Q1.

Question Number	Answer	Mark
	B frequency increases ***A*** *is not correct because the danger does not increase with decreasing frequency* ***C*** *is not correct because all waves in the e-m spectrum have the same velocity* ***D*** *is not correct because all waves in the e-m spectrum have the same velocity*	**(1)** **AO1**

Q2.

Question number	**Answer**	**Additional guidance**	**Mark**
	infrared (1) thermal (1)	must be in first sentence space must be in second sentence space award 2 marks for answers in this **order**	**(2)** **AO2**

Q3.

	Answer	Additional guidance	Mark
(i)	x-ray(s)	allow X x no mark if more than one wave given e.g. x-rays and gamma rays scores 0	**(1)** **AO1**

	Answer	Additional guidance	Mark
(ii)	infrared	allow any recognisable spelling IR ir no mark if more than one wave given e.g. infrared and gamma rays scores 0	**(1)** **AO1**

	Answer	Additional guidance	Mark
(iii)	infrared	allow any recognisable spelling IR ir no mark if more than one wave given e.g. infrared and gamma rays scores 0	**(1)** **AO1**

	Answer	Additional guidance	Mark
(iv)	gamma (rays)	allow any recognisable spelling y no mark if more than one wave given e.g. gamma rays and UV scores 0	**(1)** **AO1**

Q4.

Question number	Answer	Additional guidance	Mark
	An explanation that combines application of knowledge (1 mark) and reasoning (1 mark) linking: • (faces of) people are at a higher temperature than the background (1) • therefore they emit more (infrared) at shorter wavelengths than background (1)	accept higher frequency / higher intensity	**(2)**

Q5.

	Answer	Additional guidance	Mark
	example 1 e-m wave (1) corresponding result of energy transfer (1) example 2 e-m wave (1) corresponding result of energy transfer (1)	e.g. radio waves: communication, oscillations (of electrons) in wires microwaves: cooking, communications and satellite transmissions, internal heating of body cells, increase KE/vibration of water molecules infrared: cooking, thermal imaging, optical fibres, television remote controls, skin burns ultraviolet: security marking, fluorescent lamps, detecting forged bank notes and disinfecting water, damage to surface cells and eyes, skin cancer x-rays: observing the internal structure of objects, airport security scanners and medical x-rays, mutation or damage to cells in the body, cancer gamma rays: including sterilising food and medical equipment, and the detection of cancer and its treatment, mutation or damage to cells in the body, cancer additional effect for visible light scores 1 mark e.g. : including vision, photography and illumination	**(4)** **AO1**

Q6.

Question number	Answer	Additional guidance	Mark
	An answer that combines the following points of understanding to provide a logical description: • radio waves will not reach the satellites (from Earth) / be received (on Earth) from the satellites (1) • because they are reflected by the atmosphere (1)	 ORA for microwaves reflected by ionosphere / before reaching satellite	**(2)**

Q7.

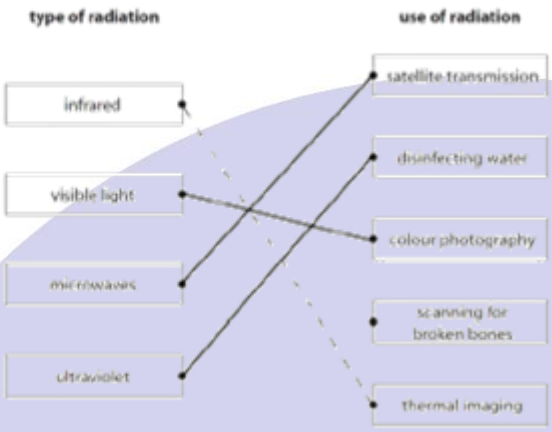
	Answer	Acceptable answers	Mark
(i)	a suggestion from any **two** of the following: (areas of the hand) show • Patches / (shaded) areas / brightness / colour(s) (1) • Indication of temperature / heat (1)	blood flow / veins / arteries / named part of hand thermal / hot / cold / warm / cool / hotter / colder / warmer / cooler any colour identified as hot or cold / any part of the hand identified as hot or cold (2) **Ignore** germs / bacteria / nerves	**(2)**
(ii)	an explanation linking **two** of the following: X-rays mutate / damage / harm / ionise cells or DNA (1) the energy / frequency / wavelength / penetration is different (1) Correctly identified difference (1)	kills/destroys cells / causes cancer / tumours / ionising Penetrates the skin / body x-rays have more energy / high(er) frequency / short(er) / low(er) wavelength / great(er) penetration (2) RA for infrared **Ignore** power	**(2)**

Q8.

