Physics Cheat Sheet (IB New/Old Spec) (AP Physics B/C)

1. Kinematics

Motion

$v = u + at$

$s = ut + \frac{1}{2}at^2$

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

$s = \frac{(v+u)t}{2}$

$a = \frac{\mathrm{d}v}{\mathrm{d}t}$

v: velocity
a: acceleration
t: time elapsed
s: distance
a: the rate of velocity changing

Forces

$W = mg$

$F = ma$

$F_{fs} = \mu_d N$

$F_{fd} \leq \mu_s N$

$F_b = \rho V g$

$F_d = 6\pi\eta r v$

$a = \frac{v^2}{r} = \omega^2 r = \frac{4\pi^2 r}{T}$

W: weight
F: force
M: mass
μ_d: coefficient of friction (dynamic)
μ_s: coefficient of friction (static)
F_{fs}: friction (dynamic)
F_{fd}: friction (static)
F_b: buoyancy
F_d: drag force
r: radius
η: viscosity
ω: angular speed
F=ma: Newton's 2nd Law
T: time-period

Work, Energy and Power

$W = Fs\cos\theta = \int F\,\mathrm{d}r$

$E_k = \frac{1}{2}mv^2$

$E_P = \frac{1}{2}k\Delta x^2$

$E_p = mgh$

$P = Fv$

$E\% = \frac{E_U}{\sum E}$

W: work done
θ: angle of the slope
r: vector
E_k: kinetic energy
E_P: elastic potential Energy
E_g: gravitational potential energy
k: elastic coefficient
h: height
Δx: change in displacement
P: power

Momentum and Impulse

$p = mv$

$p_i = p_f$

$E_k = \frac{p^2}{2m}$

$J = F\Delta t = \Delta p = \int F\,\mathrm{d}t$

$F = \frac{\Delta p}{\Delta t}$

p: momentum
$p_i=p_f$: conservation of momentum
J: impulse
F: the rate of changing momentum (Newton's 2nd Law)

Rotational Mechanics* (AP Physic C) (New Spec HL) (Old Spec Option B)

$\tau = rF\sin\theta = I\alpha$

$\omega_f = \omega_i + \alpha t$

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

$\Delta\theta = \frac{\omega_i + \omega_f}{2}t = \omega_i t + \frac{1}{2}\alpha t^2$

$I = \sum mr^2$

$L = I\omega$

$\Delta L = \tau\Delta t = \Delta(I\omega)$

$E_k = \frac{1}{2}I\omega^2 = \frac{L^2}{2I}$

τ: torque
α: angular acceleration
ω_i: angular speed (initial)
ω_f: angular speed (final)
Δθ: angular displacement
I: inertia
L: angular momentum

x', u', t': position, speed and time in the second reference frame
x, u, t: position, speed and time in the first reference frame
γ: Lorenz factor
c: speed of light
Δt: time between events
Δs: spacetime interval
Δx: distance
Δt: relativistic time
Δt_0: proper relativistic time

Special Relativity* (New Spec HL) (Old Spec Option A)
$x' = x - vt$ $u' = u - v$ $\gamma = \frac{1}{(1-\frac{v^2}{c^2})^{\frac{1}{2}}}$ $x' = \gamma(x - vt)$ $t' = \gamma(t - \frac{vx}{c^2})$ $u' = \frac{u-v}{1-\frac{uv}{c^2}}$ $\Delta s^2 = c^2\Delta t^2 - \Delta x^2$ $\Delta t = \gamma\Delta t_0$ $L = \frac{L_0}{\gamma}$ $\theta = \arctan\frac{v}{c}$

L: relativistic length
L_0: proper relativistic length
θ: angle between axes of inertial frames of reference

Q: heat energy
c: specific heat capacity
T: temperature (K)
L: specific latent heat
k: conductivity constant
A: area
Δx: length of the object
ρ: density
V: volume
σ: Stephan-Boltzmann constant
L: luminosity/power source
b: brightness

