AQA GCSE Combined Science - Trilogy | 8464

SPECIFICATION POINT 6.6.2.1

Types of electromagnetic waves

Mark schemes and examiner comments

Tier	**Higher**
Question groups	**7**
Available paper years	**2018–2024**

Using this booklet

1. Booklet answer numbers match the question booklet.
2. Use the original question number within marking tables.
3. Examiner comments are included where available.

Name: _____ **Date:** _____

Where a precise marking extract is unavailable, the full source document is included in an appendix. Any missing mark scheme is explicitly identified.

6.6.2.1 Types of electromagnetic waves

Answer 01 · Mark scheme June 2018 | 8464/P/2H | Original Q5

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.1	in a longitudinal wave, the oscillations / vibrations are parallel to the direction of energy transfer	allow direction of travel for energy transfer	1	AO1 6.6.1.1
	in a transverse wave, the oscillations / vibrations are perpendicular to the direction of energy transfer	allow direction of travel for energy transfer if no other mark scored allow **1** mark for (oscillations / vibrations of) longitudinal waves are parallel **and** (oscillations / vibrations of) transverse waves are perpendicular if no other mark scored allow **1** mark for transverse waves have peaks and troughs **and** longitudinal waves have compressions and rarefactions	1	
05.2		an answer of 0.063 (m) scores **3** marks		AO2 6.6.1.2
	$3.0 \times 10^8 = 4.8 \times 10^9 \times \lambda$	allow $\lambda = \frac{3.0 \times 10^8}{4.8 \times 10^9}$ this mark may be awarded if the standard form values are incorrectly converted	1	
	$\lambda = 0.0625$ (m)		1	
	$\lambda = 0.063$ (m) **or** $\lambda = 6.3 \times 10^{-2}$ (m)	allow an answer to 2 sig figs that is consistent with their calculated value of λ and has required rounding	1	

6.6.2.1 Types of electromagnetic waves

Answer 01 · Mark scheme

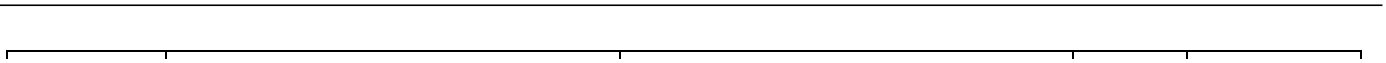
June 2018 | 8464/P/2H | Original Q5

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.3	any **three** from: • (the car aerial) absorbs radio waves or energy • electrons are made to vibrate (in the aerial) • creating an alternating current (in the aerial circuit) • the (signal) frequency is the same (as the radio wave)		3	AO1 6.6.2.3
Total			**8**	

6.6.2.1 Types of electromagnetic waves

Answer 01 · Mark scheme

June 2018 | 8464/P/2H | Original Q5



6.6.2.1 Types of electromagnetic waves

Answer 02 · Mark scheme June 2019 | 8464/P/2H | Original Q1

Question	Answers	Extra information	Mark	AO / Spec. Ref.	ID
01.1	(4 - 0) + (10 - 7) **or** 4 + 3 **or** 10 - 3 7 (s)	an answer of 7 (s) gains **2** marks	1 1	AO2 6.5.4.1.5	E
01.2	gradient = $\frac{0-2}{24-14}$ (-)0.2 (m/s^2)	an answer of 0.2 (m/s^2) gains **2** marks allow readings from any two points correctly substituted allow correct use of $a = \frac{\Delta v}{t}$	1 1	AO2 6.5.4.1.5	E
01.3	(there are no wires) to get tangled / disconnected	allow easier to move arms allow wires are inconvenient allow easier to transfer data	1	AO3 6.6.2.4	E
01.4	wave speed = frequency × wavelength	allow v = f λ allow any correct re-arrangement	1	AO1 6.6.1.2	E
01.5	300 000 000 = 2 400 000 000 × λ λ = $\frac{300\,000\,000}{2\,400\,000\,000}$ λ = 0.125 (m)	an answer of 0.125 (m) or 0.13 (m) scores **3** marks allow λ = 0.13 (m)	1 1 1	AO2 6.6.1.2	E
01.6	range is far enough (for most uses) power is not too great so the battery will not drain quickly	allow power not too great so the phone will not overheat allow the range per milliwatt is greatest or 4 metres	1 1	AO3 6.6.2.4	E

