
Student Number

SCEGGS Darlinghurst

HSC Course
Trial Examination, 2003

PHYSICS

General Instructions

- Reading time - 5 minutes
- Working time – 3 hours
- Write using blue or black pen.
- Draw diagrams using pencil.
- Use Multiple Choice Answer Sheet provided.
- Board-approved calculators may be used.
- A data sheet, formulae sheets and Periodic Table are provided at the back of this paper.
- Write your Student Number at the top of the Multiple Choice Answer Sheet and pages 1 and 9.

Section I Pages 1 - 17

Total marks **(75)**

- This section has two parts, Part A and Part B

Part A

Marks **(15)**

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

Part B

Marks **(60)**

- Attempt Questions 16 – 26
- Allow about 1 hour and 45 minutes for this part.

Section II Page 18

Total marks (**25**)

- Attempt question 27
- Allow about 45 minutes for this section.

Section I
75 marks

Part A – 15 marks

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

Use the multiple-choice answer sheet.

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

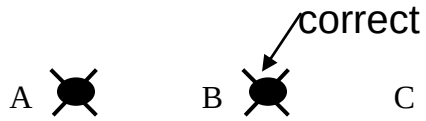
Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

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 the correct answer by writing the word correct and drawing an arrow as follows.



1. The following information, for the weight of the same stationary object at different locations on the surface of the Earth, was obtained using an accurate measuring device.

Position	Weight (N)
1	9.810
2	9.821
3	9.796
4	9.814

Which of the following could explain the variation in the measurements?

(A) The measurements were made at different altitudes.

(B) The measurements were made at different latitudes.

(C) The measuring device was faulty.

(D) Both (A) and (B) could explain the results.

2. A bullet is fired into the air and followed a flight path, represented by the diagram below,

If all effects due to air friction are negligible while the bullet is in flight, which of the following statements is true?

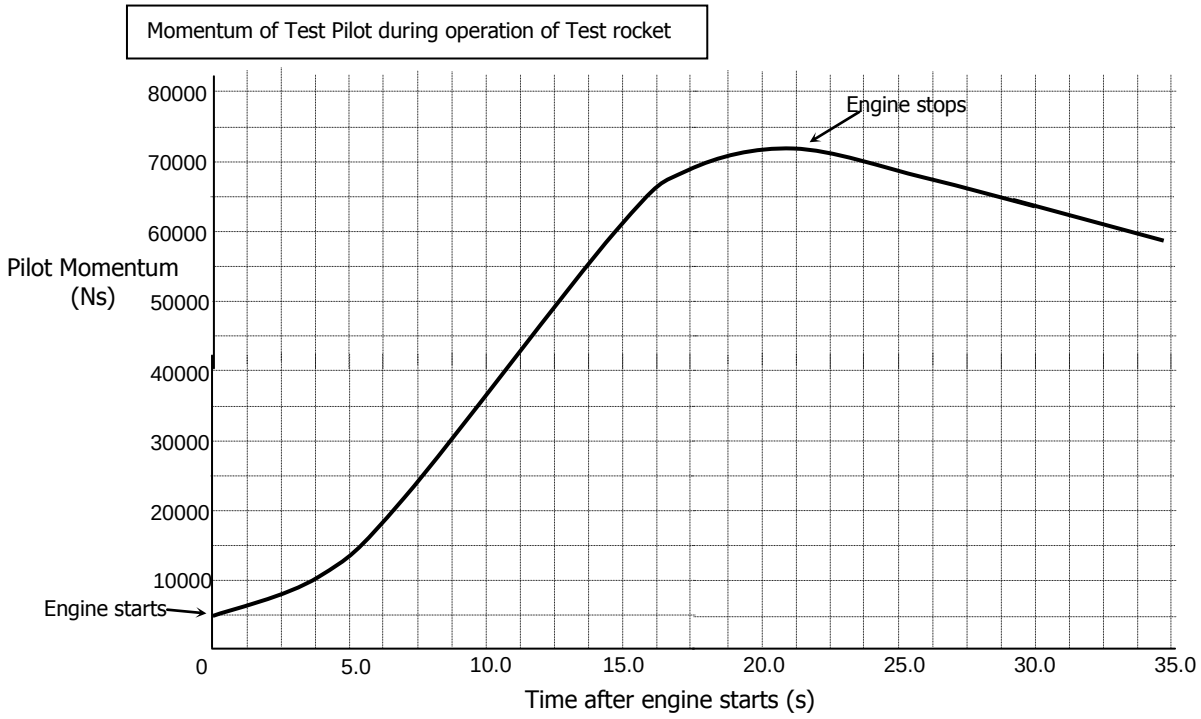
(A) The energy and acceleration of the bullet remain constant.

(B) The energy of the bullet varies while the acceleration remains constant.

(C) The energy of the bullet remains constant while the acceleration varies.

(D) Both the energy and acceleration of the bullet vary while in flight.

3. The following graph shows the way the momentum of a 100 kg test pilot changed during the trial of a new rocket engine.



Based on the evidence from the graph, which of the following statements is correct?

(A) The pilot experienced maximum g-force just before the engine stopped.

(B) The maximum acceleration produced by the rocket was close to 40 ms^{-2}.

(C) The pilot was travelling at 50 ms^{-1} when the rocket started, experiencing a maximum of about 3.6*g* before the engine stopped.

(D) The pilot reached a speed of about 720 ms^{-1}, experiencing a maximum of about 5g.

4. In the future, a spacecraft leaves Earth for a trip to examine a nearby star, a distance 9.0 light years from Earth. Before the launch, an atomic clock on the spacecraft is synchronised with a second atomic clock that remains on Earth. The spacecraft flies to the star, completes a single orbit, and then returns directly to Earth. The spacecraft has an average speed of 0.81c. for the trip. On returning to Earth, which of the following is most likely to correctly describe the observed results?

   (A) Both the clock on Earth and the clock on the spacecraft would record the same time for the trip.

   (B) The clock on Earth would record about 22.2 years have elapsed while the clock on the spacecraft will have registered a shorter time for the trip.

   (C) The clock on Earth would record about 11.1 years have elapsed while the clock on the spacecraft will have registered a shorter time for the trip.

   (D) The clock on Earth would record about 22.2 years have elapsed while the clock on the spacecraft will have registered a longer time for the trip.

