

IB Physics SL & HL Formula Sheet

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Fundamental Constants		
Symbol	Quantity	Approximate Value
g	Free fall acceleration (Earth's surface)	9.8 m s^{-2}
G	Gravitational constant	$6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
N_A	Avogadro's constant	$6.022 \times 10^{23} \text{ mol}^{-1}$
R	Gas constant	$8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
k_B	Boltzmann's constant	$1.38 \times 10^{-23} \text{ J K}^{-1}$
σ	Stefan-Boltzmann constant	$5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$
k	Coulomb constant	$8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$
ϵ_0	Free space permittivity	$8.85 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$
μ_0	Free space permeability	$4\pi \times 10^{-7} \text{ T m A}^{-1}$
c	Speed of light in a vacuum	$3.00 \times 10^8 \text{ m s}^{-1}$
h	Planck's constant	$6.63 \times 10^{-34} \text{ J s}$
e	Elementary charge	$1.60 \times 10^{-19} \text{ C}$
m_e	Electron rest mass	$9.110 \times 10^{-31} \text{ kg} = 0.000549u$ $= 0.511 \text{ MeV } c^{-2}$
m_p	Proton rest mass	$1.673 \times 10^{-27} \text{ kg} = 1.007276u = 938 \text{ MeV } c^{-2}$
m_n	Neutron rest mass	$1.675 \times 10^{-27} \text{ kg} = 1.008665u = 940 \text{ MeV } c^{-2}$
u	Unified atomic mass unit	$1.661 \times 10^{-27} \text{ kg} = 931.5 \text{ MeV } c^{-2}$
S	Solar constant (Earth's surface)	$1.36 \times 10^3 \text{ W m}^{-2}$
R_0	Fermi Radius	$1.20 \times 10^{-15} \text{ m}$

Geometry and Trigonometry Equations	
Circumference (circle)	$C = 2\pi r$
Area (triangle)	$A = \frac{1}{2}(bh)$
Area (circle)	$A = \pi r^2$
Curved Surface Area (cylinder)	$A = 2\pi rh$
Surface Area (sphere)	$A = 4\pi r^2$
Volume (sphere)	$V = \frac{4}{3}\pi r^3$
Volume (cylinder)	$V = \pi r^2 h$
Volume (prism)	$V = Ah$
Volume (cuboid)	$V = lwh$
Trigonometric relationships	$\tan \theta = \frac{\sin \theta}{\cos \theta}$ $\sin^2 \theta + \cos^2 \theta = 1$
Vector Components	$A_H = A \cos \theta$ $A_V = A \sin \theta$ A_H = horizontal component of vector A , A_V = vertical component of vector A , θ = the angle relative to the horizontal

Metric Prefixes		
Symbol	Prefix	Value
P	peta-	10^{15}
T	tera-	10^{12}
G	giga-	10^9
M	mega-	10^6
k	kilo-	10^3
h	hecto-	10^2
da	deca-	10^1
d	deci-	10^{-1}
c	centi-	10^{-2}
m	milli-	10^{-3}
μ	micro-	10^{-6}
n	nano-	10^{-9}
p	pico-	10^{-12}
f	femto-	10^{-15}

Unit Conversions	
1 radian (rad)	$\frac{180^\circ}{\pi}$
Temperature (K)	Temperature ($^\circ\text{C}$) + 273
1 light year (ly)	$9.46 \times 10^{15} \text{ m}$
1 parsec (pc)	3.26 ly
1 astronomical unit (AU)	$1.50 \times 10^{11} \text{ m}$
1 kilowatt-hour (kWh)	$3.60 \times 10^6 \text{ J}$
hc	$1.99 \times 10^{-25} \text{ J m} = 1.24 \times 10^{-6} \text{ eV m}$

Uncertainty Calculations	
Addition and Subtraction	If: $y = a \pm b$ then: $\Delta y = \Delta a + \Delta b$
Multiplication and Division	If: $y = \frac{ab}{c}$ then: $\frac{\Delta y}{y} = \frac{\Delta a}{a} + \frac{\Delta b}{b} + \frac{\Delta c}{c}$
Exponentiation	If: $y = a^n$ then: $\frac{\Delta y}{y} = \left n \frac{\Delta a}{a} \right $

Where a, b, c and y are quantities with absolute uncertainties Δa , Δb , Δc and Δy

