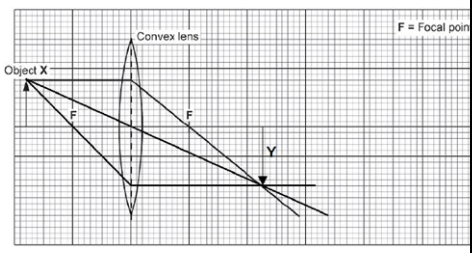
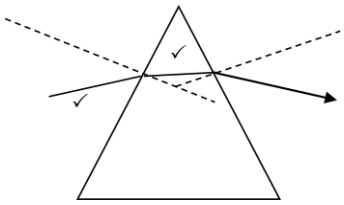
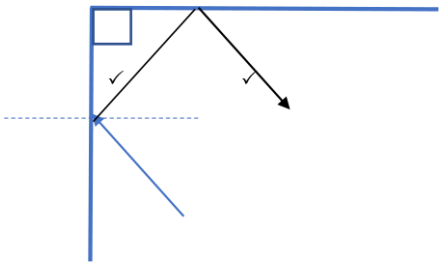
Mark scheme – The Electromagnetic Spectrum (H)

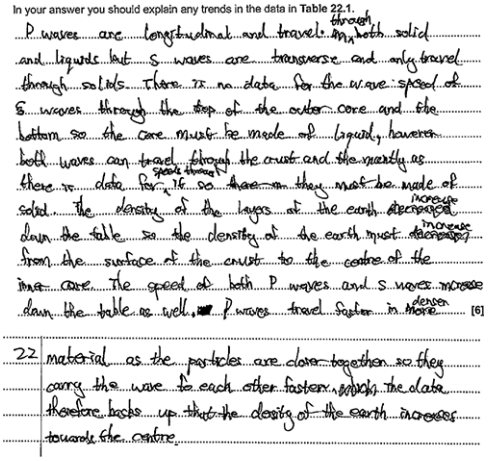
Question			Answer/Indicative content	Marks	Guidance
1			**B** ✓	**1 (AO1.2)**	**Examiner's Comments** Higher ability candidates were able to correctly apply their knowledge of refraction through a prism (option B). Most lower ability candidates chose one of the distractors and were unable to explain why violet light is refracted more than red light.
			Total	**1**	
2			**D** ✓	1 (AO2.2)	
			Total	**1**	
3	a		There is no (known) risk associated with ultrasound / ultrasounds are safer than X-rays / X-rays pass through soft tissue (so would not detect the kidney) / X-rays are ionising (radiation) ✓	1 (AO1.1)	**ALLOW** X-rays used to detect bones/pass through kidney **ALLOW** ultrasound detects soft tissue/organs
	b	i	0.0022 (m) ✓	1 (AO2.2)	
		ii	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 2.0 × 10^6 (Hz) award 4 marks** (Rearrange: frequency =) speed / wavelength **OR** (f =) 4500 / 0.0022 ✓ (f =) 2 045 455 (Hz) ✓ (f =) 2 000 000 (Hz) ✓ (f =) 2.0 × 10^6 (Hz) ✓	4 (AO1.2) (AO2 x 2.1) (AO1.2)	**ALLOW** ecf from **(i)** **ALLOW** three marks for 2.0 MHz **ALLOW** a mark for their answer to 2 significant figures **ALLOW** a mark for their answer in standard form
	c		Decreases ✓ Stays the same ✓	2 (AO2 × 2.1)	
	d	i	(Partial) reflection/absorption at the front of the kidney ✓ (Partial) reflection at the back of the kidney ✓	2 (AO2 × 2.1)	Both of the marking points can be awarded by a suitably clear diagram (or additional drawings on the given diagram) **ALLOW** 1 mark maximum for just reflection/bounces back
		ii	Measure the time between reflections ✓	2 (AO2 × 2.2)	