5. In the launch of a particular satellite, the satellite was released from a rocket such that it moved into a stable orbit around the Earth. After the satellite had completed a number of orbits of Earth, each taking 90 minutes, rockets on board were used to propel the satellite into a much more distant stable orbit, with a radius 10 times larger than the original. Based on this information, which of the following would be closest to the orbital period of the satellite in the final more distant orbit?

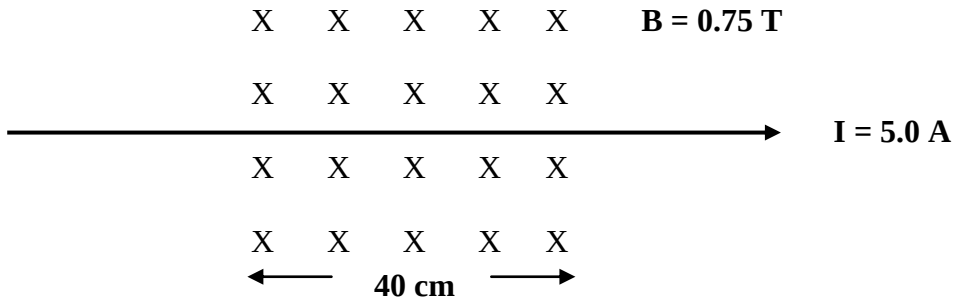
   (A) 47.4 hours

   (B) 38.7 hours

   (C) 22.5 hours

   (D) 15 hours

6. A conductor carries a current through a region of uniform magnetic field as shown below.



   Which of the following would be closest to the force acting on the wire?

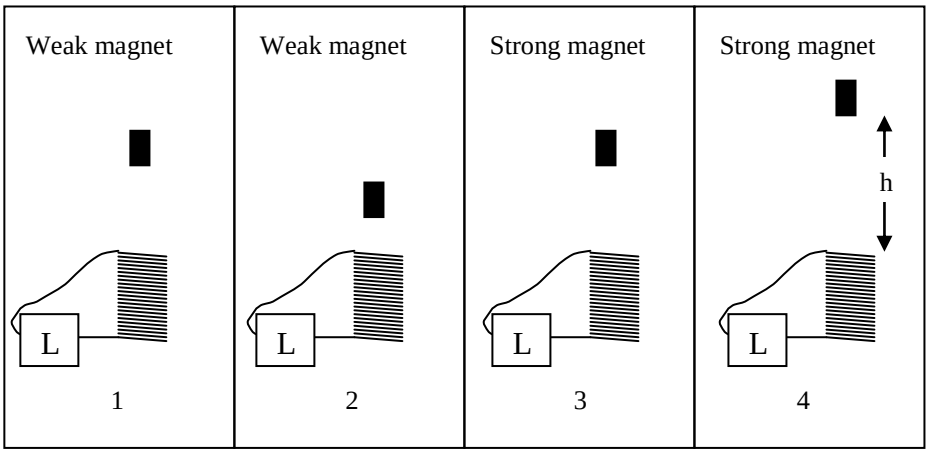
   (A) 150 N into the page

   (B) 150 N up the page

   (C) 1.5 N up the page

   (D) 1.5 N down the page

7. A student performed an experiment in which two magnets were dropped through a coil from different heights (h), shown in the diagram below. The coil was connected to a data-logger (L) that measured the potential difference across the coil each time a magnet was dropped through it.



Which of the following correctly ranks the experiments in order of *increasing* maximum potential difference that would have been recorded by the data-logger?

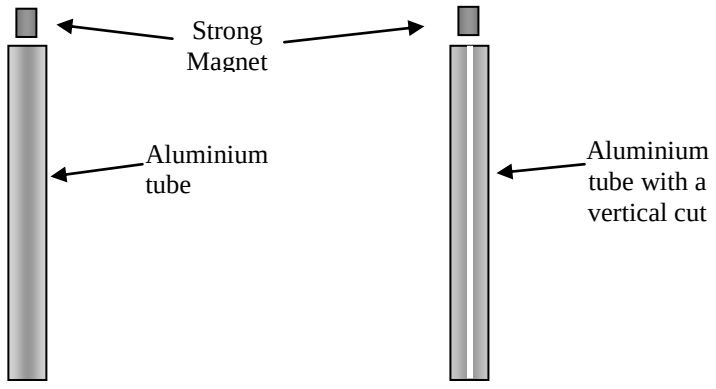
(A) 4, 3, 2, 1

(B) 4, 3, 1, 2

(C) 1, 3, 2, 4

(D) 2, 1, 3, 4

8. A student dropped a small but very strong magnet down through two aluminium tubes as shown below. One of the tubes had a vertical cut down one side.



After repeating the experiment several times, the student noted that the magnet seemed to float slowly down through the complete tube and fell much faster through the tube with the vertical cut.

Which of the following is a reasonable conclusion from these results?

(A) The magnet lost its magnetic field when it was inside the tube with the vertical cut.

(B) Larger magnetic forces produced inside the complete tube slowed the magnet's progress.

(C) There were no magnetic forces slowing the magnet's progress through the cut tube.

(D) Aluminium is a magnetic metal that is only attracted to strong magnets.

9. A transformer has 200 turns of wire on its primary coil and 1500 turns on its secondary coil. If 50 V AC was connected to the primary coil, and there were no energy losses, which of the following would be closest to the output voltage provided from the secondary coil?

   (A) 75 000 V

   (B) 6 000 V

   (C) 375 V

   (D) 6.7 V

10. Which of the following correctly describes the function of the split-ring commutator in a DC generator?

   (A) It ensures that the current to the external circuit always flows in the same direction.

   (B) It changes the current direction in the generator coils so that it is always flows through them in the same direction.

   (C) It changes the direct current produced by the rotating coil into alternating current for use in the external circuit.

   (D) It ensures that the torque on the generator coil is always in the same direction so that it continues rotating in the same direction.

11. After the discovery of cathode rays, study of the rays produced debate as to whether they were electromagnetic waves or streams of particles. The experiment that collected convincing evidence to resolve this debate was performed by which of the following scientists?

