1)

Question			Expected Answers	Marks	Additional Guidance
	a	i	λ distance between (neighbouring) identical points/points with same phase (on the wave) f number of waves passing a point /cycles/vibrations (at a point) per unit time/second v distance travelled by the wave (energy) per unit time/second	B1 B1 B1	**accept** peak/crest to peak/crest, etc. **accept** number of waves produced by the wave source per unit time/second **not** v = f λ and not 'in one second'
		ii	in 1 second f waves are produced each of one wavelength λ distance travelled by first wave in one second is f λ = v	M1 A1	**accept** time for one λ to pass is 1/f so v = λ/(1/f) =f λ **give** max 1 mark for plausible derivations purely in terms of algebra (no words)
	b	i	infra red is part of the e-m spectrum lower f **or** longer λ than the visible region/light **or** suitable value or range of λ	B1 B1	**accept** any single λ in range 10^{-5} m to 7.5 x 10^{-7} m or any reasonable wider range
		ii1	λ = c/f = 3.0 x 10^{8}/ 6.7 x 10^{13} 4.5 x 10^{-6} (m)	C1 A1	**accept** 4.48 x 10^{-6} or more s.f.
		2	T = 1/f = 1/6.7 x 10^{13} T = 1.5 x 10^{-14} (s)	C1 A1	**accept** 1.49 x 10^{-14}
		iii	at least one cycle of a sine or cosine curve as judged by eye amplitude 8.0 x 10^{-12} m period = 1.5 x 10^{-14} s	B1 B1 B1	**ecf (b)(ii)2**
			Total question 5	**14**	

2)

a	**i**	paths spread out after passing through a gap or around an obstacle/AW	B1	
	ii	wavelength of electrons must be comparable/of the order of magnitude of the atomic spacing	M1 A1	**allow** electrons behave as waves/AW **allow** must be about 10^{-10} m
b		λ = h/mv v = 6.6(3) x 10^{-34} / 9.1(1) x 10^{-31} x 1.2 x 10^{-10} = 6.0 or 6.1 x 10^{6} (m s^{-1})	C1 M1 A1	mark for selecting formula correct manipulation and subs. shown **give** all 3 marks for answers to 3 figs or more: i.e. 6.04, 6.06 or 6.07

3)

a	**i**	a quantum/lump/unit/packet/particle of (e-m) energy/light	B1	
	ii	all wavelengths/frequencies are present (in the radiation)/AW	B1	**accept** colours
b	**i**	**1** infra red **2** the bulb of the lamp is **hot**	B1 B1	
	ii	5/100 x 24 = 1.2 W n = 1.2/4 x 10^{-19} = 3.0 x 10^{18}	C1 C1 A1	**allow** 2 marks if forgotten 5% and obtain 6 x 10^{19} allow 3 x 10^{18} – no SF as estimate

4)

(a)		**is a transfer of energy** as a result of oscillations (of the source/medium/particles through which energy is travelling)	**M1** A1	**allow** carries **allow** information **accept** without the transfer of the medium/particles/matter
(b)		displacement/oscillation (of particles) is normal/perpendicular to direction of energy transfer in transverse wave displacement/oscillation (of particles) is parallel to direction of energy transfer in longitudinal wave	B1 B1	**allow** vibrations **allow** to direction of wave motion/propagation/velocity/travel **NOT** transverse wave can travel through a vacuum give max 1 mark for 2 similar poor definitions, e.g. direction of travel, waves oscillate, etc. (two such errors scores zero)
(c)	(i)	wavefronts/paths spread out after passing through a gap or around an obstacle/AW	B1	**NOT** wave changes direction
	(ii)	use a slit/hole/ barrier width of gap/position beyond barrier comparable to wavelength microphone/observer's ear suitably placed sound detected/heard outside 'geometrical shadow' region (showing diffraction)	B1 B1 B1 B1	**accept** doorway/end of wall **accept** position of detector beyond doorway **N.B.** good diagram can illustrate first 3 marking points **allow** 'hears sound' in suitable context only observation mark which is QWC mark must be in words 2 marks max for double slit experiment(1st and 3rd m.p.)

