HSC Physics Formula Sheet

Original worked revision examples with notes on units and assumptions.

Use the board PDF below for the official sheet. Coverage of examples varies by subject.

Official reference material

Official NESA reference PDF

What to work out beyond the sheet

Draw a force diagram and choose a positive direction before substituting into the motion equations.

Formulas and worked examples

Motion · constant acceleration

Formula or reference: $s = ut + at^2/2$. $v^2 = u^2 + 2as$. $v = u + at$.

Units and conditions: Use metres, seconds and signed components along the chosen axis.

Worked example: At $u = 2$ m/s and $a = 1$ m/s² for 4 s, $v = 6$ m/s and $s = 16$ m. The time-free form gives $6^2 = 2^2 + 2 \times 1 \times 16$.

Forces · Newton’s second law

Formula or reference: $F_{net} = ma$, as a vector equation.

Units and conditions: Force in N, mass in kg and acceleration in m/s².

Worked example: A net 15 N to the east on a 5 kg mass gives acceleration 3 m/s² east.

Energy · work and power

Formula or reference: $W = F_{\parallel}s = Fs\cos\theta$. $P = \Delta E/\Delta t$. Instantaneous $P = F_{\parallel}v = Fv\cos\theta$.

Units and conditions: Energy and work in J, power in W. Use the angle between force and displacement or velocity as appropriate.

Worked example: A 10 N force along 3 m does 30 J of work. If that takes 2 s, average power is 15 W. At speed 4 m/s along the force, instantaneous power is 40 W.

Energy · potential and kinetic

Formula or reference: $\Delta U = mg\Delta h$ near Earth’s surface. $K = mv^2/2$.

Units and conditions: Use kg, m and s to obtain J.

Worked example: A 2 kg object rises 3 m and reaches 4 m/s. Its potential energy rises by 58.9 J at $g = 9.81$ m/s², and its final kinetic energy is 16 J.

Collisions · kinetic energy and momentum

Formula or reference: Elastic: $\Sigma(mv^2/2)_{before} = \Sigma(mv^2/2)_{after}$. Isolated system: $\Sigma(mv)_{before} = \Sigma(mv)_{after}$.

Units and conditions: Momentum uses signed or vector velocities in m/s. Energy is in J and momentum in kg m/s.

Worked example: In a head-on elastic collision, equal masses can exchange velocities. A 1 kg mass at +3 m/s and a stationary 1 kg mass keep total momentum +3 kg m/s and kinetic energy 4.5 J after swapping velocities.

Momentum · impulse

Formula or reference: $\Delta p = F_{net}\Delta t$ for a constant or average net force.

Units and conditions: Impulse in N s equals change of momentum in kg m/s.

Worked example: A net 5 N to the right for 0.4 s adds 2 N s of rightward momentum.

Rotation · angular speed and torque

Formula or reference: $\omega = \Delta\theta/t$. $\tau = r_\perp F = rF \sin\theta$.

Units and conditions: Use radians and seconds for angular speed. Torque in N m. The torque angle is between the lever arm and force.

Worked example: A rotation of π radians in 2 s averages $\pi/2$ rad/s. A perpendicular 20 N force on a 0.3 m lever produces 6 N m.

Motion · circular speed, acceleration and force

Formula or reference: $v = 2\pi r/T$. $a_c = v^2/r$. $F_c = mv^2/r$.

Units and conditions: Use m, s and kg. Centripetal acceleration and net force point inward.

Worked example: For $r = 2$ m and $T = \pi$ s, $v = 4$ m/s. The inward acceleration is 8 m/s² and the net inward force on 3 kg is 24 N.

Gravity · force and potential energy

Formula or reference: $F = GMm/r^2$. $U = -GMm/r$, taking zero potential energy at infinity.

Units and conditions: Use centre-to-centre distance in m, mass in kg, force in N and energy in J.

Worked example: For $GMm = 120$ J m and $r = 4$ m, attraction has magnitude 7.5 N and $U = -30$ J.

Orbits · circular period and radius

Formula or reference: $r^3/T^2 = GM/(4\pi^2)$

Units and conditions: Use orbital radius in m and period in s. M is the central mass.

Worked example: Around the same body, increasing circular orbital radius by a factor of four increases period by $4^{3/2} = 8$.

Waves · speed and period

Formula or reference: $v = f\lambda$. $f = 1/T$.

Units and conditions: Use Hz, s, m and m/s.

Worked example: A 0.25 s period gives $f = 4$ Hz. With wavelength 1.5 m the wave speed is 6 m/s.

Waves · beats

Formula or reference: $f_{beat} = |f_2 - f_1|$

Units and conditions: Frequency in Hz.

Worked example: Tones at 440 Hz and 444 Hz produce 4 beats per second.

Waves · classical Doppler shift

Formula or reference: $f' = f(v_{wave} + v_{observer})/(v_{wave} - v_{source})$ with positive speeds for approach in the corresponding terms.

Units and conditions: Speeds relative to the medium in matching units. Frequency in Hz.