Theme A: Space, Time and Motion

A.1 Kinematics

Uniform Acceleration Equations	$v = u + at ; s = ut + \frac{1}{2}at^2 ; v^2 = u^2 + 2as ; s = \frac{v+u}{2}t$ <p>v = final velocity, u = initial velocity, a = acceleration, t = time, s = displacement</p>
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A.2 – Forces & Momentum

Friction	$F_f \leq \mu_s F_N ; F_f = \mu_d F_N$ <p>F_f = frictional force, F_N = normal reaction force, μ_s = static friction coefficient, μ_d = dynamic friction coefficient</p>
Hooke's Law for Springs	$F_H = -kx$ <p>F_H = restoring force, k = spring constant, x = displacement from equilibrium</p>
Drag Force in Fluids (Stokes' Law)	$F_d = 6\pi\eta rv$ <p>F_d = drag force, η = viscosity of fluid, r = radius of cross section, v = relative motion to fluid</p>
Buoyant Force	$F_b = \rho Vg$ <p>F_b = buoyant force, ρ = density of displaced fluid, V = volume of displaced fluid, g = gravitational field strength</p>
Force of Gravity (Weight)	$F_g = mg$ <p>F_g = gravitational force, m = mass of object, g = gravitational field strength</p>
Definition of Momentum	$p = mv$ <p>p = momentum, m = mass, v = velocity</p>
Impulse	$J = F\Delta t$ <p>J = impulse, F = net force, Δt = time interval</p>
Newton's Second Law	$F = ma = \frac{\Delta p}{\Delta t}$ <p>F = net force, m = mass, a = acceleration, Δp = change in momentum, Δt = time interval</p>
Centripetal Acceleration	$a = \frac{v^2}{r} = \omega^2 r = \frac{4\pi^2 r}{T^2}$ <p>a = acceleration, v = speed, r = radial distance, ω = angular speed, T = period</p>
Relationship between Tangential and Angular Velocity	$v = \frac{2\pi r}{T} = \omega r$ <p>v = tangential velocity, r = radial distance, T = period, ω = angular velocity</p>

A.3 – Work, Energy, and Power

Definition of Work	$W = Fscos\theta$ <p>W = work done, F = force, s = displacement, θ = angle between force and displacement</p>
Definition of Kinetic Energy	$E_K = \frac{1}{2}mv^2 = \frac{p^2}{2m}$ <p>E_K = kinetic energy, m = mass, v = speed, p = momentum</p>
Gravitational Potential Energy in a Uniform Field	$\Delta E_p = mg\Delta h$ <p>ΔE_p = change in gravitational potential energy, m = mass, g = gravitational field strength, Δh = change in height</p>
Definition of Elastic Potential Energy	$E_H = \frac{1}{2}k\Delta x^2$ <p>E_H = elastic potential energy, k = spring constant, Δx = compression or expansion of spring</p>
Power	$P = \frac{\Delta W}{t} = Fv$ <p>P = power, ΔW = work done, t = time, F = force, v = velocity</p>
Efficiency	$\eta = \frac{\text{useful work out}}{\text{total work in}} = \frac{\text{useful power out}}{\text{total power in}}$ <p>η = efficiency</p>

A.4 Rotational Mechanics

HL Definition of Torque	$\tau = Fr\sin\theta$ <p>τ = torque, F = force, r = radial distance to force, θ = angle between force and radial vector</p>
HL Angular Acceleration Equations	$\Delta\theta = \frac{(\omega_i + \omega_f)}{2}t \quad \omega_f = \omega_i + \alpha t \quad \Delta\theta = \omega_i t + \frac{1}{2}\alpha t^2 \quad \omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$ <p>$\Delta\theta$ = angular displacement, ω_i = initial angular speed, ω_f = final angular speed, α = angular acceleration, t = time</p>
HL Moment of Inertia	$I = \Sigma mr^2$ <p>I = moment of inertia, m = mass, r = radial distance</p>
HL Newtons Second Law (Rotational)	$\tau = I\alpha$ <p>τ = net torque, I = moment of inertia, α = angular acceleration</p>
HL Definition of Angular Momentum	$L = I\omega$ <p>L = angular momentum, I = moment of inertia, ω = angular velocity</p>
HL Change in Angular Momentum	$\Delta L = \tau\Delta t \quad \Delta L = \Delta(I\omega)$ <p>ΔL = change in angular momentum, τ = net torque, t = time, I = moment of inertia, ω = angular speed</p>
HL Rotational Kinetic Energy	$E_k = \frac{1}{2}I\omega^2 = \frac{L^2}{2I}$ <p>E_k = rotational kinetic energy, I = moment of inertia, ω = angular speed, L = angular momentum</p>

