T-LEVELS | Institute for Apprenticeships & Technical Education

T Level Technical Qualification in Healthcare Science

Core knowledge and understanding

Paper B

Elements 11-12

Mark scheme

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NCFE CACHE

This Mark Scheme has been written by the Assessment Writer and refined, alongside the relevant questions, by a panel of subject experts through the external assessment writing process and at standardisation meetings.

The purpose of this Mark Scheme is to give you:

- examples and criteria of the types of response expected from a student
- information on how individual marks are to be awarded
- the allocated assessment objective(s) and total marks for each question.

Marking guidelines

General guidelines

You must apply the following marking guidelines to all marking undertaken throughout the marking period. This is to ensure fairness to all students, who must receive the same treatment. You must mark the first student in exactly the same way as you marked the last.

- The Mark Scheme must be referred to throughout the marking period and applied consistently. Do not change your approach to marking once you have been standardised.
- Reward students positively giving credit for what they have shown, rather than what they might have omitted.
- Utilise the whole mark range and always award full marks when the response merits them.
- Be prepared to award zero marks if the student's response has no creditworthy material.
- Do not credit irrelevant material that does not answer the question, no matter how impressive the response might be.
- The marks awarded for each response should be clearly and legibly recorded in the grid on the front of the question paper.
- If you are in any doubt about the application of the Mark Scheme, you must consult with your Team Leader or the Chief Examiner.

Guidelines for using extended response marking grids

Extended response mark grids have been designed to assess students' work holistically. They consist of levels-based descriptors and indicative content.

Levels-based descriptors. Each level is made up of several descriptors across the assessment objective (AO) range: AO1–AO3, which when combined provide the quality of response that a student needs to demonstrate. Each levels-based descriptor is worth varying marks.

The grids are broken down into levels, with each level having an associated descriptor indicating the performance at that level. You should determine the level before determining the mark.

Indicative content reflects content-related points that a student may make but is not an exhaustive list, nor is it a model answer. Students may make all, some, or none of the points included in the indicative content, as its purpose is as a guide for the relevance and expectation of the responses. Students must be credited for any other appropriate response.

Application of extended response marking grids

When determining a level, you should use a bottom-up approach. If the response meets all the descriptors in the lowest level, you should move to the next one, and so on, until the response matches the level descriptor. Remember to look at the overall quality of the response and reward students positively, rather than focussing on small omissions. If the response covers aspects at different levels, you should use a best-fit approach at this stage and use the available marks within the level to credit the response appropriately.

When determining a mark, your decision should be based on the quality of the response in relation to the descriptors. You must also consider the relative weightings of the assessment objectives, so as not to over/under credit a response. Standardisation materials, marked by the Chief Examiner, will help you with determining a mark. You will be able to use exemplar student responses to compare to live responses, to decide if it is the same, better, or worse.

Assessment objectives

This assessment requires students to:

AO1: Demonstrate knowledge and understanding of contexts, concepts, theories and principles in healthcare science.

AO2: Apply knowledge and understanding of contexts, concepts, theories and principles in healthcare science to different situations and contexts.

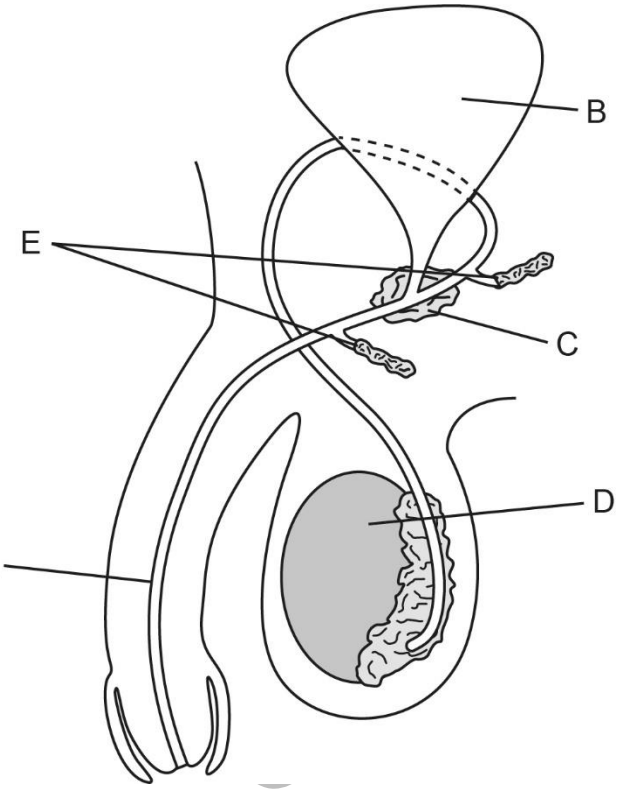
AO3: Analyse and evaluate information and issues related to contexts, concepts, theories and principles in healthcare science to make informed judgements, draw conclusions and address individual needs.

The weightings of each assessment objective can be found in the Qualification Specification.

Section A: Biology

Total for this section: [45 marks]
plus 3 marks for quality of written communication (QWC)

1 Figure 1: **diagram of the human male reproductive organs**



(a) **Identify structures A, C and E shown in** Figure 1**.**

[3 marks]

AO1 = 3 marks

Award **one** mark for each correct identification, up to a maximum of **three** marks.

A Urethra (1)
C Prostate (gland) (1)
E Seminal vesicle. (1)

(b)	**Drinking alcohol reduces production of antidiuretic hormone (ADH). Name the structure** labelled B **in** Figure 1 **and describe what effect a reduction in ADH would have on this structure.** [2 marks]

AO1 = 1 mark
AO2 = 1 mark

Award a maximum of one AO1 mark for correctly identifying structure B and a maximum of one AO2 mark for correctly describing the effect of a reduction in ADH on this structure (1).

Structure B

- Bladder (1).

Effect of reduction in ADH

- less water being absorbed by the kidneys meaning a higher volume of urine would be produced which is stored in the bladder (1)
- It would be fuller and enlarged (1)
- It will need to empty more often (1)

Accept any other suitable response.

(c)	Structure D **needs to be at a temperature slightly below body temperature to function.** **Explain** one **possible consequence if the temperature of** structure D **was maintained at body temperature.** [2 marks]

AO2 = 2 marks

Award **two** marks for a description, up to a maximum of **two** marks:

- Structure D would not be able to produce sperm as well / at all (1) leading to sterility / no sperm production / low sperm production / low sperm count (1)
- Structure D would not be able to produce testosterone (1) so secondary sexual characteristics would not develop / male would not reach puberty (1).

