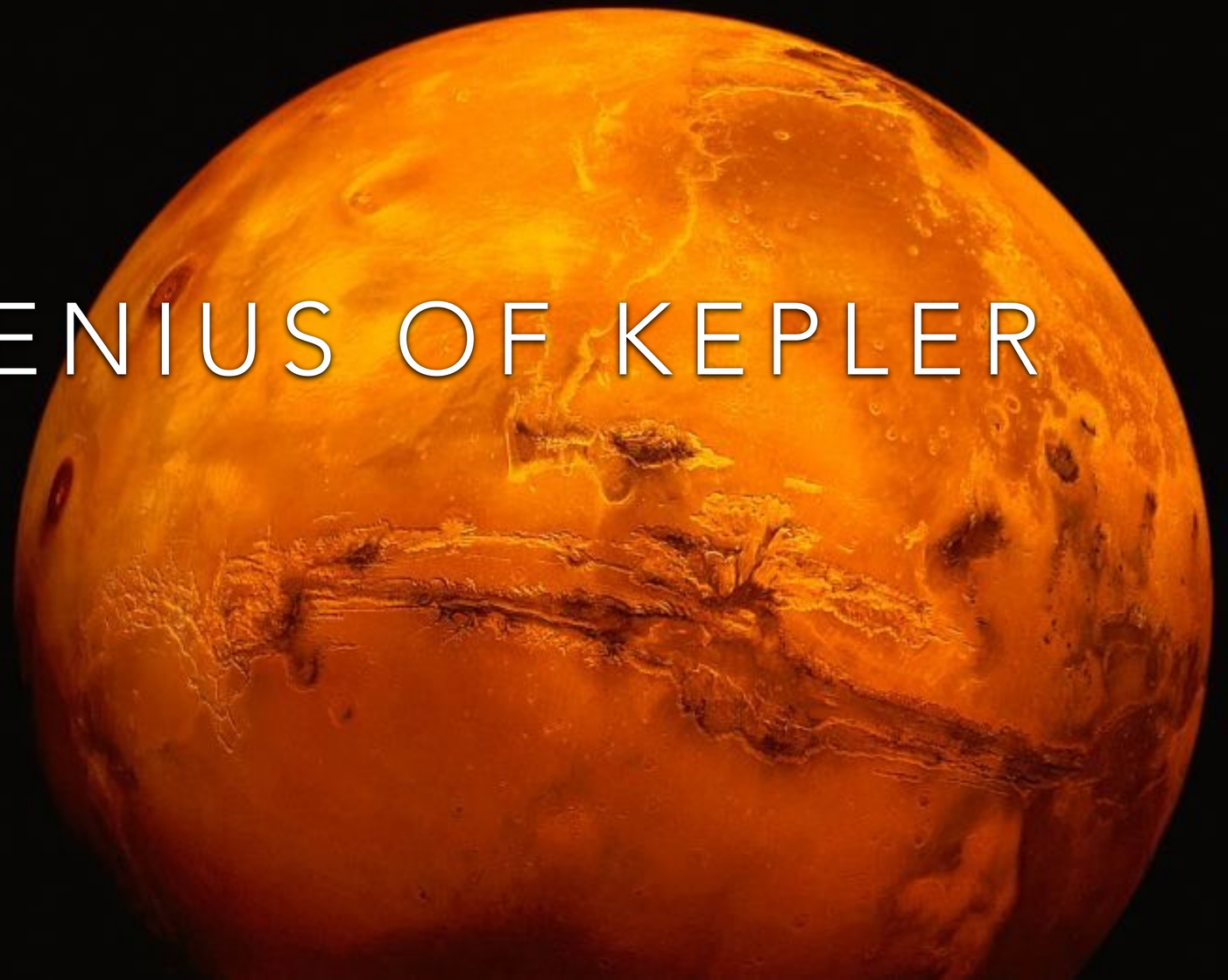
LAB 5

THE GENIUS OF KEPLER



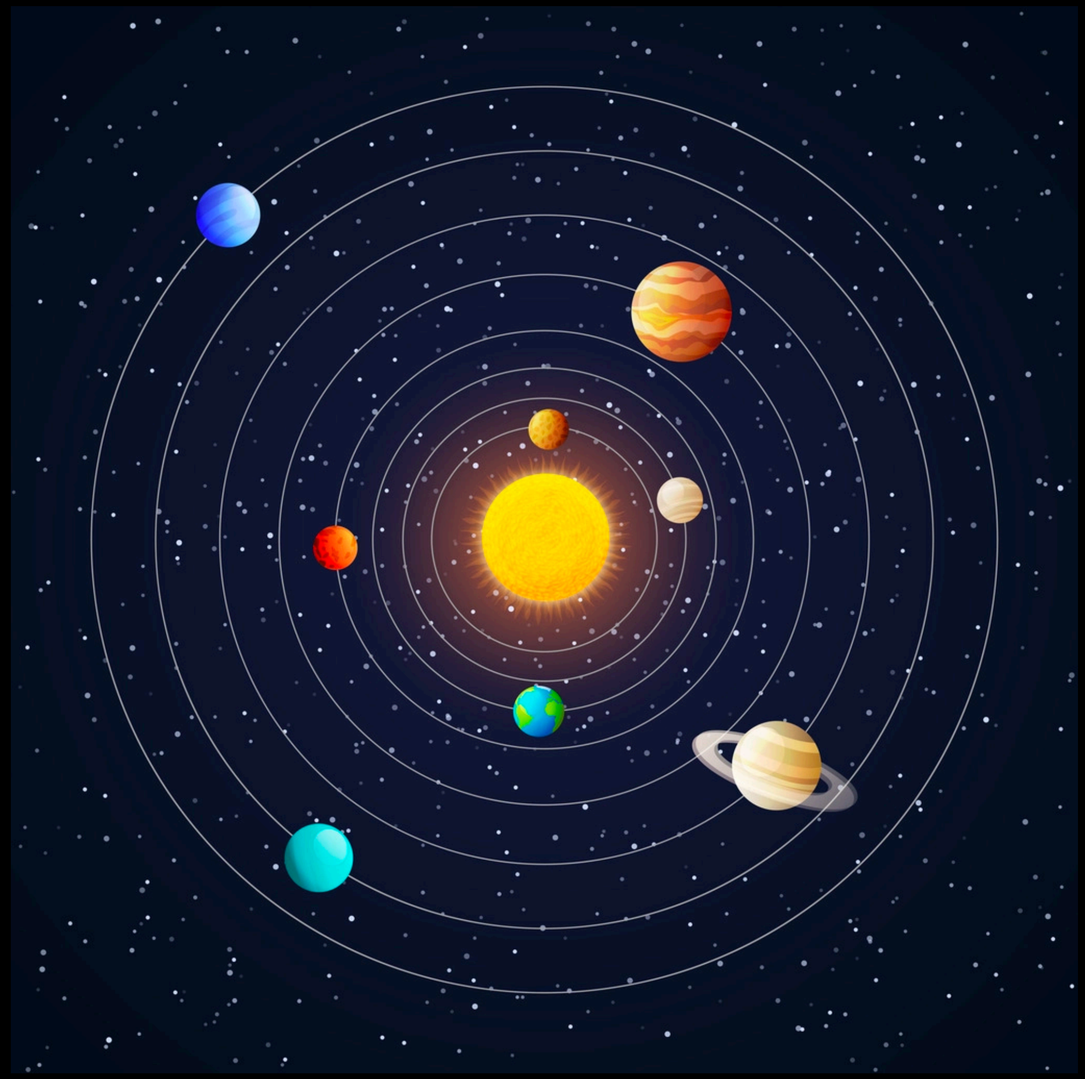
RUBRIC

ASTR 101 Kepler: /9 + /12 + /9 + /12 + /24 + /18 + /6 + /10(neatness) = /100

Grade Value	0	1	2	3	Weight
Objective & Introduction	Content missing	Basic content. Non-scientific jargon and wording. Difficult to understand sentences.	Acceptable content. Some attempt at scientific terminology. Sentences acceptable.	Excellent content. Proper use of jargon and scientific wording. Assumptions noted and justified.	3
Grade Value	0	1	2	3	Weight
Procedure	Content missing	Basic content. No special equipment described, minimal description of procedure, no discussion of measurement uncertainties.	Acceptable content. Special equipment noted, important points of procedure noted, basic discussion of measurement uncertainties.	Excellent content. Special equipment addressed and discussed, procedure detailed and informative, measurement uncertainties noted.	4
Grade Value	0	1	2	3	Weight
Observations, Tables & Graphs	Content missing	Basic content. Incomplete information. Tables missing title, or other details. Graphs missing titles, labels, and/or too small. Sketches lacking detail.	Acceptable content. Minor details missing from graphs, tables and sketches, but all major details present.	Excellent content. Tables and graphs complete. Observations thorough.	3
Grade Value	0	1	2	3	Weight
Calculations	Content missing.	Basic content. Many calculations missing. Units and significant figures ignored. No detailed calculations at the end of the report.	Acceptable content. Most calculations present, but some details missing. Units and significant figures use inconsistent.	Excellent content. All calculations included. Units and significant figures present in all calculations.	4
Grade Value	0	1	2	3	Weight
Questions & Answers	Content missing.	Basic content. Questions answered simplistically; answers show lack of insight. Results not clearly discussed. Units neglected. No link between objective and results.	Acceptable content. Questions mostly answered correctly. Results mentioned, with spotty units. Weak link provided between objective and results.	Excellent content. Questions answered in detail. Clear connection between objective and results. Units clearly included.	8
Grade Value	0	1	2	3	Weight
Discussion	Content missing.	Basic content. Lacking discussion about expectations, assumptions, and consistency. No discussion about broader context.	Acceptable content. Limited discussion of expectations, assumptions and consistency. Limited discussion of broader context.	Excellent content. Expectations, assumptions and consistency clearly and correctly addressed. Broader context discussed.	6
Grade Value	0	1	2	3	Weight
Conclusion & References	Content missing.	Basic content. Conclusion unclear or lacking insight. References limited or missing.	Acceptable content. Correct conclusion but limited. Some references included.	Excellent content. Conclusion correct and focused. Detailed references included.	2