A.5 Special Relativity

HL	Galilean Transformations	$x' = x - vt$ $t' = t$ $u' = u - v$ x, u, t = position, speed, and time in first reference frame, x', u', t' = position, speed, and time in second reference frame, v = relative velocity of second reference frame to first reference frame
HL	Relativistic Transformations	$x' = \gamma(x - vt)$ $t' = \gamma\left(t - \frac{vx}{c^2}\right)$ $u' = \frac{u-v}{1-\frac{uv}{c^2}}$ x, u, t = position, speed and time in first reference frame, x', u', t' = position, speed and time in second reference frame, γ = Lorentz factor, v = relative velocity of second reference frame to first reference frame
HL	Lorentz Factor	$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$ γ = Lorentz factor, v = speed, c = speed of light
HL	Spacetime interval	$(\Delta s)^2 = (c\Delta t)^2 - \Delta x^2$ Δs = spacetime interval, c = speed of light, Δt = time between events according to observer, Δx = distance between events acc. to observer
HL	Time Dilation	$\Delta t = \gamma\Delta t_0$ Δt = relativistic time, γ = Lorentz factor, Δt_0 = proper time
HL	Length Contraction	$L = \frac{L_0}{\gamma}$ L = relativistic length, γ = Lorentz factor, L_0 = proper length
HL	Space-time diagram angle	$\tan \theta = \frac{v}{c}$ θ = angle between axes of inertial frames of reference, v = relative speed of frames of reference, c = speed of light

Theme B: The Particulate Nature of Matter

B.1 – Thermal Energy Transfers

Density	$\rho = \frac{m}{V}$ ρ = density, m = mass, V = volume
Average Kinetic Energy of an Ideal Monatomic Gas	$\bar{E}_k = \frac{3}{2} k_b T$ \bar{E}_k = average kinetic energy, k_b = Boltzmann's constant, T = temperature in Kelvin
Specific and Latent Heat	$Q = mc\Delta T$; $Q = mL$ Q = heat, m = mass, c = specific heat capacity, L = specific latent heat
Thermal Conduction	$\frac{\Delta Q}{\Delta t} = -kA \frac{\Delta T}{\Delta x}$ $\frac{\Delta Q}{\Delta t}$ = rate of heat transfer, k = conductivity constant, A = cross-sectional area, ΔT = temperature difference, Δx = length of object
Stefan-Boltzmann Law	$L = \sigma AT^4$ L = luminosity/power, σ = Stefan-Boltzmann constant, A = surface area, T = temperature in Kelvin
Brightness as a Function of Distance	$b = \frac{L}{4\pi d^2}$ b = brightness/intensity, L = power of source, d = distance from source
Wien's Law	$\lambda_{max} T = 2.9 \times 10^{-3} mK$ λ_{max} = peak wavelength of blackbody, T = temperature in Kelvin

B.2 – Greenhouse Effect

Definition of Emissivity	$emissivity = \frac{\text{power radiated per unit area}}{\sigma T^4}$ σ = Stefan-Boltzmann constant, T = kelvin temperature
Definition of Albedo	$albedo = \frac{\text{total scattered power}}{\text{total incident power}}$

B.3 – Ideal Gas Model

Definition of Pressure	$P = \frac{F}{A}$ F = force, A = area
Amount in Moles	$n = \frac{N}{N_A}$ n = amount in moles, N = number of particles, N_A = Avogadro's Constant
Combined Gas Law	$\frac{PV}{T} = \text{constant}$ P = pressure, V = volume, T = temperature
Ideal Gas Equation of State	$PV = nRT = Nk_b T$ pressure = P, V = volume, n = amount in moles, R = gas constant, T = temperature in Kelvin, N = number of particles, k_b = Boltzmann's constant
Pressure of an Ideal Gas	$P = \frac{1}{3} \rho v^2$ P = pressure, ρ = density, v = average particle speed
Internal Energy of an Ideal Gas	$U = \frac{3}{2} nRT = \frac{3}{2} Nk_b T$ U = internal energy, n = number of moles, R = gas constant, T = temperature in Kelvin, N = number of particles, k_b = Boltzmann's constant