5)

(a)	(i)	gamma rays, u.v., visible/light, i.r., microwaves	B1	**two** out of five needed for mark
	(ii)	*similarity*: travel in a vacuum/same speed (in vacuum)/at c/transverse (wave)/can be polarised/caused by accelerating charges/are oscillating electric and magnetic fields *difference:* different λ, f, (photon) energy	B1 B1	any **one** for mark **NOT** can be reflected/refracted/diffracted/interfere,etc. any **one** for mark
	(iii)	wavelength of X-rays is close to atomic spacing/AW **or** wavelength of radio waves many/million times the atomic separation maximum/significant diffraction occurs when radiation wavelength ~ spacing (between diffracting planes) within material	B1 B1	
(b)		**advantage** produces vitamin D (in skin cells) **disadvantage** damage DNA/cause cancer/sunburn, etc.	B1 B1	**allow** any sensible use, e.g. sterilise equipment, forensic science, disco lighting, etc. **NOT** tanning, photosynthesis
(c)	(i)	2×10^{-10} m	B1	
	(ii)	$E = hc/\lambda$ $= 6.63 \times 10^{-34} \times 3.0 \times 10^{8} / 2 \times 10^{-10}$ $= 9.9(5) \times 10^{-16}$ number = 1×10^{9}	C1 C1 A1 B1	Select equation and attempt to apply it **ecf (c)(i)** accept 1×10^{-15}, i.e 1 SF mark scored for 1×10^{-6}/value of E
(d)	(i)	diode symbol all three components in series	B1 B1	**allow** LED symbol; basic requirement is triangle along wire direction with bar, with or without circle and line through **ecf** for diode symbol
	(ii)	maximum ammeter reading when aerials in line/parallel zero signal/current when aerials at 90° to each other at 180° same signal/ammeter reading as at 0° quoting $I = I_0\cos^2\theta$ to indicate variation through 180°	B1 B1 B1 B1	**accept** ammeter reading falls as aerial is rotated **accept** minimum **allow** full marks for answers in terms of only ammeter reading or signal strength max 3 out of 4 marking points
		Total	**17**	

6)

a	**i**	travel through a vacuum	B1	**allow** travel at c (in a vacuum)
b	**ii**	A gamma; C uv; F microwave	B3	**allow** 1 mark for A radio; C ir; F X-ray
c	**i**	$3.0 \times 10^{8} = 1.0 \times 10^{9} \lambda$ $\lambda = 0.30$ m	C1 A1	 **allow** 0.3 no SF error
	ii	aerial length = $\lambda/2 = 0.15$ m	A1	**ecf (c)(i)**
	iii	emitted wave is (plane) polarised detecting aerial will receive weaker signal/cos θ component when it is rotated (through angle θ)/AW signal falls to zero at 90° and then rises to max again at 180°	B1 B1 B1	**allow** max signal initially/at 0° **max 3 marks** from 4 marking points
d	**i**	UV-A causes tanning or skin ageing ; most of (99%) uv light; 400-315 nm UV-B causes damage or sunburn or skin cancer; 315-260 nm UV-C is filtered out by atmosphere/ozone layer; 260-100 nm	B1 B1 B1	accept values within ranges with tolerance of 20 nm **allow** $\lambda_A > \lambda_B > \lambda_C$ for 1 mark **max 3 marks** from 7 marking points
	ii	filters out/blocks/reflects/absorbs UV(-B)	B1	**allow** chemicals prevent sunburn/skin cancer **not** stops UV penetrating skin
e		energy of the infra-red photon is less than the work function of the metal surface	B1 B1	**accept** frequency and threshold frequency **or** wavelength and threshold wavelength used correctly in place of energy and work function **1 mark** only: energy of the uv photon greater than work function with no mention of ir
		Total question 5	**16**	

7)

(a)		travel in a vacuum same speed (in vacuum)/at c caused by accelerating charges are (oscillating) electric and magnetic fields	**B1** **B1**	**max** 2 marks from 4 marking points for any one incorrect property, max of 1/2 if 2 incorrect properties, score 0
(b)		10^{-4} microwaves; 10^{-6} ir; 10^{-8} uv; 10^{-12} gamma	**B1** **B1**	4 correct 2 marks 2 correct 1 mark
(c)	(i)	the incident wave is reflected at the sheet to produce return wave of same frequency/AW reflected wave is weaker **OR** the reflected wave has travelled a greater distance	**B1** **B1**	**accept** incident and reflected waves are from same source/of same wavelength/AW **allow** wave amplitude decreases with distance

8)