   (A) Heinrich Hertz

   (B) J.J. Thomson

   (C) William Crookes

   (D) Max Planck

12. Which of the following would best describe the material composing a p-type semiconductor?

   (A) extremely pure silicon with some of the silicon electrons removed leaving holes in the resulting crystal lattice

   (B) extremely pure silicon with a certain number of extra electrons added leaving some free electrons in the resulting crystal lattice

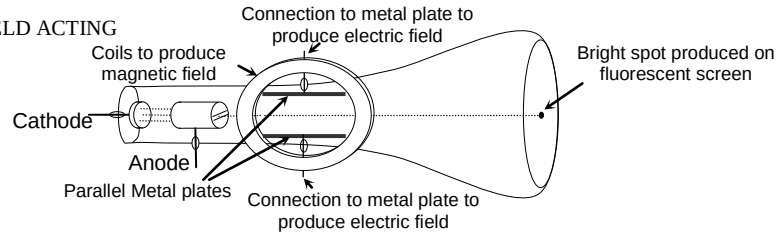
   (C) pure silicon that has small amounts of an element, that has one fewer valence electron than a silicon atom, added to result in a crystal lattice where some of the silicon atoms in the lattice have a space for another electron

   (D) pure silicon that has small amounts of an element, that has one more valence electron than a silicon atom, added to result in a crystal lattice with a number of extra electrons

13. During an experiment with cathode rays, a highly evacuated glass tube included a set of parallel metal plates inside the tube which could be attached to a source of potential difference, to allow an electric field to be set up inside the tube. The apparatus also included a set of coils that, when attached to a power supply and a current flows through them, produce a magnetic field in the same region where the parallel metal plates produce the electric field.

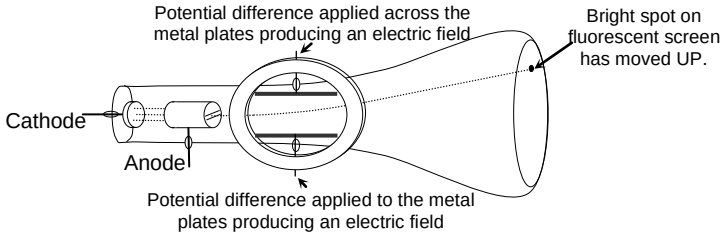
In Part 1 of the experiment, the magnetic and electric fields were NOT acting. The result produced is shown in the following diagram.

Part 1 Neither ELECTRIC or MAGNETIC FIELD ACTING



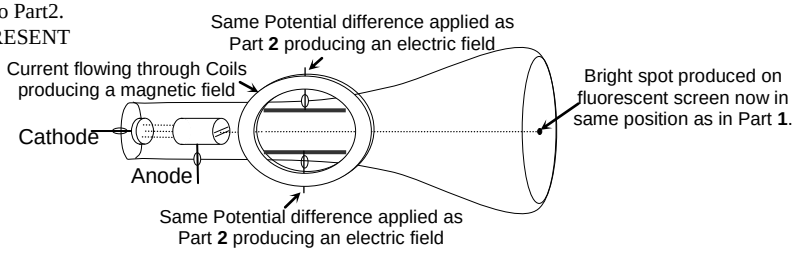
In the Part 2 of the experiment, an electric field was produced by applying a potential difference to the connections to the metal plates. The bright spot was observed to change its position on the fluorescent screen, as shown below.

Part 2 ONLY ELECTRIC FIELD ACTING



In the Part 3 of the experiment the electric field was left on, as in Part 2, but a DC current was now supplied to the coils to also produce a magnetic field. The strength of the magnetic field was adjusted, producing the result shown below.

Part 3 ELECTRIC FIELD ACTING identical to Part2.
BUT a MAGNETIC FIELD is ALSO PRESENT



Based on the results observed in the parts of the experiment, which of the following would correctly describe the direction of the magnetic field that was acting in Part 3?

(A) down the page

(B) into the page

(C) up the page

(D) out of the page

14. Which of the following changes is most likely to increase the resistance of particular wire?

(A) reducing the temperature of the wire

(B) increasing the diameter of the wire

(C) adding impurities to the metal that makes up the wire

(D) reducing the length of the wire

15. Which of the following would best describe the basic idea behind the BCS theory in its attempt to explain superconductivity?

(A) Electrons come together in pairs that are able to travel through the lattice of the superconductor with no interactions at all with the nuclei in the lattice.

(B) Electron pairs interact with each other to produce magnetic fields that allow the paired electrons to travel through the lattice of the superconductor with no resistance.

(C) Groups of electrons interact with the nuclei to allow the electrons to combine and move through the lattice of the superconductor with no resistance to their motion.

(D) The nuclei and the electrons interact to allow pairs of electrons to move through the crystal lattice of the superconductor with no resistance to their motion.

Student Number

Section I (continued)

Part B – 60 marks

Attempt Questions 16 – 26
Allow about 1 hour and 45 minutes for this part

Answer the questions in the spaces provided.

Show ALL relevant working in questions involving calculations.

Question 16 (5 marks) **Marks**

Three newly discovered planets all orbit a very distant star nicknamed "N-Chig".
The following data has been collected.

	Planet		
	A	**B**	**C**
diameter (km)	84 200	21 100	168 400
mass (kg)	2.99×10^{26}	2.87×10^{26}	3.71×10^{26}
orbital period	48 Earth days	284 Earth days	14 Earth years
rotational period (h)	200	46	20

(a) On which of the planets would you expect the gravitational acceleration at the surface to be the greatest? Justify your answer. **3**

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(b) Planet B is found to be orbiting a distance of 1.50×10^{11} m from the star N-Chig and to move with an orbital speed of $55.8\ kms^{-1}$. Calculate the gravitational force that N-Chig is exerting on planet B. **2**

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Question 17 (6 marks) **Marks**

A futuristic spacecraft arrives back to Earth having been on a successful mission into deep space testing a revolutionary propulsion system. The whole test spacecraft had ended up with a mass of only 2.54×10^6 kg after its construction on Earth. The spacecraft was propelled by a newly created anti-matter propulsion system that allows the engine to produce enormous thrust with only 50 kg of the fuel required for a 100 year mission. After leaving the Earth and entering space, the trial had involved propelling the spacecraft to its top speed of 0.92c, and then maintaining this speed while the spacecraft completed an enormous loop through deep space, to eventually return to Earth. A scientist on Earth notes, with the return of the spacecraft, it has been 2.0 years since the spacecraft had departed on the trial.