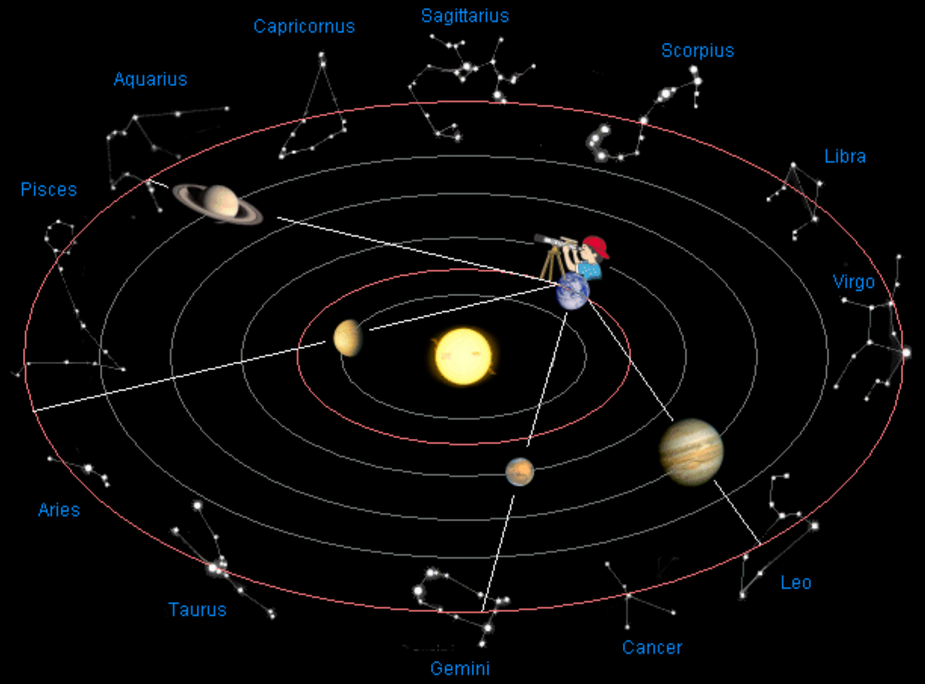
OUR SOLAR SYSTEM

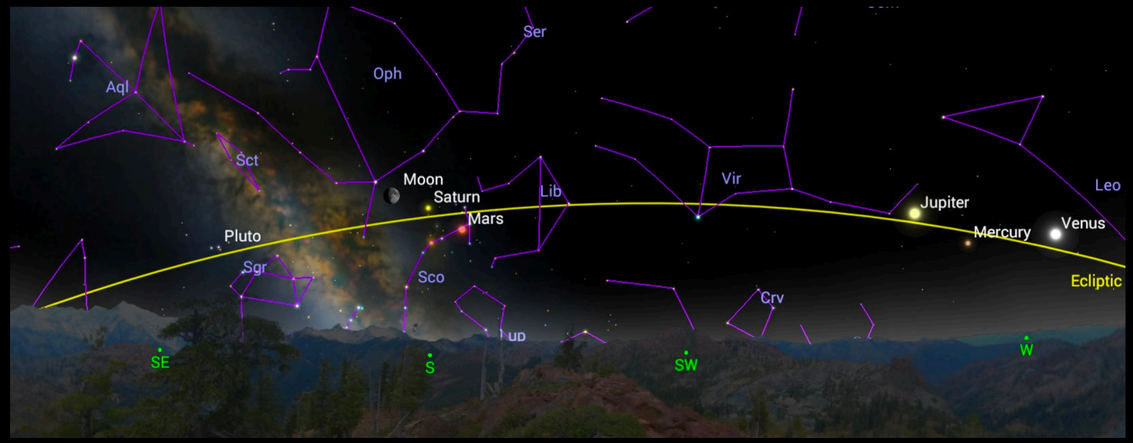
- 8 planets in our solar system (including Earth).
- Planets orbit the sun.
- All planets orbit on same plane.
- Orbits are close to circular.



PERSPECTIVE FROM EARTH

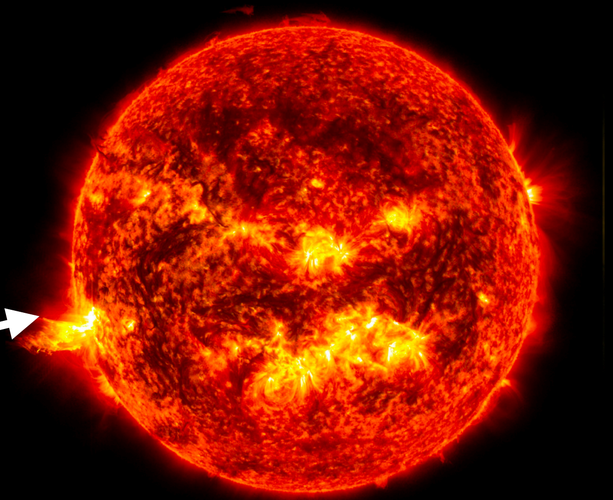
- Planets orbit around the Sun, but we don’t see that on Earth.
- We see the Sun and planets move in the sky.
- Sun and other planets move along the Ecliptic.

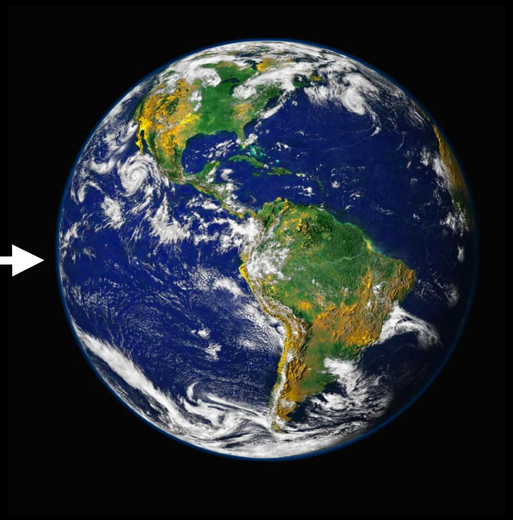


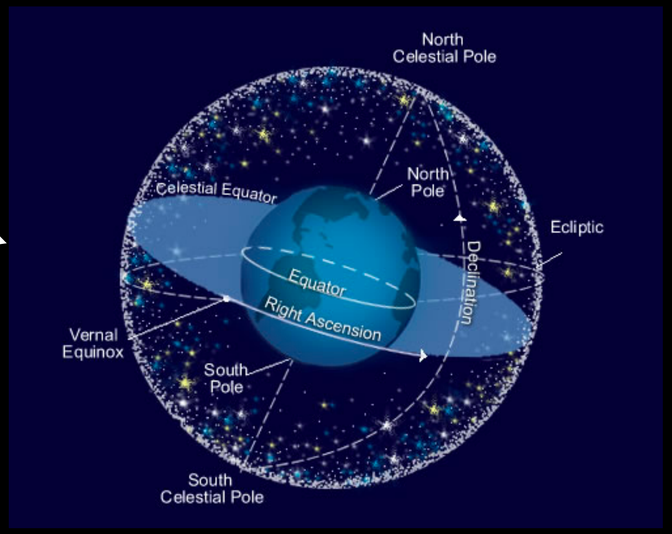


3 MAIN COORDINATE SYSTEMS

- **Heliocentric**
- **Geocentric**
- Equatorial

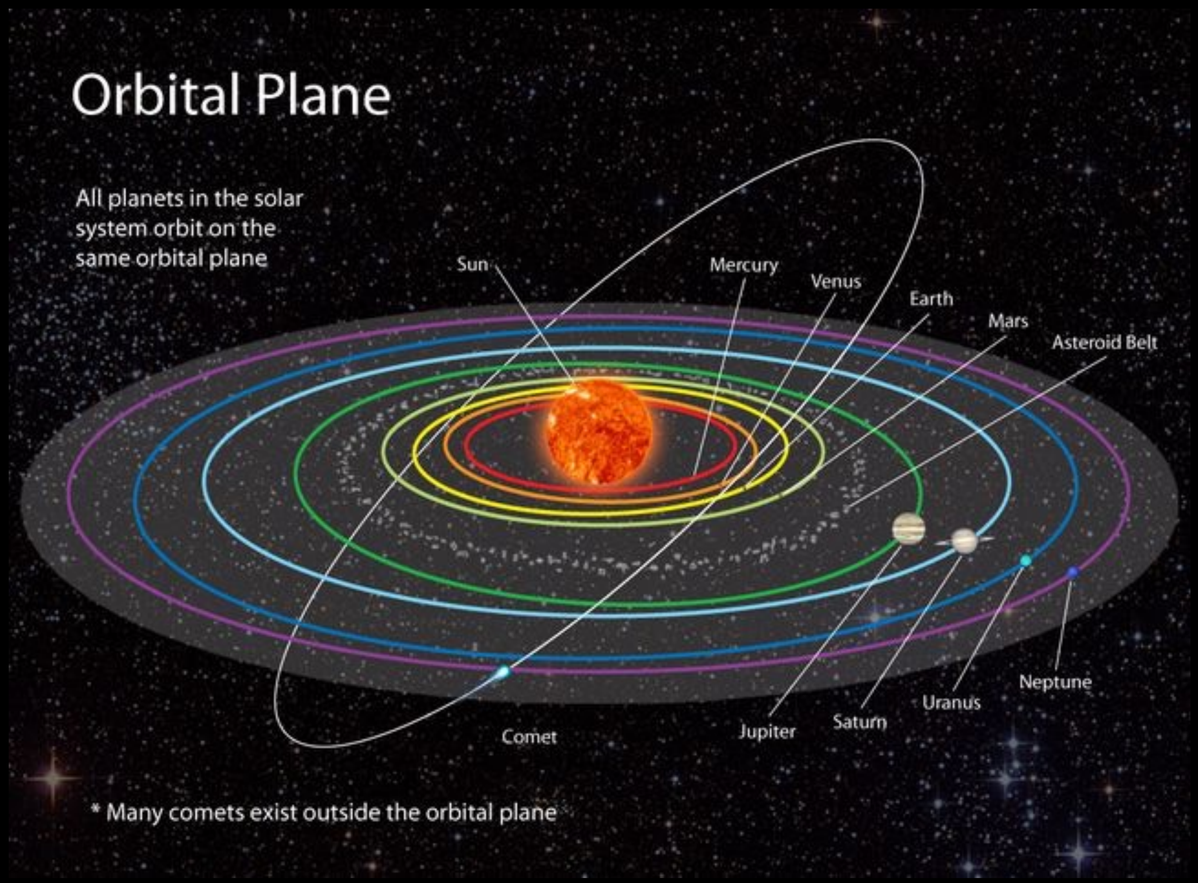






HELIOCENTRIC

- Centered around the sun.
- Longitude is counterclockwise from 0 to 360 degrees.
- Latitude is -90 to 90 degrees.
- 0 degrees longitude is with respect to the First Point of Aries.