2 Figure 2: **volume of expired air against time**

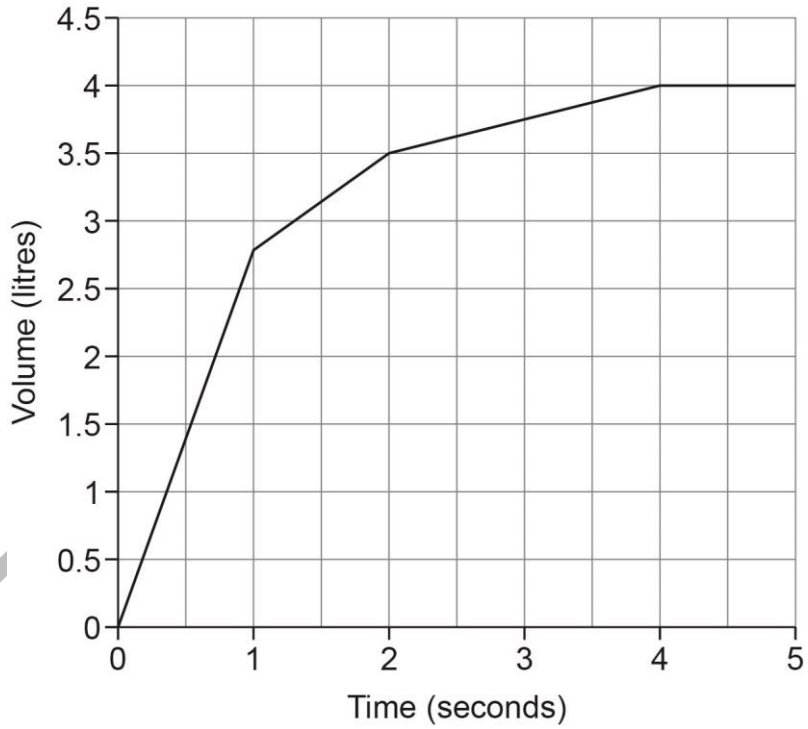


Figure 2 **represents a spirometer reading from an adult, who has exhaled fully after taking a maximum breath.**

(a) **Give the period of time in which exhalation rate was maximum.**

[1 mark]

AO2 = 1 mark

Award a **maximum** of **one** mark for correct identification of period of time:

0 – 1 seconds (1).

N.B. award mark for period without units

(b) **Describe** two **differences you would expect to see for a plot line in** 2(a) **if the same adult developed Chronic Obstructive Pulmonary Disease (COPD).**
[2 marks]

AO2 = 2 marks

Award **one** mark for each of the points below, up to a maximum of **two** marks:

- the line would be lower on the Y axis than the original line throughout the plot (1)
- the gradient of the line would be lower than the original line throughout the plot (1)

N.B. accept reference to rate of exhalation as opposed to the gradient of the line, if students say the volume would be lower OR any relevant description of gradient.

(c) **A student stated that 'the plot shown in** Figure 2 **must represent a female as the plot for a male would have a higher final volume'.**

Evaluate the validity of the student's statement, providing conclusions.
[3 marks]

AO3 = 3 marks

Award **one** mark for each evaluative point, up to a maximum of **three** marks:

- the student's statement has some validity as the average male exhalation will be higher than the average female exhalation due to average size difference (1)
- the student's statement may not be valid as the spirometer reading could be taken from a male who is smaller than average, therefore giving a lower reading (1)
- the student's statement may not be valid as the spirometer reading could be taken from a female who is larger than average, therefore giving a higher reading (1)
- the student's statement may not be valid as the spirometer reading could be taken from a male who has some form of (undiagnosed) respiratory condition which reduces lung volume therefore giving a lower reading (for example Chronic Obstructive Pulmonary Disease / COPD) (1)
- the student's statement may not be valid as the spirometer reading could be taken from a male who is a smoker, which can reduce lung volume, therefore giving a lower reading (1).
- the student's statement is not valid as there is no reference to the average spirometer readings for male and females and therefore no statement can be made (1)
- the student's statement may not be valid as it could be a reading from an athletic female, meaning the spirometer reading is higher than expected (1)

Accept any other suitable response.

3	**The average maximum heart rate for a healthy 20 year old male is 200 beats per minute (bpm).** **The average maximum heart rate for a healthy 30 year old male is 190 bpm, a reduction of 10 bpm.** **Using the information above, calculate the percentage reduction in average maximum heart rate from the age of 20 to the age of 30.** **Show your working.** [2 marks]

AO2 = 2 marks

Award **one** mark for each correct stage of the working, up to a maximum of **two** marks.

- % reduction in heart rate = (10/200) x 100 (1)
  or
- % reduction in heart rate = (30-20/200) x 100 (1)
  and
- = 5**%** (1)

NB: An answer of 5 with no working, should be awarded **one** mark.

4	**Virus X is a newly emerging pathogen (disease causing organism),** three **of its features are described below:** • **found in significant quantities in the blood and sexual fluids of infected individuals** • **degrades rapidly when outside the body, if not in blood or sexual fluids** • **degrades rapidly when exposed to the secretions of the digestive system.** **(i) Give** three **ways in which it may be transmitted from person to person.** **(ii) Justify your choices with reference to the features described.** [6 marks]

AO2 = 3 marks
AO3 = 3 marks

Award **one** AO2 mark for each correct transmission method up to a maximum of **three** marks.

Award **one** AO3 mark for each appropriate justification up to a maximum of **three** marks.

Transmission method:

- sharing of needles. (1)

Justification:

- the needle will contain small quantities of blood from one person, if this person has the virus, it will be present in the blood and will enter the body of the next person when the needle is used again. (1)

Transmission method:

- unprotected sexual contact. (1)

Justification:

- if the sexual fluids of an infected person enter the body of another person, the virus in the fluids may be able to enter the blood stream. (1)

Transmission method:

- being bitten by an infected vector (for example, mosquito). (1)

Justification:

- if the insect has bitten an infected person, it may contract the virus through its saliva / in its mouth parts. When it bites a second person, the virus can be introduced to that person's body. (1)

Transmission method:

- blood transfusion. (1)

Justification:

- if the person donating the blood is infected, and the blood is not screened for this virus, the virus will enter the body of the patient receiving the blood. (1)

Accept any other suitable response.

5 Table 1: **information about various diseases**

Disease	Causative organism(s)	Inadequate sanitary condition associated with disease	Annual cases
Cholera	***Vibrio cholerae***	**Contaminated food and water**	**1.3 – 4 million**
Diarrhoea	**Numerous species of bacteria and viruses**	**Contaminated food and water**	**1.7 billion**
Typhoid	***Salmonella typhi***	**Contaminated food and water**	**11 – 21 million**
Malaria	***Plasmodium* species via Anopholes mosquito bite**	**Stagnant standing water acts as a breeding ground for mosquitos**	**229 million**

Table 1 **gives some details of the main cause of spread of** four **diseases in populations, the causative organism(s) and the approximate annual number of cases worldwide.**

The vast majority of cases for each of these diseases are in the developing world.

Inadequate sanitary conditions are examples of factors which can contribute to disease spreading in a population.

(a) **Identify** three **other factors.**

[3 marks]

AO1 = 3 marks

Award **one** mark for each correct identification of a contributing factor, up to a maximum of **three** marks:

- dense populations / lack of social distancing (1)
- inadequate healthcare (1)
- lack of accessible health promotion information (1).

