000$ pc	H10 • Correct use of formula for absolute magnitude and correct distance . . . . . 2 • Correctly writing and substituting into the formula for absolute magnitude OR • Correct value of the distance 1
(iv)	$m_1 + m_2 = \frac{4\pi^2 r^3}{GT^2}$, using the Earth–Sun system as a reference. $m_1 + m_2 = \frac{r^3}{T^2}$ $m_1 + m_2 = \frac{20^3}{50^2}$ $m_{total} = 3.2$ solar masses	H6 • One mark for correctly writing and substituting into the formula • One mark for the correct total mass 2
(v)	X will die first in a supernova explosion. It will leave the main sequence and become a red giant star. Then subsequent nuclear reactions in the star will increase the heat of its core and its rate of reactions. The final result will be the implosion then explosion of the star which will spread out in all directions. Y will take longer to die. Its death will be as a slowly cooling white dwarf star. It will become a red giant star, but it will not get so hot that nuclear reactions go beyond the fusion of helium. Ultimately it will run out of fuel and start to cool. Its outer layers will drift away from the star and the hot core will be exposed. This will gradually cool.	H7 • A clear discussion of at least two differences . . . . . 3 • A general discussion of two differences . . 2 • A response with some indication of the supernova and white dwarf ending 1

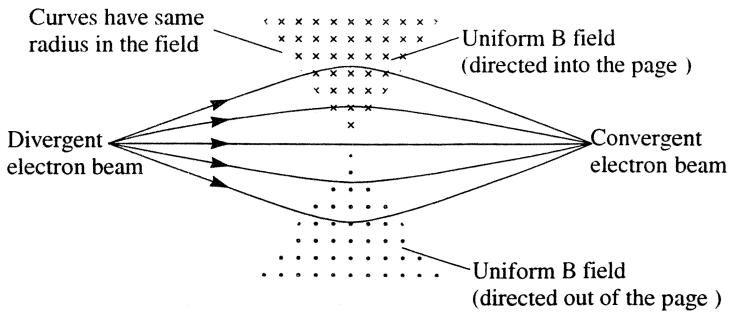
Question 33 Astrophysics (Continued)

	Sample answer	Outcomes and marking guide
(c)	Stellar spectra have an enormous impact on the understanding of stars. Stellar spectra enable astronomers to know: • The elements present in the outer layers of stars: Spectral lines for each element are unique. • The surface temperature of stars: Spectral lines are less common in hotter stars. • The velocity of stars: The shift in spectral lines indicates movement relative to the Earth, due to the Doppler effect. • The rate of spin of stars: Broader lines indicate that one side of the star is spinning towards us and the other spinning away from us. • The density of stars: Broader lines can indicate density as energy levels of atoms are not as precise if a collision is taking place when the electrons are absorbing photons. • The presence of binary stars: Periodic doubling of spectral lines indicates a binary star. • The distance to stars: The spectroscopic parallax method involves determining a star's absolute magnitude based on its spectrum, and hence finding the distance to the star. Finally, by classifying stars using the spectra it is possible to graph them on a Hertzsprung-Russell diagram. This has led to the present theory on the life cycle of stars.	H2 • At least five examples and clear discussion of how they have helped understanding of stars, with the impact clearly stated . . . . . 6 • At least five examples and some indication of how they have helped understanding . . 5 • Three or four examples and some indication of how they have helped understanding . . 4 • Two examples with good links to impact . 3 • Two or less examples poorly linked to impact . . . . . 2 • One example given 1

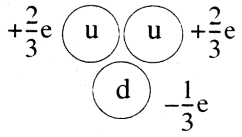
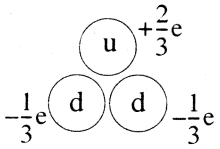
Question 34 From Quanta to Quarks

