AQA GCSE Combined Science - Trilogy | 8464

SPECIFICATION POINT 6.6.2.4

Uses and applications of electromagnetic waves

Mark schemes and examiner comments

Tier	**Higher**
Question groups	**13**
Available paper years	**2018–2025**

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.

6.6.2.4 Uses and applications of electromagnetic waves

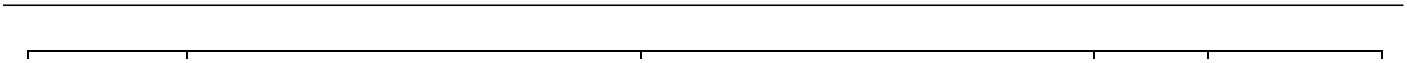
Answer 01 · Mark scheme June 2018 | 8464/P/1H | Original Q4

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.1	2 charged particles and 2 neutral particles		1	AO1 6.4.2.1
04.2	it is the type of radiation with a negative charge		1	AO1 6.4.2.1
04.3	it has a very long range in air		1	AO1 6.4.2.1
04.4	risk / activity associated with iodine-131 has decreased by a large amount		1	AO3 6.4.2.3
	because of short half-life	allow many half-lives have passed allow half-life is only 8 days 2nd marking point dependent on 1st marking point	1	
	risk / activity associated with caesium-137 will not have decreased by much	allow activity has halved	1	
	because of long half-life	allow only one half-life has passed 4th marking point dependent on 3rd marking point	1	
04.5		an answer of 2136 scores **3** marks		AO2 6.4.2.3
	5 half-lives	allow any correct method eg ½ × ½ × ½ × ½ × ½ = 1/32	1	
	5 × 30 = 150		1	
	1986 + 150 = 2136	any calculation using a value of 137 scores zero	1	
Total			**10**	

6.6.2.4 Uses and applications of electromagnetic waves

Answer 01 · Mark scheme

June 2018 | 8464/P/1H | Original Q4



6.6.2.4 Uses and applications of electromagnetic waves

Answer 02 · 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	1	
		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		
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 $\lambda = \frac{3.0 \times 10^8}{4.8 \times 10^9}$	1	
		this mark may be awarded if the standard form values are incorrectly converted		
	$\lambda = 0.0625$ (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	

6.6.2.4 Uses and applications of electromagnetic waves

Answer 02 · Mark scheme

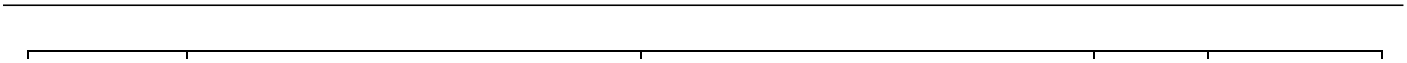
June 2018 | 8464/P/2H | Original Q5

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**	

6.6.2.4 Uses and applications of electromagnetic waves

Answer 02 · Mark scheme

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



6.6.2.4 Uses and applications of electromagnetic waves

Answer 03 · Mark scheme June 2019 | 8464/P/1H | Original Q6

Question	Answers	Extra information	Mark	AO / Spec. Ref.	ID
06.1	mass number stays the same, charge stays the same		1	AO1.1 6.4.2.2	A
06.2	gamma radiation is only weakly ionising **or** most gamma radiation will pass through any detector	 allow gamma radiation is very penetrating	1	AO1.1 6.4.2.1	E
06.3	 any two from • the radiation spreads out in all directions • only some of the radiation goes into the G-M tube • only some of the radiation passing into the GM tube is detected	allow **2** marks for only some of the radiation passing into the GM tube is detected because gamma is weakly ionising	 2	AO1.1 6.4.2.4	E
06.4	to reduce the amount of radiation received because radiation increases the risk of cancer or (genetic) mutation	allow to reduce irradiation (of the teacher) allow causes cancer or (genetic) mutation ignore references to contamination	1 1	AO1.1 6.4.2.1 WS 1.4	E

6.6.2.4 Uses and applications of electromagnetic waves

06.5	a calculation of the product of thickness and count rate a second calculation of the product of thickness and count rate a comparison of the calculated values and a recognition that they are different **OR** A calculation of half the count rate (1) A comparison with the count rate for double that thickness (1) A recognition that the values are different (1)	examples of calculations 0.5 × 110 = 55 1.0 × 60 = 60 1.5 × 33 = 50 2.0 × 18 = 36 2.5 × 10 = 25 e.g. $\frac{110}{2}$ = 55 the first two marks may be scored for a count rate divided by 3, 4 or 5 compared with the corresponding count rate for 3, 4 or 5 times the thickness e.g. 55 ≠ 60	1 1 1	AO3.1b 6.4.2.1	E
06.6	$^{140}_{57}La \longrightarrow {}^{0}_{-1}e + {}^{140}_{58}Ce$	allow **1** mark for correct numbers on electron allow **1** mark for correct numbers on Ce	2	AO1.1 AO1 in isolation AO1.2 6.4.2.2	E

