VCE Physics: Unit 2 AOS 1 Cheat Sheet

How Is Motion Understood? — 2023–2027 Study Design — 2026 Course

1. Scalars, Vectors and Motion

- **Scalar:** Magnitude only. Examples: distance, speed, mass, time and energy.
- **Vector:** Magnitude and direction. Examples: displacement, velocity, acceleration, force and momentum.
- **Vector Components:**

$$A_x = A\cos\theta, \qquad A_y = A\sin\theta$$

Used to resolve a vector into perpendicular components. A = vector magnitude, A_x, A_y = components, θ = angle from the chosen x-direction.

- **Magnitude from Components:**

$$A = \sqrt{A_x^2 + A_y^2}$$

Used when perpendicular components are known.

- **Direction from Components:**

$$\theta = \tan^{-1}\left(\frac{A_y}{A_x}\right)$$

Check signs/quadrant.

- **Resultant Vector:**

$$\vec{R} = \vec{A} + \vec{B} + \dots$$

Resultant = vector sum of all contributing vectors.

- **Sign Convention:** Choose a positive direction first; quantities opposite to it are negative.

2. Distance, Displacement, Speed and Velocity

- **Distance:** Total path travelled; scalar.
- **Displacement:**

$$\Delta x = x_f - x_i$$

Change in position; vector. x_i = initial position, x_f = final position.

- **Average Speed:**

$$v_{\text{speed,av}} = \frac{\text{total distance}}{\Delta t}$$

Average rate at which distance is travelled.

- **Average Velocity:**

$$v_{\text{av}} = \frac{\Delta x}{\Delta t}$$

Average rate of change of displacement.

- Units: distance/displacement in m; speed/velocity in $\text{m}\,\text{s}^{-1}$.

3. Acceleration and Motion Graphs

- **Acceleration:**

$$a = \frac{\Delta v}{\Delta t} = \frac{v - u}{t}$$

Rate of change of velocity. u = initial velocity, v = final velocity, a = acceleration, t = time.

- Negative acceleration means acceleration points in the chosen negative direction; it does not automatically mean slowing down.

Graph	Gradient	Area
Position–Time	Velocity	—
Velocity–Time	Acceleration	Displacement
Acceleration–Time	—	Change in Velocity

- **Instantaneous Velocity:** Tangent gradient of an $x - t$ graph.
- **Instantaneous Acceleration:** Tangent gradient of a $v - t$ graph.
- **Displacement from $v - t$:**

$$\Delta x = \text{signed area under } v - t$$

- **Distance from $v - t$:** Add magnitudes of all areas.
- **Change in Velocity from $a - t$:**

$$\Delta v = \text{signed area under } a - t$$

4. Constant Acceleration

Use only when acceleration is constant.

- $$v = u + at$$

Use when s is not required.

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

Use when v is not required.

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

Use when t is not required.

- $$s = \frac{1}{2}(u + v)t$$

Use when a is not required explicitly.

- $$s = vt - \frac{1}{2}at^2$$

Use when u is not required.

s = displacement (m), u = initial velocity,
v = final velocity, a = acceleration,
t = time (s).

Free Fall:

$$g = 9.8\,\text{m}\,\text{s}^{-2}$$

vertically downward. Give g the correct sign for the chosen axis.

5. Newton's Laws and Net Force

- **Net Force:**

$$\vec{F}_{\text{net}} = \sum \vec{F}$$

Vector sum of all external forces on one object.

- **Newton's First Law:** An object remains at rest or constant velocity unless acted on by a non-zero net force.

$$\vec{F}_{\text{net}} = 0 \Rightarrow \vec{a} = 0$$

- **Inertia:** Resistance to change in velocity. Greater mass means greater inertia.
- **Newton's Second Law:**

$$\vec{F}_{\text{net}} = m\vec{a}$$

Used to relate net force and acceleration. F_{net} = net force (N), m = mass (kg), a = acceleration ($\text{m}\,\text{s}^{-2}$).

- **Newton's Third Law:**

$$\vec{F}_{\text{on A by B}} = -\vec{F}_{\text{on B by A}}$$

Equal magnitude, opposite direction, same interaction, acting on **different objects**.

6. Weight, Normal Force and Friction

- **Weight:**

$$F_g = mg$$

Gravitational force near Earth's surface. F_g = weight (N), m = mass (kg), $g = 9.8\,\text{N}\,\text{kg}^{-1}$.
Weight acts vertically downward through the centre of mass.