(b) **Define the term epidemiology.**

[1 mark]

AO1 = 1 mark

Award a maximum of **one** mark for the correct definition:

- the study and analysis of the distribution and patterns of disease in populations and why they occur (and influencing factors) (1).

N.B. award mark with or without and influencing factors.

(c) **Name** one **influencing factor in the epidemiology of disease.**

[1 mark]

AO1 = 1 mark

Award a maximum of **one** mark for a correctly named factor:

- diet (1)
- environment (1)
- ethnicity (1)
- age (1)
- sex (1)
- co-medications (1)
- recreational drugs (1)

(d) **Availability of toilets and safe disposal of sewage is often very low in countries with poor access to modern healthcare, unlike the UK.**

Using the table in 5(a), **to what extent would providing access to toilets with safe sewage disposal for all, significantly reduce the incidence of these diseases.**

[4 marks]

AO3 = 4 marks

Award **one** mark for each evaluative point, up to a maximum of **four** marks:

- access to toilets and safe sewage disposal, would ensure that soil used for growing crops and drinking water is less likely to be contaminated (with the causative organisms of cholera, diarrhoea, and typhoid) therefore reducing the incidence of these diseases (1)
- although access to toilets and safe sewage disposal would reduce the likelihood of contamination, if clean drinking water is not provided the incidence of these diseases is less likely to be reduced (significantly) (1)
- as malaria is not spread through contaminated water, access to toilets and safe sewage disposal would have little effect on its incidence (1)
- raising awareness / education would be required to ensure that the toilets are used by as many people as possible, otherwise, the incidence of these diseases would be less likely to be reduced (significantly) (1)
- although access to toilets and safe sewage disposal would reduce the likelihood of contamination, raising awareness / education would also need to be provided regarding personal hygiene, food preparation etc, to as many people as possible, otherwise incidence of these diseases would be less likely to be reduced (1)
- although access to toilets and safe sewage disposal should reduce the incidence of these diseases, other factors such as overcrowding / dense population or lack of adequate healthcare could also contribute to their spread (1)
- raising awareness / education may be more difficult in developing countries which could reduce the effectiveness of the provision (1).

Accept any other suitable response.

6	**Investigations have shown that smoking can significantly reduce the effectiveness of mucociliary transport.** **A student states that 'smokers are more likely to suffer from respiratory problems than non-smokers, as a result of this reduction in effectiveness'.** **Using your knowledge of the mechanism and function of mucociliary transport, evaluate this statement.** **Your response should include reasoned judgements and/or conclusions.** [6 marks]

AO2 = 3 marks
AO3 = 3 marks

Award **one** AO2 mark for each correct application, up to a maximum of **three** marks:

- as smoking significantly reduces the effectiveness of mucociliary transport, less mucus will be transported away from the lungs (1)
- as less mucus is transported away from the lungs, fewer bacteria / viruses will be transported away from the lungs (1)
- as less mucus is transported away from the lungs, fewer dust / smoke particles etc will be transported away from the lungs (1)
- as non-smokers will have more effective mucociliary transport, more dust particles and bacteria / viruses will be transported away from the lungs (1).

Award **one** AO3 mark for each correct evaluative point, up to a maximum of **three** marks:

- the student's statement has validity, as smoking reduces the effectiveness of mucociliary transport, fewer bacteria / viruses etc are transported away from the lungs, therefore the possibility of respiratory infections will increase (1)
- the student's statement has validity as smoking reduces the effectiveness of mucociliary transport, meaning less mucus is transported away from the lungs and fewer particles will be transported away, therefore increasing the possibility of respiratory problems as a consequence (1)
- the student's statement has less validity as factors other than smoking, for example air pollution / second-hand smoke, may also reduce the effectiveness of mucociliary transport, therefore non-smokers may be just as likely to develop respiratory problems as smokers (1)
- the student's statement has less validity as some respiratory problems have genetic causes, for example cystic fibrosis, and these are just as likely to affect non-smokers as smokers (1).

Accept any other suitable response.

7 Table 2 **shows the maximum resolution of** three **different types of microscopes.**

Type of microscope	Maximum resolution (nanometre (nm))
Light microscope	**200**
Scanning electron microscope (SEM)	**1-20**
Transmission electron microscope (TEM)	**< 1**

Resolution is the smallest distance between two points that can be seen as separate.

A virologist wishes to examine the detailed surface structure of a particular virus species, the average diameter of this virus is 220 nm, however it can range from 150 nm to 250 nm.

Using your knowledge and understanding of the properties of different types of microscopes, and the information provided, discuss which type of microscope would be most suitable in this scenario.

Your response should include reasoned judgements and/or conclusions.

[9 marks plus 3 marks for QWC]

AO1 = 3 marks
AO2 = 3 marks
AO3 = 3 marks
QWC = 3 marks

Band	Marks	Descriptor
3	7-9	**AO3:** Discussion of the of the suitability of each microscope is **comprehensive**, **effective** and **relevant**, showing **logical** and **coherent** chains of reasoning throughout that are **fully** supported with **rational** and **balanced** judgements and conclusions. **AO2: All relevant** knowledge of light microscopes, SEMs and TEMs is applied **effectively** to the given context. **AO1:** A **wide** range of relevant knowledge and understanding of the characteristics of light microscopes, SEMs and TEMs is evident. A **wide** range of **appropriate** technical terms are used. The answer demonstrates **comprehensive** breadth and/or depth of understanding.
2	4-6	**AO3:** Discussion of the suitability of each microscope, is in **most** parts **effective** and **mostly relevant**, showing in **most** parts **logical** and **coherent** chains of reasoning, which are **mostly** supported with rational and balanced judgements and conclusions.

		AO2: Most of the relevant knowledge of light microscopes, SEMs and TEMs is applied **effectively** to the given context, although on occasions there **may** be a lack of clarity. **AO1:** Knowledge and understanding of characteristics of light microscopes, SEMs and TEMs is in **most** parts **clear** and in **most** parts **accurate**, although on **occasion** may lose focus. The answer demonstrates **reasonable** breadth and / or depth of understanding, with occasional inaccuracies and / or omissions.
1	1-3	**AO3:** Discussion of the suitability of each microscope is in **some** parts **effective** but may **at times** have **little relevance**. **Brief** conclusions supported by judgements and conclusions that consider only **basic** arguments and show **tenuous** relevance to the question aims are evident. **AO2: Limited** knowledge of the characteristics of light microscopes, SEMs and TEMs is **applied** to the given context. **AO1:** Knowledge and understanding of characteristics of light microscopes, SEMs and TEMs shows **some** but **limited accuracy, focus** and **relevance.** The answer is **basic** and shows **limited** breadth and/or depth of understanding, with inaccuracies and omissions
	0	No creditworthy material

Indicative Content

AO1: Knowledge and understanding of the characteristics of light microscopes, SEMs and TEMs **that may include:**

- TEMs can reveal the internal structure of objects / materials
- TEMs can produce a 2D image of the inner surface
- SEMs produce a 3D image of the outer surface
- SEMs can produce a more detailed image of the surface than a TEM
- both types of electron microscope require significant training / expertise to use
- light microscopes are easy to use / require minimal training
- light microscopes are much lower cost than electron microscopes.