06.7		an answer of $\frac{1}{32}$ or equivalent scores **4** marks		AO3.1a 6.4.2.3	E
	half-life = 50 seconds	this may be indicated on Figure 7	1		
	250 seconds difference in age = 5 half lives	allow 100 seconds = 2 half lives **and** 350 seconds = 7 half lives	1		
	ratio = $\left(\frac{1}{2}\right)^5$ **or** ratio = $\frac{1}{2}\times\frac{1}{2}\times\frac{1}{2}\times\frac{1}{2}\times\frac{1}{2}$	allow this mark if they have halved $1.25(\times 10^{23})$ five times to get $0.0390625(\times 10^{23})$ for example $1.25(\times 10^{23})$ → $0.625(\times 10^{23})$ → $0.3125(\times 10^{23})$ → $0.15625(\times 10^{23})$ → $0.078125(\times 10^{23})$ → $0.0390625(\times 10^{23})$	1		
	ratio = $\frac{1}{32}$ **or** ratio = 1:32	allow ratio = 0.031 allow 32:1 **or** 32	1		
06.8	tangent drawn on graph	do not allow a line drawn that crosses the graph line	1	AO2.2 6.4.2.1	E
	use of gradient = $\frac{(\Delta \text{ no. of atoms})}{\Delta \text{ time}}$	values must be taken from their tangent drawn at 20 seconds	1		
	gradient = 5.3 $(\times 10^{21})$ (Bq)	allow gradient = 0.053 $(\times 10^{23})$ (Bq) allow a range between 4.7 $(\times 10^{21})$ (Bq) and 5.9 $(\times 10^{21})$ (Bq)	1		
Total			**18**		

6.6.2.4 Uses and applications of electromagnetic waves

Answer 04 · Mark scheme

November 2020 | 8464/P/1H | Original Q2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
02.1	A = 206		1	AO2 6.4.2.2
02.2	Z = 82		1	AO2 6.4.2.2
02.3	89 39	numbers must be in this order	1 1	AO2 6.4.2.2
02.4	electromagnetic waves		1	AO1 6.4.2.1

6.6.2.4 Uses and applications of electromagnetic waves

Answer 04 · Mark scheme

November 2020 | 8464/P/1H | Original Q2

Question	Answers	Mark	AO / Spec. Ref.
02.5	**Level 3:** Relevant points (reasons/causes) are identified, given in detail and logically linked to form a clear account.	5–6	AO1 6.4.1.2 6.4.2.1 6.4.2.2
	Level 2: Relevant points (reasons/causes) are identified, and there are attempts at logical linking. The resulting account is not fully clear.	3–4	
	Level 1: Points are identified and stated simply, but their relevance is not clear and there is no attempt at logical linking.	1–2	
	No relevant content	0	
	Indicative content <u>alpha radiation</u> • an alpha particle is the same as a helium nucleus • alpha is the least penetrating • alpha is stopped by paper or skin • alpha has the shortest range in air • alpha will travel a few cm in air • because alpha is most ionising • because alpha has a charge of +2 <u>beta radiation</u> • a beta particle is an electron (emitted from the nucleus) • beta penetrates less than gamma and more than alpha • beta is stopped by a thin sheet of aluminium • beta has a shorter range than gamma • beta will travel up to 1m in air • because beta is more ionising that gamma and less ionising than alpha • because beta has a charge of -1 <u>gamma radiation</u> • gamma radiation is an electromagnetic wave • gamma is the most penetrating • gamma is reduced/stopped by several cm of lead or thick concrete • gamma has the largest range in air • gamma will travel very large distances in air • because gamma is least ionising • because is uncharged to access level 3 the answer should compare alpha, beta and gamma radiation and provide some explanation of their properties		

Total			11

6.6.2.4 Uses and applications of electromagnetic waves

Answer 04 · Mark scheme November 2020 | 8464/P/1H | Original Q2

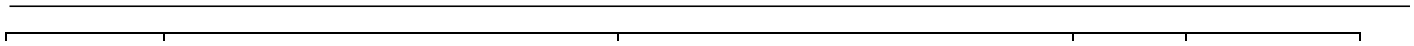
Answer 05 · Mark scheme November 2020 | 8464/P/2H | Original Q5

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**	

6.6.2.4 Uses and applications of electromagnetic waves

Answer 05 · Mark scheme

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



6.6.2.4 Uses and applications of electromagnetic waves

Answer 06 · Mark scheme

November 2021 | 8464/P/1H | Original Q2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
02.1	more than 10 000 times bigger		1	AO1 6.4.1.1
02.2	the atom becomes a positive ion the atom loses an electron		1 1	AO1 6.4.1.2
02.3	beta radiation is only weakly ionising		1	AO3 6.4.2.1