B.4 - Thermodynamics

HL	First Law of Thermodynamics	$Q = \Delta U + W$ Q = heat added, ΔU = change in internal energy, W = work done by the gas
HL	Work Done by a Gas	$W = P\Delta V$ W = work done by the gas, P = pressure, ΔV = change in volume
HL	Change in Internal Energy of an Ideal Gas	$\Delta U = \frac{3}{2} nR\Delta T = \frac{3}{2} Nk_b \Delta T$ ΔU = change in internal energy, n = moles, R = gas constant, ΔT = change in temperature, N = number of particles, k_b = Boltzmann's constant
HL	Entropy – Macroscopic Formula	$\Delta S = \frac{\Delta Q}{T}$ ΔS = change in entropy, ΔQ = heat transferred, T = temperature in Kelvin
HL	Entropy – Microscopic Formula	$S = k_b \ln \Omega$ S = entropy, k_b = Boltzmann's constant, Ω = number of microstates
HL	Adiabatic Change of State Formula	$PV^{\frac{5}{3}} = \text{constant}$ P = pressure, V = volume
HL	Efficiency	$\eta = \frac{\text{useful work}}{\text{input energy}}$ η = efficiency
HL	Carnot Efficiency	$\eta_{carnot} = 1 - \frac{T_c}{T_h}$ η_{carnot} = Carnot efficiency, T_c = temperature of cold reservoir, T_h = temperature of hot reservoir

B.5 – Electric Circuits

Definition of Electrical Current	$I = \frac{\Delta q}{\Delta t}$ <p>I = electrical current, q = charge, t = time</p>
Potential Difference (Voltage)	$V = \frac{W}{q}$ <p>V = potential difference, W = work, q = charge</p>
Definition of Resistance	$R = \frac{V}{I}$ <p>R = resistance, V = potential difference, I = current</p>
Resistivity	$\rho = \frac{RA}{l}$ <p>ρ = resistivity, R = resistance, l = length, A = cross-sectional area</p>
Electrical Power	$P = IV = I^2R = \frac{V^2}{R}$ <p>P = power, V = potential difference, I = current, R = resistance</p>
Series Circuit Relationships	$I = I_1 = I_2 = \dots \quad V = V_1 + V_2 + \dots \quad R_s = R_1 + R_2 + \dots$ <p>I = current in the circuit, V = total voltage across all elements, I_1, I_2, V_1, V_2 = current/voltage in circuit elements, R_s = equivalent resistance, R_1, R_2 = resistances of circuit elements</p>
Parallel Circuit Relationships	$I = I_1 + I_2 + \dots \quad V = V_1 = V_2 = \dots \quad \frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$ <p>I = total current to parallel elements, V = voltage in each parallel branch, R_p = equivalent resistance, R_1, R_2 = resistances of circuit elements</p>
Model of Internal Resistance	$\epsilon = I(R + r)$ <p>ϵ = emf, I = current, R = resistance of external circuit, r = internal resistance</p>

Theme C: Wave Behaviour

C.1 – Simple Harmonic Motion

Defining Equation of SHM		$a = -\omega^2 x$ a = acceleration, ω = angular frequency, x = displacement
Relationship between Period and Frequency		$T = \frac{1}{f} = \frac{2\pi}{\omega}$ T = period, f = frequency, ω = angular frequency
Period of a Mass-Spring System		$T = 2\pi \sqrt{\frac{m}{k}}$ T = period, m = mass, k = spring constant
Period of a Pendulum		$T = 2\pi \sqrt{\frac{l}{g}}$ T = period, l = length, g = gravitational field strength
HL	Displacement as a Function of Time	$x = x_0 \sin(\omega t + \phi)$ x = displacement, x_0 = max displacement, ω = angular frequency, t = time, ϕ = phase angle
HL	Velocity as a Function of Time	$v = \omega x_0 \cos(\omega t + \phi)$ v = velocity, ω = angular frequency, x_0 = max displacement, t = time, ϕ = phase angle
HL	Velocity as a Function of Position	$v = \pm \omega \sqrt{(x_0^2 - x^2)}$ v = velocity, ω = angular frequency, x_0 = max displacement, x = displacement
HL	Total Energy in SHM	$E_T = \frac{1}{2} m \omega^2 x_0^2$ E_T = total energy, m = mass, ω = angular frequency, x_0 = max displacement
HL	Potential Energy as a Function of Position	$E_p = \frac{1}{2} m \omega^2 x^2$ E_p = potential energy, m = mass, ω = angular frequency, x = displacement

