AM-05.03 — Ellipse, periapsis, apoapsis and eccentricity: reading a non-circular orbit

Essential answer

Ellipse, periapsis, apoapsis and eccentricity: reading a non-circular orbit. Circular orbits are useful for learning, but many real trajectories are elliptical. An ellipse has a nearest point and a farthest point. Those simple ideas unlock transfers, capture orbits and aerobraking. The rest of the course turns that idea into an auditable line of reasoning: explicit units, stated assumptions, reproducible calculations, order-of-magnitude checks and interpretation limits. A result is useful only when the reader can explain what it measures, where every input came from and which engineering decision it can support.

Reasoning map

1. 1 — Build a mental picture before using a formula
2. 2 — Essential vocabulary before going further
3. 3 — Understand the mechanism step by step
4. 4 — The formula, only now
5. 5 — What the units tell you

Circular orbits are useful for learning, but many real trajectories are elliptical. An ellipse has a nearest point and a farthest point. Those simple ideas unlock transfers, capture orbits and aerobraking.

ellipse — a closed elongated curve; a circle is a special case.

Before calculating

Quantity:	AM-05.03 — Ellipse, periapsis, apoapsis and eccentricity: reading a non-circular orbit
Check:	units + order of magnitude + assumptions
Decision:	state what the result actually supports

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2 — Essential vocabulary before going further

ellipse — a closed elongated curve; a circle is a special case.

periapsis — closest point to the central body.

semi-major axis — half the ellipse’s longest diameter.

eccentricity — dimensionless measure of elongation.

3 — Understand the mechanism step by step

Around Earth, perigee and apogee are common; around the Sun, perihelion and aphelion. Periapsis and apoapsis are generic.

A spacecraft moves faster near periapsis and slower near apoapsis as kinetic and potential energy trade with one another.

A circle has e = 0. Bound ellipses become more elongated as e approaches 1.

4 — The formula, only now

How to read it: e is eccentricity; r_a is apoapsis radius; r_p is periapsis radius. Both are measured from the body's centre in this simplified model.

With r_p = 7,000 km and r_a = 14,000 km: difference = 7,000 km, sum = 21,000 km, so e = 7,000/21,000 ≈ 0.333.

5 — What the units tell you

Active reading

Sections:	2 — Essential vocabulary before going further ; 3 — Understand the mechanism step by step
Verification:	A value is usable only with its unit and calculation boundary.
Exercise:	change one assumption and predict the direction of change before recalculating

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6 — Three concrete demonstrations

rp = 7,000 km and ra = 7,100 km give e ≈ 0.0071.

rp = 7,000 km and ra = 14,000 km give e = 1/3 ≈ 0.333 and semi-major axis 10,500 km.

A spacecraft may first enter a highly elliptical Mars orbit, then lower apoapsis through burns or aerobraking.

7 — Why this matters for a Mars mission

Elliptical geometry is central to transfer orbits and capture trajectories.

8 — Common traps and misleading intuitions

assuming periapsis always means dangerously low.

assuming constant speed in an ellipse.

9 — What I should be able to explain at the end

explain the idea in ordinary words

read and pronounce the important symbols

repeat at least one calculation without hidden steps

identify what the simplified model assumes and does not prove

Reading an ellipse as a map of orbital energy

Active reading

Sections:	6 — Three concrete demonstrations ; 7 — Why this matters for a Mars mission
Verification:	A value is usable only with its unit and calculation boundary.
Exercise:	change one assumption and predict the direction of change before recalculating

AM-05.03 — Ellipse, periapsis, apoapsis and eccentricity: reading a non-circular orbit

An ellipse is more than a visually stretched circle. The central body sits at one focus, so distance changes continuously. Periapsis is the closest point and apoapsis the farthest. Semi-major axis sets orbital energy in the two-body model, while eccentricity describes the shape.

The vis-viva relation $v^2 = \mu(2/r - 1/a)$ links position and speed directly. At fixed a, speed rises as r decreases toward periapsis and falls toward apoapsis. This is why the same impulse has different consequences depending on where it is applied.

Operationally, periapsis and apoapsis can become safety, heating, eclipse or communications constraints. Around Mars, a small periapsis error can strongly change atmospheric interaction, so these are navigation quantities, not merely vocabulary.

10 — Guided exercises and answers

11 — NASA / JPL sources for further study

NASA Science — Basics of Space Flight, Gravity & Mechanics

NASA Science — Basics of Space Flight, Trajectories

Active reading

Sections:	10 — Guided exercises and answers ; 11 — NASA / JPL sources for further study
Verification:	NASA Science — Basics of Space Flight, Gravity & Mechanics | NASA Science — Basics of Space Flight, Trajectories
Exercise:	change one assumption and predict the direction of change before recalculating