- **Normal Force (N):** Contact force perpendicular to a surface. Do not automatically assume $N = mg$.
- **Friction:** Contact force parallel to a surface opposing relative sliding or tendency to slide.

7. Resolving Forces and Inclines

- **Force Components:**

$$F_x = F\cos\theta, \qquad F_y = F\sin\theta$$

Used to split an angled force into perpendicular components.

- **Parallel Weight Component:**

$$F_{g,\parallel} = mg\sin\theta$$

Acts down the slope.

- **Perpendicular Weight Component:**

$$F_{g,\perp} = mg\cos\theta$$

- If there is no perpendicular acceleration and no other perpendicular force:

$$N = mg\cos\theta$$

- **Frictionless Incline:**

$$ma = mg\sin\theta \Rightarrow a = g\sin\theta$$

8. Free-Body Diagrams

- Isolate one object.
- Draw only forces acting on that object.
- Choose positive directions.
- Resolve angled forces.
- Apply:

$$\sum F_x = ma_x, \qquad \sum F_y = ma_y$$

9. Connected Bodies

- Objects joined by an ideal taut string have the same magnitude of acceleration.
- **System Acceleration:**

$$a = \frac{\sum F_{\text{external,net}}}{m_1 + m_2 + \dots}$$

Treat connected objects as one system.

- Internal tensions cancel when analysing the complete system.
- Isolate one object afterwards and use:

$$\sum F = ma$$

to calculate tension or another internal force.

10. Momentum

- **Linear Momentum:**

$$\vec{p} = m\vec{v}$$

Used to describe motion using mass and velocity.
$\vec{p}$ = momentum ($\text{kg}\,\text{m}\,\text{s}^{-1}$ or $\text{N}\,\text{s}$), m = mass, $\vec{v}$ = velocity.
Momentum is a vector; retain signs/directions.

- **Change in Momentum:**

$$\Delta\vec{p} = \vec{p}_f - \vec{p}_i$$

For constant mass:

$$\Delta\vec{p} = m(\vec{v} - \vec{u})$$

11. Impulse

- **Impulse:**

$$\vec{I} = \vec{F}\Delta t$$

- **Impulse–Momentum Relationship:**

$$\vec{I} = \Delta\vec{p}$$

Therefore:

$$\vec{F}\Delta t = m\Delta\vec{v} = \Delta\vec{p}$$

I = impulse ($\text{N}\,\text{s}$), F = average force, Δt = interaction time.

- **Force–Time Graph:**

$$I = \text{signed area under } F - t$$

- **Average Force:**

$$F_{\text{av}} = \frac{\Delta p}{\Delta t}$$

12. Conservation of Momentum

- In an isolated system or where external impulse is negligible:

$$\sum \vec{p}_{\text{before}} = \sum \vec{p}_{\text{after}}$$

- For two objects:

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

Used to calculate unknown velocities in collisions/interactions.
Choose one direction positive; velocities in the opposite direction are negative.

- **Objects Stick Together:**

$$m_1u_1 + m_2u_2 = (m_1 + m_2)v$$

- **Elastic Collision:** Momentum and kinetic energy conserved.
- **Inelastic Collision:** Momentum conserved; some kinetic energy becomes heat, sound or deformation.
- **Completely Inelastic Collision:** Objects stick together.

13. Work

- **Work Done by a Constant Force:**

$$W = Fs\cos\theta$$

Energy transferred by a constant force through a displacement.
W = work (J), F = force (N), s = displacement (m), θ = angle between force and displacement.

$$\theta = 0^\circ \Rightarrow W = Fs$$
$$\theta = 90^\circ \Rightarrow W = 0$$
$$\theta = 180^\circ \Rightarrow W = -Fs$$

- **Force–Distance Graph:**

$$W = \text{area under } F - s$$

14. Kinetic and Gravitational Energy

- **Kinetic Energy:**

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

Energy associated with translational motion. E_k = kinetic energy (J), m = mass, v = speed.

- **Work–Energy Theorem:**

$$W_{\text{net}} = \Delta E_k$$

Net work done equals change in kinetic energy.

- **Gravitational Potential Energy:**

$$\Delta E_g = mg\Delta h$$

Change in gravitational potential energy near Earth's surface.
ΔE_g = change in GPE (J), m = mass, $g = 9.8\,\text{N}\,\text{kg}^{-1}$, Δh = vertical height change.
Only vertical height change matters, not path taken.

15. Springs

- **Hooke's Law:**

$$F = -kx$$

Restoring force of an ideal spring.
F = restoring force (N), k = spring constant ($\text{N}\,\text{m}^{-1}$), x = extension/compression (m).
Negative sign means force acts opposite to displacement.