2. Thermal Physics

Thermal Concepts	Gas Modelling
$Q = mc\Delta T$ $Q = mL$ $\frac{\Delta Q}{\Delta t} = -kA\frac{\Delta T}{\Delta x}$ $\rho = \frac{m}{V}$ $L = \sigma AT^4$ $b = \frac{L}{4\pi d^2}$	$P = \frac{F}{A}$ $n = \frac{N}{N_A}$ $pV = nRT$ $\overline{E_k} = \frac{3}{2}k_BT = \frac{3}{2}\frac{R}{N_A}T$ $U = \frac{3}{2}k_BNT$ $P = \frac{1}{3}\rho v^2$ $P_1V_1 = P_2V_2$ $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ $Q = \Delta U + W$

P: pressure
N: number of particles
N_A: Avogadro constant
n: number of moles
R: gas constant
$\overline{E_k}$: average kinetic energy
U: total energy (ideal)
k_B: Boltzmann constant
v: average particle speed
Q: total heat energy
ΔU: change in internal energy
W: work done by gas
$P_1/T_1=P_2/T_2$: Charles' Law
$P_1V_1=P_2V_2$: Boyle's Law

Thermodynamics* (AP Physics B) (New Spec HL)

W: work done by gas
ΔS: change in entropy
ΔQ: heat transferred
S: entropy
Ω: number of microstates
T_c: temperature of cold reservoir
T_h: temperature of hot reservoir

$$W = P\Delta V$$

$$\Delta S = \frac{\Delta Q}{T}$$

$$S = k_B \ln\Omega$$

$$\text{Carnot efficiency} = 1 - \frac{T_c}{T_h}$$

$$PV^{\frac{5}{3}} = \text{Constant}$$

3. Electricity

Electric Fields

I: Current
Q: Charge
Columb's Law – F: force, r: radius
k: constant
ε_0: permittivity of free space
V: potential difference
W: work done by charge
E: electric field strength
I: current in a wire
n: number of charged particles
v: drift velocity
q: average charge

$$I = \frac{Q}{t}$$

$$F = \frac{kq_1q_2}{r^2}$$

$$k = \frac{1}{4\pi\varepsilon_0}$$

$$V = \frac{W}{q}$$

$$E = \frac{F}{q} = -\frac{\Delta V}{\Delta R}$$

$$I = nAvq$$

Electric Currents

Kirchhoff's Law – total p.d. in a loop, total current in a junction equals to 0
Ohm's Law – R: resistance
P: Power
Circuit Laws – total resistance: the sum of resistances (series); reciprocal total resistance: the sum of reciprocals of resistance (parallel)
L: length of the material
A: area
ε: emf
r: internal resistance

$$\sum V_{\text{Loop}} = 0$$

$$\sum I_{\text{Junction}} = 0 \text{ (Junction)}$$

$$R = \frac{V}{I}$$

$$P = VI = I^2R = \frac{V^2}{R} = \frac{\Delta W}{\Delta t}$$

$$\sum R_{\text{Series}} = R_1 + R_2 + \dots$$

$$\sum R_{\text{Parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

$$R = \frac{\rho L}{A}$$

$$\varepsilon = I(R + r)$$

Power Generation* (Old Spec HL)

I_0, V_0: Peak current, voltage
I_{rms}, V_{rms}: Root mean square current, voltage
P_{max}: Peak power
$\overline{P}$: Mean power

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

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

$$R = \frac{V_{rms}}{I_{rms}}$$

$$P_{max} = I_0V_0$$

$$\overline{P} = \frac{1}{2}I_0V_0$$

Capacitance* (AP Physics C) (Old Spec HL)

C: capacitance
κ: dielectric constant
ε: emf
Capacitance Laws – the total capacitance (parallel): the sum of capacitances; the reciprocal of total capacitance (series): the sum of reciprocals capacitances
τ: time constant

$$C = \frac{q}{V} = \frac{\kappa\varepsilon_0 A}{d} = \frac{\varepsilon A}{d}$$

$$\sum C_{\text{Parallel}} = C_1 + C_2 + \dots$$

$$\frac{1}{\sum C_{\text{Series}}} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$$

$$U = \frac{1}{2}CV^2 = \frac{1}{2}EV$$

$$\tau = RC$$

Transformer:
ε_p: primary emf
ε_s: secondary emf
N_p: primary coil turns
N_s: secondary coil turns
I_p: primary coil current
I_s: secondary coil current

