	a		**The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High Level (Good to excellent): 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. *The candidate provides a comprehensive and coherent answer that includes a stated property of light such as interference or diffraction that can only be explained in terms of the wave nature of light and a stated property such as photoelectricity that can only be explained in terms of the particle nature of light. In each case, a relevant specific observational feature should be referred to and should be accompanied by a coherent explanation of the observation. Both explanations should be relevant and logical.* *For full marks, the candidate may show some appreciation as to why the specific feature of either the named wave property cannot be explained using the particle nature of light or the named particle property cannot be explained using the wave nature of light.* **Intermediate Level (Modest to adequate): 3 or 4 marks** The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. *The candidate provides a logical and coherent explanation that includes a stated property of light such as interference or diffraction that can only be explained in terms of the wave nature of light* ***and*** *a stated property such as photoelectricity that can only be explained in terms of the particle nature of light.* *For 4 marks, the candidate should be able to refer to a relevant specific observational feature of each property, at least one of which should be followed by an adequate explanation of the observation. Candidates who fail to refer to a relevant specific observational feature for one of the properties may be able to score 3 marks by providing an adequate explanation of the observational feature referred to.*	max 6

Low Level (Poor to limited): 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

The candidate provides some relevant information relating to two relevant stated properties for 1 mark. Their answer may lack coherence and may well introduce irrelevant or incorrect physics ideas in their explanation.

Points that can be used to support the explanation:

Wave-like nature property

- property is either interference **or** diffraction
- observational feature is either the bright and dark fringes of a double slit interference pattern or of the single slit diffraction pattern (or the spectra of a diffraction grating)
- explanation of bright or dark fringes (or explanation of diffraction grating spectra) in terms of path or phase difference
- particle/corpuscular theory predicts two bright fringes for double slits or a single bright fringe for single slit or no diffraction for a diffraction grating

Particle-like nature

- property is photoelectricity
- observational feature is the existence of the threshold frequency for the incident light **or** instant emission of electrons from the metal surface
- explanation of above using the photon theory including reference to photon energy *hf,* the work function of the metal and '1 photon being absorbed by 1 electron'
- wave theory predicts emission at all light frequencies **or** delayed emission for (very) low intensity

b	i	m (= m_o $(1 - v^2 / c^2)^{-0.5}$ = 9.11×10^{-31} $(1 - 0.890^2)^{-0.5}$) (= 1.998×10^{-30} kg) = $2.0(00) \times 10^{-30}$ kg ✓ $\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{2.0(0) \times 10^{-30} \times 0.89(0) \times 3.0(0) \times 10^8}$ ✓ (= $1.2(4) \times 10^{-12}$ m)	2

b	ii	$E_{Ph} = \left(hf = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^8}{1.24 \times 10^{-12}}\right)$ = $1.6(0) \times 10^{-13}$ J ✓	1

b	iii	$E_K = (m - m_o)\, c^2$ = $(1.998 \times 10^{-30} - 9.11 \times 10^{-31}) \times (3.0 \times 10^8)^2$ = 9.78×10^{-14} J ✓ 3 sf only ✓	2

2)

Quality of written communication: **Good – Excellent (5-6 marks)** The candidate provides a comprehensive, coherent and logical explanation which recognises what a stationary wave is and that the conditions for the formation of a stationary wave are present. They should know that nodes and antinodes are formed at alternate positions along XY which are equally spaced with nodes every half wavelength. They should know how the detector is used to locate the position of each node or antinode and how the wavelength is determined from the distance between two such positions. They may know that the nodes can be located more accurately than the antinodes and that their chosen two positions should be as far apart as possible. Their answer should be well-presented in terms of spelling, punctuation and grammar. **Modest – Adequate (3-4 marks)** The candidate provides a logical explanation which recognises what a stationary wave is and what some of the conditions for the formation of a stationary wave are. They may know that nodes and antinodes are formed at alternate positions along XY with nodes every half- wavelength. They may know how the detector is used to locate the position of each node or antinode and how the wavelength is determined from the distance between two such positions. They may know that the nodes can be located more accurately than the antinodes and that their chosen two positions should be as far apart as possible. Their answer should be well-presented in terms of spelling, punctuation and grammar. **Poor to Limited (1-2 marks)** The candidate may recognise that the reflector reflects radio waves which then form a stationary wave pattern with the	6	**For top band ,** explanation = at least b and e description = at least f, g,h ***Explanation of stationary wave formation ;-*** a. radio waves from the transmitter are reflected back towards the transmitter✓ b. reflected and incident waves pass through each other ✓ c. both waves have same frequency (and speed) and amplitude✓ d. superposition (of reflected and incident waves) occurs to form a stationary wave (as above) ✓ e. (equally spaced) nodes and antinodes formed along XY✓ ***Description* of measurement of wavelength ;-** f. Detector signal is zero (or least) along XY at nodes ✓ g. distance between adjacent nodes is ½ λ ✓ h. move detector along XY to measure distance between adjacent nodes and double to give the wavelength ✓ i. measure distance over n nodes and divide by n-1 to give distance between adjacent nodes ✓

