VCE Physics Essentials

A comprehensive revision guide for VCE Physics Units 1-4, designed to help students quickly recall core concepts, master essential formulas, and navigate common exam challenges. This cheatsheet distills complex topics into easily digestible segments, complete with tips and examples.

MECHANICS: MOTION, FORCES & ENERGY

KINEMATICS & UNIFORM ACCELERATION

SUVAT Equations (Constant Acceleration):

- `v = u + at`
- `s = ut + 0.5at²`
- `v² = u² + 2as`
- `s = 0.5(u + v)t`

Variables:

- `s` : displacement (m)
- `u` : initial velocity (m/s)
- `v` : final velocity (m/s)
- `a` : acceleration (m/s²)
- `t` : time (s)

Key Concept: Free Fall

- Acceleration due to gravity `g ≈ 9.8 m/s²` (downwards).
- Ignore air resistance unless stated.

Example: A ball dropped from rest.
`u = 0`, `a = 9.8 m/s²` (positive if downwards is positive direction).

Graphs of Motion:

- **Displacement-Time (s-t):** Gradient = Velocity.
- **Velocity-Time (v-t):** Gradient = Acceleration; Area = Displacement.
- **Acceleration-Time (a-t):** Area = Change in Velocity.

Exam Tip: Always define your positive direction for motion problems (e.g., upwards positive, or downwards positive). This is crucial for signs of displacement, velocity, and acceleration.

NEWTON'S LAWS & DYNAMICS

Newton's First Law (Inertia): An object at rest stays at rest, and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force.

Newton's Second Law: `F_net = ma`

- `F_net` : net force (N)
- `m` : mass (kg)
- `a` : acceleration (m/s²)

Newton's Third Law: For every action, there is an equal and opposite reaction.

Common Forces:

- **Weight (Gravity):** `W = mg` (downwards)
- **Normal Force (** `N` **):** Perpendicular to surface, preventing penetration.
- **Friction (** `f` **):** Opposes motion or tendency of motion.
- **Tension (** `T` **):** Force transmitted through a string/cable.

Free-Body Diagrams (FBDs):

1. Represent object as a point or box.
2. Draw all forces acting *on* the object, originating from the center.
3. Label forces with symbols and magnitude (if known).
4. Show direction of acceleration (if any) separately.

Example: Block on a rough incline.

- Weight (down)
- Normal Force (perpendicular to surface)
- Friction (up or down incline, opposing motion)

Common Misconception: Action-reaction pairs *never* act on the same object. They act on *different* objects.

WORK, ENERGY & POWER

Work Done: `W = Fd cos(θ)`

- `F` : force (N)
- `d` : displacement (m)
- `θ` : angle between force and displacement.
- Work is a scalar, measured in Joules (J).
- Only force components *parallel* to displacement do work.

Types of Energy (J):

- **Kinetic Energy (KE):** `KE = 0.5mv²`
- **Gravitational Potential Energy (GPE):** `GPE = mgh` (relative to a reference point)
- **Elastic Potential Energy (EPE):** `EPE = 0.5kx²` (for springs)

Mechanical Energy (E_mech): `E_mech = KE + PE`

- Conserved if only conservative forces (gravity, spring force) do work.

Work-Energy Theorem: `W_net = ΔKE`

- The net work done on an object equals its change in kinetic energy.

Power (`P` **):** Rate at which work is done or energy is transferred.

- `P = W/t` or `P = ΔE/t`
- `P = Fv cos(θ)` (for constant velocity)
- Units: Watts (W), where `1 W = 1 J/s`

Example: A car engine provides 100 kW of power while moving at 20 m/s.
`F = P/v = 100,000 W / 20 m/s = 5000 N`

Exam Tip: When applying Conservation of Energy, ensure you account for any work done by non-conservative forces (like friction or air resistance) as energy 'loss' or 'gain' from the system.

ELECTROMAGNETISM & WAVES

DC CIRCUITS & OHM'S LAW

Ohm's Law: $V = IR$

- V : Voltage / Potential Difference (Volts, V)
- I : Current (Amperes, A)
- R : Resistance (Ohms, Ω)

Definitions:

- **Current:** Rate of flow of charge ($I = \Delta Q/\Delta t$).
- **Voltage:** Energy per unit charge ($V = \Delta E/\Delta Q$).
- **Resistance:** Opposition to current flow.