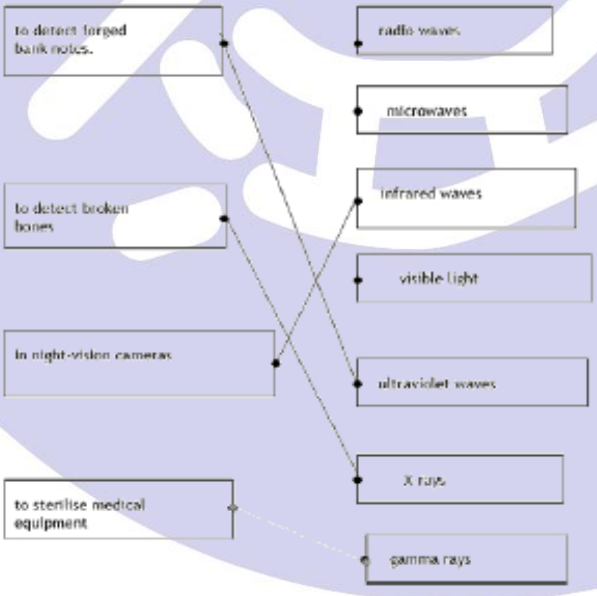
		Indicative Content	Mark
QWC	*	A discussion including some of the following points Possible dangerous e-m radiations Microwaves Infrared Ultraviolet (UV) X-rays gamma rays Correctly linked to Internal heating of body cells (microwaves) Skin burns (infrared) Damages skin cells/sunburn (UV) Damages eyes (UV) Can cause skin cancer (UV) Can cause cataracts (UV) Damage to cells inside the body(X-rays) Mutate/ kill cells in the body (gamma) Damages DNA (X-rays and gamma rays) Link to frequency As the frequency increases/wavelength decreases (microwave -> gamma) the waves become more penetrating and do more damage/danger as they have more energy.	**(6)**
Level	**0**	No rewardable content	
1	**1 - 2**	• a limited description e.g. gives at least 2 correct radiations and links both to correct damage OR at least 2 correct radiations named with link to correct damage from one and idea that frequency is linked to damage	

		OR just has link between higher frequency and more damage/dangerous e.g. infrared burns your skin and X-rays can damage cells. OR X-rays have a higher frequency than microwaves and can cause cancer OR Higher frequencies cause more damage to cells. • the answer communicates ideas using simple language and uses limited scientific terminology • spelling, punctuation and grammar are used with limited accuracy
2	**3 - 4**	• a simple description e.g. gives most of the correct radiations and links to correct damage, at least one with detail of the damage that is caused OR links two to detail of the damage, AND has a link between frequency and energy/danger e.g. Microwaves are absorbed by water in body cells. UV can cause skin cancer and damages your eyes. Xrays and gamma rays can damage cells inside your body OR Gamma and X-rays can penetrate deep into the body. Gamma does most damage as it has the highest frequency. • the answer communicates ideas showing some evidence of clarity and organisation and uses scientific terminology appropriately • spelling, punctuation and grammar are used with some accuracy
3	**5 - 6**	• a detailed description e.g. gives most of the correct radiations with links to detail of the damage AND explains the link between frequency and energy/danger. e.g Microwaves heat up the water in cells. UV can cause cataracts. Gamma rays are the most penetrating and can mutate cells inside the body because they have the highest frequency. • The answer communicates ideas clearly and coherently uses a range of scientific terminology accurately • spelling, punctuation and grammar are used with few errors

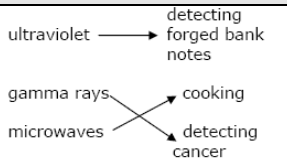
Q9.

Question Number	Answer	Additional guidance	Mark
(i)		award one mark for each correct line up to three marks reject for a mark two lines starting or ending at the same box	(3) AO1

Q10.

Question number	Answer	Additional guidance	Mark
		award 1 mark for each line from the three left-hand boxes more than one line from a box loses the mark for that box	(3)

Q11.