6.6.2.1 Types of electromagnetic waves

Answer 02 · Mark scheme

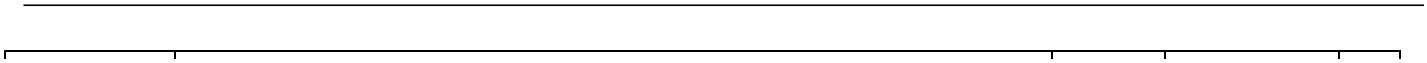
June 2019 | 8464/P/2H | Original Q1

Total			**11**		

6.6.2.1 Types of electromagnetic waves

Answer 02 · Mark scheme

June 2019 | 8464/P/2H | Original Q1



6.6.2.1 Types of electromagnetic waves

Answer 03 · Mark scheme June 2019 | 8464/P/2H | Original Q7

Question	Answers	Extra information	Mark	AO / Spec. Ref.	ID
7.1	speed / velocity in the glass is lower	speed / velocity changes is insufficient allow the refractive index of glass is higher than that of air allow glass has a higher optical density than air	1	AO1 6.6.2.2	E
	so the edge of the wave(front) entering the glass slows down		1		
	but the part of the wave(front) in the air continues at the higher speed / velocity (causing a change in direction)		1		
7.2	correct ray in the prism bent towards the normal		1	AO1 6.2.2.2	E
	second normal at 90° at the point the ray emerges		1		
	correct emergent ray bent away from the normal	this mark can be awarded without a normal line drawn	1		
7.3	violet has the shortest wavelength (400 nm)		1	AO3 6.2.2.2	E
	violet light travels the slowest in water		1		
	violet light undergoes the greatest change in speed (and direction)		1		
Total			**9**		

6.6.2.1 Types of electromagnetic waves

Answer 04 · Mark scheme

November 2020 | 8464/P/2H | Original Q5

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.1	X-rays are absorbed by bone		1	AO1 6.6.2.4
	but can pass through flesh	ignore skin	1	
05.2	taking lots of X-rays would give a large dose		1	AO3 6.6.2.3
	which would increase the radiographer's risk		1	
	the screen absorbs some of the X-rays	allow screen reduces the risk/dose received by the radiographer	1	
05.3	electrical current / oscillations in the transmitter producing radio waves		1	AO1 6.6.2.3
	radio waves are absorbed by the receiver inducing electrical current / oscillations in the receiver		1	
	at the same frequency	if no other mark is awarded, allow **1** mark for radio waves transfer information/energy through the air	1	
Total			**8**	

Answer 04 · Mark scheme

November 2020 | 8464/P/2H | Original Q5

6.6.2.1 Types of electromagnetic waves

Answer 05 · Mark scheme

November 2021 | 8464/P/2H | Original Q5

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.1	different temperatures emit different intensities of infrared which are represented (on the infrared camera) as different shades / colours	 allow wavelength / frequency / amount for intensity throughout	1 1	AO1 AO3 6.6.2.4
05.2	visible light		1	AO3 6.6.2.1
05.3	both ionising radiation so some risk of cancer the whole body is irradiated by gamma rays when an X-ray is taken only part of the body is exposed exposure time for gamma rays is longer		1 1 1 1	AO1 AO3 AO3 AO3 6.6.2.3
05.4	$1.2 \times 10^{-13} = F \times 0.015$ $F = \frac{1.2 \times 10^{-13}}{0.015}$ $F = 8.0 \times 10^{-12}$ N	 allow a correct rearrangement using an incorrectly / not converted value of s allow 8×10^{-12} allow a correct calculation using an incorrectly / not converted value of s	1 1 1	AO2 6.5.2