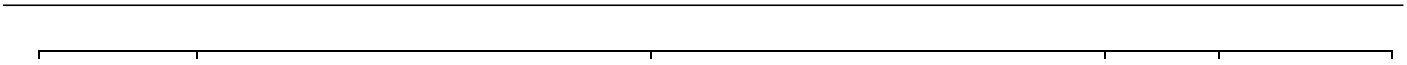
Answer 06 · Mark scheme

Question	Answers	Mark	AO / Spec. Ref.
02.4	**Level 3:** The method would lead to the production of a valid outcome. The key steps are identified and logically sequenced.	5–6	AO3 6.4.2.1
	Level 2: The method would not necessarily lead to a valid outcome. Most steps are identified, but the method is not fully logically sequenced.	3–4	
	Level 1: The method would not lead to a valid outcome. Some relevant steps are identified, but links are not made clear.	1–2	
	No relevant content	0	
	Indicative content • move the detector very close to the source • record the count rate • position the paper between the source and the detector • record the new count rate • alpha radiation will not penetrate through paper • if the count rate with the paper is (significantly) less than without then the source emits alpha radiation • remove the paper and position the aluminium between the source and the detector • record the new count rate • (alpha and) beta radiation will not penetrate through the aluminium • if the count rate has (significantly) reduced compared with using paper then beta radiation is present • if radiation penetrates through the aluminium then gamma radiation is present • the experiment should be repeated and mean results calculated because radioactivity is a random process To access level 3, the candidate must use the paper sheet, the aluminium sheet and no sheet, and describe how the results would indicate the presence of alpha, beta or gamma radiation.		
Total		**10**	

6.6.2.4 Uses and applications of electromagnetic waves

Answer 06 · Mark scheme

November 2021 | 8464/P/1H | Original Q2



6.6.2.4 Uses and applications of electromagnetic waves

Answer 07 · 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

6.6.2.4 Uses and applications 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**	

6.6.2.4 Uses and applications of electromagnetic waves

Answer 07 · Mark scheme

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

Question 5

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.1	**any two pairs from**		4	
	• place each flask the same distance from the infrared lamp	allow use two lamps at an equal distance from each flask		AO3
	• so the intensity of infrared radiation incident on each flask is the same			AO1
	• use flasks of the same shape and size			AO3
	• so the surface area is the same			AO1
				6.6.2.2
	• use equal volumes of water • because volume of water affects the rate at which the water temperature increases	allow use equal masses of water		

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.2	7.5	allow 8	1	AO3 6.6.2.2
	240		1	

Answer 08 · Mark scheme

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.3	(black flask line has) a greater gradient **or** temperature (of the black flask) increased more (during the same time)		1	AO3 6.6.2.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.4	the flasks absorb infrared radiation **and** transfer energy to surroundings (by heating and emission of infrared)	allow water for flasks throughout	1	AO3 6.6.2.2
	initially the rate of absorption of infrared is greater than the rate of energy transfer to the surroundings (causing the temperature to increase)		1	
	(rate of) energy transfer to surroundings increases as the temperature of the flasks increase		1	
	eventually the rate of energy transfer to surroundings = rate of energy transfer to flasks (causing the temperature to become constant)		1	

Total Question 5		**11**

6.6.2.4 Uses and applications of electromagnetic waves

Answer 09 · 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

6.6.2.4 Uses and applications of electromagnetic waves

Answer 09 · 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	$3.0 \times 10^{8} = f \times 5.0 \times 10^{-7}$ $f = \dfrac{3.0 \times 10^{8}}{5.0 \times 10^{-7}}$ $f = 6 \times 10^{14}$ (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

6.6.2.4 Uses and applications of electromagnetic waves

Answer 10 · 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

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

6.6.2.4 Uses and applications of electromagnetic waves

Answer 10 · Mark scheme

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

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**

Question 4

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.1	*alpha particle* (a particle consisting of) two neutrons **and** two protons (from the nucleus) *beta particle* (a high-speed) electron (from the nucleus) *gamma ray* (a high frequency / energy) electromagnetic wave / radiation (from the nucleus)	allow helium nucleus	1 1 1	AO1 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.2	198 0 80 –1	**1** mark for the top row **1** mark for the bottom row	1 1	AO1 6.4.2.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.3	2.75 (days)	allow 2.7 to 2.8 allow an answer consistent with a correct pair of values for activity allow **1** mark for a horizontal line drawn from 11	2	AO2 6.4.2.3

Answer 11 · Mark scheme

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.4	activity = 6.0 (kBq)	subsequent marks may be awarded if an activity of 7.0 (kBq) is used	1	AO3
	$\frac{22-6.0}{22}\times 100$		1	AO2
	72.7…(%)		1	AO2
	73 (%)	allow a percentage calculated using data from the graph given to two significant figures	1	AO2 6.4.2.3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.5	Any **two** from: • beta only has a short range (in tissue) • increases the chance of killing the cancer cells • decreases the risk to healthy cells		2	AO3 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.6	the risk of removing the sample is greater than the risk of leaving the sample in the patient **or** the activity will reduce to a safe level in a short time	allow the risk of leaving the sample in the patient is very small	1	AO3 6.4.2.1 6.4.2.4

