IB Physics Formula Sheet (from the *Physics Data Booklet*)

Topic 1: Measurement and uncertainties

1.1. Measurements in physics

1.2. Uncertainties and errors

If $y = a \pm b$ then $\Delta y = \Delta a + \Delta b$

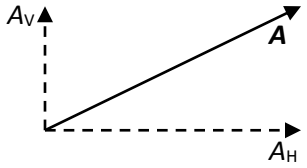
If $y = ab/c$ then $\Delta y/y = \Delta a/a + \Delta b/b + \Delta c/c$

If $y = a^n$ then $\Delta y/y = |n\, \Delta a/a|$

1.3.Vectors and scalars

$A_H = A \cos\theta$

$A_V = A \sin\theta$



Topic 2: Mechanics

2.1. Motion

$v = u + at$

$s = ut + (1/2)at^2$

$v^2 = u^2 + 2as$

$s = (1/2)(v + u)/t$

2.2. Forces

$F = ma$

$F_f \le \mu_s R$

$F_f \le \mu_d R$

2.3. Work, energy and power

$W = Fs \cos\theta$

$E_K = (1/2)mv^2$

$E_P = (1/2)k\Delta x^2$

$\Delta E_P = mg\Delta h$

power = Fv

Efficiency = $W_{out}/W_{in} = P_{out}/P_{in}$

2.4. Momentum and impulse

$p = mv$

$F = \Delta p/\Delta t$

$E_K = p^2/2m$

Topic 3: Thermal concepts

3.1. Thermal concepts

$Q = mc\Delta t$

$Q = mL$

3.2. Modelling a gas

$p = F/A$

$n = N/N_A$

$pV = nRT$

$E_K = (3/2)k_B T = (3/2)RT/N_A$

Topic 4: Waves

4.1. Oscillations

$T = 1/f$

4.2. Travelling waves

$c = \lambda f$

4.3. Wave characteristics

$I \propto A^2$

$I \propto x^{-2}$

$I = I_0 \cos\theta$

4.4. Wave behaviour

4.5. Standing waves

Topic 5: Electricity and magnetism

5.1. Electric fields

$I = \Delta q/\Delta t$

$F = kq_1q_2/r^2$

$k = 1/(4\pi\varepsilon_0)$

$V = W/q$

$E = F/q$

$I = nAvq$

5.2. Electric currents

$\Sigma V = 0$ (loop)

$\Sigma I = 0$ (junction)

$R = V/I$

$P = VI = I^2R = V^2/R$

$R_{total} = R_1 + R_2 + \ldots$

$1/R_{total} = 1/R_1 + 1/R_2 + \ldots$

$\rho = RA/L$

5.3. Electric cells

$\varepsilon = I(R + r)$

5.4. Magnetic effects

$F = qvB \sin\theta$

$F = BIL \sin\theta$

Topic 6: Circular motion and gravitation

6.1. Circular motion

$v = \omega r$

$a = v^2/r = 4\pi^2 r/T^2$

$F = mv^2/r = m\omega^2 r$

6.2. Newton's law of gravitation

$F = GMm/r^2$

$g = F/m$

$g = GM/r^2$

Topic 7: Atomic, nuclear and particle physics

7.1. Discrete energy and radioactivity

$E = hf$

$\lambda = hc/E$

7.2. Nuclear reactions

$\Delta E = \Delta m\, c^2$

7.3. The structure of matter

Charge	Quarks			Baryon number
(2/3)*e*	u	c	t	1/3
-(1/3)*e*	d	s	b	1/3
All quarks have a strangeness number of 0 except the strange quark that has a strangeness number of -1				

Charge	Leptons		
-1*e*	e	μ	τ
0	ν_e	ν_μ	ν_τ
All leptons have a lepton number of 1 and antileptons have a lepton number of -1			

	Gravitational	Weak	Electromagnetic	Strong
Particles experiencing	All	Quarks, leptons	Charged	Quarks, gluons
Particles mediating	Graviton	W^+, W^-, Z^0	γ	Gluons