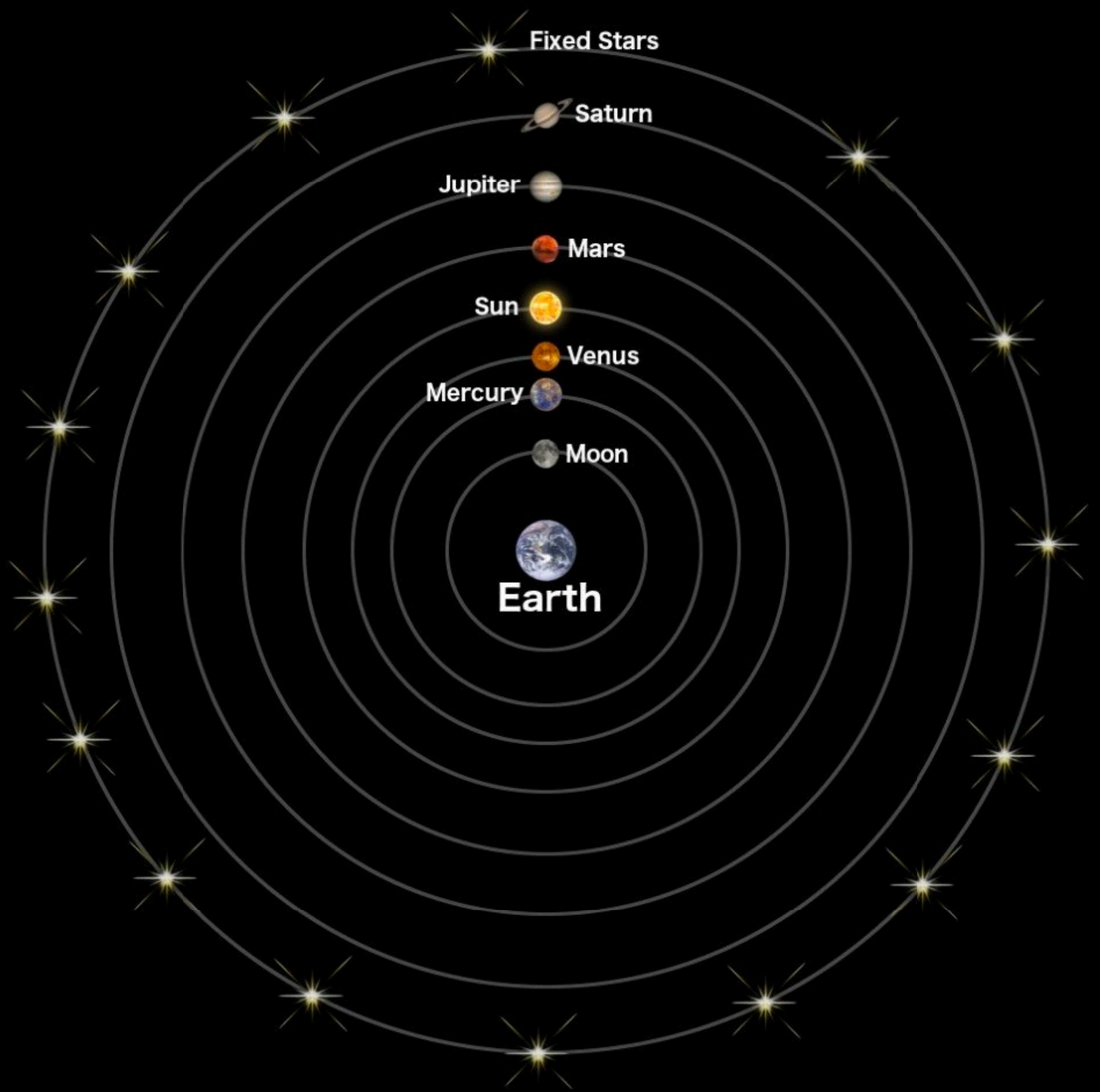


GEOCENTRIC

Earth is at center.

Longitude and Latitude are
similar to the heliocentric model.

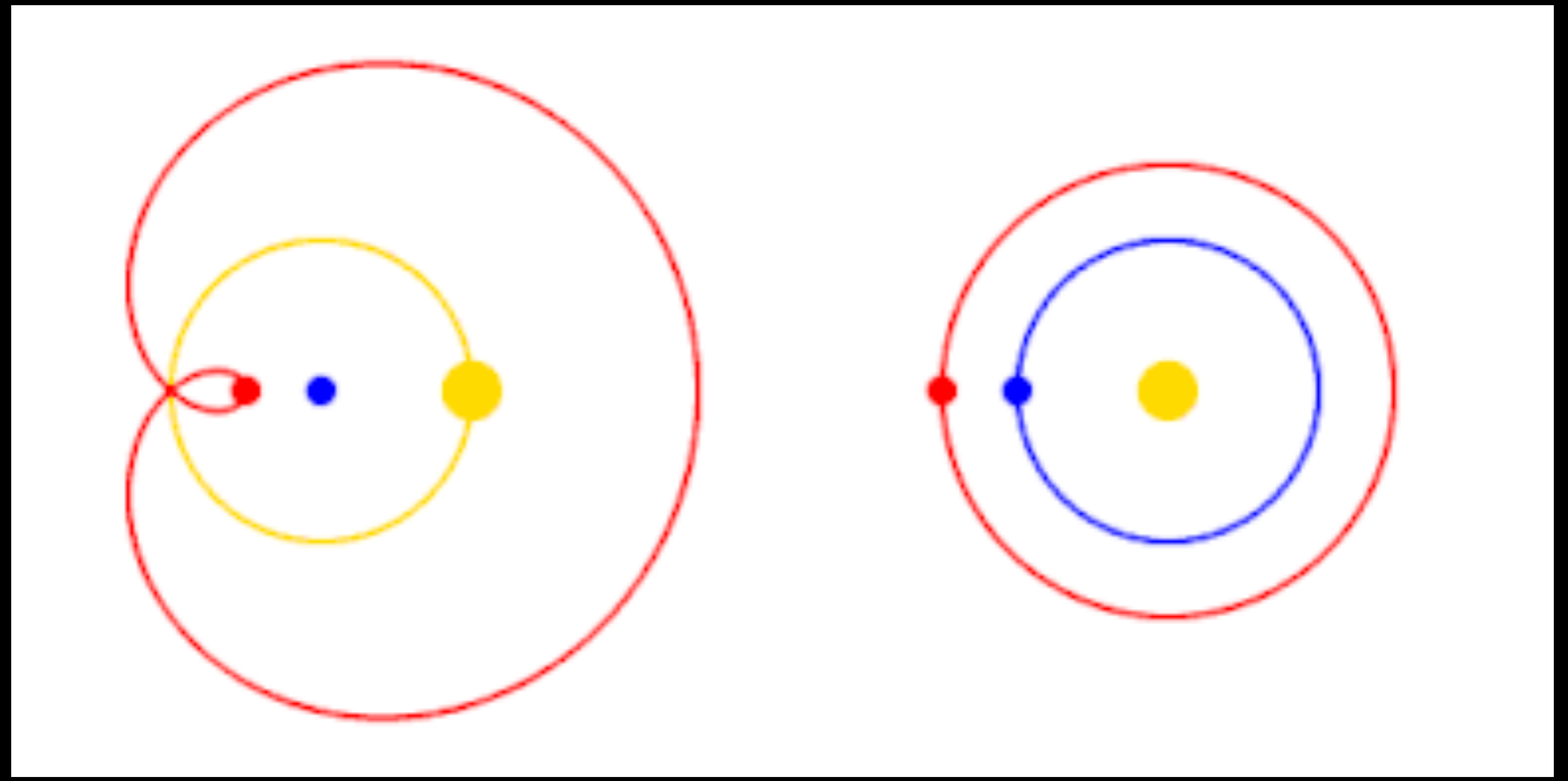
0 degrees longitude is also
respect to the First Point of Aries.



GEOCENTRIC VS. HELIOCENTRIC VIEW

Geocentric View

Heliocentric View



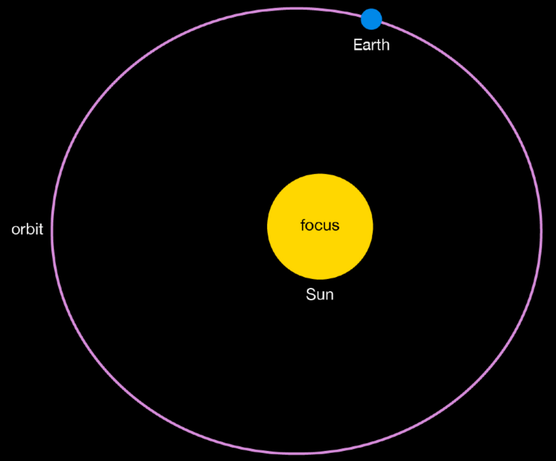
Earth

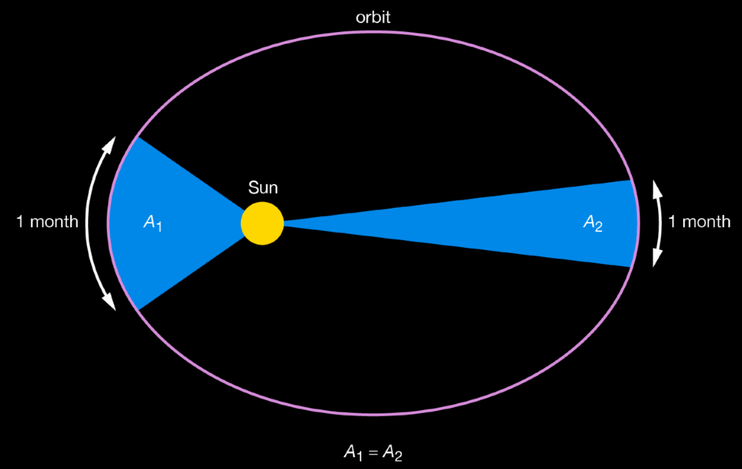
Mars

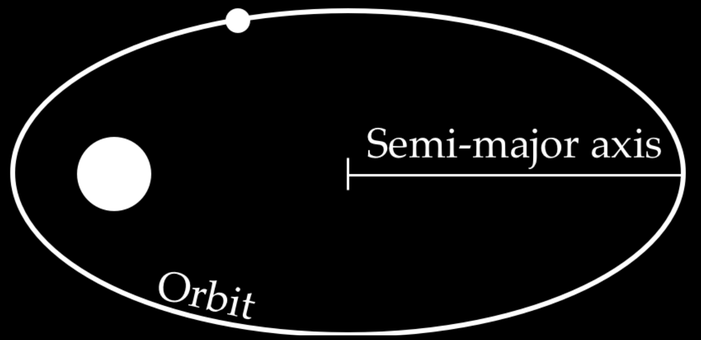
Sun

KEPLER'S LAWS

- 1st: Planets are on elliptical orbits around its star.
- 2nd: Equal area in the same amount of time, ie A1 = A2
- 3rd: Period of orbit squared is equal to the semi-major axis cubed, ie $P^2 = a^3$