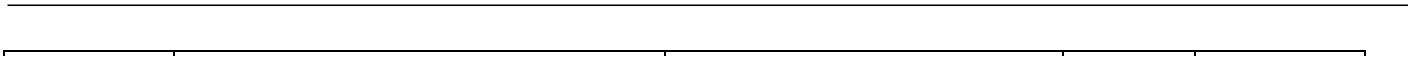
6.6.2.1 Types of electromagnetic waves

05.5	some of the energy of the electrons causes heating (therefore) increasing the temperature (so using tungsten) allows more electrons to be collided per second than using any other metal	 allow (so using tungsten) enables more energy per second to be transferred than using any other metal	1 1 1	AO1 AO3 AO3 6.5.2
Total			**13**	

6.6.2.1 Types of electromagnetic waves

Answer 05 · Mark scheme

November 2021 | 8464/P/2H | Original Q5



6.6.2.1 Types of electromagnetic waves

Answer 06 · Mark scheme

June 2023 | 8464/P/2H | Original Q1

Question 1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.1	**A** radio waves **B** microwaves **C** X-rays	allow **1** mark if 2 correct	2	AO1 6.6.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.2	**Similarity** any **one** from: • same speed (in a vacuum) • both transfer energy • both transverse	allow both can travel through a vacuum allow both are ionising allow both can harm living tissue allow both can be used for medical treatment / imaging	1	AO1 6.6.2.2
	Difference any **one** from: • gamma has a higher frequency • gamma has a shorter wavelength • gamma is more ionising • gamma is more penetrating	allow gamma has more energy	1	

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.3	refraction		1	AO1 6.6.2.2

6.6.2.1 Types of electromagnetic waves

Answer 06 · Mark scheme

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.4	wave speed = frequency × wavelength **or** $v = f\lambda$		1	AO1 6.6.1.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.5	$3.0 \times 10^{8} = f \times 5.0 \times 10^{-7}$ $f = \frac{3.0 \times 10^{8}}{5.0 \times 10^{-7}}$ $f = 6 \times 10^{14}$ (Hz)	 allow a correct rearrangement using incorrect powers of 10 allow a correct calculation of f using incorrect powers of 10 allow 6.0×10^{14} (Hz)	1 1 1	AO2 6.6.1.2

Total Question 1	9

6.6.2.1 Types of electromagnetic waves

Answer 07 · Mark scheme

June 2024 | 8464/P/2H | Original Q3

Question 3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.1	speed (in a vacuum/air) **or** transfer energy	ignore they can travel through air allow they can be reflected / refracted	1	AO1 6.6.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.2	oscillations / vibrations are perpendicular to the direction of energy transfer	allow wave travel for energy transfer	1	AO1 6.6.1.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.3	microwaves	allow radio waves	1	AO1 6.6.2.4

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.4	violet	allow purple	1	AO1 6.6.2.1

6.6.2.1 Types of electromagnetic waves

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.5	any **two** from • (ultraviolet and /or X-rays and / or gamma rays) can cause mutations in genes / DNA • ultraviolet can cause skin to age and / or skin cancer • X-rays and / or gamma rays increase the risk of cancers	 allow can damage / kill cells ignore mutations in cells allow ultraviolet can cause sunburn or eye damage allow X-rays and / or gamma rays can cause cancers if no other mark awarded allow **1** mark for (the three highest frequency groups) can cause cancer	2	AO1 6.6.2.3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.6	$4.0 \times 10^{-10} = \frac{1}{\text{frequency}}$ $\text{frequency} = \frac{1}{4.0 \times 10^{-10}}$ 2.5×10^{9} (Hz)	 only award if answer is in standard form	1 1 1	AO2 6.6.1.2