	Answer	Acceptable answers	Mark
(b)	 three correct (2) one or two correct (1)		**(2)**

Q12.

Question Number	Answer	Mark
	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. **AO1 strand 1 (6 marks)** • radio waves are (often) produced intentionally (by humans) • gamma rays are (often) produced spontaneously / randomly • radio waves are produced by (free) electrons • radio waves are produced by oscillating (free) electrons / alternating current (ac) • radio waves are produced in electrical circuits / aerials • gamma rays may result from radioactive decay • gamma rays produced in the nucleus • gamma rays produced by energy changes / rearrangement in the nucleus • gamma rays produced to stabilise the nucleus • gamma rays produced in annihilations (PET scanning etc) • gamma rays may be produced as a result of (nuclear) fission or fusion	**(6)**

Level	Mark	Descriptor
	0	• No rewardable material.
Level 1	1-2	• Demonstrates elements of physics understanding, some of which is inaccurate. Understanding of scientific ideas lacks detail. (AO1) • Presents an explanation with some structure and coherence. (AO1)
Level 2	3-4	• Demonstrates physics understanding, which is mostly relevant but may include some inaccuracies. Understanding of scientific ideas is not fully detailed and/or developed. (AO1) • Presents an explanation that has a structure which is mostly clear, coherent and logical. (AO1)
Level 3	5-6	• Demonstrates accurate and relevant physics understanding throughout. Understanding of the scientific ideas is detailed and fully developed. (AO1) • Presents an explanation that has a well-developed structure which is clear, coherent and logical. (AO1)

Summary for guidance			
Level	**Mark**	**Additional Guidance**	**General additional guidance – the decision within levels** e.g. - At each level, as well as content, the scientific coherency of what is stated will help place the answer at the top, or the bottom, of that level.
	0	No rewardable material.	
Level 1	1–2	Additional guidance isolated fact(s) about one radiation	Possible candidate responses gamma rays are (often) produced spontaneously / randomly
Level 2	3–4	Additional guidance Some understanding shown i.e. a limited comparison made including some facts about the production of each radiation OR more detailed facts given about the production of one of them	Possible candidate responses radio waves produced in wires and gamma produced in nucleus radio waves produced by AC in wires
Level 3	5–6	Additional guidance Understanding is detailed and fully developed. detailed comparison made with linked facts about the production of each (one radiation may have significantly more detail than the other but both should feature for level 3)	Possible candidate responses radio waves produced by electrons oscillating in wires; gamma produced by annihilation of electrons interacting with positrons

Q13.

Question Number		Indicative Content	Mark
QWC	* **(c)**	A description including some of the following points • Harmful effects include (skin) burns, eye damage, (skin) cancer, cell damage, mutation • IR and UV are on either side of visible light (in the em spectrum) • UV has shorter wavelength than IR • UV has higher frequency than IR • higher energy (associated) with UV • IR causes (skin) burns • UV causes damage to eyes / (skin) cancer / damage to cells (not just damage to skin) / sunburn • (potential) danger increases with frequency Ignore • irrelevant information e.g. UV used to scan unborn babies	**(6)**
Level	**0**	No rewardable content	
1	**1 - 2**	• a limited description stating one fact about a harmful effect or frequency e.g. skin burns **OR** UV has high frequency (no comparison) • the answer communicates ideas using simple language and uses limited scientific terminology • spelling, punctuation and grammar are used with limited accuracy	
2	**3 - 4**	• a simple description making a correct <u>comparison</u> of harmful effects **OR** a frequency comparison e.g. IR causes skin burns and UV causes (skin) cancer **OR** the higher the frequency the more harm they cause **OR** UV has a high<u>er</u> frequency (than IR) • the answer communicates ideas showing some evidence of clarity and organisation and uses scientific terminology appropriately • spelling, punctuation and grammar are used with some accuracy	
3	**5 - 6**	• a detailed description including harmful effects of both UV and IR **AND** relating at least one to <u>frequency</u> e.g. UV causes skin cancer but IR (only) causes skin burns as UV has a high(er) frequency • the answer communicates ideas clearly and coherently uses a range of scientific terminology accurately • spelling, punctuation and grammar are used with few errors	

Q14.