- **Magnitude:**

$$|F| = kx$$

- **Spring Constant from Graph:**

$$k = \frac{\Delta F}{\Delta x}$$

Gradient of the linear force–extension region.

- **Elastic Potential Energy:**

$$E_s = \frac{1}{2}kx^2$$

Energy stored in an ideal spring. Also equals area under the spring's $F - x$ graph.

16. Mechanical Energy

- If no energy is transferred to/from the mechanical system:

$$E_k + E_g + E_s = \text{constant}$$

$$E_{k,i} + E_{g,i} + E_{s,i} = E_{k,f} + E_{g,f} + E_{s,f}$$

  Used to relate speed, height and spring extension.
- If friction, drag or deformation transfers energy:

$$E_{\text{initial}} = E_{\text{final}} + E_{\text{transferred}}$$

  Energy is transferred/transformed, not destroyed.

17. Power and Efficiency

- **Power:**

$$P = \frac{E}{t} = \frac{\Delta E}{\Delta t}$$

  Rate of energy transfer.
  P = power (W), E = energy (J), t = time (s).

$$1\,\text{W} = 1\,\text{J}\,\text{s}^{-1}$$

- **Mechanical Power:**

$$P = Fv$$

  when force is parallel to velocity.
  More generally:

$$P = Fv\cos\theta$$

- **Efficiency:**

$$\eta = \frac{E_{\text{useful}}}{E_{\text{input}}}$$

$$\eta(\%) = \frac{E_{\text{useful}}}{E_{\text{input}}} \times 100\%$$

  or:

$$\eta(\%) = \frac{P_{\text{useful}}}{P_{\text{input}}} \times 100\%$$

18. Torque

- **Torque:** Turning effect of a force about a pivot.

$$\tau = r_\perp F$$

  τ = torque (N m), F = force (N), $r_\perp$ = perpendicular distance from pivot to the force's line of action.
- If distance r and angle θ are known:

$$\tau = rF\sin\theta$$

  because:

$$r_\perp = r\sin\theta$$

- A force whose line of action passes through the pivot has:

$$r_\perp = 0 \Rightarrow \tau = 0$$

- Example sign convention:

$$\text{anticlockwise} = +, \qquad \text{clockwise} = -$$

19. Translational and Rotational Equilibrium

- **Translational Equilibrium:**

$$\sum \vec{F} = 0$$

  In two dimensions:

$$\sum F_x = 0, \qquad \sum F_y = 0$$

  Means zero linear acceleration.
- **Rotational Equilibrium:**

$$\sum \tau = 0$$

  or:

$$\sum \tau_{\text{clockwise}} = \sum \tau_{\text{anticlockwise}}$$

- **Complete Static Equilibrium:**

$$\sum F_x = 0, \qquad \sum F_y = 0, \qquad \sum \tau = 0$$

- Weight acts through the centre of mass.
- Choose the pivot through an unknown force when possible so that force produces zero torque.
- Equal and opposite forces can give $\sum F = 0$ while still giving non-zero torque if their lines of action differ.

20. Equilibrium Problem Method

1. Draw all external forces.
2. Include weight mg through centre of mass.
3. Include support forces, normal forces and tensions.
4. Choose positive directions.
5. Choose a convenient pivot.
6. Find each perpendicular lever arm $r_\perp$.
7. Apply:

$$\sum \tau = 0$$

8. Then apply:

$$\sum F_x = 0, \qquad \sum F_y = 0$$

21. Vehicle Safety

- Momentum change:

$$\Delta p = m\Delta v$$

- Impulse:

$$F_{\text{av}}\Delta t = \Delta p$$

  Therefore:

$$F_{\text{av}} = \frac{\Delta p}{\Delta t}$$

- For the same momentum change:

$$\Delta t \uparrow \Rightarrow F_{\text{av}} \downarrow$$

- **Seatbelts:** Increase stopping time and prevent continued forward motion.
- **Airbags:** Increase stopping time and spread force over a larger area.
- **Crumple Zones:** Increase collision time and transform kinetic energy into deformation, thermal energy and sound.
- Do not say an airbag "reduces momentum" if initial and final velocities are unchanged; it mainly increases the time over which momentum changes.