6.6.2.1 Types of electromagnetic waves

Answer 07 · Mark scheme

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.7	radio waves are produced (by the transmitter)	allow microwaves are produced (by the transmitter)	1	AO1 6.7.2.1
	the detector absorbs the waves / energy		1	
	(which produces) an alternating current	allow causing electrons to oscillate	1	
	with the same frequency as the (transmitted) waves	allow with the same frequency as the oscillations in the transmitter	1	

Total Question 3	**13**

6.6.2.1 Types of electromagnetic waves

Answer 01 · Examiner comments

June 2018 | 8464/P/2H | Original Q5

Question 5 (standard & standard / high demand)

05.1 Nearly 13% gave accurate answers to score both marks. A further 20% were able to score a compensation mark by vague references to parallel and perpendicular, but it was clear that many students do not realise the importance of what is oscillating and the direction of energy transfer. There were many vague incorrect descriptions of 'up and down' and 'side to side'.

05.2 25% gained full marks, and a further 18% gained two marks, usually not giving the answer to two significant figures. There were a large number of responses using an incorrect rearrangement of the equation and generally the use of standard form was not the cause of the errors.

Answer 01 · Examiner comments

June 2018 | 8464/P/2H | Original Q5

05.3 This was very poorly done, with just over 1% gaining full marks. There were many vague responses and a significant number of candidates wrote about transverse and longitudinal waves. There was also considerable reference to radio waves being reflected off the ionosphere.

A significant minority of students did not attempt this question which might suggest that they were unfamiliar with the material.

6.6.2.1 Types of electromagnetic waves

Answer 05 · Examiner comments November 2021 | 8464/P/2H | Original Q5

Question 5 (standard/high demand and high demand)

05.1 Only 10% of students scored marks on this question. At high demand it is expected that where a question follows a figure, students should use information from the figure. Very few students linked the amount of infra-red radiation to temperature, or stated that different temperatures are displayed at different colours, despite that information being given in Figure 8.

05.2 This was a demanding question - students had to compare wavelengths given in nm and mm and in standard form. They then had to use their understanding of the electromagnetic spectrum. Less than 30% of students answered this question correctly.

05.3 The vast majority of the 40% of students that scored marks on this question only scored 1 mark, and that was mostly for saying that there is some risk of cancer with both.

05.4 This question performed as expected with 30% of students scoring 2 marks. Only 8% of students included the conversion to gain full marks.

Answer 05 · Examiner comments November 2021 | 8464/P/2H | Original Q5

05.5 20% of students gained at least 1 mark. Most of those stated that the energy from the electrons would cause heating and increase the temperature. Some went on to say that tungsten could be heated to a higher temperature than any other metal. No student scored full marks for explaining this meant that more electrons could be collided.

6.6.2.1 Types of electromagnetic waves

Answer 06 · Examiner comments June 2023 | 8464/P/2H | Original Q1

Question 1 (Standard demand)

01.1 60% of students correctly identified all three parts of the electromagnetic spectrum and scored both marks. However, 30% of students scored no marks.

01.2 50% of students were able to gain at least one mark on this question. The similarity was more accessible and was how the majority of the 35% that scored one mark got the mark. Many identified that both waves are transverse. For the difference, most students did not refer to a property of electromagnetic waves.

01.3 A little over 65% of students correctly identified that the process is called refraction.

01.4 Over 99% of students gained the mark. Students were given the equation sheet, which will have contributed to the overall performance on this question.

01.5 Over 70% of students were able to substitute correctly and give the correct answer to the question, to the correct order of magnitude. Approximately 20% of students correctly rearranged and substituted but did not use their calculator to evaluate the numbers in standard form, so scored 2 marks.