Question Number	Answer	Acceptable answers	Mark
(a)(i)	C travel with the same speeds in a vacuum, have different frequencies		**(1)**

Question Number	Answer	Acceptable answers	Mark
(a)(ii)	{damage to/ionise/mutate} {cells / DNA/tissue/ organs/ fetus} / cause {cancer/tumour}	kills cells/bacteria	**(1)**

Question Number	Answer	Acceptable answers	Mark
(b)(i)	Gamma, γ, 8, Y	UV, ultraviolet (rays/waves/radiation) Ignore X-rays	**(1)**

Question Number	Answer	Acceptable answers	Mark
(b)(ii)	one correct use (for UV/X-ray/gamma ray)	for example, (UV) – sunbeds, sterilise, detect banknotes (X-ray) - viewing internal organs / broken bones/airport security (gamma ray) – treat /cure cancer, kill {cells/bacteria} If one incorrect example is given, this mark is lost	**(1)**

Question Number	Answer	Acceptable answers	Mark
(c)(i)	one from: MP1 heating of (body/human/internal) {cells / organs/tissues} (1) MP2 {heating/boiling/exciting / vibrating} water (in the body) (1)	Accept heating of blood Ignore damages, burns, cancer, mutates, heating (on its own), skin	**(1)**

Question Number	Answer	Acceptable answers	Mark
(c)(ii)	explanation to include any **three** of: MP1 (Phones/ they) use lower frequencies / RA (1) MP2 lower frequency: lower energy / RA (1) MP3 lower {frequency/energy} less (potential) danger / RA (1) MP4 (phones /they) emit less (intense) radiation RA (1) MP5 phones are less powerful (1)	wavelength can suitably replace frequency eg use longer wavelength condone use lower MHz (comparison needed not just values quoted) Accept lower frequency (not energy) does {less /no} {damage/harm} for 2 marks ignore references to penetration ignore references to energy replacing power here For 2 marks -The resonant frequency of water molecules is the same as the oven frequency	**(3)**

Q15.

Question	Answer	Additional guidance	Mark
(i)	An explanation linking UVC/it has the smallest wavelength / highest frequency/ highest energy/most ionising (1) (it doesn't cause harm to people because) 100% absorbed by the Earth's atmosphere/no UVC reaches the Earth's surface/people (1)	allow shortest wavelength allow smaller for smallest / higher for highest / more for most	**2 AO3.2**

Q16.

	Answer	Additional guidance	Mark
	An explanation linking **two** from: to preserve food (1) by 'killing' bacteria (1) (gamma) is (very) penetrating (and so reaches all the food). (1) sterilising (1)	 stop food going off	**(2)** **AO2**

Q17.

Question number	Answer	Additional guidance	Mark
	explanation linking two from: (damage to) cell(s) (1) (because gamma rays are) ionising / high frequency/very energetic (1) (causing / curing/diagnosing) cancer / mutation / chromosomal damage / dna damage/burns (1)	 (rapid/unwanted) division of cells	**(2)**

Q18.

Question Number	Answer	Additional guidance	Mark
	an explanation linking: infrared is absorbed / blocked (by the armchair / objects) / cannot pass through **OR** radio waves can go through (the armchair/objects) (1) **WITH** (infrared and radio have) different wavelengths / frequencies OR infrared requires 'line-of-sight' (idea) OR radio waves do not require 'line-of-sight' (idea) OR diffraction (idea) (1)	stopped transmitted accept comparison	**(2)**

Q19.

Question number	Answer	Additional guidance	Mark
	An explanation that combines identification – understanding (1 mark) and reasoning/justification – understanding (1 mark): • the heating effect for the oven and the phone depends on their power (1) • and since the power of an oven is much greater than the power of a phone, the oven produces a greater heating effect (1)	allow not the same wavelength/microwaves cover a range in wavelengths	**(2)**

Q20.

Question Number	Answer	Mark
	B frequency increases ***A*** *is not correct because the danger does not increase with decreasing frequency* ***C*** *is not correct because all waves in the e-m spectrum have the same velocity* ***D*** *is not correct because all waves in the e-m spectrum have the same velocity*	**(1)** **AO1**

Q21.

Question number	Answer	Additional guidance	Mark
	D a TV remote control		**(1)**

Q22.

Question number	Answer	Additional guidance	Marks
	B radio waves	Multiple choice	(1)

Q23.