incident waves. They may be unaware what the conditions for the formation of a stationary wave are and their understanding of nodes and antinodes may be poor. They may have some awareness that the stationary wave causes the detector signal to vary with position along XY and that the wavelength can be determined from this variation although they might not be able to link the wavelength to the changes of detector position correctly. Their answer may lack coherence and may contain a significant number of errors in terms of spelling and punctuation. **The explanations expected in a good answer should include most of the following physics ideas** ***Explanation of stationary wave formation ;-*** a. radio waves from the transmitter are reflected back towards the transmitter✓ b. reflected and incident waves pass through each other ✓ c. both waves have same frequency (and speed) and amplitude✓ d. superposition (of reflected and incident waves) occurs to form a stationary wave (as above) ✓ e. equally spaced nodes and antinodes formed along XY✓ ***Description* of measurement of wavelength ;-** f. Detector signal is zero (or least) along XY at nodes ✓ g. distance between adjacent nodes is ½ λ ✓ h. move detector along XY to measure distance between adjacent nodes and double to give the wavelength ✓ i. measure distance over n nodes and divide by n-1 to give distance between adjacent nodes ✓		**For middle band ,** explanation = at least any two of a-e description = at least any two of f-i **For lowest band ,** Any 2 points ,must be 1 of each for 2 marks ***Explanation of stationary wave formation ;-*** a. radio waves from the transmitter are reflected back towards the transmitter✓ b. reflected and incident waves pass through each other ✓ c. both waves have same frequency (and speed) and amplitude✓ d. superposition (of reflected and incident waves) occurs to form a stationary wave (as above) ✓ e. (equally spaced) nodes and antinodes formed along XY✓ ***Description* of measurement of wavelength ;-** f. Detector signal is zero (or least) along XY at nodes ✓ g. distance between adjacent nodes is ½ λ ✓ h. move detector along XY to measure

		distance between adjacent nodes and double to give the wavelength ✓ i. measure distance over n nodes and divide by n-1 to give distance between adjacent nodes ✓

Speed of radio waves (obtained by Hertz) is the same as the speed of light ✓ Speed of electromagnetic waves (calculated or predicted by Maxwell) is the same as the speed of light (or of radio waves) so radio waves are electromagnetic waves ✓	2	

3)

(a)(i)	Appreciation that one component changes speed while the other component at right angles does not✓ When entering a denser medium a corpuscle /light accelerates or its velocity/momentum increases perpendicular to the interface ✓ There is a (short range) attractive force between light corpuscle and the (denser) material✓	Not allowed: Attraction due to opposite charges Force making them move faster is not enough Accelerate in medium Not gains energy	3	
(a)(ii)	Light (was shown by experiment to) travel slower in (optically)denser medium OWTTE✓ Newton's theory required light to travel faster, wave theory suggested slower speed✓ or Newton's theory could not explain the slower speed or Huygens theory could explain the slower speed	Condone 'waves..' instead of 'light' OWTTE e.g. speed in vacuum higher than speed in other medium Not allowed: Reference to Young's two slit- question asks them about refraction.	2	
(a)(iii)	A corpuscular theory predicts only two (bright) lines/high intensity patches of light whereas a wave theory predicts many fringes✓ Corpuscles can only travel in straight lines or waves can produce fringes because (diffract and) interfere/superpose/ arrive in and out of phase/have different path differences ✓	Need to describe the patterns ie not just interference fringes are seen for the first mark	2	
(b)	Substitutes data in photon wavelength = *hc/E* ; Allow for substitution with no conversion to J✓ 2.48×10^{-10} m✓ Type to enter text For electron: Substitution in $\lambda = \frac{h}{\sqrt{2mE}}$ 2.48×10^{-10}(or their λ) $= 6.6 \times 10^{-34}/(2 \times 9.11 \times 10^{-31} \times 1.6 \times 10^{-19}\ V)^{1/2}$ ✓ V = 24(.4) V✓ $=1.49 \times 10^{-18}/(\text{their } \lambda)^2$✓ May calculate v using $v = h/m\lambda$ then substitution in $V = ½\, mv^2/e$ ✓(for third mark)	No conversion to J gives $\lambda \approx 4 \times 10^{-29}$ and $V \approx 9 \times 10^{38}$ V) Allow small rounding errors in dp	4	