AO2: Application and understanding of relevant knowledge of light microscopes, SEMs and TEMs is applied **effectively** to the given context **that may include:**

- the average size of the virus is (slightly) larger than the maximum resolution of the light microscope
- some virus particles may be smaller than the maximum resolution of the light microscope
- certain features / structures on the virus surface may be smaller than the maximum resolution of the light microscope
- the smallest size of the virus is larger than the maximum resolution of the SEM
- the smallest size of the virus is larger than the maximum resolution of the TEM.

AO3: Discussion to include reasoned judgement and conclusions of the suitability of each microscope in this scenario that may include:

- as the average virus dimensions are (slightly) larger than the maximum resolution of the light microscope, it would be able to produce an image (in most cases)
- however, the virus particles present in the sample, may be smaller than average and lower than the maximum resolution of the light microscope, therefore it may not be able to produce an image
- as the virologist wishes to examine the detailed surface structure of the virus, many of the features / structures are likely to be smaller than the maximum resolution of the light microscope therefore it would not be able to provide a clear image of these features / structures
- as the virus dimensions are larger than the maximum resolution of the TEM, it would be able to produce a clear 2D image of the inner surface
- as the virus dimensions are larger than the maximum resolution of the SEM, it would be able to produce a clear 3D image of the outer surface and any relevant structures found there
- the dimensions of certain features / structures of the viral surface may be smaller than the maximum resolution of both types of electron microscope, therefore neither electron microscope could produce a clear image of these features
- as the maximum resolution of the SEM is lower than that of the TEM it is less likely to be able to produce a clear image of the smallest features/structures.

Conclusions may include:

- the virologist wishes to examine the detailed structure of the external surface of the virus; therefore, the SEM is the only type of microscope that could provide a suitable clear image (of the surface)
- none of the three types of microscopes would produce a perfect image
- the light microscope is likely to be the least suitable.

Accept any other suitable response.

Quality of written communication (QWC) = 3 marks

Mark	Descriptor
3	The answer is **clearly expressed** and **well structured**. The rules of grammar are used with **effective control** of meaning overall. A **wide range** of appropriate technical terms are used effectively.
2	The answer is generally **clearly expressed** and **sufficiently structured**. The rules of grammar are used with **general control** of meaning overall. A **good range** of appropriate technical terms are used effectively.
1	The answer **lacks some clarity** and is generally **poorly structured**. The rules of grammar are used with **some control** of meaning and any errors do **not** significantly hinder the overall meaning. A **limited range** of appropriate technical terms are used effectively.
0	There is **no answer** written or none of the material presented is creditworthy. **Or** The answer does **not** reach the threshold performance level. The answer is **fragmented and unstructured**, with **inappropriate use of technical terms**. The errors in grammar severely hinder the overall meaning.

Section B: Physics **Total for this section: [26 marks] plus 3 marks for QWC**

8 **State the direction in which a transverse wave oscillates in relation to its direction of travel.**

[1 mark]

AO1 = 1 mark

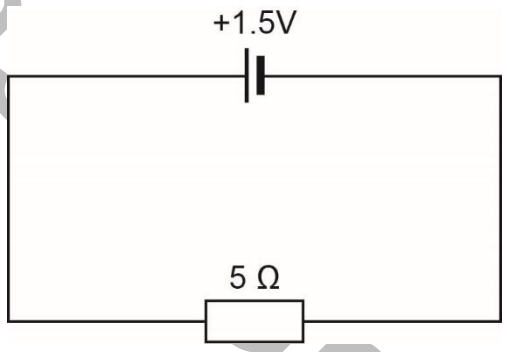
Award **one** mark for stating any one of the following:

- perpendicular (1)
- orthogonal (1)

or

- at right angles (1).

9 Figure 3: **a series circuit**



Study Figure 3**. Calculate the charge that passes through the resistor over a 30 second period.**

The following equations will help you:

I = V / R
Q = It

Show your working and give units in your answer.

[4 marks]

AO2 = 4 marks

Award **one** mark for substituting values into the equation:

I = 1.5 / 5 (1).

Award **one** mark for the correct calculation of the current:

I = 0.3 A (1).

Award **one** mark for substituting their value for current into the equation:

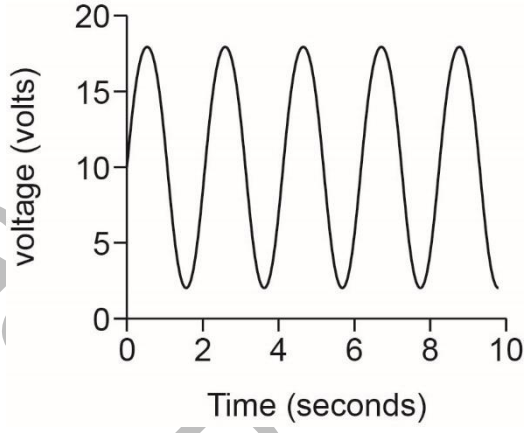
Q = 0.3 x 30 (1).

Award **one** mark for the correct calculation of the charge:

Q = 9 C (1).

NB Allow error carried forward if the student has calculated current incorrectly.

10 Figure 4: **voltage readings from a power source over a 10 second period**



A scientist is investigating a power source, which is to be connected to an electric motor.

The voltage across the power source is recorded over a 10 second period and shown in Figure 4**.**

The scientist concludes that the power source will cause the motor to spin continuously and at a uniform speed. Therefore, it is an appropriate selection.

Using your knowledge of voltage, current and the motor effect, discuss this conclusion.

[3 marks]

AO3 = 3 marks

Award **one** mark for each discussion point, up to a maximum of **three** marks:

- the voltage shown in the trace fluctuates, therefore, assuming the resistance is constant, the current will also fluctuate (1)
- as the current fluctuates, this means the strength of the magnetic field also changes, resulting in the motor spinning at different speeds (1)
- as the voltage never decreases to 0V, this means there will always be a current flowing and therefore the motor will spin continuously (1)
- whether or not the power source is appropriate will depend on the use of the motor, if it requires a uniform speed then it will not be appropriate (1)

- as the voltage (and therefore current) is not constant, the speed of the motor will vary, but the direction will stay the same (1).