Topic 8: Energy production

8.1. Energy sources

Power = *energy*/*time*

Power = (1/2) $A\rho v^3$

8.2. Thermal energy transfer

$P = e\sigma AT^4$

$\lambda_{max} = 2.90\times10^{-3}/T$

I = *power*/A

albedo = *total scattered power / total incident power*

Topic 9: Simple harmonic motion

9.1. SHM

$\omega = 2\pi/T$

$a = -\omega^2 x$

$x = x_0 \sin \omega t$; $x = x_0 \cos \omega t$;

$v = \omega x_0 \cos \omega t$; $v = -\omega x_0 \sin \omega t$;

$v = \pm\omega$ sqrt $(x_0^2 - x^2)$

$E_K = (1/2)m\,\omega^2 (x_0^2 - x^2)$

$E_T = (1/2)m\,\omega^2 x_0^2$

Pendulum: $T = 2\pi$ sqrt (l/g)

Mass-spring: $T = 2\pi$ sqrt (m/k)

9.2. Single-slit

$\theta = \lambda/b$

9.3. Interference

$n\lambda = d \sin\theta$

Constructive interference: $2dn = (m + ½)\lambda$

Destructive interference: $2dn = m\,\lambda$

9.4. Resolution

$\theta = 1.22\,\lambda/b$

$R = (\lambda/\Delta\lambda) = mN$

9.5. Doppler effect

Moving source: $f' = fv/(v \pm u_s)$

Moving observer: $f' = f(v \pm u_o)/v$

$\Delta f/f = \lambda/\Delta\lambda \approx v/c$

Topic 10: Fields

10.1. Describing fields

$W = q\Delta V_e$

$W = m\Delta V_g$

10.2. Fields at work

$V_g = -GM/r$;

$g = -\Delta V_g/\Delta r$;