(a) An observer viewed the spacecraft from Earth with a powerful telescope, and watched it travelling at its top speed, just as the spacecraft reaches the point halfway through the mission. Explain any changes to the spacecraft that would have been observed. **2**

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(b) From the moment of launch, a sensor on board continually measured the mass of the spacecraft while it was on the mission. This information was automatically transmitted to Earth. What would have been observed by the scientist on Earth who was responsible for continually monitoring the data received on the mass from the spacecraft? Justify your answer. **2**

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(c) Outline the considerations for the spacecraft as it was approaching the Earth towards the end of its mission. **2**

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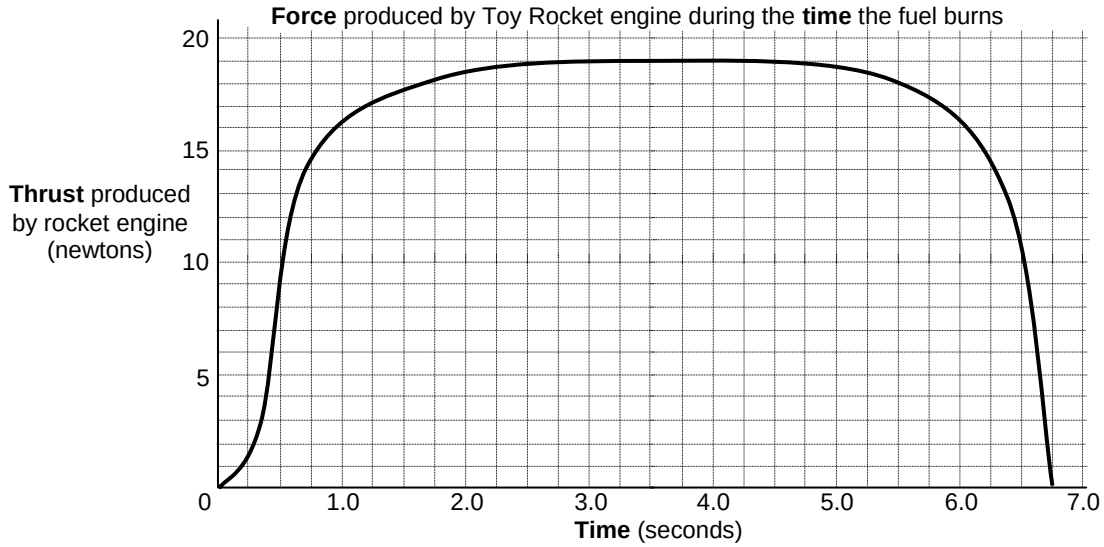
Question 18 (4 marks) **Marks**

The following graph shows the experimental results collected by a group of students where a toy rocket engine was tested using a force sensor and computer. A rocket engine was positioned in a mounting attached to the force sensor, the sensor triggered, and then the rocket engine fired. This allowed the thrust (force) produced by the rocket engine to be recorded over the time the fuel burnt.



As part of the experiment, an identical rocket engine was mounted in position in an actual rocket, resulting in the rocket to be launched having a total mass of 435 g. The rocket was carefully set up so that when the engine was ignited, the rocket was launched vertically up and, after reaching a maximum height, fell back to the ground landing in the spot where it had been launched. The students then compared the measured maximum height of the rocket with the value they had predicted based on their analysis of the graph.

(a) Describe how the students could use information from the graph to determine the expected maximum acceleration of the final toy rocket. **2**

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(b) Explain how the students might have used the information from the graph to predict the maximum speed their rocket would reach when launched. **2**

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Question 19 (5 marks) **Marks**

Discuss the aether, including reasons for its proposal and any significant contributions to resolve whether it existed. **5**

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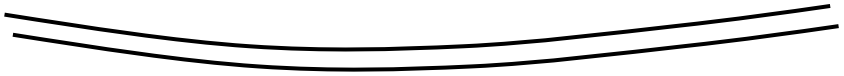
Question 20 (5 marks)

Two conductors 3.0 m in length were hung beside each other, as shown below. The conductors were parallel and separated by a distance of 50 mm. When a switch in a circuit with the conductors was closed and a current flowed, the conductors were observed to move towards each other.



(a) If the wires each carry a current of 5.0 A, calculate the magnitude of the force between the wires. **2**

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Question 20 (continued) **Marks**

(b) Explain why the wires moved towards each other when the switch was closed. **3**

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Question 21 (6 marks)

(a) Outline the difference between a step-up and a step-down transformer. **2**

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(b) In a transformer, the primary and secondary coils are not electrically connected to each other. Describe how the voltage is produced in the secondary coil. **2**

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(c) Describe ONE benefit for modern society arising from the development of transformers. **2**

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Question 22 (5 marks) **Marks**

You carried out a first-hand investigation to examine the principles involved in an AC induction motor. Explain how the principles of an AC induction motor were demonstrated in your investigation. You should include appropriate diagrams and relevant information on the procedure used. **5**

Question 23 (4 marks) **Marks**

Discuss the energy losses that occur in the transmission of electrical energy produced by a large generator at a power station to supply the electrical energy for use by consumers a distance away. **4**

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Question 24 (8 marks) **Marks**

A certain substance has a work function of 2.2 eV. It is lit with two separate beams of light, blue light of wavelength 450 nm and orange light of wavelength 650 nm.

(a) Explain the concept of a "threshold frequency" as it applies to the photoelectric effect. **2**

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(b) Calculate the frequency of a photon of orange light. **2**

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Question 24 (continued) **Marks**

(c) Which of the two colours of the beams of light is more likely to cause photoelectrons to be emitted from the surface of the substance? Justify your choice *without* making calculations. **4**

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Question 25 (5 marks)

Cathode ray tubes allow the manipulation of a stream of particles using electric and magnetic fields.

(a) Calculate the potential difference that would have to be applied to parallel conducting plates 4.0 mm apart to produce an electric field strength of 2.5×10^3 NC^{-1}. **2**

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(b) Calculate the magnitude of the magnetic field that would need to be applied to produce the same size force on an electron travelling at 1200 ms^{-1} as the electric field described in part (a). **2**

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(c) Identify the type of cathode ray tube used to demonstrate that cathode rays have momentum. **1**

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Question 26 (7 marks)

Compare the accepted models that are used to describe how an electric current flows in: **7**

- a metallic conductor at room temperature,
- a doped semiconductor at room temperature, and
- a superconductor below its critical temperature.

Section II
25 marks

Attempt Question 27 – Medical Physics
Allow about 45 minutes for this section

Answer the question on the writing paper provided. Write your student number at the top of each page and staple the bundle together when you have finished the option.

Show all relevant working in questions involving calculations.

Question 27 – Medical Physics (25 marks) **Marks**

(a) (i) Calculate the acoustic impedance of brain tissue using the values below. **1**

Tissue	Density (kgm^{-3})	Velocity of sound (ms^{-1})
blood	1025	1570
brain	1090	1541

(ii) Describe how ultrasound is used to measure bone density. **2**

(b) (i) Use a diagram to show how light is transferred through an optical fibre. **2**

(ii) Explain the need for coherent bundles of optical fibres in an endoscope. **2**

(c) (i) Which of the following technologies has been used to produce the image below?