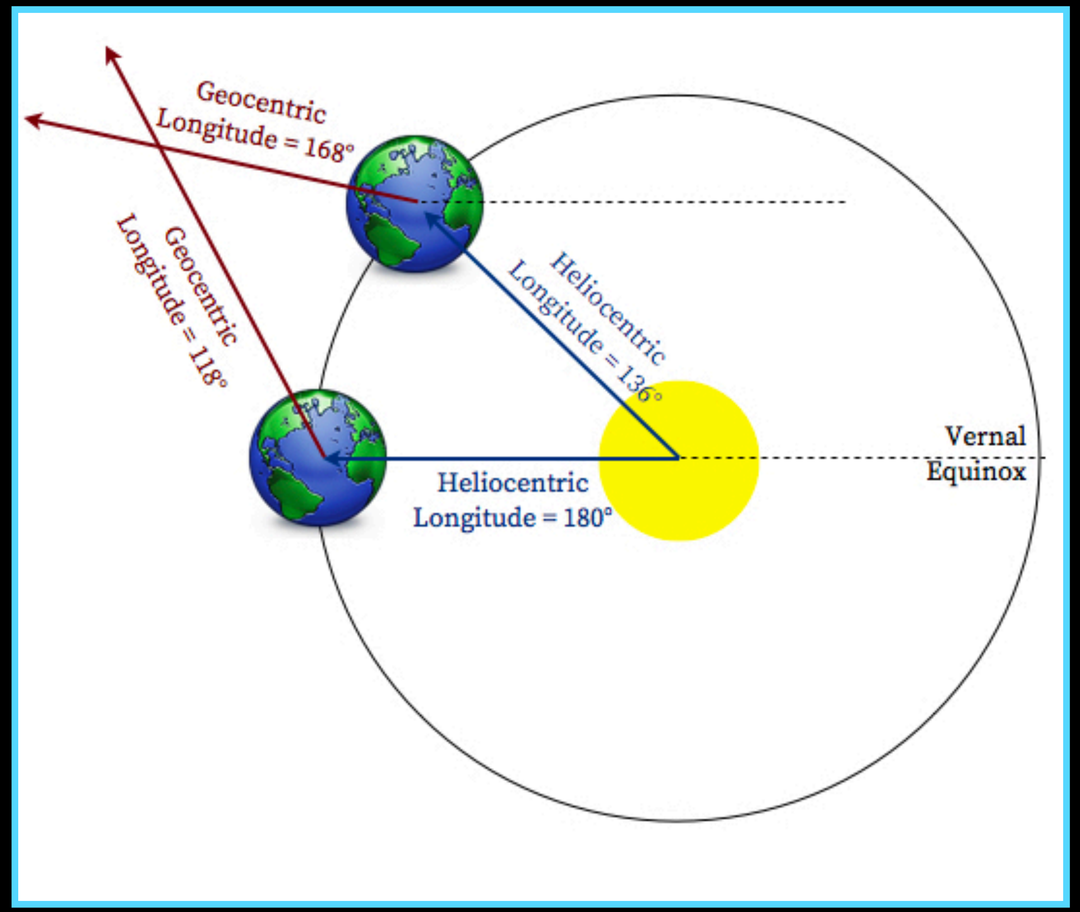






TRIANGULATION

- Uses geometry of ellipses to calculate orbits of other planets from Earth.
- Need to know heliocentric longitude (HL) of Earth and geocentric longitude (GL) of other planet from two vantage points.
- Planet being measured needs to be at same location at both times. Need to know orbital period prior!



DATA POINTS

PERIOD OF MARS ORBIT = 687 DAYS

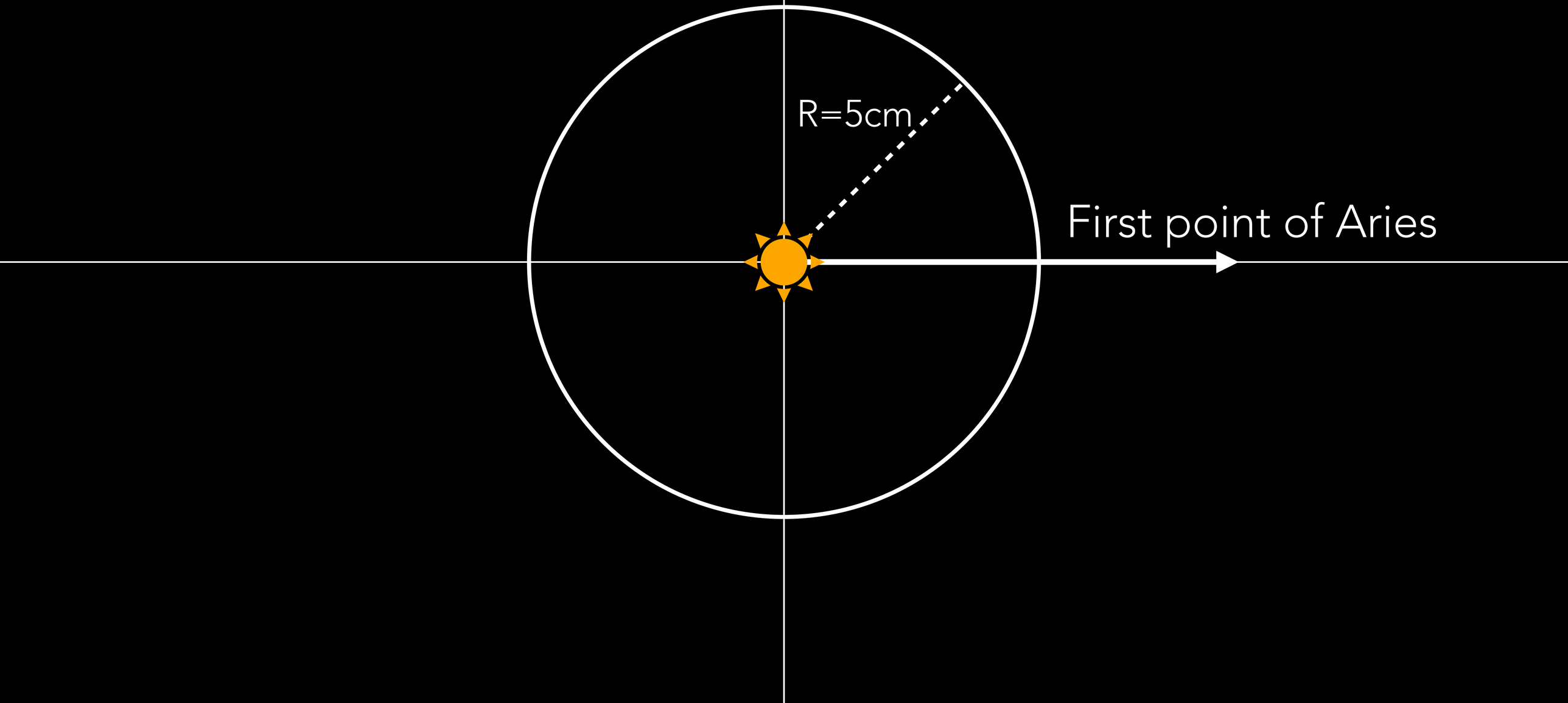
Table 1: Orbital positions of Earth and Mars.

Position	Date	HL_E	GL_M
		[degrees]	[degrees]
A	2001-Oct-10	17	290
A	2005-Jul-15	293	21
B	2009-Aug-11	318	79
B	2011-Jun-29	277	64
C	2004-Apr-13	203	73
C	2006-Mar-01	160	63
D	2010-Mar-28	187	125
D	2013-Dec-31	99	191
E	2006-Oct-16	22	203
E	2010-Jul-21	298	175
F	2005-Mar-22	181	303
F	2008-Dec-25	93	268

Heliocentric longitude of Earth (HL_E), and corresponding geocentric longitude of Mars (GL_M) given in degrees for a series of dates in the range 2001 to 2013. Both longitudes are measured counterclockwise from the direction of the First Point of Aries. These positions are given in pairs, as indicated in the first column. Each pair is used to triangulate for the corresponding position of Mars.

NOTE: THE 2 DATES IN EACH PAIR ARE EITHER 687 DAYS APART OR 1,374 DAYS APART.