		Sample answer	Outcomes and marking guide
(a)	(i)	$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ $\frac{1}{\lambda} = 1.097 \times 10^7\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$ $\lambda = 6.56 \times 10^{-7}$ m	H2 H10 H14 • One mark for correctly writing and substituting into formula. • One mark for correct wavelength 2
	(ii)	$E = hf = \frac{hc}{\lambda}$ $= \frac{6.626 \times 10^{-34}}{6.5 \times 10^7}$ $= 1.01 \times 10^{-41}$ J	H7 H10 H14 • One mark for correctly writing and substituting into the formula. • One mark for correct energy 2
(b)	(i)	Bohr attempted to explain spectral data in terms of the internal structure of the atom. He applied his postulates to the hydrogen emission spectrum and the theories of Planck. He suggested that the energy associated with a particular line (the energy of a photon emitted) in the emission spectrum coincides with the energy difference between two of the stationary energy states.	H1 H2 H10 H13 • A response which clearly explains Bohr's postulation relating lines in the emission spectrum to differences between stationary energy states . . . . . 2 • A response which mentions Bohr's proposal of a connection between spectral observations and atomic structure OR • A response which mentions Bohr's proposal of stationary energy states 1
	(ii)	Possible answers • Bohr's model failed to explain the spectra of atoms with two or more electrons in the outermost shell. • It was ad hoc in that it contained a mixture of classical and quantum physics. • It could not explain the superfine lines in the hydrogen spectrum. • It could not predict the relative intensities of spectral lines. • It failed to explain the splitting of spectral lines when the sample was placed in a magnetic field (the Zeeman effect).	H2 H13 • A clearly stated inadequacy of the Bohr model 1
(c)	(i)	$\lambda = \frac{h}{mv}$ $\lambda = \frac{6.626 \times 10^{-34}}{9.109 \times 10^{-31} \times 1.4 \times 10^6}$ $= 5.2 \times 10^{-10}$ m	H1 H8 H14 • One mark for correctly writing and substituting into the formula • One mark for the correct wavelength 2

Question 34 From Quanta to Quarks (Continued)

		Sample answer	Outcomes and marking guide
	(ii)	The peak in the number of diffracted electrons at 50° is predicted by the theory of diffraction for waves. Rather than finding a more even distribution of electrons, as would be expected from a particle on particle collision, this peak is in agreement with de Broglie's formula for a wavelength of a moving electron. The electron wavelength in this experiment can be calculated to be 1.7×10^{-10} m for the specific energy of 8.6×10^{-18} J given. This is the same order of magnitude as the spacing of the atoms in the nickel crystal. The result is interpreted as support for the de Broglie hypothesis, that moving particles exhibit wavelike properties.	H2 H8 H13 • A response which explains the significance of the peak in terms of the different predictions of particle and wave models of electron behaviour, which refers to the de Broglie formula or states the wavelength of 1.7×10^{-10} m obtained from it, and which states the relevance of the similarity in size of the electron wavelength and the crystal spacing ..... 3–4 • A response which states that the peak is predicted by a wave model and states the calculated wavelength of these electrons or mentions a relationship between size properties of the crystal and electron wavelength ..... 2 • A response which states that the peak is predicted by a wave model OR • A response which mentions a connection between electron wavelength and size properties of the crystal 1
(d)	(i)	A light microscope has a resolution of approximately 0.2 μm. An electron microscope can resolve to about 0.2 nm. This is effectively 1000 times better than a light microscope.	H1 • A response which correctly states the approximate resolution of both types of microscope ..... 2 • A response which correctly states the approximate resolution difference in relative terms 1
	(ii)	Electromagnetic lenses have a solenoid with magnetic pole pieces that concentrate and determine the shape of the magnetic field. By passing the electron beam through such set of high-powered lenses the beam can be focused.  	H8 H10 H13 • A clear explanation and mostly correct, relevant diagram ..... 2 • A basic description of the principles of a magnetic lens OR • A mostly correct diagram 1
(e)	(i)	Sample A is a β source and sample C is an α source.	H11 • Correct answer 1

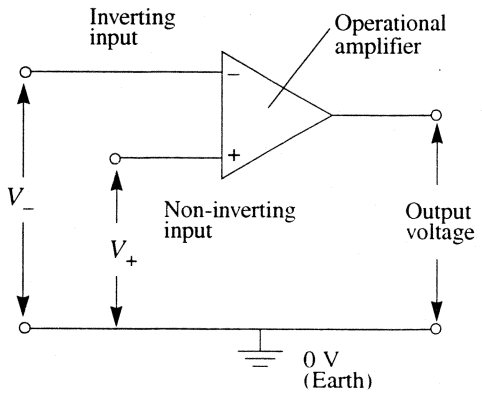
Question 34 From Quanta to Quarks (Continued)