Total Question 4	**14**

Question 3

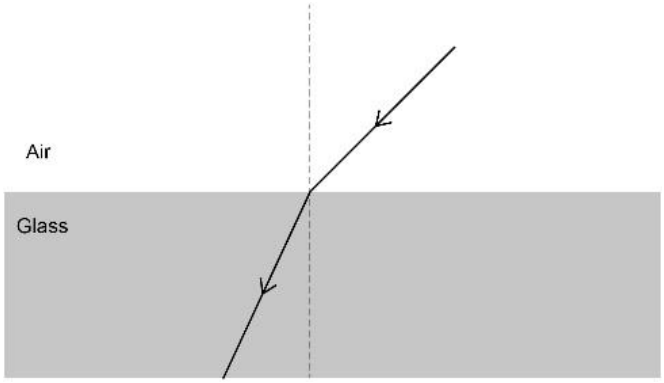
Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.1	oscillations / vibrations are perpendicular to the direction of energy transfer	allow oscillations / vibrations are perpendicular to the direction of wave travel allow **1** mark for oscillations/ vibrations are perpendicular	2	AO1 6.6.1.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.2	skin cancer **or** causes skin to age (prematurely)	allow skin cell mutation ignore cancer unqualified	1	AO1 6.6.2.3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.3	shorter		1	AO1 6.6.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.4	$3.00 \times 10^{8} = 6.25 \times 10^{14} \times \lambda$ $\lambda = \dfrac{3.00 \times 10^{8}}{6.25 \times 10^{14}}$ $\lambda = 4.80 \times 10^{-7}$ (m) $\lambda = 480$ (nm)	 allow a correct conversion to nm of their incorrectly calculated value of λ using the numbers from the question	1 1 1 1	AO2 6.6.1.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.5	the speed of the light / waves / wavefronts decreases (when entering the lens) (so) one end of the wavefront slows before the other end	allow the speed of light / waves / wavefronts is less in the lens (than in air) ignore lens has a higher density than air ignore references to refractive index	1 1	AO1 6.6.2.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.6	normal line drawn ray drawn with an angle of refraction of 28°  ignore ray below the glass	allow a normal line that only extends from the boundary into the glass	1 1	AO2 6.6.2.2

Total Question 3	12

Answer 13 · Mark scheme

June 2025 | 8464/P/2H | Original Q5

Question 5

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.1	random		1	AO3 6.6.2.2 RPA 21

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.2	range = 0.5 – (–0.5) **or** range = 1 **or** uncertainty = $\frac{0.5 - (-0.5)}{2}$	allow $0.5-\left(\frac{0.5+0.2-0.3+0.5+0.1}{5}\right)$ allow $\left(\frac{0.5+0.2-0.3+0.5+0.1}{5}\right)-0.5$	1	AO3 6.6.2.2 RPA 21
	uncertainty = (±) 0.5 (°C)		1	

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.3	*y*-axis scale of 10 °C per cm		1	AO2
	all points plotted correctly	allow **1** mark for 3 or 4 points plotted correctly allow a tolerance of ± ½ small square'	2	AO2
	curved line of best fit ignoring anomalous point at 8 minutes		1	AO3 6.6.2.2 RPA 21

Answer 13 · Mark scheme

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.4	2 minutes = 120 seconds	subsequent marks may be awarded if time is incorrectly / not converted	1	AO2 6.6.2.2 RPA21
	rate = $\frac{63 - 18}{120}$		1	
	rate = 0.375 (°C/s)	allow 0.38 (°C/s)	1	

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.5		ignore references to heat throughout		AO1 6.6.2.2 RPA21
	black surfaces are good absorbers (and emitters of infrared / radiation)		1	
	white surfaces are poor absorbers (and emitters of infrared / radiation)		1	
	as the temperature of the cubes increases the cubes emit infrared / radiation at a greater rate		1	
	at maximum / constant temperature, each cube emits infrared /radiation at the same rate that it absorbs infrared / radiation		1	

Total Question 5	14

6.6.2.4 Uses and applications of electromagnetic waves

Answer 01 · Examiner comments June 2018 | 8464/P/1H | Original Q4

Question 4 (Standard/high demand)

04.1 51% of students knew what an alpha particle consists of.

04.2 70% of students knew that a particle of beta radiation has a negative charge.

04.3 63% of students knew that gamma radiation has a very long range in air.

04.4 45% of students scored marks on this question. Students who failed to score often understood there is a risk associated with nuclear radiation but were unable to relate that to the changing levels of radiation with time. There were lots of misconceptions about half-life, the most common being that iodine-131 would not emit any radiation after two half-lives.

Answer 02 · 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.

6.6.2.4 Uses and applications of electromagnetic waves

Answer 02 · 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.

Answer 03 · Examiner comments

June 2019 | 8464/P/1H | Original Q6

Question 6 (High demand)

06.1 Just under half of students gained this mark.

06.2 Slightly less than 30% of students gained this mark for identifying that gamma radiation is weakly ionising or very penetrating.

06.3 Around 10% of students gained marks on this question. There was a very common apparent misunderstanding about what is meant by the term count-rate, with many students stating that the count-rate is the total number of decays that have happened since the radioactive source was created. It was also quite common to see answers about the random nature of decay making the count-rate unpredictable.

06.4 While about a quarter of all students gained at least 1 mark on this question, very few gained both marks. The most common reason for gaining a mark was mentioning a cancer risk. Many students stated that standing away from the source would prevent irradiation completely, rather than reducing the level of irradiation and therefore reducing the risk. A common misconception was that if the teacher stood closer to the experiment then this would affect the results.