4)

a		μ_0 and ε_0 determined experimentally (or μ_0 and ε_0 values were known) ✓ (substitution of values of μ_0 and ε_0 into) predicted equation gives 3(.0) × 10^8 m s^{-1} (or the speed of light)✓ which is the speed of light (or 3(.0) × 10^8 m s^{-1}) ✓	max 2
b	i	magnetic wave vibrations perpendicular to (plane of) loop ✓ (magnetic wave) causes alternating (or changing) magnetic flux (linkage or cutting) through the loop ✓ alternating magnetic flux (or field) induces an alternating (or changing) emf (or pd) in the loop ✓ [**or** equivalent E-field statements E-wave (or field) vibrations parallel to loop ✓ E-wave (or field) induces emf (or pd) in wire of loop ✓ E-wave (or field) alternates so induced emf is alternating ✓]	3

b	ii	no magnetic flux (linkage or cutting) through the loop (as loop is now parallel to magnetic wave vibrations) so no induced emf (or pd) ✓ (**or** electric field perpendicular to loop so no induced emf (or pd) ✓)	1

5)

a	i	Newton's other theories were successful (or Newton was more eminent so Newton's view was accepted) ✓ **alternatives**, Huygens' theory was based on longitudinal waves which can not explain polarisation **or** Huygens' theory could not explain sharp shadows	**1**
a	ii	**either** Newton predicted that light travels faster in glass than in air, Huygens' predicted the opposite ✓ **or** there was no evidence (for many years) that light travels slower or faster in glass than in air ✓ the speed of light in water (or glass) was (eventually) found to be less than the speed of light in air ✓ diffraction/interference observations not conclusive ✓	**max 2**

b	**The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High Level (Good to excellent): 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate provides a comprehensive, coherent and logical explanation which recognises that the pattern is due to interference of light which is a wave property. They should know that at a bright fringe, the waves from the two slits are in phase and therefore reinforce each other and this can happen at positions where the path difference is zero or a whole number of wavelengths. They may not refer to the need for the waves to be coherent. Their answer should be well-presented in terms of spelling, punctuation and grammar. **Intermediate Level (Modest to adequate): 3 or 4 marks** The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate provides a logical explanation which recognises that interference of light is a wave property. They should know either a bright fringe is where the waves from the two slits are in phase or a dark fringe is where they are out of phase by 180° and be aware there are different positions where these conditions apply. They may know the general condition for the path difference for a bright fringe or a dark fringe although they may not recognise that this condition explains why there are more than two bright fringes. Their answer should be adequately or well-presented in terms of spelling, punctuation and grammar. **Low Level (Poor to limited): 1 or 2 marks** The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate recognises that interference of light is a wave property and that the waves from the two slits reinforce at a bright fringe or cancel at a dark fringe. They may confuse path difference and phase difference and their explanation of why there are more than two bright fringes may be vague or absent. Their answer may lack coherence and may contain a significant number of errors in terms of spelling and punctuation. **Incorrect, inappropriate of no response: 0 marks** No answer or answer refers to unrelated, incorrect or inappropriate physics.	**max 6**

	Statements expected in a competent answer should include some of the following marking points. the pattern is due to interference of light from the two slits interference is a wave property light from the two slits is in phase at a bright fringe and therefore reinforces the path difference (from the central bright fringe to the two slits) is zero **either** bright fringes are formed away from the centre wherever the path difference is a whole number of wavelengths **or** dark fringes are formed away from the centre wherever the path difference is a whole number of wavelengths + a half wavelength the path difference for the m^{th} bright fringe from the centre is *m* wavelengths where *m* is any whole number since *m* is any whole number, more than two bright fringes are observed	
	Total	**9**

6)

(a)	electric field strength **and** magnetic flux density/magnetic field strength✓ They are in phase with each other ✓ **OR** Phase difference = 0 (not 2π)	Allow *E* and *B* (not E field and B field) Not electric field and magnetic field Not allowed if quantities are mentioned are not related to electric and magnetic fields(e.g. frequency & wavelength) or no quantities given	2
(b)(i)	Direct and reflected waves superpose/ Waves arriving directly interfere with reflected waves. Or Direct and reflected wave produce a stationary wave✓ When a maximum constructive interference or explanation of condition and minimum destructive interference or explanation of condition Or maximum/constructive interference at antinode and minimum /destructive interference at a node✓ Explains maximums/antinodes and minimums/nodes in terms of wavelengths, relative phase or path difference✓ i.e. there is constructive interference/antinode • reflected wave travels whole number of wavelengths further • path difference is whole number of wavelengths • waves are in phase destructive interference minimum/node when • the direct and reflected waves interfere destructively • the waves become antiphase/180° out of phase • path difference is λ/2 or (n+1/2) λ	Do not allow superimpose Do not allow out of phase	3
(b)(ii)	Wavelength = $\frac{3\times10^8}{2.2\times10^9}$ **or** 0.136 m (0.14) seen or appreciates that the reflector has to move λ/4✓ 0.034 or 0.035 (m) ✓	Penalise 1 sf answer	2
(c)	Light is diffracted when it falls on a slit: Light travels as 3×10^8 m s^{-1} in free space: ✓ Light changes speed when it enters a medium of different optical density: Light can be polarised when it is passes through polaroid:		1