Worked example: A 660 Hz source moving toward a stationary observer at 10 m/s in air with sound speed 340 m/s is heard at $660 \times 340/330 = 680$ Hz.

Waves · diffraction grating

Formula or reference: $d \sin\theta = m\lambda$

Units and conditions: d and λ in the same length unit. m is the diffraction order.

Worked example: For $d = 2.0$ µm and $\lambda = 500$ nm, first-order $\sin\theta = 0.25$, so $\theta \approx 14.5°$.

Optics · refractive index, refraction and critical angle

Formula or reference: $n = c/v$. $n_1 \sin \theta_1 = n_2 \sin \theta_2$. $\sin \theta_c = n_2/n_1$ when $n_1 > n_2$.

Units and conditions: Indices are unitless. Angles are measured from the normal.

Worked example: If light speed in a medium is 2.0×10^8 m/s, $n \approx 1.50$. From that medium to air, 30° incidence gives refraction near 48.6° and the critical angle is about 41.8°.

Optics · polarisation and spreading

Formula or reference: Malus's law: $I = I_{max} \cos^2 \theta$. For an isotropic point source: $I_1 r_1^2 = I_2 r_2^2$.

Units and conditions: Intensity in W/m², distance in m. θ is the angle between the polarisation direction and analyser axis.

Worked example: At 60°, a polariser transmits one quarter of the maximum intensity. Doubling distance from an isotropic source also reduces intensity to one quarter, by a different mechanism.

Thermal physics · heating and conduction

Formula or reference: $Q = mc\Delta T$. $Q/t = kA\Delta T/d$ for steady conduction through a slab.

Units and conditions: Use J, s and K for heat, time and temperature difference, with k in W/(m K).

Worked example: A 0.2 kg sample with $c = 500$ J/(kg K) gains 300 J for a 3 K increase. A 0.1 m slab of area 0.5 m², $k = 0.2$ W/(m K), across 10 K conducts at 10 W.

Electric fields · plates, force and potential

Formula or reference: $E = V/d$. $F = qE$ as a vector equation. $V = \Delta U/q$. Work magnitude can be qV or qEd for aligned positive magnitudes.

Units and conditions: Use V, m, N/C, C and J. For signed work use the actual direction and potential change.

Worked example: Across 0.020 m at 20 V, $E = 1000$ V/m. A +2.0 µC charge feels 0.0020 N and the field does 40 µJ of work moving it through the gap along the field.

Electric forces · Coulomb's law

Formula or reference: $F = k|q_1 q_2|/r^2$, with $k = 1/(4\pi\varepsilon_0)$.

Units and conditions: Use C and m. Determine attraction or repulsion from charge signs.

Worked example: Two +1.0 µC charges 0.30 m apart repel with magnitude about 0.100 N.

Circuits · current, voltage and power

Formula or reference: $I = q/t$. $V = IR$. $P = VI$.

Units and conditions: Use C, s, A, V, Ω and W.

Worked example: If 12 C flows in 3 s, $I = 4$ A. Through 2 Ω that requires 8 V and dissipates 32 W.

Magnetism · straight wire and ideal solenoid

Formula or reference: Straight wire: $B = \mu_0 I/(2\pi r)$. Long solenoid: $B = \mu_0 NI/L$.

Units and conditions: Use A and m to obtain T. N is total turns.

Worked example: At 0.10 m from a long straight wire carrying 5 A, $B = 1.0 \times 10^{-5}$ T. With 200 turns over 0.40 m carrying 2 A, an ideal solenoid has $B \approx 1.26 \times 10^{-3}$ T.

Magnetism · forces on charges and wires

Formula or reference: $F = |q|vB \sin \theta$ for a particle. $F = I\ell B \sin \theta$ for a wire.

Units and conditions: θ is between velocity or current and B. Use C, m/s, A, m and T to obtain N.

Worked example: For perpendicular motion at 500 m/s, a 2 µC charge in 0.2 T feels 0.0002 N. A perpendicular 0.5 m wire carrying 2 A in the same field feels 0.20 N.

Magnetism · parallel wire force per length

Formula or reference: $F/\ell = \mu_0 I_1 I_2/(2\pi r)$

Units and conditions: Use A and separation in m to obtain N/m. Currents in the same direction attract.

Worked example: Two long parallel wires carrying 2 A and 3 A, 0.10 m apart, attract at 1.2×10^{-5} N/m.

Induction · magnetic flux and EMF

Formula or reference: $\Phi = B_\perp A = BA\cos\theta$. $\varepsilon = -N\Delta\Phi/\Delta t$.

Units and conditions: θ is the angle from the area normal. Flux in Wb and EMF in V.

Worked example: A field normal to a 0.020 m^2 loop increases from zero to 0.50 T in 0.10 s. The change is 0.010 Wb per turn, giving $|\varepsilon| = 1.0$ V for 10 turns.

Motors · coil torque

Formula or reference: $\tau = nIAB\sin\theta$, with θ between the area normal and B.