Series Circuits:

- Current is the same everywhere: $I\_total = I_1 = I_2 = ...$
- Total resistance is sum: $R\_total = R_1 + R_2 + ...$
- Voltage divides: $V\_total = V_1 + V_2 + ...$

Parallel Circuits:

- Voltage is the same across all branches: $V\_total = V_1 = V_2 = ...$
- Current divides: $I\_total = I_1 + I_2 + ...$
- Reciprocal of total resistance: $1/R\_total = 1/R_1 + 1/R_2 + ...$

Resistors in Combination:

- Always simplify series/parallel combinations step-by-step.
- Complex circuits may require Kirchhoff's Laws (sum of currents entering junction = sum of currents leaving; sum of voltages in a closed loop = 0).

Circuit Diagrams:

- Standard symbols: battery, resistor, ammeter, voltmeter, switch, wires.
- Ammeter in series (measures current).
- Voltmeter in parallel (measures voltage).

Exam Tip: For series circuits, if one component breaks, the circuit is open. For parallel, if one branch breaks, others can still function.

ELECTRICAL POWER & ENERGY

Electrical Power Formulas (Watts, W):

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

These are interchangeable using Ohm's Law. Choose based on known variables.

Electrical Energy (Joules, J):

- $E = Pt$
- $E = VIt$
- $E = I^2Rt$
- $E = (V^2/R)t$

Energy consumed over time. Often converted to heat in resistors.

Example: A 12V resistor draws 2A of current. Calculate power and energy consumed in 10s.
$P = VI = 12V * 2A = 24W$
$E = Pt = 24W * 10s = 240J$

Common Misconception: Power rating on an appliance (e.g., 100W light bulb) is usually its power *at the nominal voltage* (e.g., 240V mains). Its resistance is constant, but actual power will change if voltage differs.

WAVES, SOUND & EM SPECTRUM

Wave Equation: $v = f\lambda$

- v : wave speed (m/s)
- f : frequency (Hz)
- λ : wavelength (m)

Wave Properties:

- **Amplitude:** Max displacement from equilibrium.
- **Period (T):** Time for one complete oscillation ($T = 1/f$).
- **Transverse Waves:** Oscillations perpendicular to wave propagation (e.g., light).
- **Longitudinal Waves:** Oscillations parallel to wave propagation (e.g., sound).

Reflection: Angle of incidence = Angle of reflection.

Refraction: Bending of waves as they pass from one medium to another.

- **Snell's Law:** $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$
- n : refractive index
- Light bends *towards* normal when entering denser medium (larger n).
- **Total Internal Reflection (TIR):** Occurs when $\theta_1 > \theta\_critical$ and $n_1 > n_2$.

Interference: Superposition of waves resulting in a new wave pattern.

- **Constructive:** Crest meets crest (or trough meets trough) -> larger amplitude.
- **Destructive:** Crest meets trough -> smaller amplitude (can be zero).
- **Diffraction:** Spreading of waves as they pass through an opening or around an obstacle.

Sound Waves: Longitudinal waves requiring a medium. Speed depends on medium (faster in solids > liquids > gases). Pitch = frequency, Loudness = amplitude.

Electromagnetic (EM) Spectrum: Transverse waves that do NOT require a medium (travel in vacuum at $c = 3.0 \times 10^8$ m/s).

- **Order (lowest to highest frequency/energy):** Radio, Microwave, Infrared, Visible Light (ROYGBIV), Ultraviolet, X-ray, Gamma ray.

Doppler Effect: Apparent change in frequency/wavelength of a wave due to relative motion between source and observer. $f' = f (v\_wave \pm v\_observer) / (v\_wave \pm v\_source)$ (approaching higher freq, receding lower freq).

Exam Tip: Remember that frequency (and therefore period) of a wave depends ONLY on the source, not the medium. Speed and wavelength change when a wave enters a new medium.

FIELDS & MODERN PHYSICS

FIELDS & FORCES

Gravitational Fields: Region where a mass experiences a force.

- **Field Strength (`g`):** Force per unit mass (`g = F_g / m`).
- For a point mass `M`: `g = GM / r²` (radially inwards).
- **Gravitational Potential Energy:** `E_g = -GMm / r` (for large distances).

Key Concept: Gravitational force is always attractive.

Electric Fields: Region where a charge experiences a force.

- **Field Strength (`E`):** Force per unit charge (`E = F_e / q`).
- For a point charge `Q`: `E = kQ / r²` (radially outwards for positive `Q`).
- **Electric Force:** `F_e = qE`.
- `k = 8.99 x 10⁹ N m²/C²` (Coulomb's constant)

Key Concept: Field lines point from positive to negative charges. Closer lines mean stronger field.