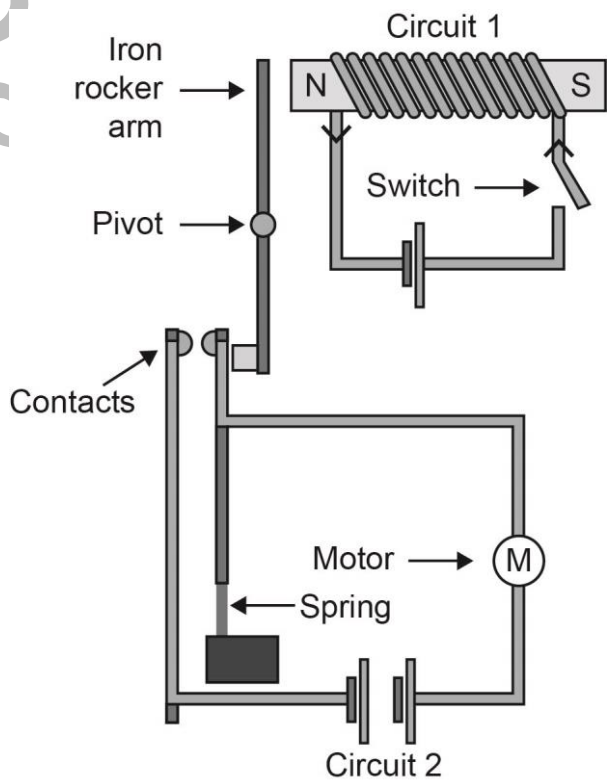
11 (a)	**Name the areas of a bar magnet where the magnetic forces are strongest.** [1 mark]

AO1 = 1 mark

Award **one** mark for naming the following:

- the poles (1)

(b) Figure 5: **diagram showing an electrical relay in a circuit that drives a motor**



Relays are small circuits containing electromagnets that are used to activate mechanical switches controlling larger circuits. A small circuit activates an electromagnet, which closes the switches (or contacts) to complete another larger circuit.

An example of a relay might be automatically switching a powerful fan off and on to keep a room at a constant temperature in a laboratory.

An electrician has been tasked with replacing the core in the electromagnet, the instructions say to use iron. This is because steel remains magnetic for a long period of time when the current is switched off whereas iron does not.

(i) **Describe how wrapping an iron core in a coil of wire produces an electromagnet.**

[1 mark]

(ii) **Explain why iron is more suitable than steel as a core in a relay.**

[2 marks]

AO1 = 1 mark
AO2 = 2 marks

Award **one** AO1 mark for either of the following, up to a maximum of **one** mark:

- current flowing through the wire produces a magnetic field which in turn cause the iron to become a temporary magnet, resulting in an electromagnet (1)

Award **one** AO2 mark for each of the following, up to a maximum of **two** marks:

- if steel was used, once the relay was activated once it would remain in that position for long periods of time (1) as it remains magnetic (1)
- as iron loses its magnetism more rapidly (1) it allows the relay to open and reset once the activating current stops (1).

Accept any other suitable response.

12 **A gamma ray travels with a frequency of 6 x 10^{19} Hz.**

The speed of light is c=3 x 10^{8} m/s.

The equation for calculating wavelength is v=fλ.

Calculate the wavelength of this wave.

Show your working.

[2 marks]

AO2 = 2 marks

Award **one** mark for using / rearranging the equation:

v=fλ -> v/f=λ
λ=(3 x 10^{8})/(6 x 10^{19}) (1).

Award **one** mark for solving the equation correctly:

λ=0.5 x 10^{-11}m or 5pm (picometres) (1).

Accept answers in picometers or metres.

13 **A scientist is investigating the decay of Fermium-252 (^{252}Fm). 100 g of ^{252}Fm is placed on a weighing scale. The mass of the sample is recorded every 12 hours.**

The radioactivity of the sample (in counts / minute) is also measured.

Figure 6: **a graph to show radioactivity over a period of 96 hours**

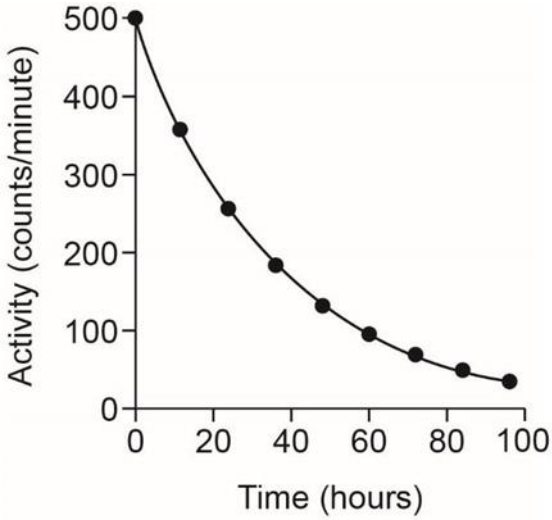


Table 3: **a table to show changes in mass of a radioactive sample over a period of 96 hours**

Time (hours)	**0**	**12**	**24**	**36**	**48**	**60**	**72**	**84**	**96**
Mass (g)	**100**	**99.5**	**99.2**	**99.0**	**98.8**	**98.7**	**98.6**	**98.6**	**98.5**

Based upon these observations (shown in Figure 6**), the scientist concludes that ^{252}Fm decays via alpha emission, with a half-life of 24 hours.**

Evaluate the accuracy of the scientist's conclusion.

[3 marks]

AO3 = 3 marks

Award **one** mark for each of the following, up to a total of **three** marks:

- the activity starts at 500, and is about 250 at 24 hours, which is consistent with the scientist's conclusion of the half-life being 24 hours (1) accept any other similar statement supported by correct data
- the mass of the sample goes down over the experiment, which is consistent with the conclusion of alpha particles being emitted (1)
- beta emission would not result in an appreciable loss of mass in the sample, suggesting that this does not occur (1)
- gamma waves may also be emitted during the decay process, so this cannot be ruled out based on the experimental data (1).

Accept any other suitable response.

14 An engineer is designing a radio system for the emergency services in a major city.

Table 4 **shows the radio wave frequencies that are available for this system.**

The engineer recommends using high frequency (HF) waves, as they all travel at the same speed and the lower power is safer for the people that will be using the system.

Table 4 **properties of different bands of radio waves that can be used in communication**

Name Band	**Power (W)**	**Wavelength Range (m)**	**Frequency Range (MHz)**	**Flat Open Terrain** *(miles)*	**Suburban Locations** *(miles)*	**Urban Areas** *(miles)*	**Inside Buildings** *(floors)*
High Frequency (HF)	4	10 to 100	3 to 30	5 - 6	2½ - 4½	1 - 3	10 - 15
Very High Frequency (VHF)	5	1 to 10	30 to 300	4½ - 6	2 - 4	1½ - 2	10 - 15
Ultra High Frequency (UHF)	6	0.1 to 1	300 to 3000	4 - 6	2½ - 4½	1½ - 3	25 - 30

Using your knowledge of the use of waves in communication, and the information above, evaluate the validity of this recommendation.

[9 marks plus 3 marks for QWC]

AO1 = 3 marks
AO2 = 3 marks
AO3 = 3 marks

Band	**Mark**	**Descriptor**
3	7-9	**AO3**: Evaluation of the recommendation of the optimal method of transmitting radio signals is **comprehensive**, **effective** and **relevant**, showing **detailed** understanding and **logical** and **coherent** chains of reasoning throughout. There are **effectively** informed judgements that are **fully** supported and rational. **Balanced** evaluations are evident. **AO2:** Application of knowledge of the implications of the properties of radio waves in order to evaluate the statement is **highly appropriate** and shows a **detailed** functional understanding. **AO1:** There is a **wide** range of **relevant** knowledge and understanding of using waves to transmit information that is **accurate** and **detailed**. The answer demonstrates **comprehensive breadth** and/or **depth** of **understanding** of the topic.