- conventional X-ray
- CAT scan
- MRI
- PET

Justify your answer. **3**

(ii) Compare the advantages and disadvantages of CAT scans and MRI scans. **4**

(d) Describe how PET scans are produced. **4**

(e) Assess the impact on society and the environment of the use of radioactivity in medical diagnosis. **7**

END OF PAPER

Student Number

Multiple Choice Answer Sheet

PART A
Total Marks (15)
Allow about 30 minutes for this part

1.	A ⬭	B ⬭	C ⬭	D ⬭
2.	A ⬭	B ⬭	C ⬭	D ⬭
3.	A ⬭	B ⬭	C ⬭	D ⬭
4.	A ⬭	B ⬭	C ⬭	D ⬭
5.	A ⬭	B ⬭	C ⬭	D ⬭
6.	A ⬭	B ⬭	C ⬭	D ⬭
7.	A ⬭	B ⬭	C ⬭	D ⬭
8.	A ⬭	B ⬭	C ⬭	D ⬭
9.	A ⬭	B ⬭	C ⬭	D ⬭
10.	A ⬭	B ⬭	C ⬭	D ⬭
11.	A ⬭	B ⬭	C ⬭	D ⬭
12.	A ⬭	B ⬭	C ⬭	D ⬭
13.	A ⬭	B ⬭	C ⬭	D ⬭
14.	A ⬭	B ⬭	C ⬭	D ⬭
15.	A ⬭	B ⬭	C ⬭	D ⬭

TOTAL Part A =

SCEGGS Physics Trial 2003 – Marking Guidelines

Part A

1. D 2. A 3. D 4. B 5. A 6. C 7. D 8. B 9. C 10. A 11. B 12. C 13. B 14. C 15. D

Part B

16. (a)

identifies that the value of gravity varies directly with mass of the planet and inversely with the square of the radius AND shows that planet B has the greatest value by substitution into equation for g (or F_G) or logical argument.	3
identifies that the value of gravity varies directly with mass of the planet and inversely with the square of the radius AND correctly deduces the planet with the greatest value of gravity from incorrect substitution/calculation OR identifies that the value of gravity varies directly with mass of the planet and inversely with the square of the radius AND states that planet B has the greatest value but does not make calculations or give a valid argument to justify answer	2
states that planet B has the greatest value of gravity OR makes some attempt to deduce the planet with the greatest value of gravity using at least one appropriate equation or argument	1

Sample answer:
$F_G = Gm_1m_2/r_2 = mg \Rightarrow g = m/r_2 \Rightarrow$ value of gravity varies directly with mass and inversely with the square or radius. Planet B will have the greatest value of gravity. Planet C will be the lowest value because it has a very large radius even though its mass is slightly larger. Planet A will have a higher value than planet C because its radius is much smaller. Planet B will be higher than planet A because even though its mass is slightly lower, its radius is significantly lower. (It might be easier to substitute into the equation without making any conversions.)

16. (b)

calculates correct value of gravitational force in newtons	2
calculates a value of gravitation force using equation for centripetal force	1

Sample answer:
$F_G = F_C = mv^2/r$
$= 2.87 \times 10^{26} \times (55.8 \times 10^3)^2/1.50 \times 10^{11}$
$= 5.96 \times 10^{24}$ N towards N-Chig

17. (a)

relates length contraction in the direction of motion to the relativistic speed of the spacecraft	2
identifies at least one correct change such as length contraction, time dilation and/or mass dilation	1

Sample answer:
Since the speed of the spacecraft is approaching the speed of light, relativistic changes may be observed. Length in the direction of motion will appear contracted, clocks will appear to run slower and masses on the spacecraft will appear to increase.

17. (b)

response includes the following points: • the small amount of mass used to propel the spacecraft is negligible so the total mass remains more or less constant • there is no relative motion between spacecraft and sensor (no mass dilation)	2
refers to only one of the above points	1

Sample answer:
The scientist on Earth should have found that the value of mass received from the sensor did not change much as the mass that is lost as fuel is burnt is fairly negligible). The sensor is moving with the spacecraft and is thus measuring rest mass so the value of mass observed by the scientist should stay pretty much the same.

17. (c)

response makes reference to the following points: • need to decrease the speed (or KE) • re-entry angle into the atmosphere	2
reference is made to one of the above points	1

Sample answer:
The spacecraft must reduce its speed significantly. It also needs to achieve an appropriate re-entry angle so that it does not bounce off (if too shallow) or cause astronauts to experience extreme g-forces and spacecraft to be subjected to excessive heating (if too steep).

18. (a)

identifies that resultant of the highest value of thrust on the graph and the weight force must be divided by mass of the rocket to calculate maximum acceleration	2
indicates that maximum value of thrust is the highest value on the graph OR suggests that the value of maximum net force can be determined from the graph and that acceleration can be determined by dividing it by mass	1

Sample answer:
ΣF_{max} = maximum thrust (highest value on graph) – weight (mass x gravity)
$\Sigma F_{max} = ma_{max}$
$\therefore a_{max}$ = [maximum thrust (highest value on graph) – weight (mass x gravity)]/m

18. (b)

relates the area of the graph to change in momentum, change in momentum to change in speed (or maximum speed) and suggests how to account for gravity	2
recognises that the area of the graph allows maximum speed to be calculated	1

Sample answer:
The area under the graph of thrust versus time equals the change in momentum of the rocket but does not take gravity into account. The weight force can be accounted for by subtracting the product of it and time from the value of area to give the net change in momentum of the rocket. If the loss of mass is small, the change in speed equals the area divided by mass since $\Delta p = m\Delta v$. Since the rocket starts at rest, $\Delta v = v - 0 = v$ and the maximum speed can be calculated.