			Use distance = ½ x speed x time (to find the size) ✓		**ALLOW** distance = speed x time and mention of time halve
			Total	**12**	
4	a		**Either** ray (centre ray or focal ray) drawn as indicated below ✓  Image upside down **AND** in the correct place ✓	2 (AO2 × 2.2)	**ALLOW** just one ray drawn If no rays drawn (or incorrect) but image is inverted, slightly larger and roughly in the correct place then award this mark **IGNORE** position of Y (if arrow is in the correct place) **ALLOW** tolerance of +/- 2 squares for image position
	b		A (red) filter is needed ✓ (The red filter) absorbs all colours/frequencies/wavelengths except red (light) ✓	2 (AO2 × 2.1)	**ALLOW** The red filter absorbs blue and green (light/frequency/wavelength) (but not red) **ALLOW** the filter transmits red light <u>only</u> / <u>only</u> lets red (light/frequency/wavelength) through
			Total	**4**	
5	a	i	(Filter X lets through) red, orange and yellow ✓	1 (AO 3.2b)	**DO NOT ALLOW** any extra colours
		ii	(Filter Y absorbs) orange and yellow ✓	1 (AO 3.2b)	**DO NOT ALLOW** any extra colours
	b	i	**Any one from:** Red (wall) absorbs all colours (in the light except red) ✓ (The wall) only reflects red light ✓	1 (AO 2.1)	**ALLOW** there is no red in the coloured light to reflect / AW **ALLOW** (wall) cannot reflect other colours (of light) **<u>Examiner's Comments</u>** Over half of the candidates were able to answer this question correctly. Incorrect answers involved misconceptions about the 'coloured lights mixing' to give black or the lights being transmitted by the wall.
		ii	**Any two from:** green ✓ blue ✓ indigo ✓ violet ✓ cyan ✓	1 (AO 2.1)	**DO NOT ALLOW** orange / yellow / magenta
	c	i	Ray of green light focused between lens and F_R ✓	1 (AO 1.2)	

		ii	green has shorter wavelength or higher frequency (than red) / shorter wavelengths refract more / show a larger change in speed / green light slows down more (than red light) / AW / ORA ✓	1 (AO 2.1)	**IGNORE** green (light) refracts more **IGNORE** just green (light) slows down **Examiner's Comments** Question 18e assessed candidates' knowledge of the refraction of different colours of light through a convex lens. It was evident that the majority of candidates did not know that green light would focus between the lens and FR because it has a shorter wavelength and therefore refracts more.
		iii	long sighted ✓ (Because lens is) convex/focusing/converging ✓	2 (AO 3.1a) (AO 3.2b)	Mark independently **Examiner's Comments** This question discriminated well. Most candidates successfully identified that the lens was suitable for correcting long-sight and the more able could also explain that it was because the lens was convex.
	d		Diagram showing correct refractions 	2 (AO 2x1.2)	If diagram is incorrect, maximum of one mark from: any rising line in air before the prism ✓ a line in the prism close to horizontal by eye and joining the exit ray ✓ **IGNORE** any arrows on rays **Examiner's Comments** This question proved very difficult for most candidates. Although some candidates could accurately draw the ray of light as it travelled through the glass prism, only the more able gained 2 marks.
	e			2 (AO 2×1.2)	One mark for each correct reflection of about 90o by eye **IGNORE** any arrows on rays
			Total	**12**	
6			(skin) cancer / (skin) aging ✓	**1** (AO1.1)	**ALLOW** sunburn / blisters / wrinkles / mutates cells / ionises cells **IGNORE** kills cells / damages cells / just burns **Examiner's Comments** The majority of candidates achieved 1 mark. Of those

					candidates who did not gain credit, most had stated that ultra-violet waves cause 'burns' rather than cause sunburn.
			Total	**1**	
7			**A** ✓	1 (AO 1.2)	**Examiner's Comments** Most candidates successfully applied their knowledge of electromagnetic waves to identify that the energy transfer for row A was correct.
			Total	**1**	
8			**D** ✓	1 (AO 1.1)	
			Total	**1**	
9			**A** ✓	1 (AO 1.1)	
			Total	**1**	
10			**D** ✓	1 (AO1.1)	
			Total	**1**	
11			**A** ✓	1 (AO1.1)	
			Total	**1**	
12			idea of 3 echoes/reflections/returning pulses (from each pulse) / AW✓ takes different times to travel (there and back) through different layers/distances/thicknesses / time (interval) between echoes is different/not regular / AW ✓✓ **BUT** the thicker the layer/the longer the distance, the bigger the time interval/takes longer to travel (there and back) / AW ✓✓	3 (AO 3×2.1)	**ALLOW** (idea of measuring) the time taken for the wave to be reflected back (for different layers) **Examiner's Comments** This question assessed candidates' ability to apply their knowledge of ultrasound. It proved challenging to a number of candidates and about one third did not gain any credit. Candidates used their knowledge of ultrasound but often did not relate this to the question asked, or their answers were not specific enough e.g. the number of pulses shows that there are 3 layers of tissue.
			Total	**3**	
13			Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question. **Level 3 (5–6 marks)** Detailed description of the structure of the Earth **AND** Detailed explanation of the trends in **Table 22.1.**	6 (AO 2×3.1a) (AO 2×3.2a) (AO 2×2.1)	**AO3.1a Analyse information and ideas to interpret some basic trends in data** • density increases as depth increases • speed (of P/S waves) increases as density increases • speed (of P/S waves) increases as depth increases