$E_P = mV_g = -GMm/r$

$F_G = Gm_1m_2/r^2$

$V_{esc} = \text{sqrt}\,(2GM/r)$

$V_{orbit} = \text{sqrt}\,(GM/r)$

$V_e = kq/r$

$E = -\Delta V_e/\Delta r$

$E_P = qV_e = kq_1q_2/r$

$F_E = kq_1q_2/r^2$

Topic 11: Electromagnetic induction

11.1. Induction

$\Phi = BA\cos\theta$

$\varepsilon = -N\,\Delta\Phi/\Delta t$

$\varepsilon = Bv\ell$

$\varepsilon = Bv\ell N$

11.2. Power generation

$I_{rms} = I_0/\sqrt{2}$

$V_{rms} = V_0/\sqrt{2}$

$R = V_0/I_0 = V_{rms}/I_{rms}$

$P_{max} = I_0V_0$

$P_{avg} = (1/2)\,I_0V_0$

$\varepsilon_p/\varepsilon_s = N_p/N_s = I_s/I_p$

11.3. Capacitance

$C = q/V$

$C_{parallel} = C_1 + C_2 + \ldots$

$1/C_{series} = 1/C_1 + 1/C_2 + \ldots$

$C = \varepsilon_0 A/d$

$E = (1/2)CV^2$

$\tau = RC$

$q = q_0e^{-t/\tau}$

$I = I_0e^{-t/\tau}$

$V = V_0e^{-t/\tau}$

Topic 12: Quantum and nuclear physics

12.1. Interaction of matter with radiation

$E = hf$

$E_{max} = hf - \phi$

$E = -13.6/n^2$ eV

$mvr = nh/2\pi$

$P(r) = |\Psi|^2\Delta V$

$\Delta x\Delta p \geq h/4\pi$

$\Delta E\Delta t \geq h/4\pi$

12.2. Nuclear physics

$R = R_0A^{1/3}$

$N = N_0e^{-\lambda t}$

$A = \lambda N_0e^{-\lambda t}$

$\sin\theta = \lambda/d$

Option A: Relativity

A.1. Beginnings of relativity

$x' = x - vt$

$u' = u - v$

A.2. Lorentz transformations

$\gamma = (1 - v^2/c^2)^{-1/2}$

$x' = \gamma(x - vt)$; $\Delta x' = \gamma(\Delta x - v\Delta t)$

$t' = \gamma(t - vx/c^2)$; $\Delta t' = \gamma(\Delta t - v\Delta x/c^2)$

$u' = (u - v)/(1 - uv/c^2)$

$\Delta t = \gamma\Delta t_0$

$L = L_0/\gamma$ $\quad (ct')^2 - (x')^2 = (ct)^2 - (x)^2$

A.3. Spacetime diagrams

$\theta = \tan^{-1}(v/c)$

A.4. Relativistic mechanics (HL only)

$E = \gamma m_0c^2$

$E_0 = m_0c^2$

$E_K = (\gamma - 1)m_0c^2$

$p = \gamma m_0v$

$E^2 = p^2c^2 + m_0^2c^4$

$qV = \Delta E_K$

A.5. General relativity (HL only)

$\Delta f/f = g\Delta h/c^2$

$R_s = 2GM/c^2$

$\Delta t = \Delta t_0/\text{sqrt}(1 - R_s/r)$

Option B: Engineering physics

B.1. Rigid bodies and rotational dynamics

$\Gamma = Fr\sin\theta$

$I = \Sigma mr^2$

$\Gamma = I\alpha$

$\omega = 2\pi f$

$\omega_f = \omega_i + \alpha t$

$\omega_f^2 = \omega_i^2 + 2\alpha\theta$

$\theta = \omega_i t + (1/2)\alpha t^2$

$L = I\omega$

$E_{Krot} = (1/2)I\omega^2$

B.2. Thermodynamics

$Q = \Delta U + W$

$U = (3/2)nRT$

$\Delta S = \Delta Q/T$

$pV^{5/3} = \text{const}$

$W = p\Delta V$

$pV^{5/3} = \text{const}$

$W = p\Delta V$

$\eta = W_{useful}/E_{input}$

$\eta_{carnot} = 1 - T_{cold}/T_{hot}$

B.3. Fluids and fluid dynamics (HL only)

$B = \rho_f V_f g$

$P = P_0 + \rho_f g d$

$Av = \text{constant}$

$(1/2)\,\rho v^2 + \rho g z + p = \text{const}$

$F_D = 6\pi\eta r v$

$R = vr\rho/\eta$

B.4. Forced vibrations and resonance (HL only)

$Q = 2\Pi(E_{stored}/E_{dissipated/cycle})$

$Q = 2\Pi \times f_{res}(E_{stored}/P_{loss})$

Option C: Imaging

C.1. Introduction to imaging

$1/f = 1/v + 1/u$

$P = 1/f$

$m = h_i/h_o = -v/u$

$M = \theta_i/\theta_o$

C.2. Imaging instrumentation

$M = \theta_i/\theta_o$ $\quad M = f_o/f_e$

$M_{near\ point} = D/f + 1$

$M_{infinity} = D/f$

C.3. Fibre optics

$n = 1/\sin c$

attenuation $= 10 \log (I/I_0)$

C.4. Medical imaging (HL only)

$L_f = 10 \log (I_1/I_0)$

$I = I_0 e^{-\mu x}$

$\mu x_{1/2} = \ln 2$

$Z = pc$

Option D: Astrophysics

D.1. Stellar quantities

$d(\text{parsec}) = 1/p(\text{arc-second})$

$L = \sigma A T^4$

$B = L/(4\pi d^2)$

D.2. Stellar evolution

$\lambda_{max} = 2.9\times10^{-3}$ m K

$L \propto M^{3.5}$

D.3. Cosmology

$z = \Delta\lambda/\lambda_0 \approx v/c$

$z = R/R_0 - 1$

$v = H_0 d$

$T \approx 1/H_0$

D.4. Stellar processes (HL only)

D.5. Further cosmology (HL only)

$v = \text{sqrt}(4\pi G\rho/3)\, r$

$\rho_c = 3H^2/(8\pi G)$