POSITION A:
[HL EARTH: 17 DEG, GL MARS: 290 DEG]
[HL EARTH: 293 DEG, GL MARS: 21 DEG]



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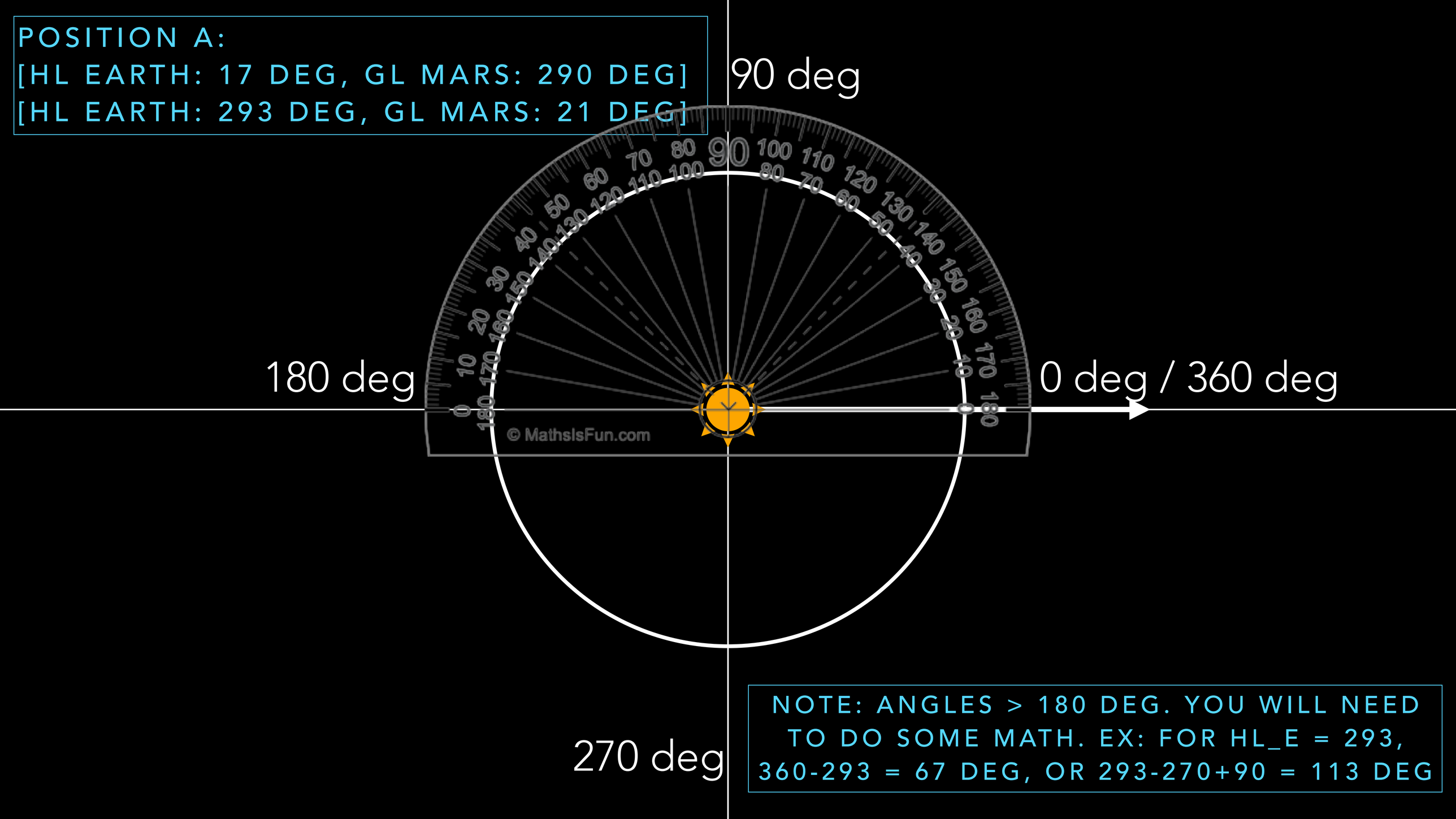

NOTE: ANGLES > 180 DEG. YOU WILL NEED TO DO SOME MATH. EX: FOR HL_E = 293, 360-293 = 67 DEG, OR 293-270+90 = 113 DEG

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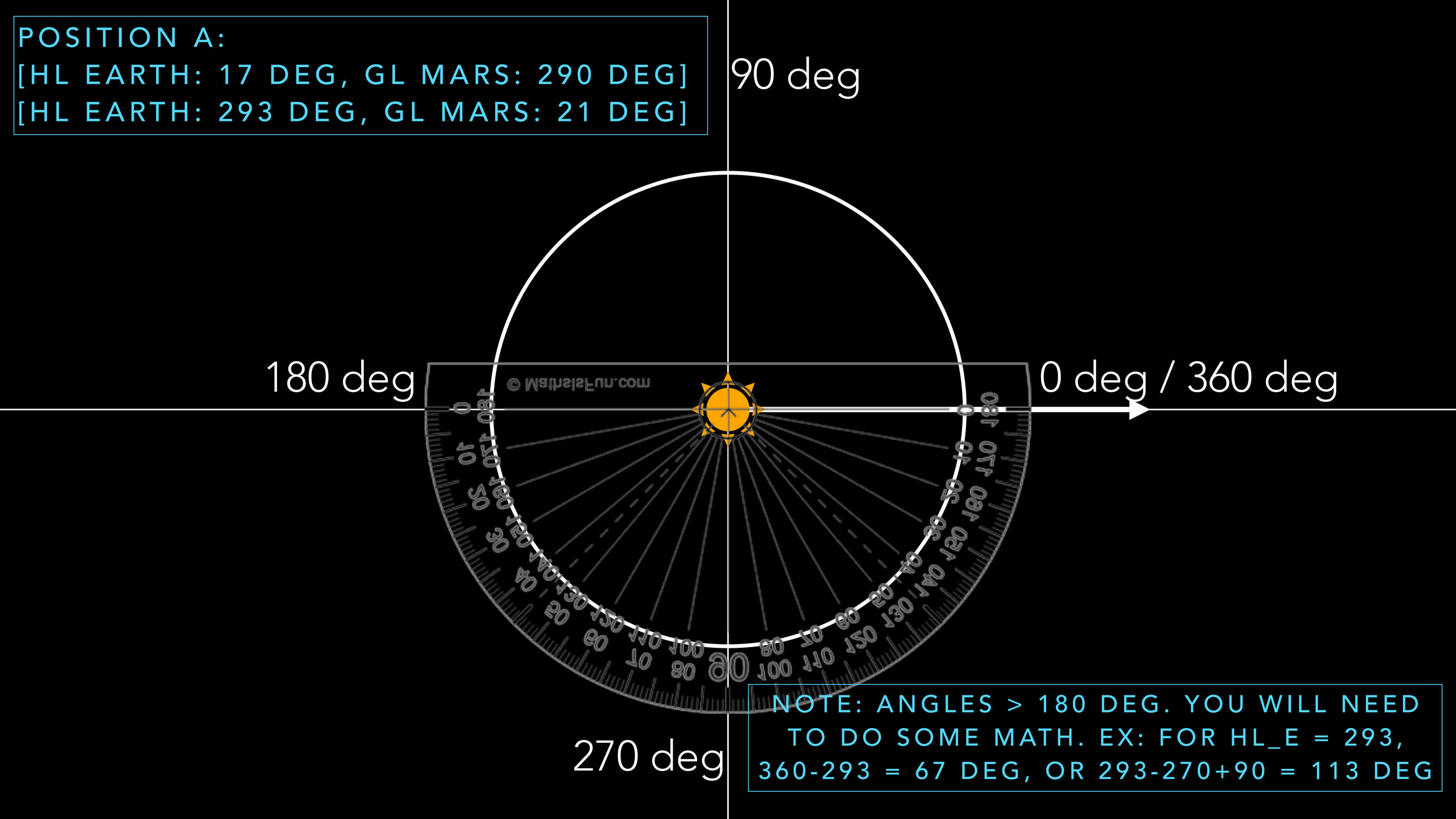

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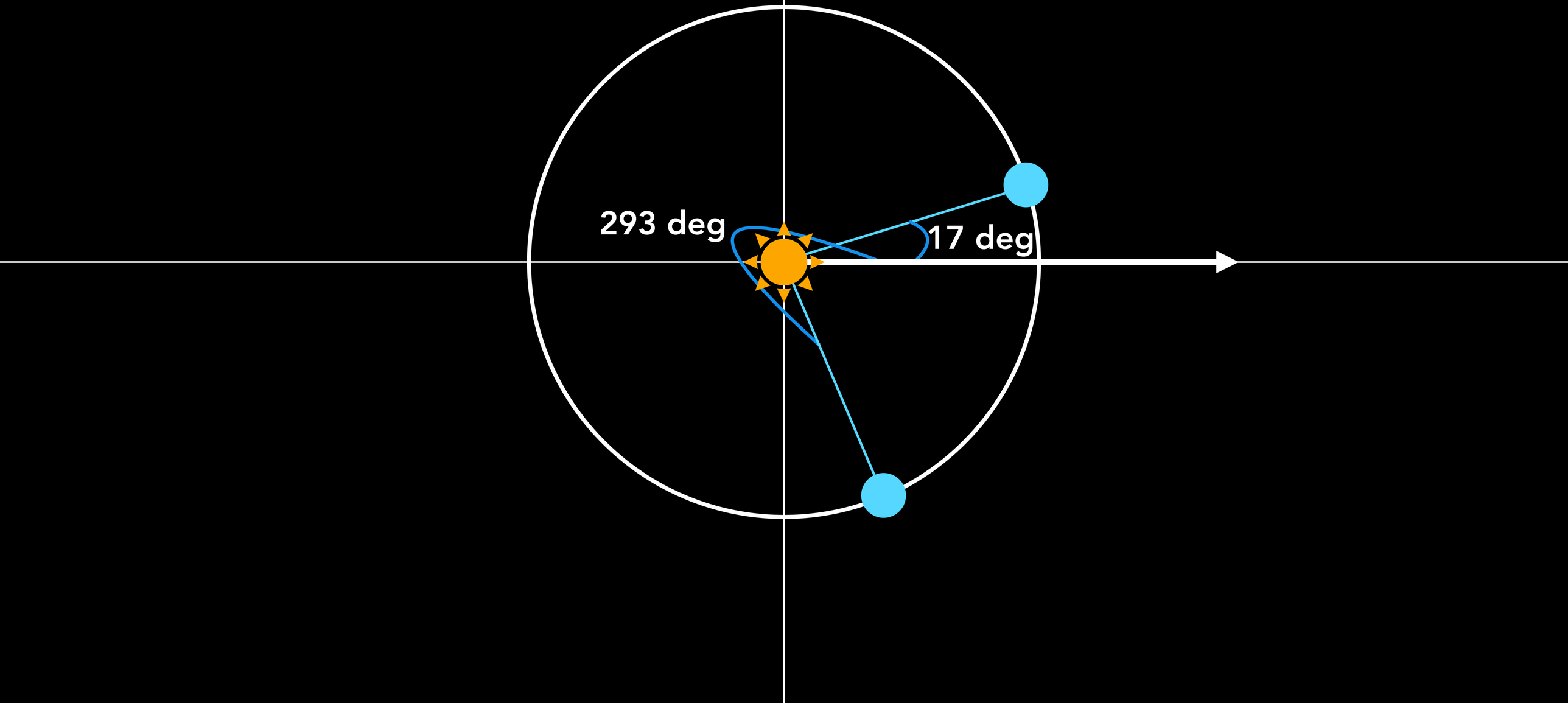