C.2 – Travelling Waves

Wave Equation		$v = f\lambda = \frac{\lambda}{T}$ v = wave speed, f = frequency, λ = wavelength, T = period of oscillation
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C.3 – Refraction, Diffraction, Superposition and Interference

Snell's Law		$\frac{n_1}{n_2} = \frac{\sin \theta_2}{\sin \theta_1} = \frac{v_2}{v_1}$ n = index of refraction, θ = angle between normal and the ray, v = speed of wave
Constructive Interference Condition		path difference = $n\lambda$ n = integer number, λ = wavelength
Destructive Interference Condition		path difference = $(n + \frac{1}{2})\lambda$ n = integer number, λ = wavelength
Two Source Interference		$s = \frac{\lambda D}{d}$ s = fringe spacing, λ = wavelength, D = distance between sources and screen, d = distance between sources
HL	Angle between Peak and Primary Minimum in Single-Slit Diffraction	$\theta = \frac{\lambda}{b}$ θ = angle, λ = wavelength, b = slit width
HL	Multi-Slit Interference	$n\lambda = d \sin \theta$ n = order, d = slit spacing, λ = wavelength, θ = angle

C.5 – Doppler Effect

Doppler Effect for Electromagnetic Waves		$\frac{\Delta f}{f} = \frac{\Delta \lambda}{\lambda} \approx \frac{v}{c}$ f = frequency, Δf = frequency shift, λ = wavelength, $\Delta \lambda$ = wavelength shift, v = relative speed, c = speed of light
HL	Doppler Effect for Mechanical Waves	Moving source: $f' = f \left(\frac{v}{v \pm u_s} \right)$ Moving observer: $f' = f \left(\frac{v \pm u_o}{v} \right)$ f' = observed frequency, f = emitted frequency, u_s = speed of moving source, u_o = speed of moving observer, v = wave speed

Theme D: Fields

D.1 Gravitational Fields

Newton's Law of Gravitation	$F = \frac{Gm_1m_2}{r^2}$ <p>F = gravitational force, G = gravitational constant, m_1, m_2 = mass, r = distance</p>
Gravitational Field Strength	$g = \frac{F}{m} = G \frac{M}{r^2}$ <p>g = gravitational field strength, F = gravitational force, m = mass of object in field, M = mass of object creating field</p>
HL Potential Energy of a Two-Mass System	$E_p = -G \frac{m_1m_2}{r}$ <p>E_p = gravitational potential energy, G = gravitational constant, M = mass, r = distance</p>
HL Gravitational Potential	$V_g = -G \frac{M}{r}$ <p>V_g = gravitational potential, G = gravitational constant, M = mass, r = distance</p>
HL Relationship between Field and Potential	$g = -\frac{\Delta V_g}{\Delta r}$ <p>g = gravitational field strength, $\frac{\Delta V_g}{\Delta r}$ = rate of change of potential</p>
HL Work Done on a Mass Moving Across a Change in Potential	$W = m\Delta V_g$ <p>W = work done, m = mass, ΔV_g = change in gravitational potential</p>
HL Escape Velocity	$v_{esc} = \sqrt{\frac{2GM}{r}}$ <p>v_{esc} = escape speed, G = gravitational constant, M = central mass, r = distance from centre of central mass</p>
HL Orbital Speed	$v_{orbital} = \sqrt{\frac{GM}{r}}$ <p>$v_{orbital}$ = orbital speed, G = gravitational constant, M = central mass, r = distance from centre of central mass</p>

D.2 – Electromagnetic Fields

Coulomb's Law	$F = \frac{kq_1q_2}{r^2}, k = \frac{1}{4\pi\epsilon_0}$ <p>F = force, k = Coulomb's constant, q_1, q_2 = charge, r = distance, ϵ_0 = free space permittivity</p>
Definition of Electric Field Strength	$E = \frac{F}{q}$ <p>E = electric field strength, F = electric force, q = charge</p>
Field Between Parallel Plates	$E = \frac{V}{d}$ <p>E = electric field strength, V = voltage across plates, d = plate separation</p>
HL Potential Energy of a Two-Charge System	$E_p = \frac{kq_1q_2}{r}$ <p>E_p = potential energy, k = Coulomb's constant, q_1, q_2 = charge, r = distance</p>
HL Electric Potential	$V_e = \frac{kQ}{r}$ <p>V_e = electric potential, k = Coulomb's constant, Q = charge, r = distance</p>
HL Relationship between Field and Potential	$E = -\frac{\Delta V_e}{\Delta r}$ <p>E = electric field strength, $\frac{\Delta V_e}{\Delta r}$ = rate of change of electric potential</p>
HL Relationship between Potential Energy and Potential	$W = q\Delta V_e$ <p>W = work done, q = charge, ΔV_e = change in electric potential</p>

