Unit 4 AOS 1 Formula Sheet – Light and Matter

Constants

Planck's constant (eV s)	$h = 4.14 \times 10^{-15}$ eV s
Planck's constant (J s)	$h = 6.63 \times 10^{-34}$ J s
Speed of light in a vacuum	$c = 3.00 \times 10^{8}$ m s^{-1}
Mass of the electron	$m_e = 9.11 \times 10^{-11}$ kg

Waves

Universal wave equation	$v = f\lambda$	v = speed of the wave (m s^{-1}) f = frequency of the wave (Hz) λ = wavelength (m) Note: for electromagnetic waves, $v = c$
Standing wave wavelength (both ends fixed)*	$\lambda_n = \frac{2l}{n}$	λ_n= wavelength of the nth harmonic (m) l = length of the string (m) n = number of the harmonic (1, 2, 3…) – same as number of antinodes
Standing wave frequency (both ends fixed)*	$f_n = \frac{nv}{2l}$	f_n= frequency of the nth harmonic (Hz or s^{-1}) v = speed of the wave (m s^{-1}) l = length of the string (m) n = number of the harmonic (1, 2, 3…) – same as number of antinodes
Constructive interference	$PD = n\lambda$	PD = path difference (m) n = integer (0, 1, 2, 3…) λ = wavelength (m)
Destructive interference	$PD = \left(n + \frac{1}{2}\right)\lambda$	PD = path difference (m) n = integer (0, 1, 2, 3…) λ = wavelength (m)
Interference pattern spacing	$\Delta x = \frac{\lambda L}{d}$ (when L >> d)	λ = wavelength (m) Δx = fringe spacing (m) L = distance between slits and screen (m) d = distance between slits (m)
Diffraction*	$Diffraction \propto \frac{\lambda}{w}$	λ = wavelength (m) w = width of gap (m) Note: is considered significant if $\frac{\lambda}{w} \geq 1$ or $\lambda \approx w$ (ie. same order of magnitude)

The nature of light and matter

Work function*	$\phi = hf_0$	ϕ = work function (J or eV) h = Planck's constant (J s or eV s) f_0 = threshold frequency of the metal (Hz)
Photoelectric effect	$E_{K\,max} = hf - \phi$	$E_{K\,max}$ = maximum kinetic energy of an emitted photoelectron (J or eV) h = Planck's constant (J s or eV s) f = frequency of the incident photon (Hz) ϕ = work function of the metal (J or eV)
Stopping voltage*	$E_{K\,max} = q_e V_0$ $E_{K\,max} = V_0$ Note: use first equation if $E_{K\,max}$ in J, second equation if $E_{K\,max}$ in eV.	$E_{K\,max}$ = maximum kinetic energy of an emitted photoelectron (J or eV) q_e = charge of an electron (C) V_0 = stopping voltage (V)
Photon Momentum* *Latter part of formula is not on VCAA sheet*	$p = \frac{h}{\lambda} = \frac{hf}{c}$	p = momentum (kg m s^{-1}) h = Planck's constant (J s) λ = wavelength (m) f = frequency of the incident photon (Hz) c = speed of light in a vacuum (m s^{-1}) Note: Planck's constant must be in J s (not eV s)
Photon energy* *Last part of formula is not on VCAA sheet*	$E = hf = \frac{hc}{\lambda} = pc$	E = photon energy (J or eV) h = Planck's constant (J s or eV s) f = frequency of the incident photon (Hz) λ = wavelength (m) c = speed of light in a vacuum (m s^{-1}) p = momentum (kg m s^{-1})
Light output power (photoelectric effect)*	$P = nhf = n(\frac{hc}{\lambda})$	P = power of the light source (W) n = number of incident photons per second (integer) h = Planck's constant (J s) f = frequency of the incident photon (Hz) λ = wavelength (m) Note: Planck's constant must be in J s (not eV s)
de Broglie Wavelength* *Latter part of formula is not on VCAA sheet*	$\lambda = \frac{h}{p} = \frac{h}{mv}$	p = momentum (kg m s^{-1}) h = Planck's constant (J s) λ = wavelength (m) m = mass of particle (kg) v = speed of particle (m s^{-1}) Note: Planck's constant must be in J s (not eV s)
Energy of electron*	$E = \frac{1}{2}mv^2 = \frac{p^2}{2m}$	E = energy of electron (J) p = momentum (kg m s^{-1}) m = mass of electron (kg) v = speed of the electron (m s^{-1})
Wavelength of electron* (alternative formula)	$\lambda = \frac{h}{\sqrt{2mE}}$	h = Planck's constant (J s) λ = wavelength (m) E = energy of electron (J) m = mass of electron (kg) Note: Planck's constant must be in J s (not eV s)

Special Relativity

Lorentz factor	$\gamma = \dfrac{1}{\sqrt{1-\frac{v^2}{c^2}}}$	γ = Lorentz factor (no unit) v = speed of the subject (m s^{-1}) c = speed of light in a vacuum (m s^{-1})
Rearranged Lorentz factor*	$v = c\sqrt{1-\frac{1}{\gamma^2}}$	v = speed of the subject (m s^{-1}) c = speed of light in a vacuum (m s^{-1}) γ = Lorentz factor (no unit)
Time dilation	$t = \gamma t_0$	t = dilated time (s) t_0 = proper time (s) γ = Lorentz factor (no unit)
Length contraction	$L = \dfrac{L_0}{\gamma}$	L = contracted length (m) L_0 = proper length (m) γ = Lorentz factor (no unit)
Relativistic mass*	$m = \gamma m_0$	m = relativistic mass (kg) m_0 = rest mass (kg) γ = Lorentz factor (no unit)
Relativistic momentum*	$p = \gamma m_0 v = \gamma p_0$	p = relativistic momentum (kg m s^{-1}) γ = Lorentz factor (no unit) m_0 = rest mass (kg) v = speed (m s^{-1}) p_0 = momentum as defined in classical mechanics (kg m s^{-1})
Energy released during nuclear fission or fusion*	$\Delta E = \Delta m c^2$	ΔE = energy released (J) Δm = mass defect (kg) c = speed of light in a vacuum (m s^{-1})
Relativistic rest energy	$E_0 = m_0 c^2$	E_0 = relativistic rest energy (J) m_0 = rest mass (kg) c = speed of light in a vacuum (m s^{-1})
Relativistic total energy	$E_{\text{total}} = E_{\text{k}} + E_0 \; = \gamma m_0 c^2$	E_{total} = relativistic total energy (J) E_k = relativistic kinetic energy (J) E_0 = relativistic rest energy (J) m_0 = rest mass (kg) c = speed of light in a vacuum (m s^{-1}) γ = Lorentz factor (no unit)
Relativistic kinetic energy	$E_{\text{k}} = (\gamma - 1) m_0 c^2$	E_k= relativistic kinetic energy (J) γ = Lorentz factor (no unit) m_0 = rest mass (kg) c = speed of light in a vacuum (m s^{-1})

**Indicates formulas not present on the VCAA formula sheet*

Unit conversions

$1 \text{ eV} = 1.6 \times 10^{-19}$ J			
p=pico=10^{-12}	n=nano=10^{-9}	μ=micro=10^{-6}	m=milli=10^{-3}
k=kilo=10^{3}	M=mega=10^{6}	G=giga=10^{9}	T=tera=10^{12}