(a)	**(i)**	is a transfer of energy as a result of oscillations (of the source/medium/particles through which energy is travelling)	M1 A1	**accept** carries/AW **accept** without the transfer of the medium/particles/matter
	(ii)	a *progressive* wave transfers energy a *progressive* wave transfers shape/information **either** every point on a *progressive* wave has the same amplitude **or** every point on a *progressive* wave oscillates all points on *a progressive* wave have different phase (in one λ)	B1 B1 B1 B1	**or** a *stationary* wave traps energy in pockets/AW **or** a *stationary* wave does not transfer shape/information **or** a *stationary* wave has nodes and antinodes **or** in a *stationary* wave some points do not move (nodes) **or** all points in a *stationary* wave between nodes are in phase **or** in adjacent loops are in antiphase **max** 2 marks
(b)	**(i)**	shape: sinusoidal and only 2 cycles amplitude constant at 0.03 m (y-axis labelled) period 0.2 s (x-axis labelled to 0.4 s) phase: cosine curve	B1 B1 B1 B1	 one correct label of 0.03 m on y-axis is enough to score mark
	(ii) 1 **2** **3**	X W W and X	B1 B1 B1	
	(iii)	Y vertically up Z vertically down	B1 B1	**award** 1 mark if directions of both reversed
(c)		v has increased by 2 so (λ has increased by same factor) new λ = 0.60 x 2 = 1.2 (m)	M1 A1	correct reasoning correct answer
(d)		f has increased by 2 so point W has to move same distance in half the time/double the distance in the same time therefore speed is doubled to 1.9 (m s^{-1})	M1 A1	**N.B.** zero marks for using v = f λ as this is the wave velocity not the particle velocity **allow** v = 2πfA **or** v proportional to f(mark BOD) **accept** 1.88 (m s^{-1})
		Total	**17**	

9)

a		all travel at speed of light through a vacuum are oscillating E and B fields **or** are caused by accelerating charges/AW	**B1** **B1**	**max** 2 marks from 3 marking points if 3 properties are given withhold one mark for each incorrect property so 2 correct and 1 incorrect would score 1 mark ;1 correct and 2 incorrect would score zero, etc
b	**i**	oscillations (of particles/e-m fields along the wave) are in one direction only perpendicular to the direction of wave propagation/of travel of the wave/of energy transfer	**B1** **B1**	
	ii	light passing through polariser 1 is vertically polarised/ only vertical oscillations of the light exist beyond the polariser 1/AW only (the component of) light in the horizontal plane can pass through polariser 2 so no light reaches the eye	**B1** **B1**	**allow** any words indicating vertical, e.g. up and down; for horizontal, e.g. at 90° to vertical or crossed polarisers **accept** using Malus' law $I_{trans} = I_{incident}\cos^2\theta$ with $\theta = 90°$ gives $I_{trans} = 0$
	iii	after polariser 1 the component of the vertically polarised light at 45° passes through polariser 3 the polarised light beyond polariser 3 has a component at 45° which passes through polariser 2 so light reaches the eye **or mark a typical answer of the form (max 2) as follows** some of the vertically polarised light passes through polariser 3 and some of this passes through polariser 2 because in each case the polarised light is not at right angles to the transmission axis of the polariser	**B1** **B1** **B1**	**QWC** statement to the effect that component of light along polarising axis of filter is transmitted **accept** using Malus' law $I_{trans} = I_{incident}\cos^2\theta$ with $\theta = 45°$ gives $I_{trans} = I_{incident}/2$ same process gives $I_{trans} = I_{incident}/2$ again so ¼ of light after polariser 1 reaches eye (assuming no absorption) accept answers in terms of amplitudes rather than intensities, i.e. $A = A_0 \cos\theta$, etc.
		Total	**9**	

10)

(a)	**(i)** **(ii)**	diffraction or refraction or superposition or interference only transverse waves can be polarised	B2 B1	**accept** any two from the four listed **accept** sound is a longitudinal wave or e-m waves are transverse
	(iii)	place transmitter and receiver facing each other rotate either transmitter or receiver through 90° about axis joining aerials **or** use two polarising filters and rotate from parallel to crossed observe signal fall to zero/minimum from initial high value on meter monitoring output of receiver explanation of observations/link between observations and polarisation	B1 B1 B1 B1	**accept** from diagram **allow** (metal) grille/polarising filter to polarise microwaves **accept** place (metal) grille/polarising filter [**not** Polaroid] between transmitter and receiver and rotate through 90° QWC mark
(b)	**(i) 1**	0.3 (mm)	B1	tolerance ±0.02 mm ie 0.28 – 0.32 (mm)
	2	T = 4.0 ms F = 1/T = 250 (Hz)	C1 A1	**allow** 0.25 Hz or any other POT error for 1 mark
	(ii)	realisation that intensity is proportional to (amplitude)^2 giving amplitude increase by √2, ie4(.2) mm sine wave of same frequency with any increased amplitude	B1 B1 B1	
	(iii)	microphone (to transfer mechanical motion to electrical signal/voltage) oscilloscope to display oscillation/wave for measurement (of period)/AW	B1 B1	**accept** computer/datalogger/frequency meter with qualification as for oscilloscope
		Total question 4	**15**	