$$\frac{\varepsilon_p}{\varepsilon_s}=\frac{N_p}{N_s}=\frac{I_s}{I_p}$$

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

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

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

$$C=-\frac{t}{R\ln\frac{Q}{Q_0}}$$

Discharge:
$q(Q)_0$, I_0, V_0: initial charge, current and p.d.
t: time

4. Wave

Simple Harmonic Motion

x: position
x_0: initial position
v: velocity
a: acceleration
$x=x_0 \sin\omega t$, $v=v\omega_0 \cos\omega t$, $a=-\omega^2x_0 \sin\omega t$: lowest point
$x=x_0 \cos\omega t$, $v=-v\omega_0 \sin\omega t$, $a=\omega^2x_0 \cos\omega t$: highest point
E_T: initial energy
E_P: potential energy
$T_{Pendulum}$: time-period for pendulum
$T_{Mass\text{-}Spring}$: time-period for mass spring

$$\omega=\frac{2\pi}{T}$$

$$a=-\omega^2x$$

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

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

$$a=-\omega^2x_0\sin\omega t\,,\ a=\omega^2x_0\cos\omega t$$

$$v=\pm\omega\,(x_0^2-x^2)^{\frac{1}{2}}$$

$$E_k=\frac{1}{2}m\omega^2(x_0^2-x^2)$$

$$E_T=\frac{1}{2}m\omega^2x_0^2$$

$$E_P=E_T-E_k$$

$$T_{\text{Pendulum}}=2\pi\sqrt{\frac{l}{g}}$$

$$T_{\text{Mass-Spring}}=2\pi\sqrt{\frac{m}{k}}$$

Diffraction, Resolution, Interference (SL)

$$\frac{n_1}{n_2}=\frac{\sin\theta_1}{\sin\theta_2}=\frac{v_2}{v_1}$$

$s=\dfrac{\lambda D}{d}$ (Double slits)

Constructive Path Difference $=n\lambda$

Destructive Path Difference $=(n+\frac{1}{2})\lambda$

Diffraction, Resolution, Interference (HL)

$\theta=\dfrac{\lambda}{b}=\dfrac{d}{D}$ (single slit)

Constructive Interference: $2dn=(m+\frac{1}{2})\lambda$

Destructive Interference: $2dn=m\lambda$

$$n\lambda=d\sin\theta$$

$$\theta=1.22\frac{\lambda}{b}$$

$$R=\frac{\lambda}{\Delta\lambda}=mN$$

Snell's Law:
n_1, n_2: refractive index of 2 mediums
θ_1, θ_2: initial angle and refracted angle
v_1, v_2: speed of wave in 2 mediums
s: fringe spacing
λ: wave length
n: integer – 1,2,3...
b: slit width
D: distance between source and screen
d: distance between sources
n: refractive index
m: integer – 1,2,3...
d: slit spacing
Rayleigh's Criterion: $\theta=1.22\lambda/b$
R: Resolvance
Δλ: smallest λ
N: number of slits

Wave Behavior

f: frequency
v: speed of wave
I: intensity
I0: initial intensity
A: area
θ: angle

$$T=\frac{1}{f}$$

$$v=f\lambda$$

$$I\propto A^2,\ I\propto x^{-2}$$

$$I=I_0\cos^2\theta$$

Doppler Effect

Moving source: $f'=f\dfrac{v}{v\pm u_s}$

Moving observer: $f'=f\dfrac{v\pm u_s}{v}$

$$\frac{\Delta f}{f}=\frac{\Delta\lambda}{\lambda}\approx\frac{v}{c}$$

Moving source:
+: moving away
- : moving towards
Moving observer:
+: moving towards
- : moving away
us: initial speed

5. Fields

Circular motion – F: centripetal force, r: radius, m: mass, v: velocity

G: gravitational constant

M: mass of the planet/stars

Gravitational Fields (SL)

$$F = \frac{mv^2}{r}$$

$$F = \frac{GMm}{r^2}$$

$$g = \frac{GM}{r^2}$$

Motion in Magnetic Fields (SL)