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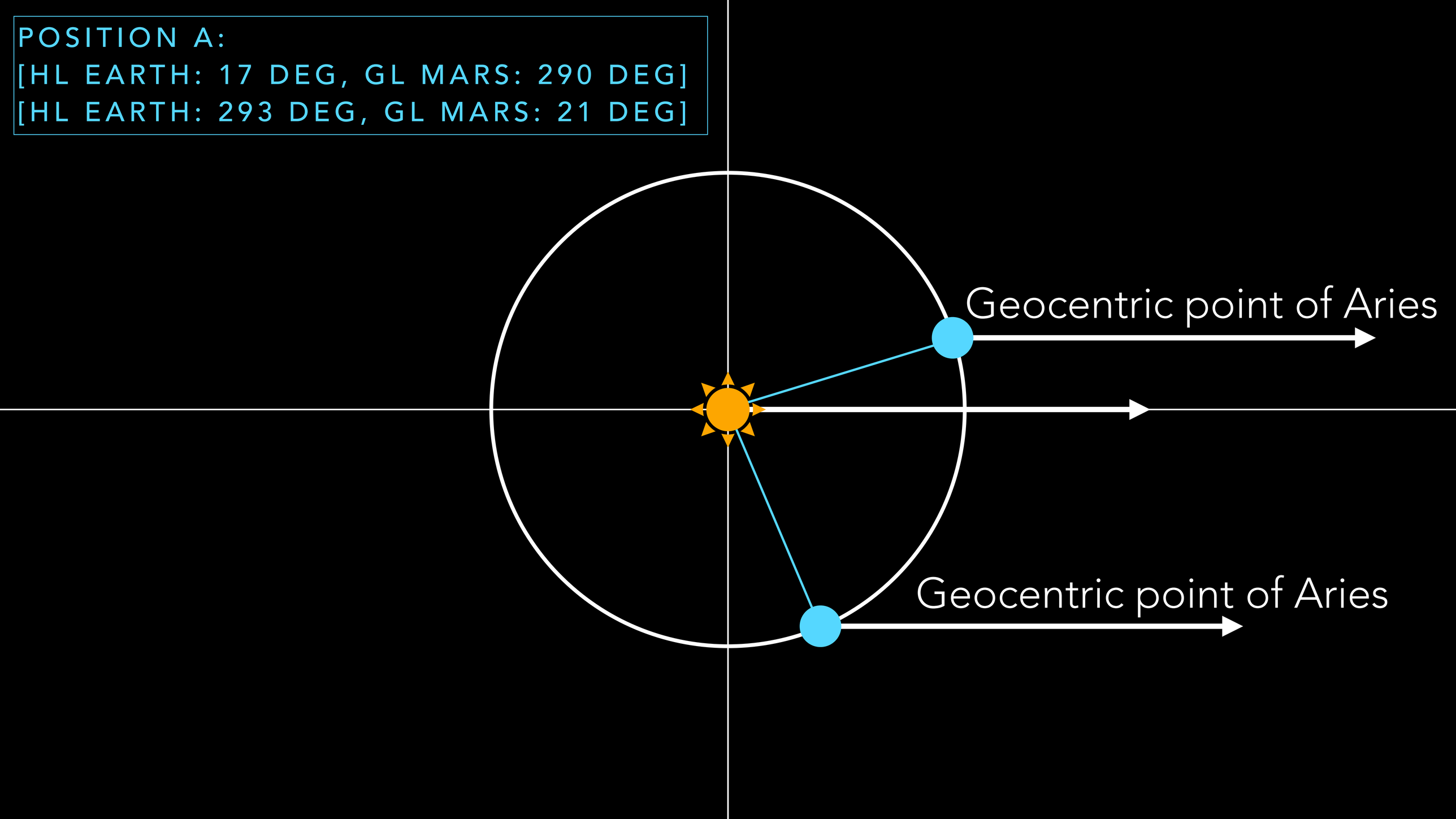

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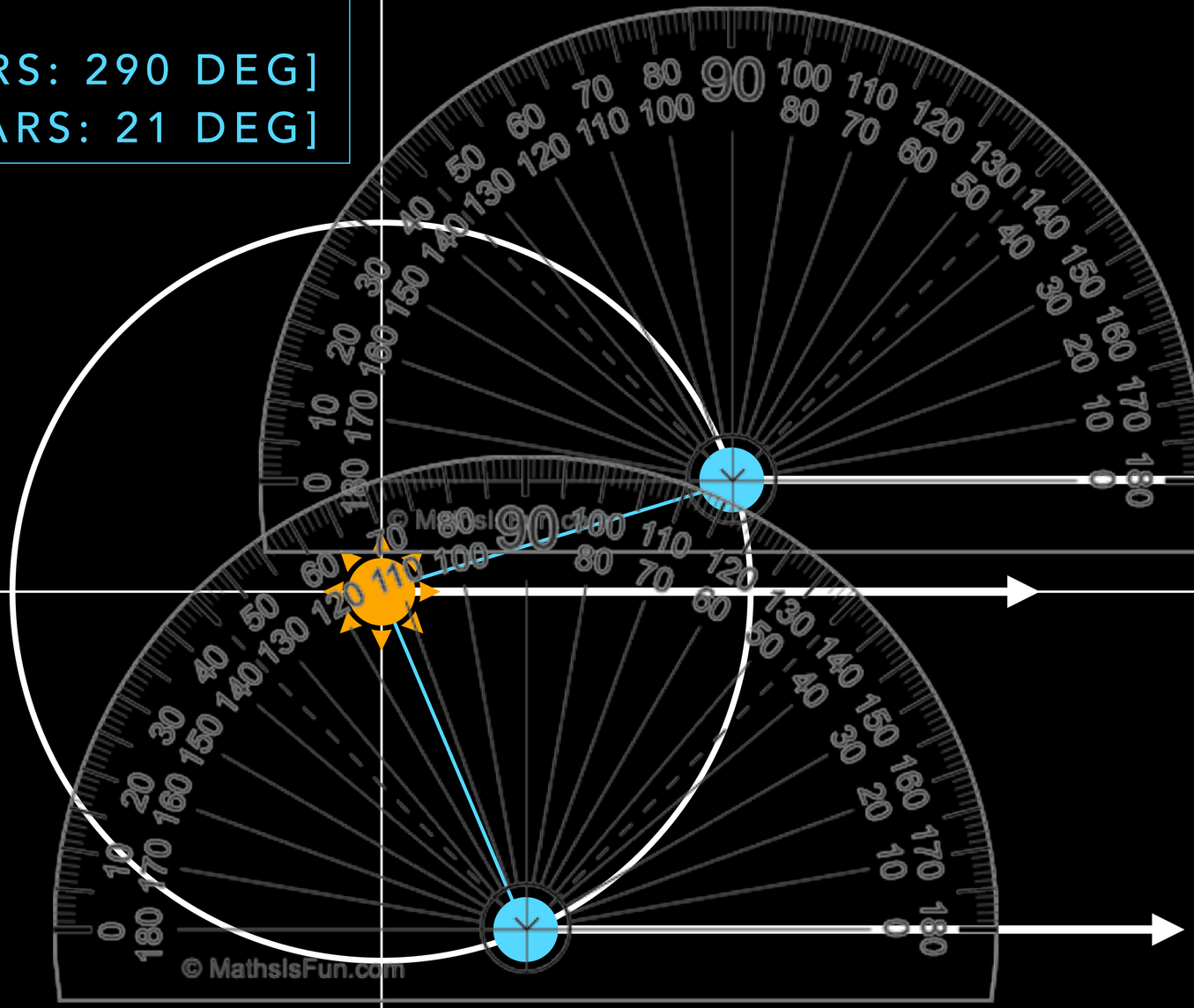

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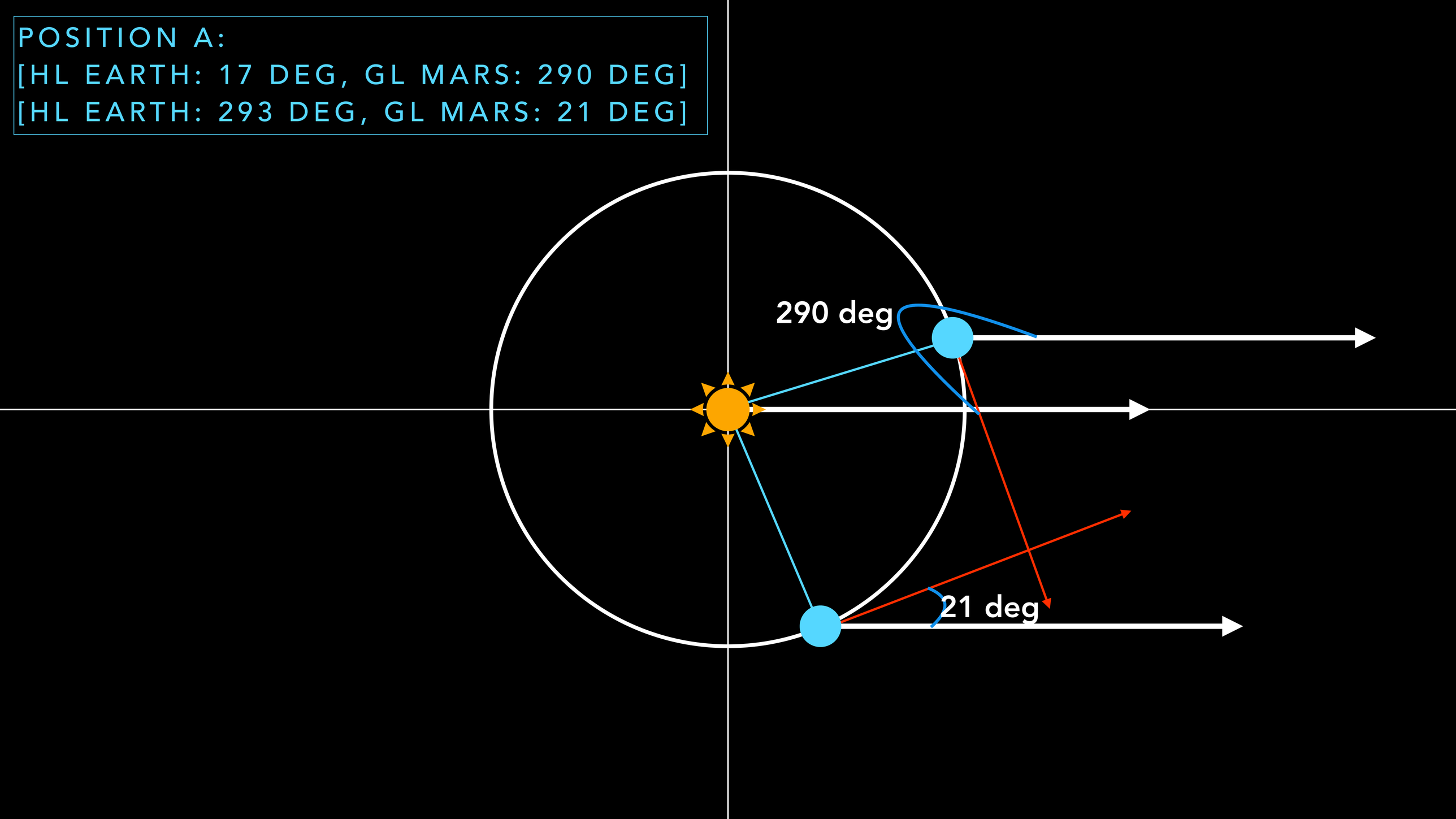