6.6.2.1 Types of electromagnetic waves

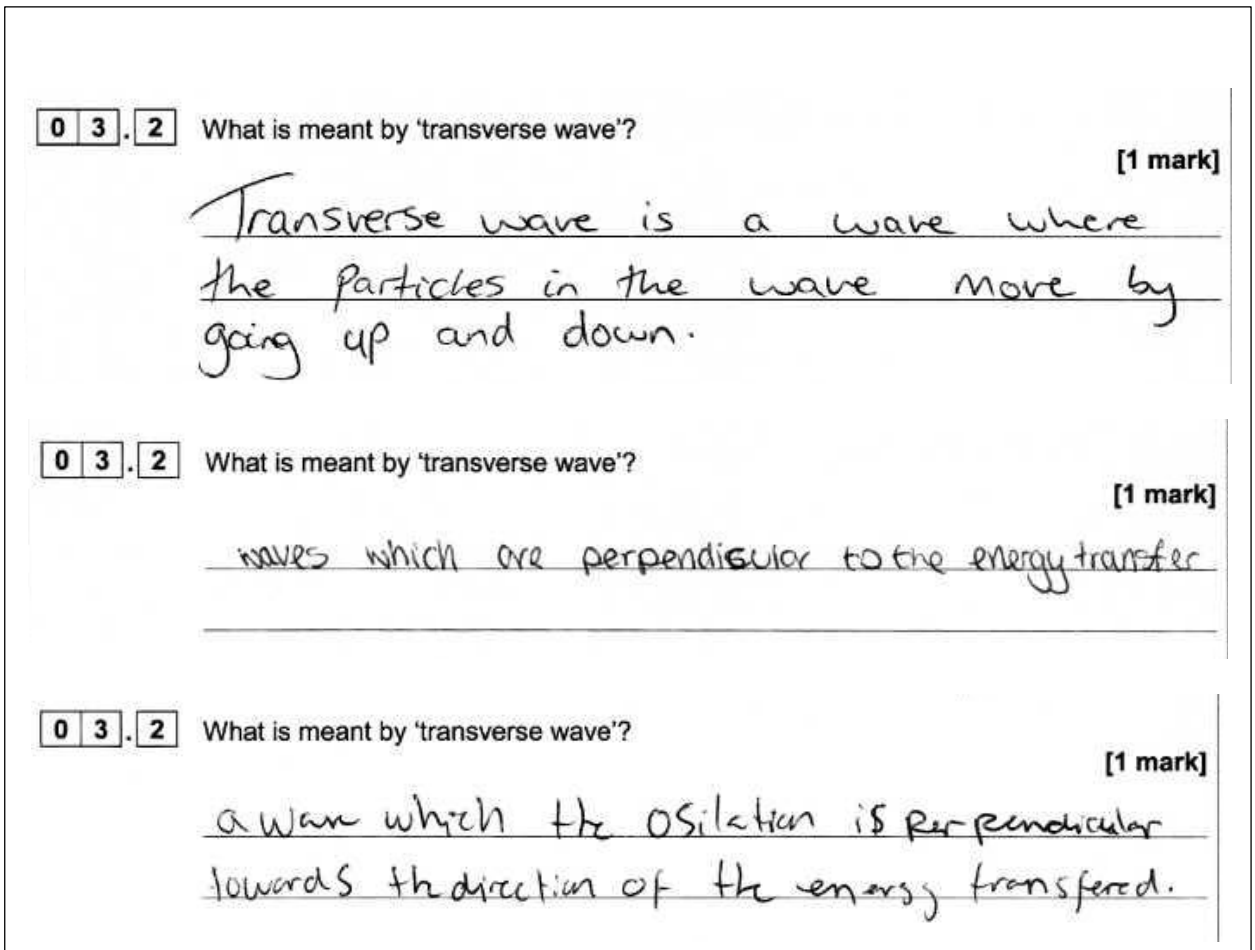
Answer 07 · Examiner comments

June 2024 | 8464/P/2H | Original Q3

Question 3 (standard, standard/high & high demand)

03.1 This question proved to be more demanding than expected, with just over 20% of students able to give a correct property of electromagnetic waves. Many students simply repeated the wording of the stem (that they can travel through a vacuum) even though they were asked of one *other* property. Some students attempted to describe a transverse wave.