Units and conditions: Use A, m^2 and T to obtain N m.

Worked example: A 20-turn coil carrying 2 A with area 0.010 m^2 in a 0.30 T field has maximum torque 0.12 N m.

Circuits · ideal transformer

Formula or reference: $V_p/V_s = N_p/N_s$. $V_pI_p = V_sI_s$.

Units and conditions: Use consistent AC voltage and current measures.

Worked example: An ideal 4:1 turns ratio changes 24 V and 0.5 A on the primary to 6 V and 2 A on the secondary.

Quantum physics · matter waves and photon energy

Formula or reference: $\lambda = h/(mv)$ for nonrelativistic matter. $E = hf$ for a photon.

Units and conditions: Use h in J s, mass in kg, speed in m/s and frequency in Hz.

Worked example: A nonrelativistic particle with momentum 3.32×10^{-27} kg m/s has wavelength about 200 nm. Light at 5.0×10^{14} Hz has photon energy about 3.32×10^{-19} J.

Quantum physics · photoelectric effect

Formula or reference: $K_{max} = hf - \varphi$ when $hf \geq \varphi$.

Units and conditions: Use the same energy unit for photon energy and work function.

Worked example: An incident photon of 4.0 eV on a 2.5 eV surface can produce an electron with maximum kinetic energy 1.5 eV.

Thermal radiation · Wien’s law

Formula or reference: $\lambda_{max} = b/T$

Units and conditions: Use T in K and b in m K to obtain m.

Worked example: For T = 5800 K and $b = 2.898 \times 10^{-3}$ m K, the peak wavelength is about 500 nm.

Atomic spectra · hydrogen wavelengths

Formula or reference: $1/\lambda = R(1/n_f^2 - 1/n_i^2)$ for emission with $n_i > n_f$.

Units and conditions: R in m^{-1} and λ in m. The quantum numbers are unitless.

Worked example: For $n_i = 3$ and $n_f = 2$, the factor is $1/4 - 1/9 = 5/36$, giving $\lambda \approx 656$ nm with the hydrogen Rydberg constant.

Relativity · mass–energy

Formula or reference: $E = mc^2$ for rest energy.

Units and conditions: Mass in kg and c in m/s give energy in J.

Worked example: A mass change of 1.0×10^{-10} kg corresponds to 9.0×10^{6} J using $c \approx 3.0 \times 10^{8}$ m/s.

Relativity · time, length and momentum

Formula or reference: $t = t_0/\sqrt{(1 - v^2/c^2)}$. $\ell = \ell_0\sqrt{(1 - v^2/c^2)}$. $p = m_0v/\sqrt{(1 - v^2/c^2)}$.

Units and conditions: Use the proper time t_0 and rest length ℓ_0. Momentum uses rest mass m_0.

Worked example: At 0.60c the square-root factor is 0.8. A proper 4 s interval is observed as 5 s, a rest length of 10 m contracts to 8 m, and momentum is $1.25m_0v$.

Nuclear physics · radioactive decay and half-life

Formula or reference: $N(t) = N_0e^{(-\lambda t)}$. $\lambda = \ln 2/t_{1/2}$.

Units and conditions: Use the same time units in t and half-life. λ is in inverse time.

Worked example: With a 4 h half-life, $\lambda \approx 0.173$ h^{-1}. After 8 h the expected remaining count is one quarter of the original.

More worked examples

Photon energy

$E = hf = hc/\lambda$.

Calculate the energy of a photon of wavelength 600 nm, using $h = 6.63 \times 10^{-34}$ J s and $c = 3.00 \times 10^{8}$ m/s.

Convert 600 nm to 6.00×10^{-7} m. $E = (6.63 \times 10^{-34} \times 3.00 \times 10^{8})/(6.00 \times 10^{-7}) = 3.315 \times 10^{-19}$ J, or 3.32×10^{-19} J to three significant figures.

Check: Substituting 600 as a length in metres gives the wrong scale. Photon energy is not power.

Circular motion

The net inward force has magnitude $F = mv^2/r$ for uniform circular motion.

A 2.0 kg object moves at 3.0 m/s in a circle of radius 1.5 m. Find the required net inward force.

$F = 2.0 \times 3.0^2 / 1.5 = 12$ N, directed towards the centre. In a physical setup, identify which actual force or combination supplies this net force.

Check: Centripetal force describes the net inward requirement; do not add it as an extra force to a free-body diagram.

Average induced EMF

Magnitude of average EMF = $N|\Delta\Phi|/\Delta t$, with $\Phi = BA \cos\theta$ and θ measured from the area normal.

A 20-turn coil has flux per turn decrease from 0.006 Wb to zero in 0.04 s. Find the average EMF magnitude.

$|\Delta\Phi| = 0.006$ Wb. $EMF = 20 \times 0.006 / 0.04 = 3$ V. Lenz's law determines the direction by opposing the change in flux, not simply the original field.

Check: Do not multiply by area again when flux is already supplied in webers. The question asks for average EMF, not an instantaneous value.