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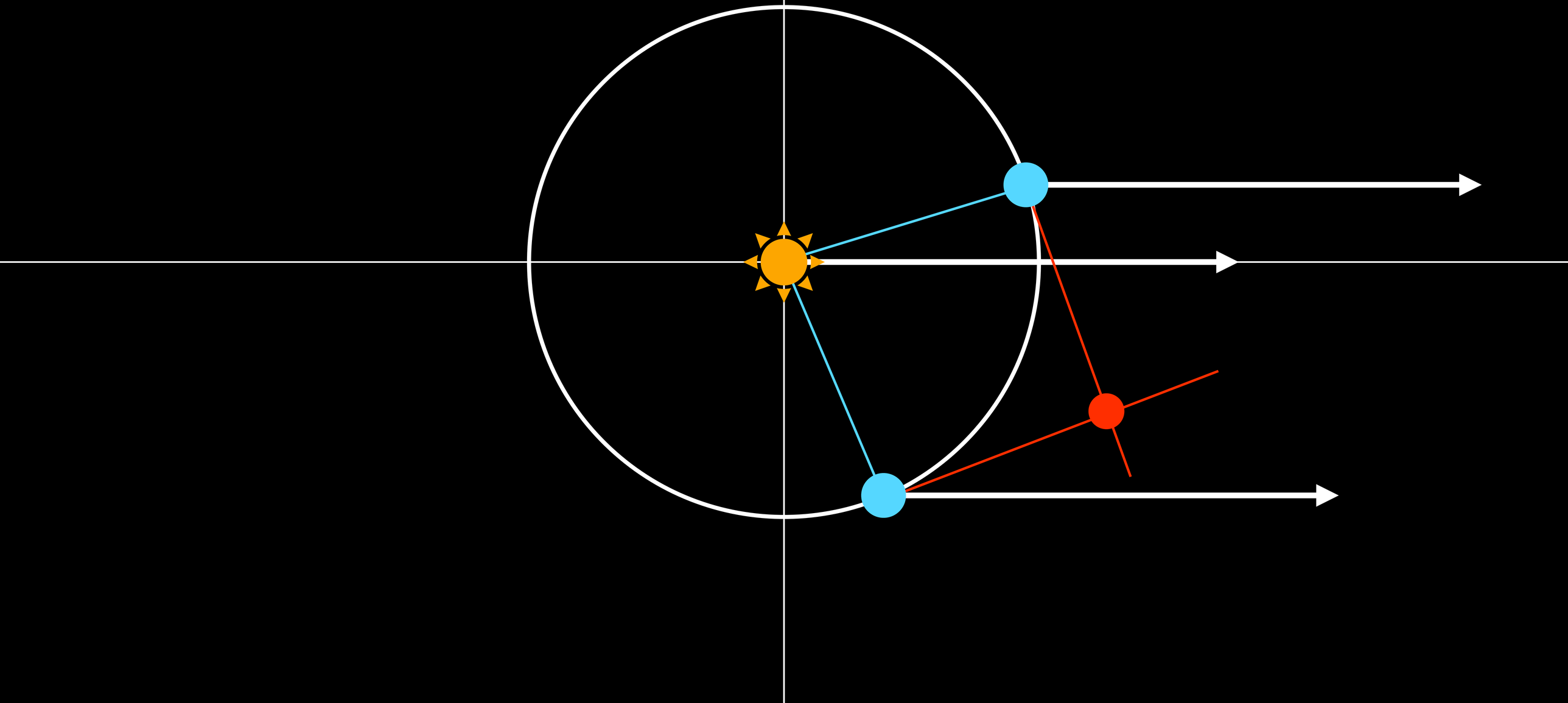

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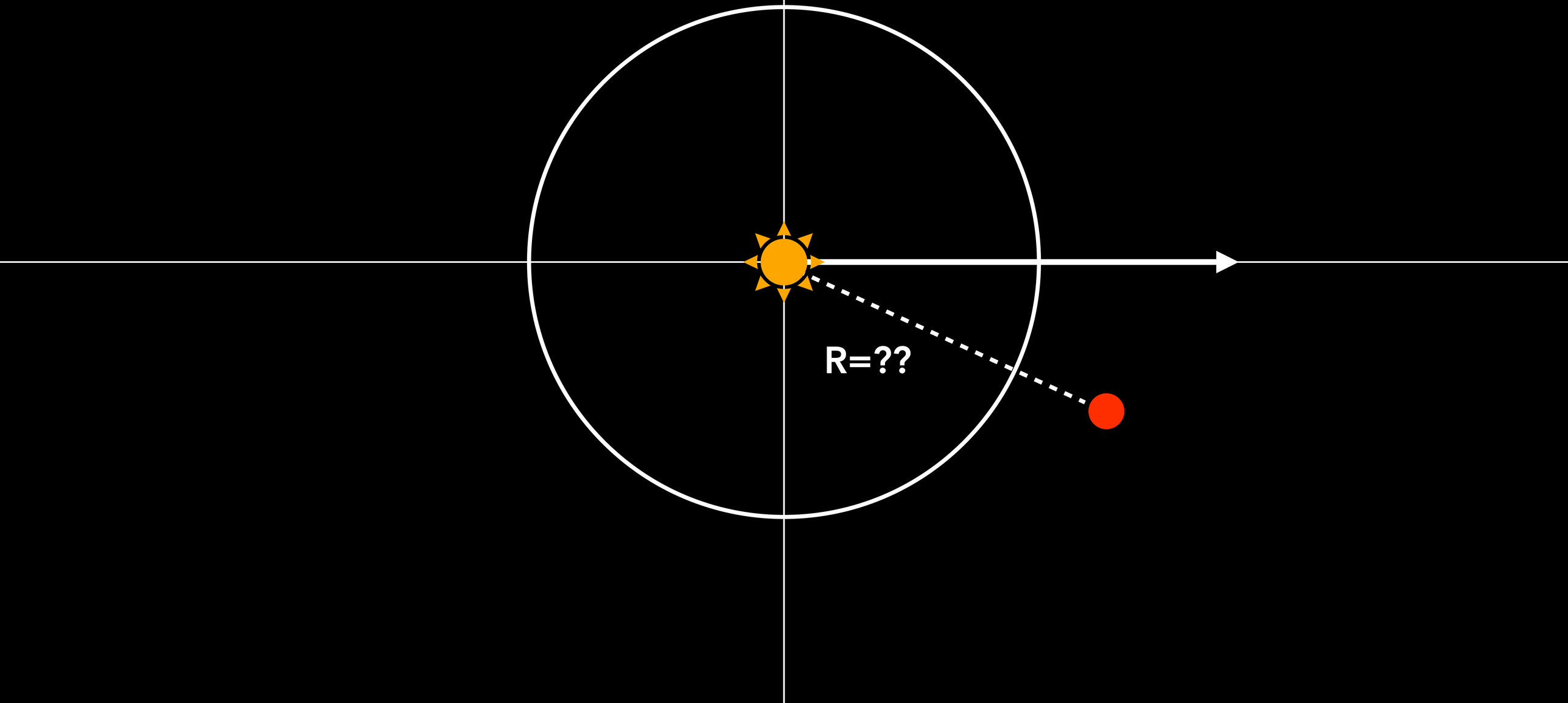
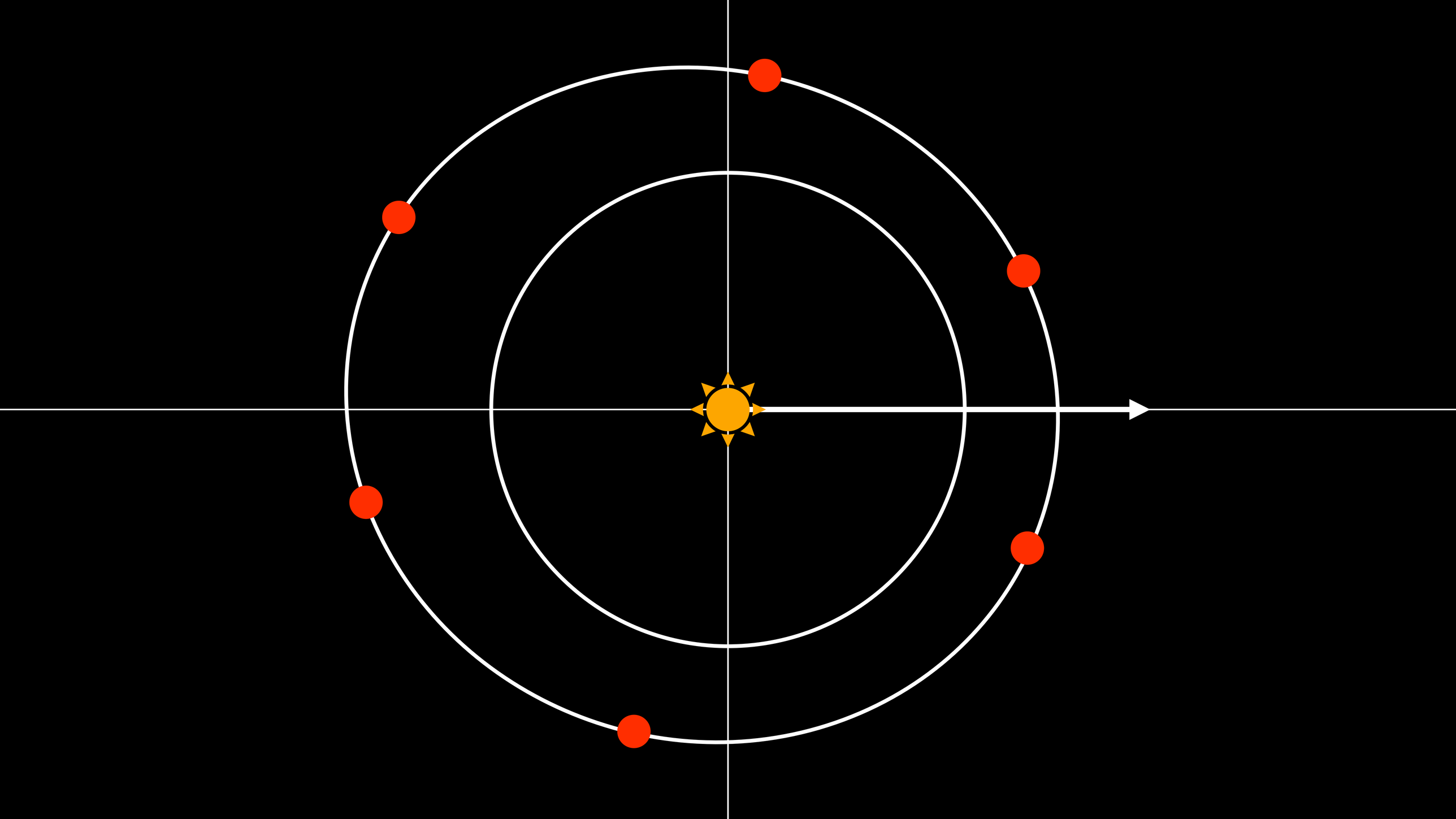
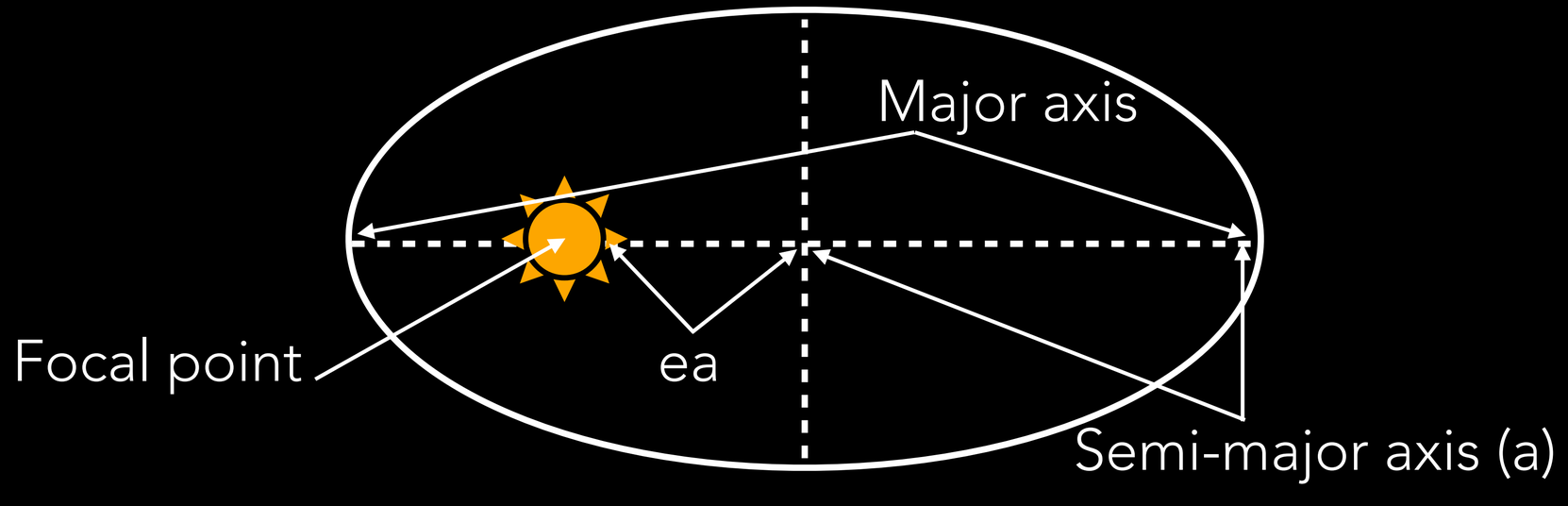