06.5 The concept of inverse proportion was not understood well. Many students incorrectly described inverse proportion as being a straight line with a negative gradient and illustrating that this was not the trend shown by pointing out that the count-rate decreased by different amounts each time an extra half centimetre of lead was introduced. Around 13% of students gained marks for their response to this question.

06.6 Around 40% of students could recall the atomic and mass numbers which go with an electron, and around a quarter of all students gained both marks on this question.

06.7 This question was aimed at the highest-attaining students, and required a high level of logical thought to arrive at the correct answer. Over a fifth of students managed to gain at least 1 mark, with just under 6% of students scoring all four marks.

06.8 This question was also aimed at the highest-attaining students and tested some of the maths content of the new science specifications at GCSE. Just under 6% of students attempted to draw a tangent on the graph, and therefore gained some credit. Many of

6.6.2.4 Uses and applications of electromagnetic waves

Answer 03 · Examiner comments June 2019 | 8464/P/1H | Original Q6

those who attempted to calculate the gradient of the tangent divided the change in *x* by the change in *y*, giving an incorrect answer.

6.6.2.4 Uses and applications of electromagnetic waves

Use of statistics

Statistics used in this report may be taken from incomplete processing data. However, this data still gives a true account on how students have performed for each question.

Mark Ranges and Award of Grades

Grade boundaries and cumulative percentage grades are available on the Results Statistics page of the AQA Website.

6.6.2.4 Uses and applications of electromagnetic waves

Answer 06 · Examiner comments November 2021 | 8464/P/1H | Original Q2

Question 02 (Standard demand)

02.1 This question was answered correctly by roughly 40% of students.

02.2 Around a third of students gained both marks, with approximately half gaining one mark.

02.3 Many students gave answers which were too vague, such as “beta radiation is not strong enough”, or stated that beta radiation is not ionising, which is incorrect. The mark was gained by just under a fifth of students.

02.4 Most students struggled to answer this question, with many struggling to write answers containing any relevant content. Many answers suggested placing the piece of paper or aluminium into the radioactive source holder, for example. A fair proportion of students did not read the question carefully, and suggested changing the radioactive source to test the equipment using one source of just alpha radiation, one of just beta, and one that emits just gamma radiation, although it was still possible to gain full credit if they did this. Some students recalled that paper stops alpha radiation, that aluminium stops beta radiation, and that gamma would penetrate both, but didn’t describe how to set up the equipment. Others described how to set up the equipment, but not how to use any measurements to draw conclusions.
Nearly one in ten students did not attempt to answer the question, and most answers did not give enough information to move out of level 1.

Answer 07 · 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.

6.6.2.4 Uses and applications of electromagnetic waves

Answer 07 · 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.

Answer 08 · Examiner comments June 2022 | 8464/P/2H | Original Q5

Question 5 (Standard/high and high demand)

05.1 Approximately 60% of students were able to suggest one improvement to the method. Normally this was to use two flasks the same size and shape. 30% of students gained 2 marks - in the majority of cases they suggested two improvements. Only about 10% of students scored 3 or 4 marks for explaining why the changes improved the investigation.

05.2 90% of students scored 1 mark on this question. Approximately 50% were able to score both marks.

05.3 Approximately 75% of students gained the mark on this question. Answers that were not given credit often referred to a higher final temperature, and not that the initial rate at which the temperature increased was higher.

05.4 This question was a high demand question and proved to be the most challenging on the paper. Very few students appreciated that the flasks were both absorbing radiation and losing energy to the environment. Most incorrect answers just stated that the water had reached its maximum temperature, with many stating that it had reached its optimum temperature.

6.6.2.4 Uses and applications of electromagnetic waves

Answer 09 · 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.