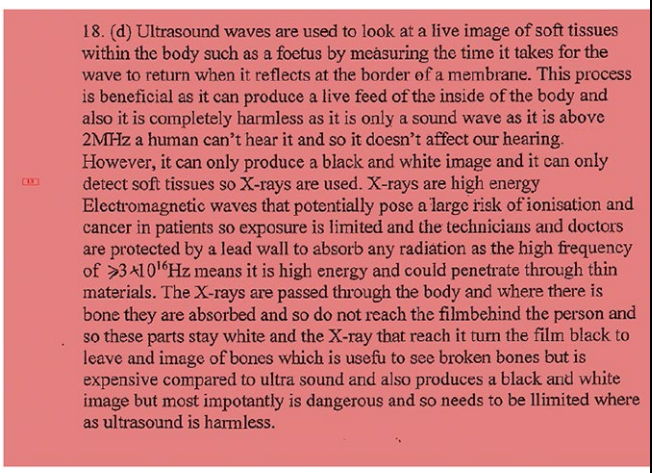
			There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated. **Level 2 (3–4 marks)** Description of the structure of the Earth. **AND** Explanation of the trends in **Table 22.1.** **OR** Detailed description of the structure of the Earth. **OR** Detailed explanation of the trends in **Table 22.1.** *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** **A basic description of the structure of the Earth.** **OR** A basic description of the trends in **Table 22.1.** *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*		**AO2.1 Apply knowledge and understanding of scientific ideas to explain trends in the data** • Earth contains layers • velocity changes at a boundary • as density changes at a boundary • particles more tightly packed • P is longitudinal, S is transverse **AO3.2a Analyse information and ideas to make judgements about the structure of the Earth** • core has highest density • core has highest speed for P waves • S waves do not travel through the core • so the outer core is a liquid • pressure highest in core / P = ρgh • pressure and so density increase with depth • large change in density between mantle and outer core **Examiner's Comments** This was the Level of Response question, targeted up to Grade 9, and assessed AO2 and AO3. There was a wide range of marks achieved and the question discriminated well. Very few candidates did not achieve any credit. The majority of candidates were able to describe some basic trends in the table for density and speed of P and S waves. More detailed responses also included a description of the structure of the Earth for Level 2. Many excellent responses from the more able candidates at Level 3 included: ● trends in the data identified and explained ● linking facts about P and S waves to an explanation of why the outer core is liquid. Poor quality of communication, including contradictions or the same facts repeated a number of times, prevented some candidates from achieving a higher mark. **Exemplar 2**

					Describe what information the data in **Table 22.1** gives about the structure of the Earth. In your answer you should explain any trends in the data in **Table 22.1**.  P waves are longitudinal and travel through both solid and liquids but S waves are transverse and only travel through solids. There is no data for the wave speed of S waves through the top of the outer core and the bottom so the core must be made of liquid, however both waves can travel through the crust and the mantle as there is data for it so there must be made of solid. The density of the layers of the earth decreases down the table so the density of the earth must increase from the surface of the crust to the centre of the inner core. The speed of both P waves and S waves increase down the table as well. P waves travel faster in more dense material as the particles are close together so they carry the wave to each other faster, which the data therefore backs up that the density of the earth increases towards the centre. [6] This response achieved Level 3, 6 marks. The candidates included a detailed description of the structure of the Earth, including ideas about density and the liquid outer core. There is also a detailed explanation of the trends shown in the table.
			Total	**6**	
14	a		A.C. (transmitted in power lines) / (electrical/electron/particle) oscillations / AW ✓ **BUT** Alternating currents/(electrical/electron/particle) oscillations produce (radio) waves/electromagnetic radiation ✓✓	2 (AO2×1.1)	**Examiner's Comments** This Assessment Objective 1 question assessed candidates' knowledge and understanding of how radio waves are produced. This proved to be one of the most difficult questions on the paper but also discriminated well. Only the most able candidates gained marks for relating the production of radio waves to the oscillations of electrons in the transmission lines. **Misconception** Common misconceptions included radio waves being produced by something in the house or because the transmission lines produced heat.
	b		(High voltage means) lower current ✓ Less heating/heat loss/power loss/energy wasted or more useful energy transmitted / ORA ✓	2 (AO2×1.1)	**IGNORE** no energy losses / prevent energy loss / AW **ALLOW** more efficient / (wires at) lower temperature **Examiner's Comments** Although this question has been asked often in past GCSE Physics papers, over one quarter of candidates did not gain credit. Many gained 1 mark for the idea of less energy lost (as heat) but only the more able candidates were able to link this to higher voltages resulting in a lower current.