D.3 – Motion in Electromagnetic Fields

Magnetic Force on a Moving Charge	$F = qvB\sin\theta$ <p>F = magnetic force, q = charge, v = velocity, B = magnetic field strength, θ = angle between field and velocity</p>
Magnetic Force on a Current-carrying wire	$F = BIL\sin\theta$ <p>F = magnetic force, I = current, L = length, θ = angle between field and current</p>
Force Between Parallel Wires	$\frac{F}{L} = \mu_0 \frac{I_1 I_2}{2\pi r}$ <p>$\frac{F}{L}$ = force per unit length, μ_0 = free space permeability, I_1, I_2 = current, r = separation distance</p>

D.4 – Electromagnetic Induction

HL Definition of Magnetic Flux	$\Phi = BA\cos\theta$ <p>Φ = magnetic flux, B = magnetic flux density, A = area, θ = angle between normal to area and field</p>
HL Faraday's and Lenz's Laws	$\epsilon = -N \frac{\Delta\Phi}{\Delta t}$ <p>ϵ = induced emf, N = turns, $\Delta\Phi$ = change in magnetic flux, Δt = change in time</p>
HL Motional EMF	$\epsilon = BvL$ <p>ϵ = induced motional emf, B = magnetic flux density, v = velocity, L = length</p>

Theme E: Nuclear and Quantum Physics

E.1 – Atomic Structure

	Energy of an Electromagnetic Wave	$E = hf$ <p>$E = \text{energy, } h = \text{Planck's constant, } f = \text{frequency}$</p>
HL	Nuclear Radius Approximation	$R = R_0 A^{\frac{1}{3}}$ <p>$R = \text{nuclear radius, } R_0 = \text{Fermi radius, } A = \text{nucleon number}$</p>
HL	Energy Levels of the Bohr Model of the Hydrogen Atom	$E = -\frac{13.6}{n^2} \text{ eV}$ <p>$E = \text{energy, } n = \text{energy level}$</p>
HL	Quantized Angular Momentum of the Bohr Model of the Hydrogen Atom	$mvr = \frac{nh}{2\pi}$ <p>$m = \text{electron mass, } v = \text{speed, } r = \text{orbital radius, } n = \text{energy level, } h = \text{Planck's constant}$</p>

E.2 – Quantum Physics

HL	Maximum Kinetic Energy of a Photoelectron	$E_{max} = hf - \Phi$ <p>$E_{max} = \text{maximum kinetic energy, } h = \text{Planck's constant, } f = \text{photon frequency, } \Phi = \text{work function}$</p>
HL	De Broglie Wavelength	$\lambda = \frac{h}{p}$ <p>$\lambda = \text{wavelength, } h = \text{Planck's constant, } p = \text{momentum}$</p>
HL	Compton Effect	$\lambda_f - \lambda_i = \Delta\lambda = \frac{h}{m_e c} (1 - \cos \theta)$ <p>$\lambda_f = \text{final wavelength, } \lambda_i = \text{initial wavelength, } h = \text{Planck's constant, } m_e = \text{electron mass, } c = \text{speed of light, } \theta = \text{scattering angle}$</p>

E.3 – Radioactive Decay

	Mass-Energy Equivalence	$E = mc^2$ <p>$E = \text{energy, } m = \text{mass}$</p>
HL	Radioactive Decay	$N = N_0 e^{-\lambda t}$ <p>$N = \text{parent nuclide count at time } t, N_0 = \text{nuclide count at } t = 0, \lambda = \text{decay constant, } t = \text{time}$</p>
HL	Activity	$A = \lambda N = \lambda N_0 e^{-\lambda t}$ <p>$A = \text{activity, } \lambda = \text{decay constant, } N = \text{parent nuclei count, } N_0 = \text{parent nuclide count at } t = 0, t = \text{time}$</p>
HL	Half-Life	$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$ <p>$T_{\frac{1}{2}} = \text{half life, } \lambda = \text{decay constant}$</p>

E.5 – Stellar Properties & Processes

	Parsec Definition	$d(\text{parsec}) = \frac{1}{p(\text{arc - second})}$ <p>$d = \text{distance in parsecs, } p = \text{parallax angle in arcseconds}$</p>
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