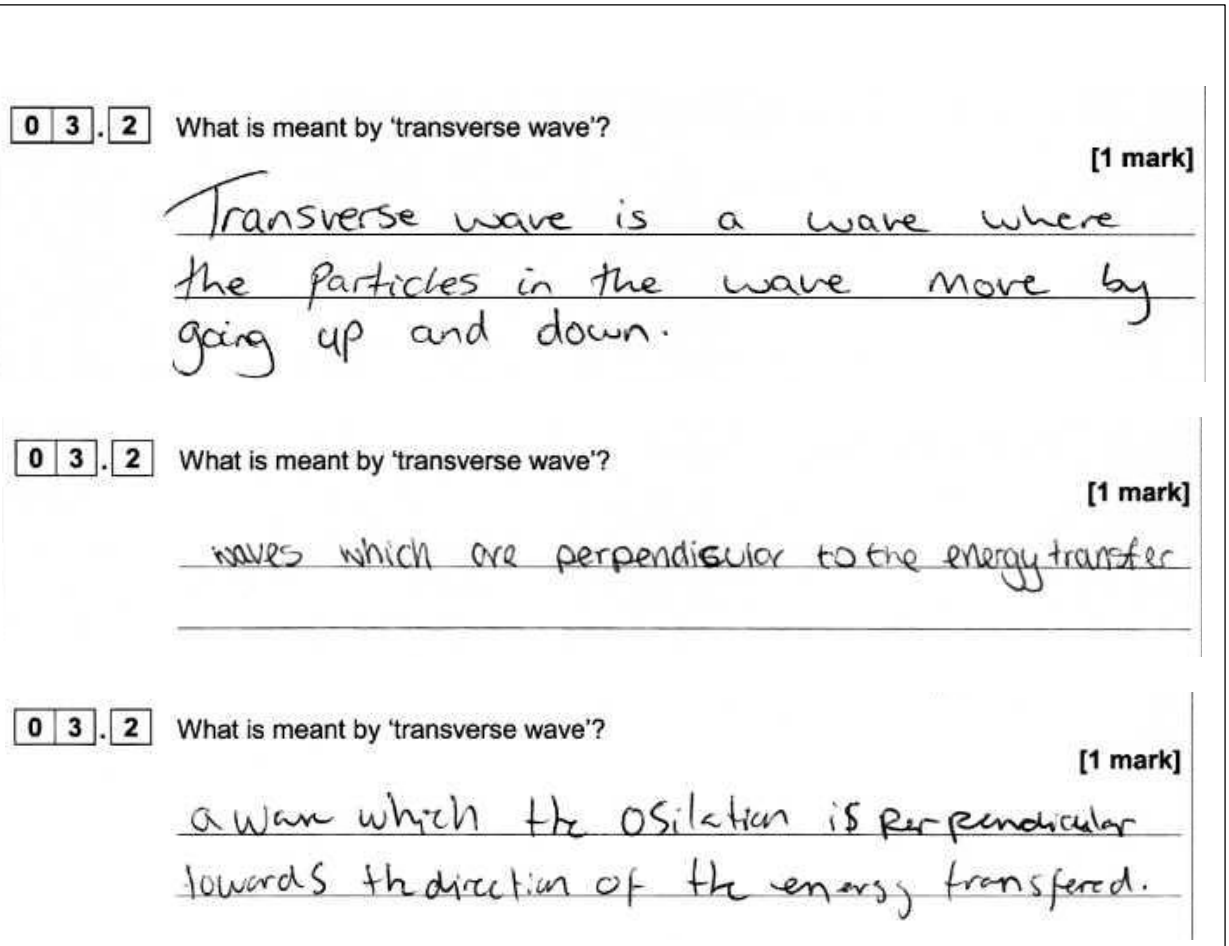
01.5 Over 70% of students were able to substitute correctly and give the correct answer to the question, to the correct order of magnitude. Approximately 20% of students correctly rearranged and substituted but did not use their calculator to evaluate the numbers in standard form, so scored 2 marks.

Answer 10 · Examiner comments

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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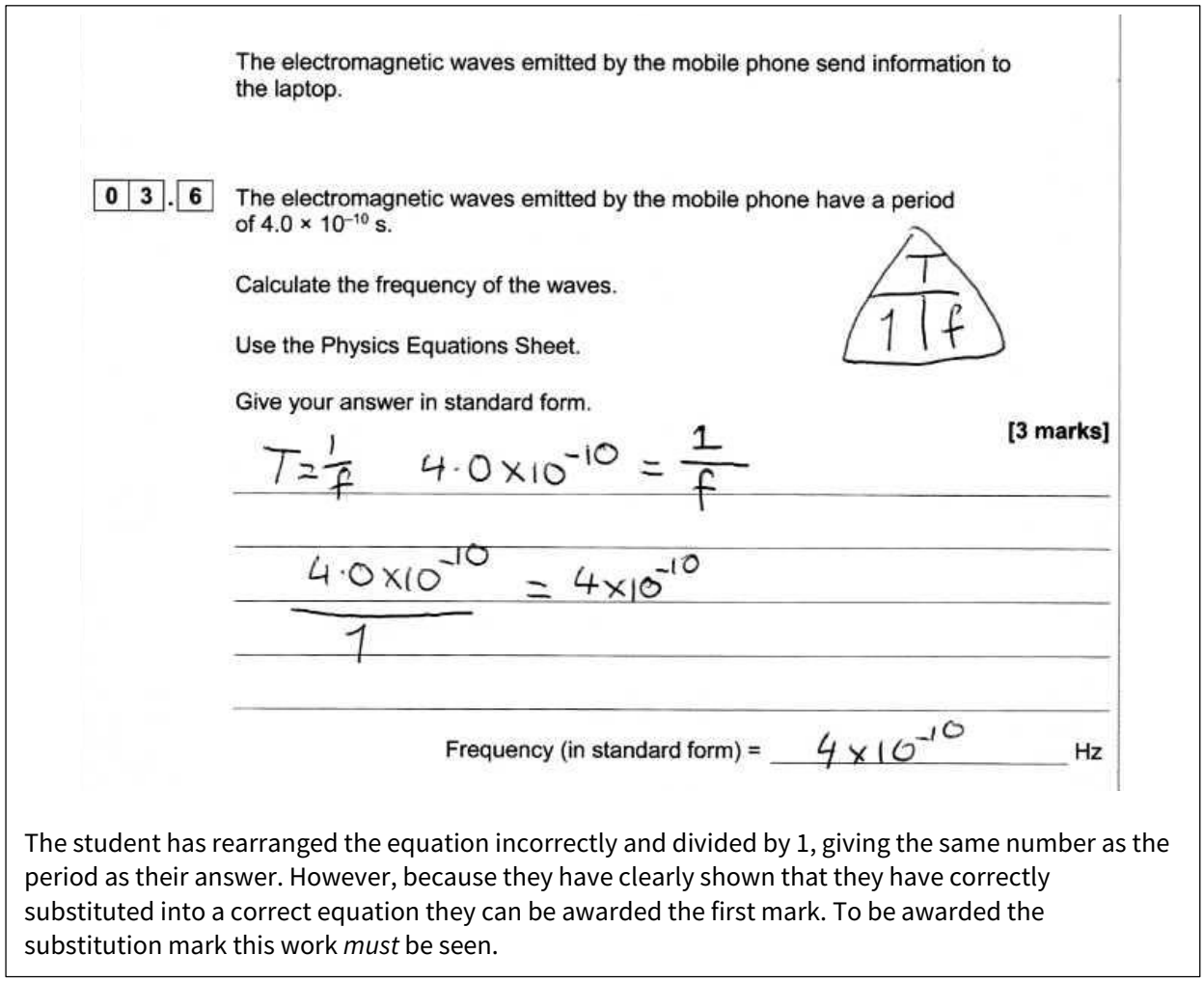
6.6.2.4 Uses and applications of electromagnetic waves