22. Sport, Devices and Structures

- **Sport:**

$$a = \frac{F_{\text{net}}}{m}$$

  Larger net force gives larger acceleration for fixed mass.
-

$$F\Delta t = \Delta p$$

  A force applied for longer can produce greater momentum change.
- **Devices:**

$$W = Fs\cos\theta$$

  gives energy transferred by a force.

$$P = \frac{\Delta E}{\Delta t}$$

  gives rate of energy transfer.
- **Structures:**

$$\sum F_x = 0, \qquad \sum F_y = 0, \qquad \sum \tau = 0$$

  used for support forces, tensions and rotational effects.

23. Common Exam / SAC Traps

- Choose a positive direction before using vector equations.
- Distance and displacement are not interchangeable.
- Speed and velocity are not interchangeable.
- Use constant-acceleration equations only when a is constant.
- $x - t$ gradient = velocity.
- $v - t$ gradient = acceleration.
- $v - t$ area = displacement.
- $a - t$ area = change in velocity.
- $F - t$ area = impulse = change in momentum.
- Force–distance area = work.
- Use **net force**, not one individual force, in $F_{\text{net}} = ma$.
- Newton's third-law pairs act on different bodies.
- Do not assume $N = mg$ unless force balance justifies it.
- Momentum is a vector; retain signs in collision calculations.
- Momentum conservation requires negligible net external impulse.
- Objects that stick together share one final velocity.
- Energy is transferred/transformed, not destroyed.
- For $\Delta E_g = mg\Delta h$, use vertical height change.
- Hooke's law applies in the linear elastic region.
- In torque calculations, use perpendicular distance to the force's line of action.
- Static equilibrium requires both force balance and torque balance.
- Weight acts through centre of mass.
- Choose a pivot through an unknown force where useful.

24. Problem-Solving Methods

Constant Acceleration

1. Choose positive direction.
2. List known values from s, u, v, a, t.
3. Give quantities correct signs.
4. Choose the equation containing known values and required unknown.
5. Solve and check direction/sign.

Force Problems

1. Draw FBD.
2. Resolve angled forces.
3. Find net force in each direction.
4. Use $\sum F = ma$.
5. If acceleration is zero, use $\sum F = 0$.

Collisions

1. Choose positive direction.
2. Give velocities signs.
3. Write total momentum before and after.
4. Set them equal.
5. If objects stick, use one common final velocity.

Energy Problems

1. Identify initial and final states.
2. Identify kinetic, gravitational and elastic energy present.
3. Include transferred energy if friction/drag/deformation occurs.
4. Apply energy conservation.

Torque Problems

1. Choose pivot.
2. Identify each force's line of action.
3. Find perpendicular lever arm.
4. Assign clockwise/anticlockwise signs.
5. Use $\sum \tau = 0$.
6. Use force balance for remaining unknowns.

25. Key Explanation Language

- **Force:**

$$F_{\text{net}} \uparrow \Rightarrow a \uparrow$$

  for constant mass.
- **Mass:**

$$m \uparrow \Rightarrow a \downarrow$$

  for constant net force.
- **Collision Safety:**

$$F_{\text{av}} = \frac{\Delta p}{\Delta t}$$

  Increasing collision time decreases average force for the same momentum change.
- **Energy:** A decrease in one energy store corresponds to an increase in another store or transfer to the surroundings.
- **Spring:**

$$E_s = \frac{1}{2}kx^2$$

  so doubling x gives four times the elastic potential energy.
- **Torque:**

$$\tau = r_\perp F$$

  A smaller force can balance a larger force if it acts farther from the pivot.
- **Power:**

$$P = \frac{\Delta E}{\Delta t}$$

  Same energy transferred in less time means greater power.
- **Efficiency:**

$$\eta = \frac{E_{\text{useful}}}{E_{\text{input}}}$$

  Efficiency cannot exceed 100%.

26. Units and Constants

- displacement / distance: m
- velocity / speed: $\text{m}\,\text{s}^{-1}$
- acceleration: $\text{m}\,\text{s}^{-2}$
- mass: kg
- force: N
- momentum: $\text{kg}\,\text{m}\,\text{s}^{-1}$
- impulse: N s
- work / energy: J
- power: W
- torque: N m
- spring constant: $\text{N}\,\text{m}^{-1}$
- $g = 9.8\,\text{m}\,\text{s}^{-2} = 9.8\,\text{N}\,\text{kg}^{-1}$
- $1\,\text{J} = 1\,\text{N}\,\text{m}$
- $1\,\text{W} = 1\,\text{J}\,\text{s}^{-1}$
- $1\,\text{N}\,\text{s} = 1\,\text{kg}\,\text{m}\,\text{s}^{-1}$