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	

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 (B or C)**	1

10	**B is the correct answer** A is not correct because E_1 should be added to the energy of the photon. C is not correct because the speed of light should be part of the numerator and wavelength should be the denominator and E_1 should be added to the energy of the photon. D is not correct because the speed of light should be part of the numerator and wavelength should be the denominator.	**1**

9	**D is the correct answer** A is not the correct answer as this corresponds to the smallest energy change B is not the correct answer as this corresponds to the smallest energy change C is not the correct answer as this corresponds to the smallest energy change	**(1)**

2	**D is the correct answer** A is not correct because the electrons need to move to lower energy levels and emit photons. B is not correct because the electrons need to move to lower energy levels. C is not correct because the electrons need to emit photons.	**1**
3	**A is the correct answer**	1

5	**The only correct answer is A (A because this emits a photon with the highest frequency)** B is not correct as a photon would be absorbed C is not correct because the frequency would be smaller so wavelength larger D is not correct as a photon would be absorbed	**1**

Question Number	Answer	Mark
16(a)	Interference/superposition takes place **(1)** Destructive (interference) occurs when (the two reflective) waves meet in antiphase (and these wavelengths are missing) **(1)** If the path difference is equal to $(n + 1/2)\,\lambda$ [Allow If $2d = (n + 1/2)\,\lambda$] **(1)**	**3**
16(b)	Use of path difference = $2d$ **(1)** Use of minimum occurs when path difference = $\lambda / 2$ **(1)** Use of $n = c/v$ (with $v = f\lambda$) **(1)** wavelength in air = 6.0×10^{-7} m **(1)** Example of calculation Path difference = $2 \times 6.5 \times 10^{-8}$ m = 1.3×10^{-7} m wavelength in coating = $2 \times 1.3 \times 10^{-7}$ m = 2.6×10^{-7} m wavelength in air = 2.6×10^{-7} m × 2.3 = 5.98×10^{-7} m = 598 nm	**4**
16(c)	Use of $I = P/A$ **(1)** Use of $P = E/t$ **(1)** Use of Efficiency = useful power output/power input **(1)** Efficiency = 0.31 **Or** 31% **(1)** Example of calculation Power incident on solar array = 1.1 kW m^{-2} × 8.7 m^2 × cos 60 = 4.785 kW Power output from solar array = 5.4×10^6 J ÷ 3600 s = 1.5 kW Efficiency = 1.5 kW ÷ 4.785 kW = 0.313	**4**
	Total for question 16	**11**

Question Number	Answer		Mark
17(a)	Electron moves to a higher energy level Then drops back (down, releasing a photon) (MP1 allow electron is excited. MP2 allow electron is de-excited) (MP2 allow returns to ground state)	**(1)** **(1)**	**2**
17(b)(i)	Use of $v = f\lambda$ with $v = 3.00 \times 10^8$ m s^{-1} Use of $E = hf$ Conversion from J to eV Photon energy = 5.7 eV Example of calculation $v = f\lambda$, f = 3.00×10^8 m s^{-1} / 218×10^{-9} m = 1.38×10^{15} Hz $E = hf$ = 6.63×10^{-34} Js × 1.38×10^{15} Hz = 9.12×10^{-19} J E (in eV) = 9.12×10^{-19} J / 1.60×10^{-19} J eV^{-1} = 5.70 eV	**(1)** **(1)** **(1)** **(1)**	**4**
17(b)(ii)	(Differences between) energy levels are discrete **Or** only certain jumps/transitions are possible No difference of 5.7 eV, so not possible (for this photon to be produced) (MP2 – allow comment consistent with their calculated value from b(i))	**(1)** **(1)**	**2**
17(c)(i)	Use of $hf = \Phi + \frac{1}{2} mv^2_{max}$ Use of $E_k = \frac{1}{2} mv^2$ with $m = 9.11 \times 10^{-31}$ kg Maximum possible speed = 1.5×10^6 m s^{-1} Example of calculation $E_k = hf - \Phi = 1.63 \times 10^{-18}$ J – 5.89×10^{-19} J = 1.04×10^{-18} J $E_k = \frac{1}{2} mv^2$, $v = \sqrt{\frac{1.04 \times 10^{-18}\text{ J}}{0.5 \times 9.11 \times 10^{-31}\text{kg}}} = 1.5 \times 10^6$ m s^{-1}	**(1)** **(1)** **(1)**	**3**
17(c)(ii)	**MAX 2** from: • There is a minimum/threshold frequency for electron release • Electrons are released instantaneously • (Changing) intensity does not affect KE/speed/release of an electron **MAX 2** from: • The energy of a photon increases as frequency increases • Photon energy has to be greater than the work function • Each photon only interacts with one electron	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**3**
	Total for question 17		**14**