					 **AfL** Candidates had many misconceptions about why energy should be transferred at high voltages. The responses often referred to incorrect ideas e.g. 'to make the energy move faster/further' or 'to transfer enough power to the home' or 'to reduce the resistance'. Candidates should also be aware that the idea of **NO** energy losses will not gain credit.
	c		**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 20 (A) award 5 marks** Recall $I^2 = P / R$ ✓ 6.156 kW = 6156 W ✓ (I^2 =) 6156 / 15.39 **OR** (I^2=) 400 ✓ (I =) √400 ✓ (I =) 20 (A) ✓	2 (AO 1.2) (AO 2.1) (AO 2.1) (AO 2.1)	**ALLOW** correct equation in any form **DO NOT ALLOW** marks to be awarded from incorrect equation e.g. I = P / R Award marks if 6.156kW has not been correctly converted to W E.g. (I^2 =) 0.4 or 6.156/15.39 ✓✓ (I=) √0.4 ✓✓✓ I = 0.63 ✓✓✓✓ **Examiner's Comments** The majority of candidates scored either zero marks or 5 marks for this question. Over a quarter of candidates did not know the correct equation: power = (current)^2 x resistance. It was common to see an incorrect version of the equation (power = current x resistance) used instead. Some candidates did show their calculations and could therefore score 1 mark for converting kW into W.
			Total	**9**	
15	a	i	(Wave speed =) frequency x wavelength ✓ $30 \times 10^9 \times 0.01$ or $30 \times 10^9 \times 1 \times 10^{-2}$ ✓	**2** (AO1.1) (AO3.2b)	**ALLOW** correct symbol equation eg (v =) f × λ **ALLOW** equation in any form **ALLOW** any frequency and corresponding wavelength from the table substituted into this equation **IGNORE** units for this marking point only **ALLOW** 30 000 000 000 × 0.01 or 30 000 000 000 × 1 × 10^{-2} **ALLOW** reverse arguments using speed and wavelength or speed and frequency **Examiner's Comments**

					This question assessed AO1 and AO3 and required candidates to recall and use the equation: *wave speed = frequency x wavelength* as well as convert 30 GHz into Hertz and 1 cm into metres. Most candidates struggled with the meaning of the prefixes and converting the units. Because many of these candidates did not write down the equation or their workings they could not be credited for any of the compensatory marks available in the mark scheme. A number of candidates used data from the table for radio or infra-red waves. Although they could not gain full marks they were credited with 1 mark for correct use of the equation.
		ii	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 100 (nm) award 3 marks** (Wavelength =) velocity ÷ frequency ✓ $\frac{3 \times 10^8}{3000 \times 10^{12}}$ or 1×10^{-7} ✓ = 100 (nm) ✓	**3** (AO1.2) (AO2.1) (AO2.1)	**ALLOW** (λ =) v ÷ f **IGNORE** v = f × λ and f = v / λ or words **ALLOW** 3×10^8 divided by any frequency from the table **IGNORE** units for this marking point only **Examiner's Comments** This question required candidates to convert the prefix Tera into a power of ten, recall and rearrange the equation: *wave speed = frequency x wavelength* to calculate the wavelength of ultra-violet, and then convert their answer into nanometres. Only the higher ability candidates gained full credit. The majority of candidates did not score any marks. Those candidates, who did gain credit, were credited with a one mark for correctly rearranged equation or for the correct application of the equation (i.e. 3×10^8 divided by any frequency from the table). **OCR support** Candidates would benefit from greater familiarity with the standard metric prefixes (WS1.4d). The Mathematical Skills Handbook provides additional support on the use of prefixes and powers of ten for orders of magnitude: http:/www.ocr.org.uk/Images/310651-mathematical-skills-handbook.pdf
	b		Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question. **Level 3 (5–6 marks)** **A detailed explanation of how ultrasound and X-rays are used.** **AND**	**6** (AO2 × 1.2) (AO1 × 2.2) (AO1 × 3.1b) (AO2 × 3.2a)	**AO1.2 Demonstrate knowledge and understanding of X-rays and ultrasound** • X-rays show bone • Ultrasound shows eg soft tissue / kidneys/ blood flow / prenatal scan