03.2 Just over 20% of students were able to describe a transverse wave. Most demonstrated some understanding, but answers were often insufficient or too vague for the mark. When describing transverse waves, it must be clear that oscillations are perpendicular to the direction of energy transfer. Most answers were missing some part of the description.



0 3 . 2 What is meant by 'transverse wave'?

[1 mark]

Transverse wave is a wave where the particles in the wave move by going up and down.

0 3 . 2 What is meant by 'transverse wave'?

[1 mark]

waves which are perpendicular to the energy transfer

0 3 . 2 What is meant by 'transverse wave'?

[1 mark]

a wave which the oscilation is perpendicular towards the direction of the energy transfered.

The first two examples here are not sufficient to gain the marks. In the first, the student demonstrates some understanding but the language is very vague and there is no mention of energy transfer. The second response gives an *almost* complete description but there is no mention of oscillations/vibrations so the mark cannot be awarded.

The third response has all the required aspects of the description so the mark is awarded.

03.3 This AO1 question was well answered with 85% of students giving the correct response.

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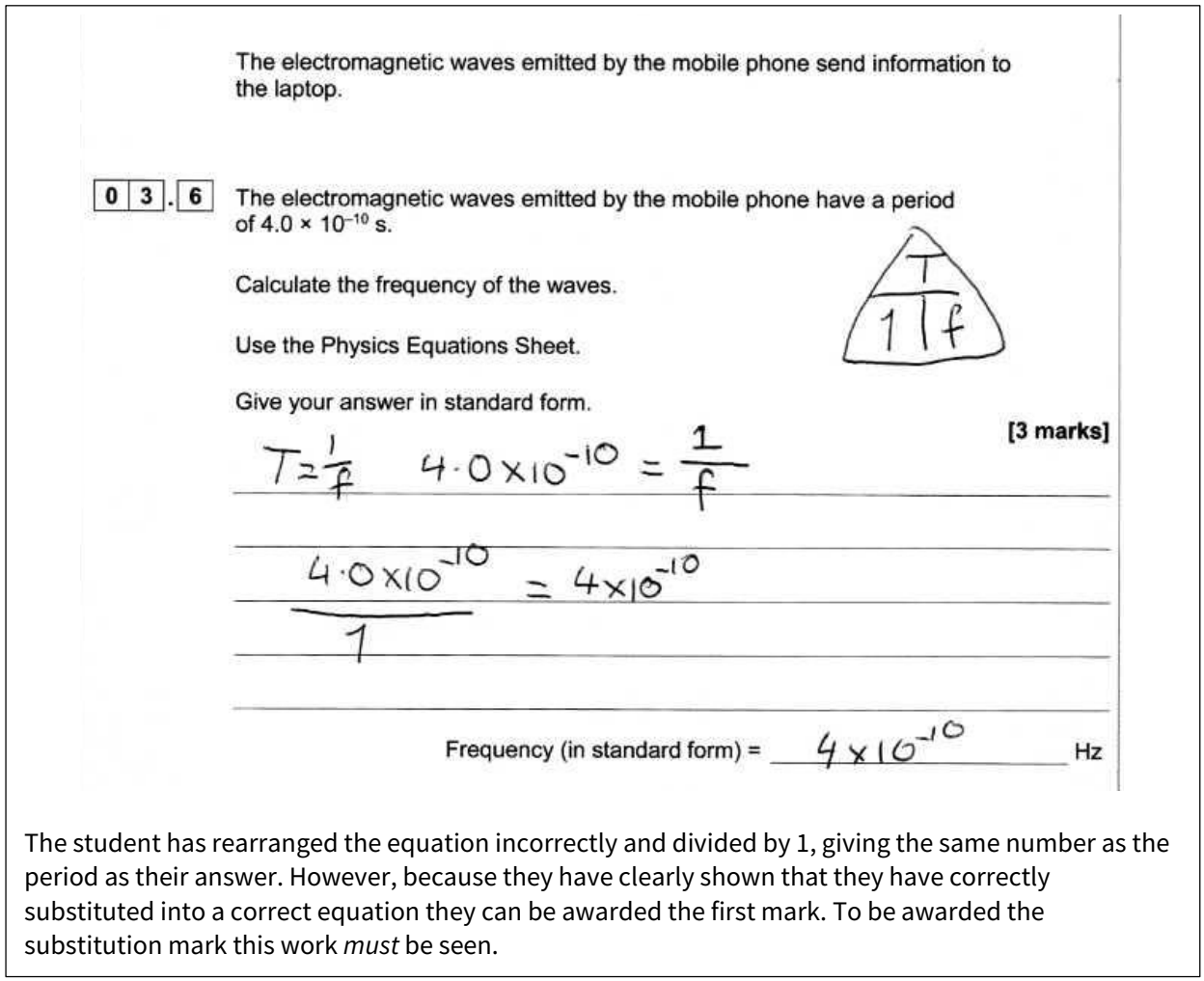
6.6.2.1 Types of electromagnetic waves