Magnetic Fields (`B`): Region where a moving charge or current experiences a force.

- **Force on a moving charge:** `F = qvB sin(θ)`
- `q`: charge (C)
- `v`: velocity (m/s)
- `B`: magnetic field strength (Tesla, T)
- `θ`: angle between `v` and `B`.
- **Force on a current-carrying wire:** `F = BIL sin(θ)`
- `I`: current (A)
- `L`: length of wire in field (m)

Right Hand Rule: For positive charge/current, point fingers in `v` / `I` direction, curl towards `B`, thumb points in `F` direction.

Circular Motion: An object moving in a circle at constant speed has constant magnitude of velocity but changing direction, thus accelerating.

- **Centripetal Acceleration (`a_c`):** `a_c = v² / r` or `a_c = 4π²r / T²` (towards center)
- **Centripetal Force (`F_c`):** `F_c = ma_c = mv² / r` or `F_c = m(4π²r / T²)` (towards center).

Key Concept: Centripetal force is *always* provided by another force (tension, gravity, friction, normal force, etc.). It is NOT a new type of force.

Example: A car turning a corner relies on friction for centripetal force. If `F_friction < mv²/r`, the car skids.

Exam Tip: For field diagrams, remember that field lines never cross. For magnetic fields, lines point from North to South. Use the right-hand grip rule for current-carrying wires/solenoids to determine field direction.

SPECIAL RELATIVITY

Einstein's Postulates:

1. The laws of physics are the same for all inertial (non-accelerating) observers.
2. The speed of light in a vacuum (`c`) is the same for all inertial observers, regardless of the motion of the source or observer.

Lorentz Factor (`γ`): `γ = 1 / sqrt(1 - v²/c²)`

- `v`: relative velocity between frames
- `c`: speed of light (`3.0 x 10⁸ m/s`)
- `γ ≥ 1`

Time Dilation: Moving clocks run slower.

- `Δt = γΔt₀`
- `Δt`: time measured by observer (dilated time)
- `Δt₀`: proper time (time measured in the object's rest frame).

Length Contraction: Lengths measured in a moving frame are shorter in the direction of motion.

- `L = L₀ / γ`
- `L`: length measured by observer (contracted length)
- `L₀`: proper length (length measured in the object's rest frame).

Mass-Energy Equivalence: `E = mc²`

- Mass and energy are interchangeable.
- Fundamental to nuclear processes.

Common Misconception: Time dilation and length contraction are not illusions; they are real physical effects due to the nature of spacetime.

Exam Tip: Identify the 'proper' quantity (the one measured in the rest frame of the event/object) before applying the formulas. It will always be `Δt₀` or `L₀`.

QUANTUM PHYSICS

Photoelectric Effect: Emission of electrons from a metal when light shines on it.

- **Photon Energy:** `E = hf` or `E = hc/λ`
- `h`: Planck's constant (`6.626 x 10⁻³⁴ J s`)
- `f`: frequency (Hz)
- `c`: speed of light (m/s)
- `λ`: wavelength (m)

Work Function (`W`): Minimum energy required to eject an electron from a metal surface.
Max Kinetic Energy of ejected electron: `KE_max = E - W` or `KE_max = hf - W`

Key Concept: Light behaves as discrete packets of energy called photons (particle nature).

De Broglie Wavelength: All matter exhibits wave-like properties.

- `λ = h / p` or `λ = h / mv`
- `p`: momentum (`mv`)

Key Concept: Particle-wave duality - particles can behave as waves, and waves can behave as particles.

Atomic Energy Levels: Electrons in atoms occupy discrete energy levels.

- When an electron moves from a higher energy level (`E_higher`) to a lower one (`E_lower`), a photon is emitted with energy `E_photon = E_higher - E_lower`.
- **Bohr Model:** Quantized orbits, electrons don't radiate while in orbit, only when changing orbits.

Spectra:

- **Emission Spectra:** Bright lines at specific wavelengths/frequencies (due to electron transitions down).
- **Absorption Spectra:** Dark lines at specific wavelengths/frequencies (due to electron transitions up).

Exam Tip: When dealing with photoelectric effect problems, ensure units are consistent (Joules for energy, Hz for frequency, m for wavelength). Often eV (electron volts) are used, where `1 eV = 1.602 x 10⁻¹⁹ J`.