Answer 10 · 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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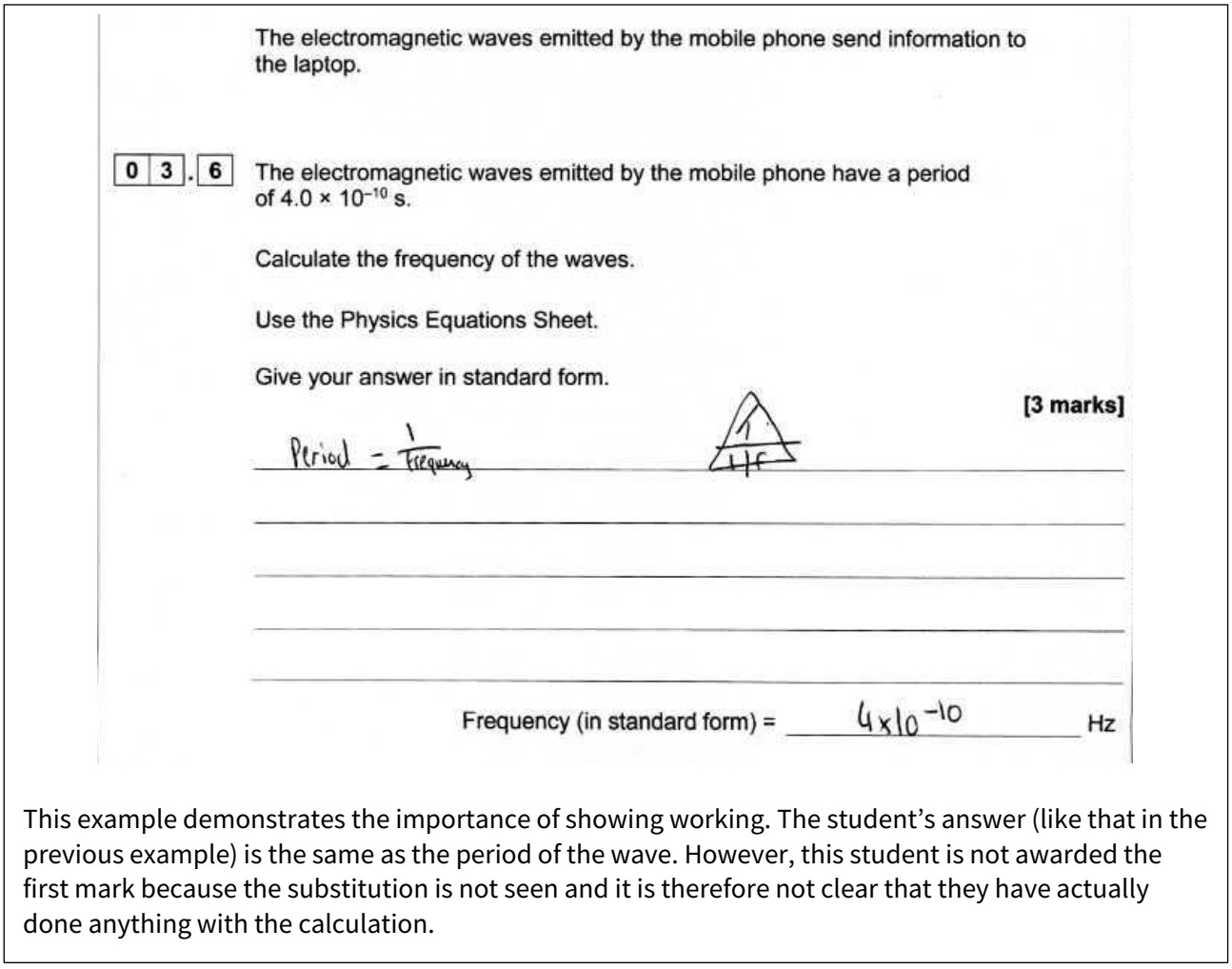
6.6.2.4 Uses and applications of electromagnetic waves

Answer 10 · 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

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.