2	4-6	**AO3:** Evaluation of the recommendation of the optimal method of transmitting radio signals is in **most** parts **effective** and **mostly relevant**, showing **logical** and **coherent** chains of reasoning throughout. There are most **mostly** accurate judgements and mostly **rational** and **balanced** conclusions are evident. **AO2:** Application of knowledge of the properties of radio waves in order to evaluate the statement is in **most** parts **appropriate**, showing some functional understanding. **AO1:** Knowledge and understanding of using waves to transmit information is in **most** part **clear** and **mostly accurate**, although on **occasion** may lose focus. The answer demonstrates **reasonable** breadth and/or depth of understanding, with **occasional** inaccuracies and/or omissions.
1	1-3	**AO3:** Evaluation of the recommendation of the optimal method of transmitting radio signals is in **some** parts **effective** and of **some relevance**, with some understanding and reasoning taking the form of generic statements with some development. Judgements are basic and brief, and conclusions will have limited rationality and balance. **AO2:** Application of knowledge of the properties of radio waves in order to evaluate the statement is **limited** and may show a **lack** of functional understanding. **AO1:** Knowledge and understanding of **accuracy** using waves to transmit information shows some but **limited**, **focus** and **relevance**. The answer is basic and shows **limited** breadth and/or depth of understanding, with inaccuracies and omissions.
0	**0**	No creditworthy material.

Indicative Content

AO1: Properties of radio waves:

- radio waves are used for communication as they transmit information over distance
- radio waves are low energy and / or not ionising
- radio waves with a longer wavelength have a lower frequency as per the wave equation ($v=f\lambda$)
- radio waves are transverse waves
- these waves are at a longer wavelength than visible light

AO2: Discussion of properties of the different radio wave properties:

- all frequency options travel long distances
- as radio waves are not ionising, none of the radio bands that are being considered for use are dangerous to the people using devices transmitting and receiving them
- UHF waves are best able to travel inside buildings, which would be useful in emergency settings, and in highly built-up areas like a city/town with tower blocks
- across open terrain and suburban areas, all waves showed similar ranges.

AO3: Reasoning and conclusions:

- UHF may be more appropriate as it is able to operate most effectively inside, and in urban environments
- HF waves have no advantages over UHF waves based upon the information available.
- all frequency options would be safe and effective, so the option may be made based upon other factors, such as cost
- increasing the power at which waves are transmitted may provide other options to reach greater distances
- more powerful radios using higher frequency bands may have poorer battery life, which may lead to issues in emergency settings.

Accept any other suitable response.

Quality of written communication (QWC) = 3 marks

Mark	Descriptor
3	The answer is **clearly expressed** and **well structured**. The rules of grammar are used with **effective control** of meaning overall. A **wide range** of appropriate technical terms are used effectively.
2	The answer is generally **clearly expressed** and **sufficiently structured**. The rules of grammar are used with **general control** of meaning overall. A **good range** of appropriate technical terms are used effectively.
1	The answer **lacks some clarity** and is generally **poorly structured**. The rules of grammar are used with **some control** of meaning and any errors do **not** significantly hinder the overall meaning. A **limited range** of appropriate technical terms are used effectively.
0	There is **no answer** written or none of the material presented is creditworthy. **or** The answer does **not** reach the threshold performance level. The answer is **fragmented and unstructured**, with **inappropriate use of technical terms**. The errors in grammar severely hinder the overall meaning.

Section C: Chemistry **Total for this section: [17 marks] plus 3 marks for QWC**

15 **Polyethylene is a polymer, often used in pharmaceutical packaging.**

(a) **State** one **property of polyethylene which makes it a good packaging material.** [1 mark]

AO1 = 1 mark

Award **one** mark for **each** stated property, up to a maximum of **one** mark:

Polyethylene is:

- chemically unreactive (1)
- an electrical insulator (1)
- strong material (1).

(b) **A team of scientists are developing a new material to transport sensitive pharmaceuticals. They are testing** three **different polymers. Their results are shown below:**

Table 5: **scientists' initial study on three potential materials**

Polymer	Melting point (°C)	Density (grams per cubic centimetre (gcm^{-3}))
Polyethylene	115	0.88
Polyvinyl chloride	110	1.33
Polypropylene	130	0.95

The scientists are looking for a strong lightweight material to use.

Based on this initial data, assess which polymer would be the most suitable to investigate further.

[3 marks]

AO2 = 1 mark
AO3 = 2 marks

Award **one** AO2 mark for **each** conclusion, up to a maximum of **one** mark:

- polypropylene would be the best because it has the highest melting point and second lowest density (1)

Or

- polyethylene because it has the lowest density and second highest melting point (1).

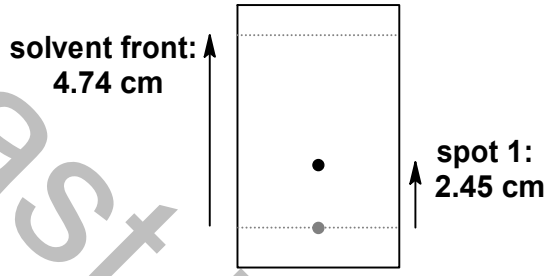
Award **one** AO3 mark for **each** assess point, up to a maximum of **two** marks:

- polypropylene and polyethylene offer one physical advantage over the other. However, they are both worthy of testing further. Perhaps additional tests could be conducted (such as stress testing) (1)
- from these initial tests, polyvinylchloride can be out ruled as its overall density is the highest and its melting point was the lowest compared to the other tested polymers (1).

Accept any other suitable response.

16 **A scientist is testing the purity of a pharmaceutical solution in the laboratory. After a TLC analysis they obtain the following chromatogram:**

Figure 7: **chromatogram of pharmaceutical solution**



To identify specific compounds, scientists use R_f values which are calculated using the following equation:

$$R_f = \frac{\text{Distance travelled by spot}}{\text{Distance of solvent front}}$$

Calculate the R_f value associated with spot 1 in Figure 7**. Give your answer to** two **decimal places.**

Show your working.

[2 marks]

AO2 = 2 marks

Award **one** mark for **each** solution, up to a maximum of **two** marks:

Calculating the R_f value associated with spot 1 as:

- R_f = 2.45/4.74 = 0.5168776371308017 (1).

Rounding this answer to two decimal places:

- = 0.52 (1).

17 **Yield is the percentage mass of a product produced in a reaction. It is calculated using the equation below:**

$$\text{Percentage Yield (\%)} = \frac{\text{Amount synthesised}}{\text{Amount expected}} \times 100$$

Scientists are producing ibuprofen and have synthesised 2.76g from a reaction. The amount that the scientists expected to produce was 4.13g.