Question Number	Answer	Mark
18a	Use of speed = distance / time (1) Calculates distance travelled by sound in 3s = 1020 (m) **Or** calculates time taken for sound to travel 1 km = 2.94 (s) **Or** calculates speed to travel 1000m in 3 seconds = 333 (ms^{-1}) (1) Time taken by light to reach 1 km is almost instantaneous / 3.3×10^{-6} s so teacher is (approximately) correct. (1) <u>Example of calculation</u> For light, $t = d/v = 1000$ m / 3.00×10^{8} ms^{-1} = 3.33×10^{-6} s For sound, $t = d/v = 1000$ m / 340 ms^{-1} = 2.94 s Difference in arrival time = 2.94 s ≈ 3 s	**(3)**
18bi	Use of $Q = It$ (1) $Q = 0.75$ C (1) <u>Example of calculation</u> $Q = It = 25{,}000$ A × (30×10^{-6} s) = 0.75C	**(2)**
18bii	Use of $P = VI$ (1) $P = 3.0 \times 10^{13}$ W (1) <u>Example of calculation</u> $P = VI = (1.2 \times 10^{9}$ V) × 25,000 A = 3.0×10^{13} W	**(2)**
18biii	Use of $A = \pi r^2$ (1) Use of $R = \rho l/A$ (1) $\rho = 0.24$ (Ω m) (1) <u>Example of calculation</u> Cross sectional area of wire = $\pi r^2 = \pi\ (2.5 \times 10^{-2})^2 = 1.96 \times 10^{-3}$ m^2 $R = V/I = (1.2 \times 10^{9}$ V) / 25,000 A = 48,000 Ω ρ = RA/l = (48,000 Ω) (1.96×10^{-3} m^2) / 400 m = 0.235 Ωm	**(3)**
18biv	Air in the lightning channel has been ionised **Or** Lightning channel unlikely to have a uniform diameter / CSA (1)	**(1)**

18ci	Energy levels (in atoms) are discrete/specific (1) (Energy makes) electrons move up energy levels **Or** Electrons are excited (1) (Electrons) move back down energy levels, releasing photons **Or** (Electrons) are de-excited, releasing photons (1) Energy difference (between levels) is proportional to frequency of photon (resulting in line spectrum being produced) **Or** Photon energy is proportional to frequency (resulting in line spectrum being produced) (1)	**(4)**
18cii	Different atoms/elements have different (differences in) energy levels (1)	**(1)**
	Total for question 18	**16**

Question Number	Answer	Mark
14a	Minimum energy required to release/emit a (photo)electron (from the surface of the metal) (1)	**(1)**
14b	Ultraviolet has a higher (photon) energy (than visible light) (1) Ultraviolet (photons) have an energy greater than the work function **Or** Visible light (photons) have an energy less than the work function (1) **OR** Ultraviolet has a higher frequency (than visible light) (1) Ultraviolet has a frequency greater than the threshold frequency **Or** Visible light has a frequency less than the threshold frequency (1) (Allow converse statements for MP1)	**(2)**
14ci	(Increased intensity means) more <u>photons</u> per second (1) (More photons leads to) more electrons emitted (per second) (1) Reading on ammeter is increased **Or** Current is increased (1) (For MP1 there needs to be an indication of rate e.g. "per unit time")	**(3)**
14cii	Use of $E = hf$ (1) Use of $V = W/Q$ (1) Use of $hf = \Phi + \frac{1}{2} mv^2_{max}$ (1) Work function = 7.6×10^{-19} (J) (1) **<u>Example of Calculation</u>** $hf = \Phi + \frac{1}{2} mv^2_{max} = hf = \Phi + QV$ $hf = (6.63 \times 10^{-34}\ \text{Js})\ (2.00 \times 10^{15}\ \text{Hz}) = 1.33 \times 10^{-18}$ J $QV/eV = (1.60 \times 10^{-19}\ \text{C})\ (3.59\ \text{V}) = 5.74 \times 10^{-19}$ J hf – eV = 7.56×10^{-19} J	**(4)**
	Total for question 14	**10**

Question Number	Answer		Mark
16a	(Sodium) electrons/atoms gain/absorb energy And electrons move to higher energy levels (Sodium) electrons drop to lower energy levels, releasing photons (For MP2 & MP3, allow excited and de-excited) (For MP2 & MP3, do not allow "atoms" for "electrons") (For "levels" accept shells, orbitals, states)	(1) (1) (1)	**3**
16b	Use of $c = f\lambda$ **and** Use of $E=hf$ Converts J to eV Energy = 2.11eV Example of calculation $f = (3.00 \times 10^{8}\ \text{m s}^{-1}) / (589 \times 10^{-9}\ \text{m}) = 5.09 \times 10^{14}\ \text{Hz}$ $E = (6.63 \times 10^{-34}\ \text{Js}) \times (5.09 \times 10^{14}\ \text{Hz}) = 3.38 \times 10^{-19}\ \text{J}$ E (in eV) $= (3.38 \times 10^{-19}\ \text{J}) / (1.60 \times 10^{-19}\ \text{J eV}^{-1}) = 2.11\text{eV}$	(1) (1) (1)	**3**
16c	Uses $\tan\theta = s / D$ Use of $n\lambda = d\sin\theta$ with $n = 1$ Grating has 301 lines / mm, so the label is correct. **OR** Uses $sin\theta = \frac{s}{\sqrt{(s^2+D^2}}$ Use of $n\lambda = d\sin\theta$ with $n = 1$ Grating has 301 lines / mm, so the label is correct. (Use of double slit or single slit equations does not gain any credit) (Allow reverse calculation to show that 300 lines per mm leads to a value of λ that is close to the given value or that 300 lines per mm leads to a value of d or θ that is close to a value calculated). Example of calculation $\tan\theta = 0.234\ \text{m} / 1.30\ \text{m} = 0.18$ $\theta = 10.2°$ $n\lambda = d\sin\theta$, so $d = 589 \times 10^{-9}\ \text{m} / \sin 10.2° = 3.33 \times 10^{-6}\ \text{m}$ lines per mm $= 1 / 3.33 \times 10^{-3}\ \text{m} = 301$.	(1) (1) (1) (1) (1) (1)	**3**
	Total for question 16		**9**