			A detailed evaluation of the risks / benefits of using the two different waves to scan patients in hospital, which may include use of information from the table. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** **An explanation of how ultrasound and X-rays are used.** **AND** **An evaluation of the risks / benefits of using the two different waves to scan patients in hospital.** *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** **EITHER** **An explanation of how ultrasound and X-rays are used.** **OR** **An evaluation of the risks / benefits of using the two different waves to scan patients in hospital.** **OR** **An explanation of ultrasound or X-rays AND an evaluation of the risks / benefits of ultrasound or X-rays.** *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** - *No response worthy of credit*.		**AO2.2 Applies knowledge and understanding of X-rays and ultrasounds** • X-rays damage / ionise living cells / causes cancer / damage foetus • Ultrasound is harmless **AO3.1b Analyses information to evaluate the differences in X-rays and ultrasound** • X-rays are absorbed by bone but do not show up soft tissues • Ultrasound is (partially) reflected for soft tissues only **AO3.2a Analyses information to make judgements about the risks and benefits:** • Ultrasound always safe **and** useful for soft tissue scanning • X-rays can cause cancer **but** save lives with identifying bone problems • X-rays have a frequency greater than 3×10^{16} Hz / (very small) wavelengths less than 10 nm to penetrate the body **Examiner's Comments** This Level of Response question assessed all three Assessment Objectives and provided an opportunity for candidates to demonstrate Grade 9 performance. Most candidates gained some credit for their written responses. The majority demonstrated a good knowledge of X-rays in particular and two thirds of the candidates demonstrated Level 2 or Level 3 performance. Many excellent responses at Level 3 included detailed explanations of absorption of X-rays by bones, reflection of ultrasound for soft tissues, and a detailed evaluation of the risks and benefits of the two different waves. Most responses successfully identified the risks / benefits of X-rays but a common misconception was that ultrasound could also cause cell mutations or harm (to the baby). **Misconception** Most candidates successfully identified the risks and benefits of X-rays but a significant number of candidates mistakenly believed that ultrasound could also cause cell

					mutations or harm to the baby. **Exemplar 4**  18. (d) Ultrasound waves are used to look at a live image of soft tissues within the body such as a foetus by measuring the time it takes for the wave to return when it reflects at the border of a membrane. This process is beneficial as it can produce a live feed of the inside of the body and also it is completely harmless as it is only a sound wave as it is above 2MHz a human can't hear it and so it doesn't affect our hearing. However, it can only produce a black and white image and it can only detect soft tissues so X-rays are used. X-rays are high energy Electromagnetic waves that potentially pose a large risk of ionisation and cancer in patients so exposure is limited and the technicians and doctors are protected by a lead wall to absorb any radiation as the high frequency of $\geq 3 \times 10^{16}$Hz means it is high energy and could penetrate through thin materials. The X-rays are passed through the body and where there is bone they are absorbed and so do not reach the filmbehind the person and so these parts stay white and the X-ray that reach it turn the film black to leave and image of bones which is usefu to see broken bones but is expensive compared to ultra sound and also produces a black and white image but most impotantly is dangerous and so needs to be llimited where as ultrasound is harmless. This is a six mark, Level 3 answer. The candidate included a detailed explanation of how both X-rays and ultrasound are used to scan patients. There is also a detailed evaluation of risks / benefits of both waves, which includes the use of some data from the table.
	c	i	120 (minutes) ✓	**1** (AO2.2)	**Examiner's Comments** Almost every candidate answered this question correctly.
		ii	Any two from: children have (more) sensitive skins ✓ children have cells / skins that are more at risk from skin cancers ✓ children lack awareness of the time they spend in the sunshine ✓ the idea that they advise a higher SPF than they (really) need just to be sure they are safe ✓	**2** (AO1.1) (AO2.1)	**IGNORE** just to reduce risk of burning **ALLOW** skin is vulnerable / more easily damaged / more affected by UV / delicate / has less melanin / AW **ALLOW** idea that damage to cells builds up over time **ALLOW** children are outside for longer / spend more time in the sun **Examiner's Comments** Most candidates were credited with one mark for the idea that children have more sensitive skins. Around a quarter of candidates were credited with both marks, frequently because they recognised that children spend more time in the sun.
			Total	**14**	