Using the equation above, calculate the percentage yield.

Give your answer to three **significant figures and show your working.**

[2 marks]

AO2 = 2 marks

Award **one** mark for substituting the values into the equation given:

- Percentage yield = (2.76/4.13) x 100 (1)

Award **one** mark for a correct answer to three significant figures:

- 66.8 (%) (1)

18 **Scientists are developing a new pharmaceutical compound (R). As part of this development, they modify the pharmaceutical compound with** three **different chemical groups that vary in acidity (pH) and record the reaction rate (*k*). Their results are displayed in the table below.**

Table 6: **pH and reaction rate data from the scientist's initial laboratory studies.**

Group (X)	pH	Reaction rate (*k*)
OH	**11**	**0.67**
SO_4H	**2.75**	**1.67**
SH	**4.97**	**1.51**

From these observations in Table 6**, the scientists conclude that the pH of the group does not play a significant role in this reaction, as the rates between SO_4H and SH are similar compared to that of OH.**

Using your knowledge of the pH scale and acidity, evaluate the scientists' conclusions.

Your answer should include reasoned judgements and / or conclusions.

[9 marks plus 3 for QWC]

AO1 = 3 marks
AO2 = 3 marks
AO3 = 3 marks
QWC = 3 marks

Band	Marks	Descriptor
3	7-9	**AO3:** Evaluation of the scientist's conclusions in relation to the pH scale is **comprehensive**, **effective**, and **relevant**, showing **detailed** understanding and **logical** and **coherent** chains of reasoning throughout. Makes informed **conclusions** that are **fully** supported with **rational** and **balanced** reasoned judgements. **AO2:** Applied **relevant** knowledge of how the pH scales works. Shows a **detailed** functional understanding of how this relates to acidity. **AO1**: Demonstrates a **wide** range of **relevant knowledge** and **understanding** of the pH scale which is **accurate** and **detailed**. The answer demonstrates **comprehensive** breadth and / or depth of understanding.
2	4-6	**AO3:** Evaluation of the scientist's conclusions is in **most** parts and **mostly relevant**, showing mostly logical and coherent **effective** chains of reasoning. Given **conclusions** are supported by **reasoned** judgements that consider most of the **relevant** arguments.

		AO2: Applied **relevant** knowledge of how the pH scale works in most parts **appropriate**, showing some **functional understanding** of the scientific mechanics involved. **AO1:** Knowledge and understanding of the pH scale in this context are in **most** parts **clear** and **mostly accurate**, although on **occasion** may lose focus.
1	1-3	**AO3:** Evaluation of the scientist's conclusions is in some parts **effective** and of **some relevance**, with some **reasoning** understanding and taking the form of **generic statements** with **some development**. Judgements are **basic** and **brief**; conclusions will have **limited rationality** and **balance**. **AO2:** Applied **limited knowledge** of how the pH scale can be used and may show a **lack** of functional understanding of the scientific mechanics involved. **AO1**: Knowledge and understanding of the pH scale in this context show **some** but **limited** accuracy, focus and relevance.
	0	No creditworthy material

Indicative Content

AO1:

- the pH scale is a measure of how acidic or basic a specific solution is
- this acidity or basicity depends on certain chemical groups present within a chemical
- pH 7 on a pH scale is considered neutral, neither acidic nor basic
- therefore, pH values less than 7 are considered acidic, the lower the number the more acidic
- additionally, pH values larger than 7 are considered basic, the higher the number the more basic
- strong acids are completely dissociated in aqueous solution
- weak acids are only partially dissociated in aqueous solution

AO2:

- the recorded pH values indicate that OH is the most basic with a pH value of 11
- both SH and SO_4H are acidic with values of 4.97 and 2.75, respectively
- these are considered more acidic in relation to that of OH
- SO_4H is the most acidic group tested
- both SH and SO_4H additionally display similar reaction rates. However, these rates are higher than the basic OH group
- this may imply that ionisation needs to occur for the reaction to occur more readily as SH and SO_4H are stronger acids to that of the OH group.

AO3:

- however, based on these observations alone, the scientist's conclusion may be wrong or is incomplete as not enough groups were tested

- it could be argued that SH and SO_4H show similar reaction rates as the difference between their pH values is small compared to that of the OH group
- this could therefore mean that pH does play a significant role in the reaction rates
- there needs to be more variation in pH in order to truly test this hypothesis. For instance, more basic groups with higher pH values
- more acidic groups (pH less than 2) would be needed to verify the scientist's conclusion
- the concentration of the pharmaceutical could also be a factor. There is no suggestion in this scenario to what the concentration is.

Accept any other suitable response.

Quality of written communication (QWC) = 3 marks

Mark	Descriptor
3	The answer is **clearly expressed** and **well structured**. The rules of grammar are used with **effective control** of meaning overall. A **wide range** of appropriate technical terms are used effectively.
2	The answer is generally **clearly expressed** and **sufficiently structured**. The rules of grammar are used with **general control** of meaning overall. A **good range** of appropriate technical terms are used effectively.
1	The answer **lacks some clarity** and is generally **poorly structured**. The rules of grammar are used with **some control** of meaning and any errors do **not** significantly hinder the overall meaning. A **limited range** of appropriate technical terms are used effectively.
0	There is **no answer** written or none of the material presented is creditworthy. **or** The answer does **not** reach the threshold performance level. The answer is **fragmented and unstructured**, with **inappropriate use of technical terms**. The errors in grammar severely hinder the overall meaning.

Section D: Biology, Chemistry and Physics **Total for this section: [12 marks] plus 3 marks for QWC**

19 **A patient with a family history of bowel cancer is admitted to hospital with sudden onset bowel pains. An ultrasound scan shows a possible 'mass' in the large intestine.**

Based on family history, a practitioner observing the scan states:

'The mass is likely to be a cancerous tumour and therefore the next step should be to use radioactive tracers. During this process the most important factors to consider are:

- **the radioactive tracers have a short half-life**
- **the radioactive tracers emit gamma radiation, rather than alpha or beta, as gamma radiation is low ionising**
- **the radioactive tracers should easily be taken up by the tumour cells'.**

Evaluate the practitioner's statement, including reasoned judgements and conclusions.

[12 marks, plus 3 marks for QWC]

AO1 = 4 marks
AO2 = 4 marks
AO3 = 4 marks
QWC = 3 marks

Band	Marks	Descriptor
3	9-12	**AO3:** Evaluation of the of the student's initial diagnosis and factors for consideration is **comprehensive**, **effective** and **relevant**, showing **logical** and **coherent** chains of **reasoning** throughout that are **fully** supported with **rational** and **balanced** judgements. **AO2: All relevant** knowledge of the properties of alpha, beta and gamma radiation and the possible causes of the symptoms are applied **effectively** to the given context. **AO1:** A **wide** range of **relevant** knowledge and understanding of the properties of alpha, beta and gamma radiation is evident. A **wide** range of **appropriate** technical terms are used. The answer demonstrates **comprehensive** breadth and/or depth of understanding.
2	5-8	**AO3:** Evaluation of the student's initial diagnosis and factors for consideration, is in **most** parts **effective** and **mostly relevant**, showing in **most** parts **logical** and **coherent** chains of reasoning, which are **mostly** supported with rational and balanced judgements.