Answer 07 · Examiner comments June 2024 | 8464/P/2H | Original Q3

03.4 Just over 25% of students gave the correct colour for the shortest wavelength of visible light. Most of those that gained the mark did write violet but some stated purple, which was allowed. The most common incorrect answer was red, but a wide range of colours was given, including black and white.

03.5 Nearly 75% of students gained at least 1 mark for giving a risk, although less than 20% of students listed the three groups and correctly linked each to a specific risk such as UV causes skin cancer. Most of the 1-mark answers gained the compensation mark for stating that high-frequency electromagnetic waves cause cancer.

03.6 This question required students to manipulate numbers in standard form and 60% of students gained all 3 marks. The equation is relatively simple as it contains only two variables. However, this seemed to throw some students, who substituted correctly but then rearranged incorrectly and multiplied the period by one, so gave their final answer as the same number as the period. Approximately 10% of students inputted the power of ten incorrectly into their calculators; these students were, however, still able to score 2 marks.



The electromagnetic waves emitted by the mobile phone send information to the laptop.

0 3 . 6 The electromagnetic waves emitted by the mobile phone have a period of 4.0×10^{-10} s.

Calculate the frequency of the waves.

Use the Physics Equations Sheet.

Give your answer in standard form.

[3 marks]

$T = \frac{1}{f}$ $4.0 \times 10^{-10} = \frac{1}{f}$

$\frac{4.0 \times 10^{-10}}{1} = 4 \times 10^{-10}$

Frequency (in standard form) = 4×10^{-10} Hz

The student has rearranged the equation incorrectly and divided by 1, giving the same number as the period as their answer. However, because they have clearly shown that they have correctly substituted into a correct equation they can be awarded the first mark. To be awarded the substitution mark this work *must* be seen.