19.

reponse includes all of the following points: • the aether as the medium for light waves to propagate • important properties of the aether • aim of Michelson-Morley experiment • outline of method used in Michelson-Morley experiment • null results of Michelson-Morley experiment • Einstein's role in the suggestion that there was no need for an aether • clarity and coherence	5
response includes most of the above points	3-4
response includes some of the above points	1-2

Specimen answer:
The aether was a medium proposed by wave theorists to acts as a medium for the transmission of light waves through free space (vacuum). According to classical wave theory, a medium was required for the vibrations of wave energy to be transferred. The aether had to have remarkable properties, described as a massless, all pervading medium occupying all free space, while still allowing the planets to move through it with no friction. (Maxwell had incorporated an aether as part of his analysis of electromagnetic waves and with the verification of the existence of electromagnetic waves by Hertz.) Michelson and Morely began serious attempts to try and measure the so called "aether wind" that should be present because of the relative motion of the Earth through the aether. Their experiment, incorporating an extremely sensitive interferometer and light beams travelling at right angles to each other, was performed many times in many locations but produced a null result, i.e. it could not provide any evidence of the aether. The problem of the aether was finally resolved by Einstein when he proposed his Special Theory of Relativity, suggesting the constancy of the speed of light, no absolute motion and hence no need for an aether to allow light to travel through a vacuum.

20. (a)

correct substitution into relevant equation and correct value obtained in newtons	2
correct equation but one error either in substitution or conversion to SI units	1

Sample answer:

$F/l = kI_1I_2/d \Rightarrow F/3.0 = 2.0 \times 10^{-7} \times 5.0^2/50 \times 10^{-3}$

$\therefore F = 3.0 \times 10^{-4}$ N

20. (b)

Refers to the current direction and correctly describes how interaction of the magnetic fields around the wires determines the direction of the force on the wires and resultant movement.	3
Refers to the current direction and interaction of magnetic fields around the wires leading to the movement OR Refers to the current direction and direction of magnetic forces leading to the movement	2
Refers only to the current direction or forces as causing movement.	1

Sample answer:

The wires must have been in the same direction. Each current has an associated magnetic field – if the currents are down the page then the wire on the left will experience a magnetic field into the page whereas the wire on the right will experience a magnetic field out of the page using the right hand grip rule. The right hand palm rule can be used to give the direction of force, to the right for the wire on the left and to the left for the wire on the right. The direction of these forces causes the wires to move towards each other. (It is a good idea to use diagrams.)

21. (a)

Correctly describes difference in number of loops in primary and secondary coils AND the changes in voltage for both step-up and step-down transformer	2
Correctly describes changes in voltage for both step-up and step-down transformer OR Correctly describes the relative numbers of coils on both for the primary and secondary coils of a step-up and step-down transformer	1

Sample answer:

A step-up transformer has more coils on the secondary than the primary circuit and so the voltage gets increased whereas the step-up transformer has fewer coils on the secondary than the primary circuit and so the voltage gets decreased.

21. (b)

Response includes the following points: • AC supply to primary coil to produce changing magnetic field (or flux) • magnetic flux linkage of coils (soft iron core connecting coils) • change of magnetic flux experienced by secondary coil induces a voltage • voltage proportional to the number of turns	2
Response includes some of the above points	1

Sample answer:

An alternating current through the primary coil produces a magnetic field that is constantly changing in size and direction. The secondary coil experiences this change in magnetic field (and thus a change in flux) and so an emf (voltage) is induced in the secondary coil ($\varepsilon \alpha$ no. of coils). This effect is strengthened by the flux being linked by a soft iron core.

21. (c)

Relates a feature of transformers to a positive impact on society	2
Identifies a feature of transformers but inadequately addresses societal impact OR Provides a positive impact on society	1

Sample answer:

The development of transformers has allowed electricity to be transmitted much more efficiently (lower line loss). This means that less fossil fuel is burnt to produce the same amount of electricity in our homes.

22.

Response includes the following points: • description of metal disc + horseshoe magnet setup (first-hand investigation) • description of the main parts of an AC induction motor (squirrel cage (rotor) and electromagnets connected to 3 phase AC supply (stator)) • suitable diagrams to enhance the explanation of principles involved • magnetic field rotation in both cases $\Rightarrow \Delta\Phi$ (or ΔB) $\Rightarrow \varepsilon$ (Faraday's Law) • $\varepsilon \Rightarrow$ eddy currents in disc + horseshoe magnet setup • $\varepsilon \Rightarrow$ induced currents in the conducting bars and ring of squirrel cage • induced currents or eddy currents having direction to oppose $\Delta\Phi$ causing these currents (Lenz's Law) • magnetic force associated with induced currents (attraction) causes rotation in same direction as the magnetic field • clarity and coherence	4-5
describes an appropriate procedure to demonstrate the principles involved in an AC induction motor but does not explain the principles adequately OR explains the principles of an AC induction motor but the description of a first-hand investigation that demonstrates these principles is inadequate or incorrect	2-3
describes the parts of an AC induction motor	1

Specimen answer:
In an AC induction motor, a rotating magnetic field in the stator (produced by tri-phase AC supply to three electromagnets) induces currents in different parts of the rotor (squirrel cage consisting of metal rods connected at each end by a metal ring). The magnetic fields associated with the induced currents produce a force of attraction between the rotor and stator that causes the rotor to spin (ie. follow the rotating magnetic field of the stator). To demonstrate this, a horseshoe magnet was rotated near a metal disc mounted on an axle. The metal disc experienced a change in magnetic flux (due to the change in magnetic field) as the magnet was rotated. This change in magnetic flux caused an emf to be induced in the metal disc (Faraday's Law). Consequently, eddy currents were induced in the metal disc as the magnet was spun. The direction of the eddy currents in the metal disc is such that the magnetic field associated with the current produced a force of attraction to the spinning magnet (Lenz's Law). This caused the metal disc to spin in much the same way as the induced currents in the squirrel cage cause it to spin in an AC induction motor. (Answers should include diagrams of the metal disc + horseshoe magnet setup and the squirrel cage surrounded by electromagnets.)

23.

Refers to the following points: • use of transformers both at generator and at substations near our homes • heat (and sound) losses in transformers due to eddy currents in iron cores • lamination of iron cores as a way of reducing heat losses in transformers • concept of step-up transformers at generators and step-down ones near homes • stepping-up of voltage related to heat losses in transmission lines (line loss) • line loss due to resistance of transmission wires • line loss proportional to I^2	3-4
Refers to some of the above points	1-2

Specimen answer:
Energy is lost whenever voltage is transformed mainly in the form of heat (but some as sound) because no transformer is 100% efficient. Some energy is converted to heat in the core of a transformer as a result of eddy currents (joule heating). This can be reduced by laminating the core but cannot be completely overcome. There is also some conversion of electrical energy into heat in the actual wires used in the coils of the transformer. The advantages of transforming electrical energy outweigh the negatives. Voltage is stepped-up at the generator so that the current at which it is transmitted can be reduced to minimise the line loss (losses of energy in the form of heat in the transmission wires due to their resistance, R). Line loss = I^2R so decreasing I has a big impact on line loss. It is usually too expensive to significantly reduce resistance ($R = \rho L/A$) by much. The distances involved mean that length, L is large and copper is used because it has a low resistivity, ρ. It would cost too much to make the copper wires thicker to benefit from the decrease in resistance provided by a greater cross-sectional area, A. The high voltages need to be stepped back down for safety at substations nearer our homes and again there will be energy losses in this inefficient conversion.