		AO2: Most of the relevant knowledge of the properties of alpha, beta and gamma radiation and the possible causes of the symptoms are applied **mostly** effectively, although there **may** be lack of clarity. **AO1:** Knowledge and understanding of alpha, beta and gamma radiation is in **most** parts **clear** and in **most** parts **accurate**, although on **occasion** may lose focus. The answer demonstrates **reasonable** breadth and / or depth of understanding, with **occasional** inaccuracies and / or omissions
1	1-4	**AO3:** Evaluation of the student's initial diagnosis and factors for consideration is in **some** parts **effective** but may **at times** have **little relevance**. **Brief** conclusions supported by judgements that consider only **basic** arguments and show **tenuous** relevance to the question aims are evident. **AO2: Limited** knowledge of properties of alpha, beta and gamma radiation and the possible causes of the symptoms is **applied** to the given context. **AO1:** Knowledge and understanding of properties of alpha, beta and gamma radiation shows **some** but **limited accuracy, focus** and **relevance.** The answer is **basic** and shows **limited** breadth and/or depth of understanding, with inaccuracies and omissions.
	0	No creditworthy material.

Indicative Content

AO1: Knowledge and understanding of properties of alpha, beta and gamma radiation that may include:

- half-life is the time taken for half the unstable nuclei in a radioactive material to decay/the radioactive levels to halve
- gamma radiation is low ionising
- gamma radiation has high penetrating power
- gamma radiation can be used for cancer therapy
- gamma radiation is electromagnetic radiation from the nucleus
- alpha radiation is highly ionising
- alpha radiation has low penetrating power
- beta radiation is medium ionising
- beta radiation has medium penetrating power
- ionising radiation can remove/detach electrons from atoms/molecules
- diverticulitis can cause sudden bowel pain
- diverticulitis produces inflamed pouches in the wall of the large intestine.

AO2: Application and understanding of properties of alpha, beta and gamma radiation and the possible causes of the symptoms in this context that may include:

- as gamma radiation has high penetration it will be able to leave the body
- if the radioactive tracers have a short half-life, the radioactivity will decline quickly
- as ionising radiation can remove/detach electrons from atoms/molecules, it can damage the body
- as gamma radiation is low ionising, any possible damage will be reduced
- as alpha radiation has low penetration power it will not be able to be able to leave the body
- as beta radiation has medium penetrating power, it is unlikely to be able to leave the body
- if the radioactive tracers can be taken up easily by tumour cells, they will concentrate in the tumour.

AO3: Evaluation to include reasoned judgement and conclusions of the initial diagnosis and factors for consideration that may include:

- although the radioactive tracers having a short half-life is desirable, the term 'short' is relative, and could still be long enough to cause damage
- although gamma radiation is low ionising, it is still ionising, and prolonged exposure to gamma radiation is likely to cause damage to the body
- if the radioactive tracers can easily be taken up by the tumour cells, they could also easily be taken up by other cells (and cause damage)
- as alpha and beta radiation would not be able to leave the body, they would not be able to be detected and used to produce an image
- the practitioner did not mention the danger to others close to the patient (medical staff and visitors) who could be damaged by the gamma rays leaving the patient's body
- the practitioner did not suggest other methods to investigate the symptoms which would be less damaging.

Conclusions may include:

- the initial suggestion may not be valid as although the family history and the results of the scan may indicate a tumour, the symptoms could also be caused by diverticulitis, if the patient has diverticulitis, introduction of radioactive tracers is unnecessary and may damage the patient
- the statement regarding a short half-life is valid, as all radiation can be damaging a short half-life will reduce the exposure to radiation and potential damage to tissues/the body
- the statement regarding gamma being better than alpha and beta radiation is valid as alpha and beta radiation would cause more damage to the tissues/body as they are more highly ionising
- the statement regarding the ease of uptake of the tracer is valid as if it could not easily be taken up by tumour cells it would not give an accurate image of the tumour
- the overall statement which regarding the most important factors is less valid as the student did not state the importance of the radiation being able to leave the body to enable an image to be created.

Accept any other suitable response.

Quality of written communication (QWC) = 3 marks

Mark	Descriptor
3	The answer is **clearly expressed** and **well structured**. The rules of grammar are used with **effective control** of meaning overall. A **wide range** of appropriate technical terms are used effectively.
2	The answer is generally **clearly expressed** and **sufficiently structured**. The rules of grammar are used with **general control** of meaning overall. A **good range** of appropriate technical terms are used effectively.
1	The answer **lacks some clarity** and is generally **poorly structured**. The rules of grammar are used with **some control** of meaning and any errors do **not** significantly hinder the overall meaning. A **limited range** of appropriate technical terms are used effectively.
0	There is **no answer** written or none of the material presented is creditworthy. **or** The answer does **not** reach the threshold performance level. The answer is **fragmented and unstructured**, with **inappropriate use of technical terms**. The errors in grammar severely hinder the overall meaning.

Section A

Question Number	AO1	AO2	AO3	Maths	QWC	Total
1 (a)	3					3
1 (b)	1	1				2
1(c)		2				2
2(a)		1				1
2(b)		2				2
2(c)			3			3
3		2		2		2
4		3	3			6
5(a)	3					3
5(b)	1					1
5(c)	1					1
5(d)			4			4
6		3	3			6
7	3	3	3		3	12
Total	**12**	**17**	**16**	**2**	**3**	**48**
Totals required	**11–13 marks**	**17–19 marks**	**14–16 marks**	**2**	**3**	**48**
Kil	**6**					

Section B (Physics)

Question Number	AO1	AO2	AO3	Maths	QWC	Total
8	1					1
9		4		4		4
10			3			3
11 (a)	1					1
11 (b)	1	2				3
12		2		2		2
13			3			3
14	3	3	3		3	12
Total	**6**	**11**	**9**	**6**	**3**	**29**
Totals required	**5–7 marks**	**10–12 marks**	**8–10 marks**	**6**	**3**	**29**
Kil	**3**					

Section C

Question Number	AO1	AO2	AO3	Maths	QWC	Total
15(a)	1					1
15(b)		1	2			3
16		2		2		2
17		2		2		2
18	3	3	3		3	12
Total	**4**	**8**	**5**	**4**	**3**	20
Totals required	**3–6 marks**	**6–8 marks**	**4–9 marks**		**3**	**20**
Kil						

Section D

Question Number	AO1	AO2	AO3	Maths	QWC	Total
19	4	4	4		3	15
Total	**4**	**4**	**4**		**3**	**15**
Totals required	**3–4 marks**	**4–6 marks**	**3–4 marks**		**3**	**15**
Whole Paper Totals	**26**	**40**	**34**	**12**	**12**	**112**
Total Kil						

Document information

Owner: Head of Assessment Design