	Sample answer	Outcomes and marking guide
	(ii) The radiation from sample A deflects towards the positive plate (therefore is negatively charged), leaves thin tracks in the cloud chamber (i.e. these cause some ionisation of atoms or molecules in their path) and is stopped by 5 mm of aluminium shielding. All these support the source being a β source, which is a high speed electron.	H9 H10 H13 • Two relevant points . . . . . 2 • One relevant point 1
(f)	Total Mass of reactants = 14.003074 + 4.002603 = 18.005677μ Total Mass of products = 16.999131 + 1.007825 = 18.006956μ Difference in total mass = 0.001279μ Binding energy of products – Binding energy of reactants = Difference in total mass × 931.5 = 0.001279 × 931 = 1.19 MeV	H7 H14 • One mark for correct calculations of reactants and products • One mark for correct use of formula relating mass difference to binding energy difference • One mark for correct answer. 3
(g)	A proton has two up quarks and one down quark. A neutron has two down quarks and one up quark.  Proton + e  Neutron 0	H1 H10 • A correct description of the quark composition of protons and neutrons . . . . 2 • A correct description of the quark composition of either protons or neutrons OR • A response which mentions that both particle types are composed of up and down quarks 1

Question 35 The Age of Silicon

		Sample answer	Outcomes and marking guide
(a)		A transistor is a single electronic device consisting of one type of semiconductor between two layers of the other type, which can amplify or act as a switch. An integrated circuit may have multiple transistors all sharing the same semiconductor crystal substrate.	H3 H4 H13 • A response which states two features relevant to the contrast . . . . . 2 • A response which mentions a relevant feature but does not clearly express the differences 1
(b)	(i)	The non-continuous form is digital. This is achieved by transmitting pulses, produced because a circuit's output voltage is either high or low.	H4 • One mark for correct identification of digital communications • One mark for a correct description of digital communications 2
	(ii)	Signals lose power as they travel over distance. Digital signals can be regenerated (i.e. amplified) and cleaned of noise. Analogue signals can be amplified but so too is the noise.	H7 • A response which states and describes a relevant advantage . . . . . 2 • A response which only states an advantage 1
(c)	(i)	A potential divider.	H3 • A correct answer 1
	(ii)	A potential divider reduces the output voltage by passing on a fraction of the potential voltage supplied to it. This is achieved by an arrangement of resistors in the input loop and a different arrangement for the output.	H4 • A clear description of the operation of the voltage divider . . . . . 2 • A basic description 1
	(iii)	Output potential $= \frac{R_{output}}{R_{input}} \times 9$ $= \frac{1000}{1000 + 1000} \times 9$ $= 4.5$ V	H4 H14 • One mark for correct use of the formula • One mark for the correct answer 2
(d)	(i)	Input transducers can generate a voltage where ideally the voltage is in proportion to the external change causing it, e.g. microphones and light sensors that operate like solar cells. They can alter the input voltage with varying resistance such as in LDRs and thermistors.	H3 H4 H13 • Two correct points . . . . . 2 • One correct point 1
	(ii)	Light dependent resistors (LDRs) have a high resistance in the dark and a low resistance in the light. Thus changes to the light situation they detect cause a change in the output voltage.	H3 H4 • A response which correctly explains how the resistance of LDRs varies with light level and how this affects voltage . . . . . 2 • A response which states that the resistance of LDRs varies with light level 1

Question 35 The Age of Silicon (Continued)

	Sample answer	**Outcomes and marking guide**
(e) (i)		H7 H13 • A correctly labelled diagram showing inverting and non-inverting input, output voltage and correct connections to the amplifier . . . . . 3 • A mostly correct labelled diagram . . . . . 2 • A diagram showing some correct symbols, connections and labelling 1
(ii)	An inverting input changes the nature of the output voltage with respect to the input. It causes a positive voltage to become a negative output. A non-inverting input does not change the output from the input.	H7 • A correct explanation of the difference. . . 2 • A response which correctly states a property relevant to the contrast 1
(iii)	Amplifier gain $= \frac{V_{out}}{V_{in}} = \frac{8}{2} = 4$	H14 • Correct answer 1
(f)	A relay is an electromagnetic switch. A small current activates an electromagnet. This closes or opens a switch which can control the flow of a larger current in a separate circuit (e.g. a circuit with a motor).	H3 H13 • A correct explanation of the function of a relay 1
(g)	<table><tr><td>*A*</td><td>*B*</td><td>*C*</td><td>*D*</td><td>*X*</td><td>*Y*</td><td>*Z*</td></tr><tr><td>0</td><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td></tr></table>	H13 H14 • All six truth values correct . . . . . 3 • Four to five truth values correct . . . . . 2 • Two to three truth values correct. 1