Question Number	Answer	Additional guidance	Mark
	in this order infrared (wave) / IR (1) micro(wave) (1) radio (wave) (1) gamma (ray/wave)(1)	 accept μ(wave) accept γ not X	**(4)** AO 1 1

Q24.

Question number	Answer	Additional guidance	Mark
	An answer that combines the following points of understanding to provide a logical description: • radio waves will not reach the satellites (from Earth) / be received (on Earth) from the satellites (1) • because they are reflected by the atmosphere (1)	 ORA for microwaves reflected by ionosphere / before reaching satellite	**(2)**

Q25.

Question Number	Answer	Acceptable answers	Mark
(b)	A suggestion which includes any two of: 1. harmful effect e.g. damage to {skin (cells) / cancer / mutation / eyes} (1) 2. bee can 'see' objects reflecting UV radiation (1) 3. allows bees to find (more) food (1) 4. discussion of different (intensities /) {brightnesses / amounts} (1) 5. discussion of time of exposure compared to life span (1)	 sunburn {emitting/giving out} for reflecting **OWTTE** accept 'see pollen' for MP2 OR 3 **ignore** honey **ignore** making food relevant mention of more exposure/ absorption by humans discussion such as humans have long term exposure which can be cumulative	**(2)**

Q26.

Question number	Answer	Additional guidance	Mark
(i)	**One** from: seeing (broken) bones (1) radiotherapy (1) detecting cracks in metals (1) airport security (1) observing the internal structure of objects(1)	seeing inside the body	**(1)** **AO1**

Question number	Answer	Additional guidance	Mark
(ii)	**One** from: can cause cancer (1) can cause burns(1) {damage/kills/harms} cells/tissue (1) mutates DNA/cells (1)	harms organ(s) / foetus allow (highly) ionising	**(1)** **AO1**

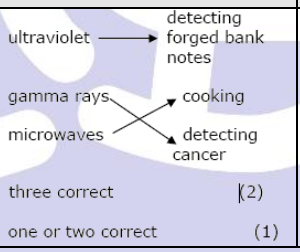
Q27.

Question number	Answer	Additional guidance	Mark
	(visible) light (1) gamma (rays) (1) radio (waves) (1) ultraviolet (waves) (1)	 γ (rays) allow microwaves UV (rays)	**4** **AO3.3**

Q28.

	Answer	Acceptable answers	Mark
	A		**(1)**

Q29.

	Answer	Acceptable answers	Mark
	 three correct (2) one or two correct (1)		**(2)**

Q30.

	Answer	Acceptable answers	Mark
(i)	C damage to the eyes (1)		**(3)**
(ii)	D all three signals arrive at the same time (1)		**(1)**
iii	Description linking **one** of the following pairs: • security marking (1) • ink absorbs UV and re-radiates (visible) light (1) • fluorescent lamps (1) • coating absorbs UV and reradiates (visible) light (1) • genuine bank notes (1) • watermark absorbs UV and reradiates (visible) light (1) • disinfecting water (1) • UV kills bacteria (1) • sun beds (1) • UV absorbed by (melanin in) skin (1) Any suitable use gains 1 mark Any suitable use + detail gains 2 marks	invisible ink/smart water glows under UV (outside of) lamp glows when hit by UV forgeries/fake bank notes/passports/fingerprints/ body fluids etc markings glow under UV tanning beds tans the skin /the body e.g. disco lighting (1) makes clothing glow (1)	**(2)**

Q31.

Question Number	Answer	Acceptable answers	Mark
(a)	**D** an ultraviolet wave		**(1)**

Question Number	Answer	Acceptable answers	Mark
(b)	Ultraviolet (from lamp) <u>absorbed</u> (by fluorescent substance/bank note) (1) (which) emits {visible/light} (into eye) (1)	Allow UV for ultraviolet Allow 'taken in' for absorbed Allow 'given out'/releases/fluoresces for emits 'Fluoresces' on its own is insufficient Mention of both ultraviolet AND visible/light only, scores 1 mark only	**(2)**

Q32.

	Answer	**Acceptable answers**	**Mark**
	A description to include The purpose of using gamma radiation (1) Some relevant detail about how it achieves the purpose (1)	Purposes may include sterilising food /medical equipment detection / treatment of cancer imaging /detect flaws in materials	**(2)**