24. (a)

identifies threshold frequency as the minimum frequency of light that will allow an electron to be emitted from the surface of a metal AND relates the frequency and energy of the photon of light to the work function	2
identifies threshold frequency as the minimum frequency of light that will allow an electron to be emitted from the surface of a metal OR relates the frequency and energy of the photon of light to the work function	1

Sample answer:
Threshold frequency is the minimum frequency of light required to cause an electron to be emitted from the surface of a metal. The energy of each photon of light depends on its frequency ($E \alpha f$) and this must be enough to overcome the work function of the metal and allow an electron to be emitted.

24. (b)

correct substitution into relevant equation and correct value obtained in Hz	2
correct equation but one error either in substitution or conversion to SI units	1

Sample answer:
$c = f\lambda \Rightarrow 3.00 \times 10^{8}\ ms^{-1} = f \times 650 \times 10^{-9}$
$\therefore f \approx 4.6 \times 10^{14}$ Hz

24. (c)

identifies blue light as more likely to cause photoemission and justifies answer by referring to the difference in wavelengths, frequencies and energies (using appropriate equations or reasoning) and relates energy required to work function	3-4
identifies blue light as more likely to cause photoemission but provides inadequate justification of the reasons for this choice OR correctly determines the colour of light that is more likely to cause photoemission on the basis of some incorrect reasoning	1-2

Sample answer:
$\lambda_b < \lambda_o$ (λ_b = 450 nm and λ_o = 650 nm is given in question)
$f_b > f_o$ ($f \alpha 1/\lambda$ since $c = f\lambda = 3.00 \times 10^{8}\ ms^{-1}$)
$E_b > E_o$ ($E \alpha f$ since $E = hf$))
$\therefore$ blue light more likely to be able to overcome the work function of the substance.

25. (a)

correct substitution into relevant equation and correct value obtained in volts	2
correct equation but one error either in substitution or conversion to SI units	1

Sample answer:
$E = V/d \Rightarrow 2.5 \times 10^{3} = V/4.0 \times 10^{-3}$
$\therefore V = 10$ V

25. (b)

equates magnetic force and electric force using correct formulae and makes correct substitutions to obtain correct value of magnetic field in teslas	2
obtains correct value of magnetic field but omits or uses incorrect unit OR equates magnetic force and electric force using correct formulae but obtains incorrect value of magnetic field	1

Sample answer:
$F_B = F_E \Rightarrow qvB = qE \Rightarrow vB = E$
$1200 \times B = 2.5 \times 10^{3}$
$\therefore B \approx 2.1$ T

25. (c)

identifies the cathode ray tube that has a paddle wheel that is free to move	1

Sample answer:
Momentum of cathode rays can be demonstrated by using a cathode ray tube that contains a paddle wheel.

26.

clearly and coherently describes the appropriate model used to explain the mechanism of charge transfer for each type of conductor AND provides similarities and differences between such aspects as the ability of charges to move, how they move, effect of temperature, resistance and related energy losses	7
describes the flow of charge through each type of conductor in some detail and makes a significant attempt to show how the models are similar and different	5-6
clearly describes at least one of the models for the three types of conductor and makes some effort to compare the way current flows in each the three types	3-4
gives correct similarity and/or difference between at least two types of conductor but provides inadequate detail about the mechanism of current flow in them OR describes one of the models for the three types of conductor in some detail	1-2

Sample answer:
Similarities: Each model explains the flow of current in terms of movement of charge through a lattice structure.
Differences: The models differ in the actual mechanism of current flow and so differ in terms of their resistance to charge movement and energy losses. There are also differences in the effect of temperature on their resistance.

In a metallic conductor at room temperature, the accepted model describes the structure as "a crystal lattice of positive ions surrounded by a cloud of electrons". The valence electrons are directly available to the conduction band and, when an electric field is applied across the metals, the valence electrons are easily mobilised into the conduction band and begin to move (producing the flow of electric current), becoming involved in collisions with the positive ions as they drift through the lattice. These interactions with the positive ions lead to the valence electrons losing kinetic energy, the conductor rising in temperature and resistance increasing.

In a doped semiconductor, small amounts of impurities added to pure silicon, give rise to, in the case of a p-type, a crystal lattice with some vacant positions (holes) remaining for some silicon atoms electrons, or in the case of a n-type, extra electrons that are not bound in the crystal lattice. When an electric field is applied to the doped semiconductor, in the case of the p-type, the presence of the holes allows a valence electron to take the place of the hole. In this way the holes drift as a positive flow from atom to atom through the crystal lattice. In the case of an n-type, the applied electric field can provide sufficient energy for the unbound electrons in the lattice to be raised into the conduction band. In this way the electrons can pass from atom to atom as a negative flow through the crystal lattice like a metallic conductor. As a consequence of the limited number of charges that are easily mobilised, doped semiconductors have a very high resistance compared to metallic conductors. Unlike metallic conductors, the resistance of doped semiconductors decreases with temperature because the extra energy promotes more electrons to the conduction band.

The model used to describe the way current flows in a superconductor below its critical temperature is the BCS theory. In this theory, quantum effects that occur below the critical temperature, allow the electrons that move in the current in the superconductor to behave very differently than conduction electrons in metallic conductors and semiconductors at room temperature. In this model, the electrons come together to form Cooper pairs, which are able to interact with the nuclei, such that they can travel through the crystal lattice of the superconductor with negligible resistance. In this way, the superconductor, unlike metallic conductors and semiconductors at room temperature, can carry large currents with no energy losses. This negligible resistance remains possible while the superconductor remains below its critical temperature, providing the size of the current does not become too large because the magnetic field created by too large a current can cause the superconductive property to be lost. If the temperature exceeds the critical temperature, Cooper pairs no longer form and resistance is no longer negligible.