Answer 11 · Examiner comments

June 2025 | 8464/P/1H | Original Q4

Question 4 (Standard/high and high demand)

04.1 Some students misinterpreted the question and did not describe an alpha particle, beta particle, and gamma ray, but described their properties. 50% of students were able to correctly describe one of them, but only 20% correctly described all three.

04.2 40% of students gained both marks. The majority of the 15% of students who only gained one mark, made a mistake on the bottom row.

04.3 60% of students gained a mark on this question. 10% of students correctly drew the line from 11, but either the line was not drawn accurately enough, or they then mis-read the scale on the *x*-axis. 50% of students gained both marks.

04.4 80% of students were able to get started on this question by correctly reading the activity as 6.0 (kBq) but could not get any further. Many of those that failed to gain any further calculation marks worked out what 6.0 was as a percentage of 22. 40% of students gained the 3 calculation marks. The mark for the correct significant figures was still awarded if an error had been made in the calculation.

04.5 Students found this high demand question challenging. 30% of students did gain a mark and most of those answered that the sample being very near to the cancer cells decreases the risk to healthy cells. Less than 5% of students gained two marks for also saying that beta only has a short range. Very few students stated that it increased the chance of killing the cancer cells.

04.6 20% of students gained the mark on this high demand question. There were approximately equal numbers of answers that stated the risk of removing the sample is greater than the risk of leaving the sample in the patient and answers that stated the activity will reduce to a safe level in a short time. A common incorrect answer was that it would protect the patient if the cancer returned, most students did not appreciate the short half-life of the gold-198.

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6.6.2.4 Uses and applications of electromagnetic waves

Answer 12 · Examiner comments June 2025 | 8464/P/2H | Original Q3

Question 3 (Standard, standard/high and high demand)

03.1 About a quarter of students were able to give a complete and correct definition of a transverse wave, with just under a fifth giving a definition that gained partial credit.

03.2 Nearly two thirds were able to give another risk caused by exposure to ultraviolet.

03.3 Just over 60% identified that ultraviolet has a shorter wavelength than visible light.

03.4 Giving an answer in nm proved to be very challenging, with just under 10% managing to work out the correct final answer.

A surprisingly large proportion of students struggled to calculate the correct power of ten to their answer, with working such as $\frac{3\times10^{8}\ \text{m/s}}{6.25\times10^{14}\ \text{Hz}} = 4.8\times10^{21}\ \text{m}$ being relatively common. Students who did this could then go on to convert their calculated value into nm and gain the final mark, but it was very common for students to multiply their answer by 10^{-9} instead of dividing by 10^{-9}, so the final mark was not often gained. Many students who attempted the conversion to nm thought that nano referred to 10^{-3} or 10^{-6}.

0 3 . 4 A wave of visible light has a frequency of 6.25×10^{14} Hz.

speed of light = 3.00×10^{8} m/s

Calculate the wavelength of this light.

Use the Physics Equations Sheet.

Give your answer in nanometres (nm).

[4 marks]

wave speed = frequency x wavelength.

wave speed / frequency = wavelength.

$3.00\times10^{8} / 6.25\times10^{14} = 4.8\times10^{21}$ m

$4.8\times10^{21} / 1000 = 4.8\times10^{18}$ nm

Wavelength = 4.8×10^{18} nm

This student correctly substituted into and rearranged the equation but made errors when calculating the wavelength in metres. This answer also illustrates the difficulties many students had in converting a value from metres to nanometres.

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6.6.2.4 Uses and applications of electromagnetic waves

Answer 12 · Examiner comments

03.5 Students struggled to explain why refraction occurs using the idea of wavefronts. It was very common for students to refer to the density of the glass, and sometimes to optical density. All of these references were ignored. Some students recalled that the wave speed changes but did not make it clear whether they thought the waves were increasing or decreasing in speed, so did not score any marks. Only about a fifth of students gained any credit in this question.

03.6 About four in ten students gained at least one mark, with approximately 20% giving a fully correct answer. The refracted rays drawn were in many different directions, but those who were able to draw the ray in the correct direction usually did so with accuracy and gained the second mark, and those that did not score the second mark tended to draw their refracted rays in completely the wrong direction. Some students gained the mark for drawing the refracted ray without having drawn a normal.

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6.6.2.4 Uses and applications of electromagnetic waves

Answer 13 · Examiner comments June 2025 | 8464/P/2H | Original Q5

Question 5 (Standard, standard/high and high demand)

05.1 Only about 15% of students were able to correctly identify the random error in the results. This perhaps illustrates a misconception that many students perceive that digital devices give a definitive value for what they are measuring, and therefore cannot possibly show random errors.

05.2 This question was not well answered, with fewer that one in five students gaining any credit. Many students correctly calculated that the sum or mean of the numbers is zero, but this gained no credit. It was also common to see students calculate the size of the range, but to state that this was equal to the uncertainty, so gained no marks.