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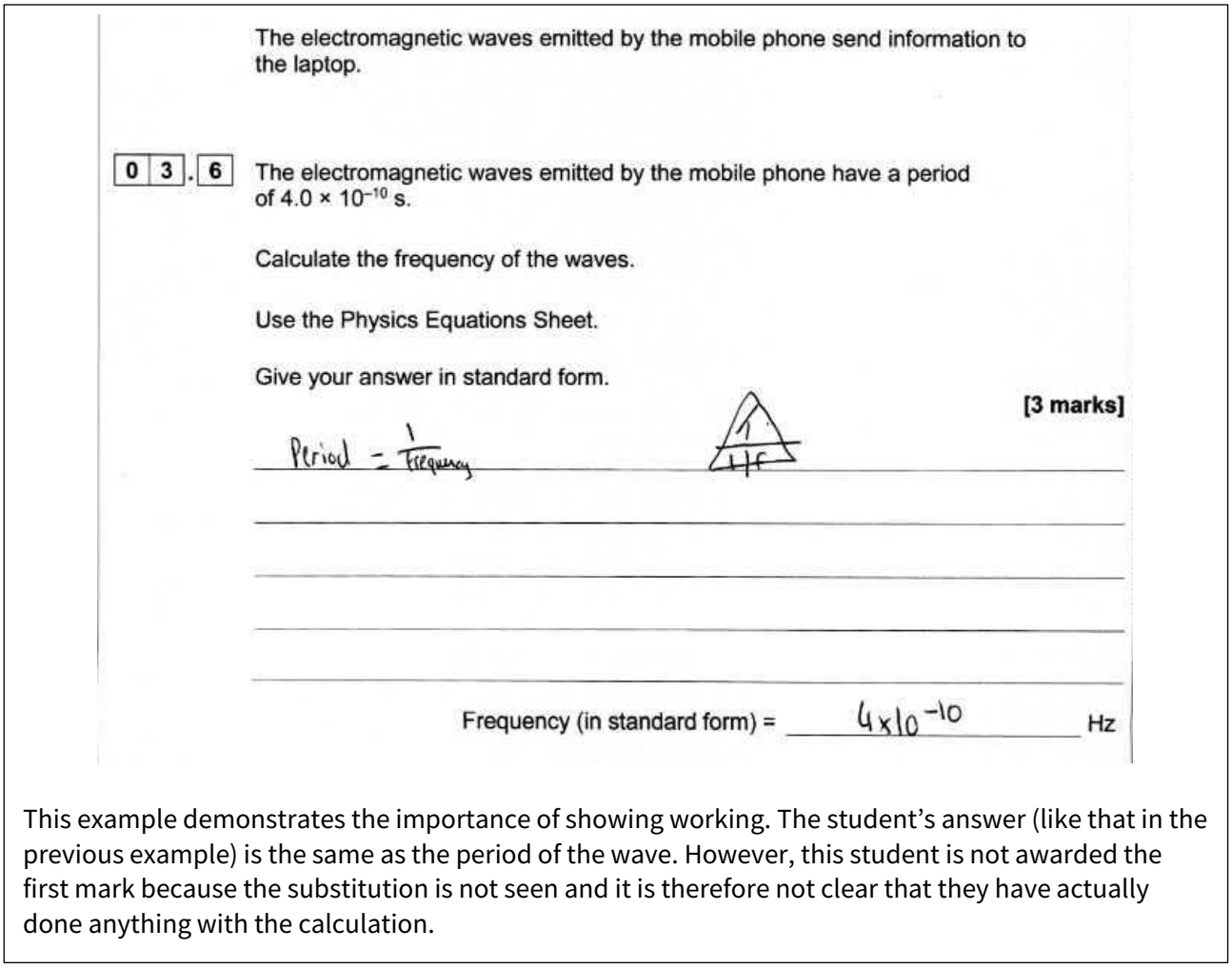
6.6.2.1 Types of electromagnetic waves

Answer 07 · Examiner comments June 2024 | 8464/P/2H | Original Q3



The electromagnetic waves emitted by the mobile phone send information to the laptop.

0 3 . 6 The electromagnetic waves emitted by the mobile phone have a period of 4.0×10^{-10} s.

Calculate the frequency of the waves.

Use the Physics Equations Sheet.

Give your answer in standard form.

[3 marks]

Period = 1 / Frequency

1 / Hf

Frequency (in standard form) = 4×10^{-10} Hz

This example demonstrates the importance of showing working. The student's answer (like that in the previous example) is the same as the period of the wave. However, this student is not awarded the first mark because the substitution is not seen and it is therefore not clear that they have actually done anything with the calculation.

03.7 The concepts being assessed in this high-demand question are very abstract and complex. Some students had obviously learnt this and wrote excellent explanations. 10% of students scored more than 1 mark.