Medical Physics

(a) (i)

correct value calculated	1

Sample answer:

$Z = \rho v = 1090 \times 1541 = 1.68 \times 10^{6}\ kgm^{-2}s^{-1}$

(a) (ii)

response includes the following points: • two transducers placed on either side of heel • several pulses are sent through the heel • broadband attenuation and speed of sound through the heel are detected • computer analyses information and compares it with normal bone density	2
response includes some of the above points	1

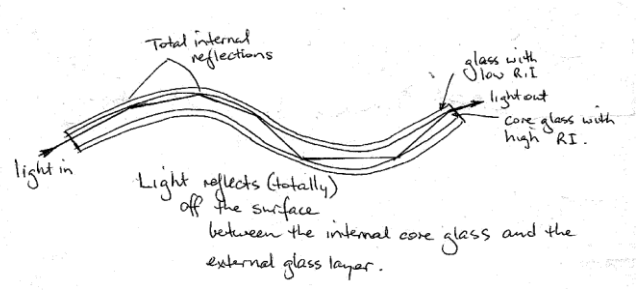
Sample answer:

Bone density tests using ultrasound are performed on the heel with shoes and socks removed. Several pulses of ultrasound are transmitted by a transducer on one side of the heel and received by another transducer on the opposite side. A computer is used to analyse the speed of sound through the heel and the broadband attenuation of the signals. This information is compared to information obtained from healthy bone samples.

(b) (i)

clear diagram of fibre with core (higher RI) and cladding (of lower RI), showing light travelling in straight lines within the core and being reflected from the internal core glass surface ($i \approx r$)	2
poor quality diagram (eg. only show single core glass, lines not ruled, angles of incidence not equal to angles of reflection and/or sloppily constructed)	1

Sample answer:



(b) (ii)

• clearly relates the relative position of the fibres to the formation of an image AND • identifies that this coherent bundle allows light to travel from inside the body OR • relates the formation of the image to the fragments captured by each fibre	2
provides one of the points above	1

Sample answer:

An endoscope is used to look inside a person's body. Light is carried inside the body along optical fibres. A second set of optical fibres carries light from inside the body to the eyepiece. Because each of these fibres carries only part of the image, the fibres need to be coherent (i.e. in the same relative position at both ends of the fibre) so that the image can be seen clearly. If the fibres were not coherent, the image would be jumbled.

(c) (i)

identifies image as MRI and explains why it cannot be each of the other modalities	3
identifies image as MRI and explains why it cannot be some of other modalities	2
explains that the image is MRI because of its high level of detail OR identifies image as a modality other than MRI using at least one suitable argument	1

Sample answer:

The image is an MRI of an ankle region. It clearly shows excellent detail of bones and soft tissue such as muscles, tendons and skin. X-rays cannot differentiate bone from tissue whereas CAT scans cannot differentiate between different types of tissue. PET scans show functional rather than such structural information about a region.

(c) (ii)

Comprehensive comparison of advantages and disadvantages with details	3-4
Lists advantages and disadvantages of each but makes no explicit comparison	1-2

Sample answer:

	CAT scans	MRI scans
Advantages	Both types provide better structural detail than other modalities ⇒ better diagnosis	
	Both types of scans provide structural information without invasive surgery.	
	CAT scan differentiate between bone/tissue	MRI differentiates between tissues
Disadvantages	Both types of scans are relatively expensive (compared with X-rays and ultrasound).	
	Both types of scans take more time than some of the other modalities.	
	Both types of scans involves patient in a gantry which can be claustrophobic	
	Neither type of scan provides functional information (excluding fMRI).	
	Both types of scans may need to involve injections to provide greater contrast	
	CAT scan less expensive than MRI scan	MRI more expensive than CAT scan
	CAT scan generally take a shorter time	MRI generally take a longer time
	CAT scan less claustrophobic and not noisy	MRI very claustrophobic and noisy
	CAT scans involves ionising radiation but are generally available in all hospitals and can be used for all types of patients	MRI has no known side effects but is not available to all hospitals nor all patients (eg. those with pacemaker)

(d)

clear description that includes details of radio pharmaceuticals, metabolism into target organs, positron emission by radioisotope, positron-electron annihilation , gamma rays at 180° to each other, gamma detectors, image produced by computer	3-4
correct reference is made to some of the details above	1-2

Sample answer:
Most patients are injected with a radiopharmaceutical that is selectively absorbed by a specific target organ. The radioisotope decays by positron emission. Each positron emission yields two gamma rays that are emitted at 180^o to each other when the positrons are annihilated by electrons in the tissues of the target organ. These gamma rays detected by gamma cameras in the gantry. A computer calculates where the gamma rays originated on the basis of arrival time differences and produces an image that shows the metabolic activity of the organ by brightness.

(e)

makes two judgments based on an excellent range of evidence provided and argued	7
makes two judgments based on a good range of evidence provided and/or argued	5-6
makes two judgments based on a limited range of evidence provided and argued OR makes a judgement based on an excellent range of evidence provided and/or argued	3-4
makes a judgment based on a limited range of evidence provided OR lists advantages and disadvantages on society/environment but makes no judgement	1-2

Sample answer:
The use of radioactivity in medical diagnosis has improved the ability of doctors to assess disorders in many organs of the body because of the functional information it provides. Advantages associated with methods such as PET and SPECT include being able to identify the location of and assess the nature of tumours without the need for invasive surgical techniques. Identifying regions of organs such as the brain that have suffered damage that was previously unidentifiable, can lead to more successful identification and treatment of illnesses such as Parkinson's disease, Alzheimer's and Schizophrenia. Methods such as these lead to better and earlier diagnosis and better treatment. In general this leads to a healthier society, less likely to need long term hospitalisation and more likely to live into later years beyond retirement. While this could place greater pressure on society in terms of providing social benefits to the increased number of elderly citizens through increased taxes etc., a society in which people can expect to have a longer and healthier life is a positive impact of the use of radioactivity. As far as the environment is concerned, the use of radioactivity for medical diagnosis has little impact. The isotopes used are generally produced at the hospital in a cyclotron or particle accelerator and produce no wastes. The isotopes manufactured and used have very short half lives to protect the patient and hence quickly decay to stable products. While most hospitals using isotopes have their own cyclotrons or accelerators, minor impact on the environment could occur if there were to be a spillage of substances during transport from a cyclotron to a hospital without its own machines. Radiopharmaceuticals produced by irradiation in a nuclear reactor are, however, a little different. There are considerable concerns about the long term environmental impact from the wastes produced in the nuclear reactors. For this reason, local cyclotrons are the preferred method of production. Overall, the impact of the use of radioactivity in medical diagnosis on society is positive, and on the environment the impact is neutral.