9	**B is the correct answer as the momentum of a photon is h/λ** A is not the correct answer as momentum is mv C is not the correct answer as it is not the speed of light, but the speed of the electron. D is not the correct answer as h is a constant.	**(1)**

4	**A is the correct answer (de Broglie wavelength = 2.43 x 10^{-9} m)** B is not the correct answer as the de Broglie wavelength = 1.82 x 10^{-9} m C is not the correct answer as the de Broglie wavelength = 1.13 x 10^{-12} m D is not the correct answer as the de Broglie wavelength = 9.93 x 10^{-13} m	**(1)**

9	**The only correct answer is B - 3** **A** is not correct because the energy transferred to the electron is not 4.91 eV **C** is not correct because the energy transferred to the electron is not 6.70 eV **D** is not correct because the energy transferred to the electron is not 7.73 eV	**1**
10	10 x (0 ... C)	1

7	**The only correct answer is A** B is not correct because an incorrect equation has been used C is not correct because the useful power output has been taken incorrectly to be 9.8 W	**1**

	D is not correct because an incorrect value for useful power output of 9.8 W has been used with the reciprocal of the correct equation	

3	**A is the correct answer** B is not correct because this would give the momentum of the electron C is not correct because this gives $\frac{1}{\text{velocity}}$ D is not correct because this would give $\frac{1}{\text{momentum}}$ for the electron	

4	**The only correct answer is B** $\left(\frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 2 \times 10^{7}}\right)$ A is not correct because $\lambda = \frac{h}{mv}$ and this is using mass of proton C is not correct because $\lambda = \frac{h}{mv}$ and this is $\lambda = \frac{mv}{h}$ D is not correct because $\lambda = \frac{h}{mv}$ and this is t is upside down and uses mass of proton not electron	**1**
5	(25 x 2π)	1

7	**B is the correct answer** A is not correct because the de Broglie wavelength would be 4λ. C is not correct because the de Broglie wavelength would be 0.5λ. D is not correct because the de Broglie wavelength would be 0.125λ.	1

4	**C is the correct answer** A is not correct because this describes an energy of 1 J B is not correct because this describes a current of 1 A D is not correct because this describes a charge of 1 C

Question Number	Answer	Mark
12ai	Use of $I = P/A$ (1) Maximum energy received in one hour = 3.6×10^{19} J (1) Example of calculation $P = I \times A = (1100\ \text{Wm}^{-2}) \times (9.2 \times 10^{12}\ \text{m}^2) = 1.0 \times 10^{16}$ W $E = P \times t = (1.0 \times 10^{16}\ \text{W}) \times (60 \times 60) = 3.6 \times 10^{19}$ J	**(2)**
12aii	Calculates total energy usage in 2014 **Or** Calculates total energy received by solar panels in 1 year (1) Comparison of energies (hours with hours or years with years) to come to a correct conclusion. (1) Allow e.c.f. from values in (a)(i) Possible comparisons: **Total energy worldwide in 2014** / **Total energy received by solar panels** 23800 TWh (in a year) / 87,600,000 TWh (if using 24 hours) 23800 TWh (in a year) / 43,800,000 TWh (if using 12 hours) 8.6×10^{19} J (in a year) / 3.2×10^{23} J (if using 24 hrs) 8.6×10^{19} J (in a year) / 1.6×10^{23} J (if using 12 hrs) 9.8×10^{15} J (in an hour) / 3.6×10^{19} J (in an hour) Example of calculation Total E worldwide in 1 year = $23{,}800 \times (3.6 \times 10^{15}\ \text{J}) = 8.6 \times 10^{19}$ J $8.6 \times 10^{19}\ \text{J} / 3.6 \times 10^{19}\ \text{J} = 2.4$ (hours), so worldwide electrical energy consumption for 2014 would be produced in less than 3 hours	**(2)**
12b	**MAX 2** from: Sand(storms) reduce amount/intensity/energy/power of light (1) Fewer electrons released in the (solar) panel (1) Sand(storms) absorbs/blocks/reflects some light (1) Sand(storms) reduces area of panel/desert (1)	**(2)**
	Total for question 12	**6**

Question Number	Answer		Mark
13a	Use of $I = P/A$	(1)	
	Use of $A = 4\pi r^2$	(1)	
	$r = 1.47 \times 10^{11}$ m	(1)	**3**
	(MP3 can only be awarded if 1410 W m^{-2} has been used)		
	Example of calculation $4\pi r^2 = (3.83 \times 10^{26}$ W) / 1410 W m^{-2}		
	r = 1.47×10^{11}m.		
13b	Mars orbits at a greater distance from the Sun than the Earth as the intensity is lower	(1)	
	Mars has a more elliptical orbit than the Earth	(1)	
	The (relative) difference between the maximum and minimum intensity for Mars is greater.	(1)	**3**
	(All 3 marking points need to be comparisons)		
	Total for question 13		**6**

Question Number	Answer		Mark
15(a)	Electrons can exhibit wave behaviour	(1)	
	Electrons diffract as they pass through the graphite **Or** graphite acts as a diffraction grating	(1)	
	Structure of graphite must be ordered/ regular / layered	(1)	
	The (de Broglie) wavelength of the electrons is similar to the spacing of gaps between atoms	(1)	4
15(b)(i)	Use of $V = W/Q$	(1)	
	$W = 3.8 \times 10^{-16}$ (J)	(1)	2
	Example of calculation $W = 1.6 \times 10^{-19}\text{C} \times 2400\text{ V} = 3.84 \times 10^{-16}$ J		
15(b)(ii)	Use of $E_k = \frac{1}{2}mv^2$	(1)	
	$v = 2.9 \times 10^{7}$ m s^{-1}	(1)	2
	(allow ecf from (b)(i))		
	Example of calculation $E_k = 3.8 \times 10^{-16}\text{ J} = \frac{1}{2}9.11 \times 10^{-31}\text{kg} \times v^2$ $v = 2.90 \times 10^{7}$ m s^{-1}		
15(b)(iii)	(Increasing the accelerating p.d.) would increase the (maximum) momentum of the electrons **Or** (Increasing the accelerating p.d.) would increase the (maximum) velocity of the electrons	(1)	
	Use of $\lambda = \frac{h}{p}$ so (de Broglie) wavelength of the electrons decreases	(1)	
	So the diameter of the circles would decrease **Or** Distance between maxima decreases	(1)	3
	Total for question 15		11

Question Number	Answer		Mark
14	For the electron (in the atom) to move from −13.6eV to −1.5eV requires 12.1eV	(1)	
	0.2eV/ remaining (kinetic) energy left for the (incoming) electron	(1)	
	Idea that energy of a photon is transferred to a single electron **Or** Idea that photon can only excite an electron if it matches the energy difference between levels **Or** Idea that photons give all of their energy (or none at all)	(1)	
	Photon energy is not exactly 12.1eV so electron/atom remains at the −13.6eV level **Or** There is no transition equivalent to 12.3 eV **Or** There is no −1.3 eV energy level	(1)	**4**
	(Ignore references to work function or photons being emitted) (MP1 – award this mark if 12.1eV is seen) (MP3 – do not award simply for saying "one photon interacts with one electron") (MP4 – Award if candidates make it clear that 12.1eV is not equal to 12.3eV in an argument to explain why photons cannot produce the change in energy levels for the electron)		
	Total for Question 14		**4**