$$F = qvB\sin\theta$$

$$F = BIL\sin\theta$$

$$\frac{F}{L} = \frac{\mu_0 I_1 I_2}{r}$$

F: magnetic force

q: charge

v: speed of charged particle

B: magnetic field strength

I: current on the rod

L: length of the rod

μ_0: free space permeability

r: separation distance

Vg: gravitational potential

g: gravitational constant

r: radius

Δr: distance travelled

EP: gravitational potential energy

m_1, m_2: mass of two objects

V_{esc}: escaping speed

V_{orbit}: orbiting speed

Gravitational Fields (AP Physics C) (HL)

$$V_g = -\frac{GM}{r}$$

$$g = -\frac{\Delta V_g}{\Delta r}$$

$$E_P = mV_g = -\frac{GMm}{r}$$

$$F_G = \frac{Gm_1m_2}{r^2}$$

$$v_{\text{esc}} = \sqrt{\frac{2GM}{r}}$$

$$v_{\text{orbit}} = \sqrt{\frac{GM}{r}}$$

Magnetic Fields (HL)

$$V_e = \frac{kq}{r}$$

$$E = -\frac{\Delta V_e}{\Delta r} = \frac{dV}{dr}$$

$$E_P = qV_e = \frac{kq_1q_2}{r^2}$$

V_e: electrical potential

E: electric field strength

E_P: Electrical potential energy

k: constant

q_1, q_2: charges of two point charges

r: distance between point charges

Gauss Law – E: field strength, A: area (gauss surface)

ε: emf

U_L: potential energy of induction

L: inductance

dB: rate of changing field strength

Electromagnetic Induction* (AP Physics C)

$$\oint E\,\mathrm{d}A = \frac{Q}{\varepsilon_0}$$

$$\varepsilon = \oint E\,\mathrm{d}l$$

$$F = \int I\,\mathrm{d}l\,B$$

$$U_L = \frac{1}{2}LI^2$$

$$\mathrm{d}B = \frac{\mu_0}{4\pi}\frac{I\,\mathrm{d}l^{*}r}{r^3}$$

Electromagnetic Induction (HL)

$$\Phi = BA\cos\theta$$

$$\varepsilon = -N\frac{\mathrm{d}\Phi}{\mathrm{d}t}$$

$$\varepsilon = BvL$$

Φ: Magnetic flux

Lenz Law: emf equals to the negative rate of changing magnetic flux linkage

v: speed of rod

L: length of rod

W: work done

ΔV_e: p.d. in magnetic field

ΔV_g: p.d. in gravitational field

Describing Fields

$$W = q\Delta V_e$$

$$W = m\Delta V_g$$

6. Nuclear and Quantum Physics

Radioactivity and Radiation (SL)

$$E = hf$$

$$\lambda = \frac{hc}{E}$$

E: energy
h: Planck constant
f: frequency
c: light speed

Radioactivity and Radiation (HL)

$$E_{max} = hf - \phi$$

$$E = -\frac{13.6}{n^2} eV$$

$$mvr = \frac{nh}{2\pi}$$

Emax: maximum kinetic energy
ϕ: Work function
E: energy
n: energy level
m: electron mass
v: speed
r: orbital radius

Heisenberg Uncertainty Principle (Old Spec HL)

$$\mathrm{P}(r) = |\psi|^2 \Delta V$$

$$\Delta x \Delta p \geq \frac{h}{4\pi}$$

$$\Delta E \Delta t \geq \frac{h}{4\pi}$$

P(r): the probability that an electron will be found in a small volume
ψ: wave function
ΔV: small volume

Nuclear Physics (SL)

$$E = mc^2$$

E: energy

Nuclear Physics (HL)

$$R = R_0 A^{\frac{1}{3}}$$

$$N = N_0 e^{-\lambda t}$$

$$A = \lambda N_0 e^{-\lambda t}$$

$$\sin\theta \approx \frac{\lambda}{D}$$

$$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

$$\lambda = \frac{h}{p}$$

$$\lambda_f - \lambda_i = \frac{h}{m_e c}(1 - \cos\theta)$$

R: nuclear radius
R_0: fermi radius
t: time
A: nucleon number
N: parent nuclide count at t
N_0: initial nuclide count (t=0)
λ: decay constant
$T_{\frac{1}{2}}$: half life
DE Broglie's formula – λ: wavelength, p: momentum
λ_i, λ_f: initial, final wavelength
m_e: electron mass
θ: scattering angle

Stellar Quantities (New Spec HL)

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

d: distance
p: parallax angle