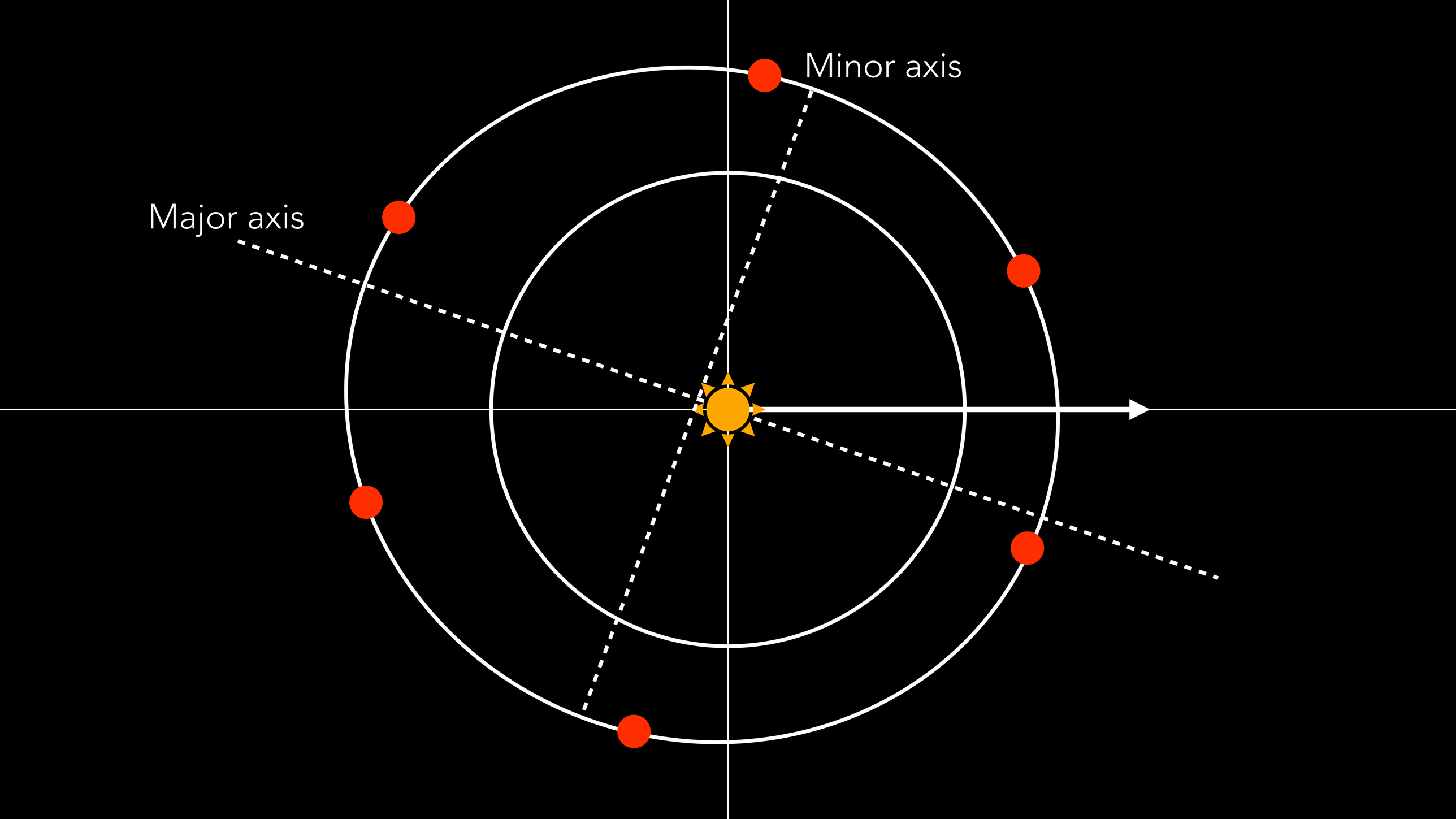


QUESTIONS

- Q 2: Measure all distances between Sun and Mars, take the average. Convert from cm to AU (Astronomical Units), R_Earth = 1 AU.

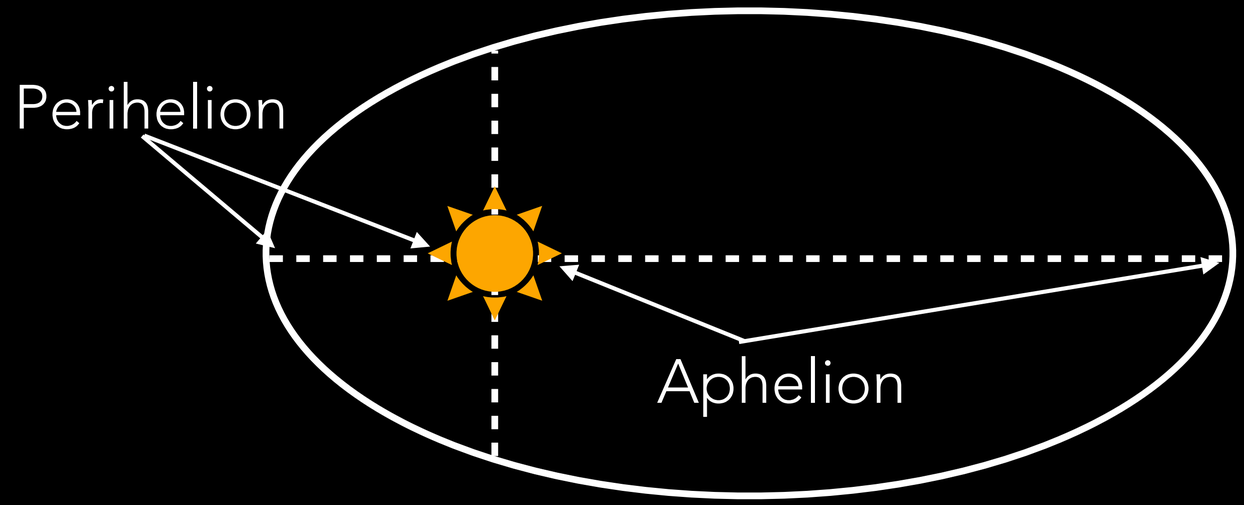
- Q 3: Eccentricity defines how elliptical or circular an orbit is. Low eccentricity = more circular, high eccentricity = more elliptical. Semi-major axis = 1/2 distance of major axis (the larger axis). **Note: e=ea/a**

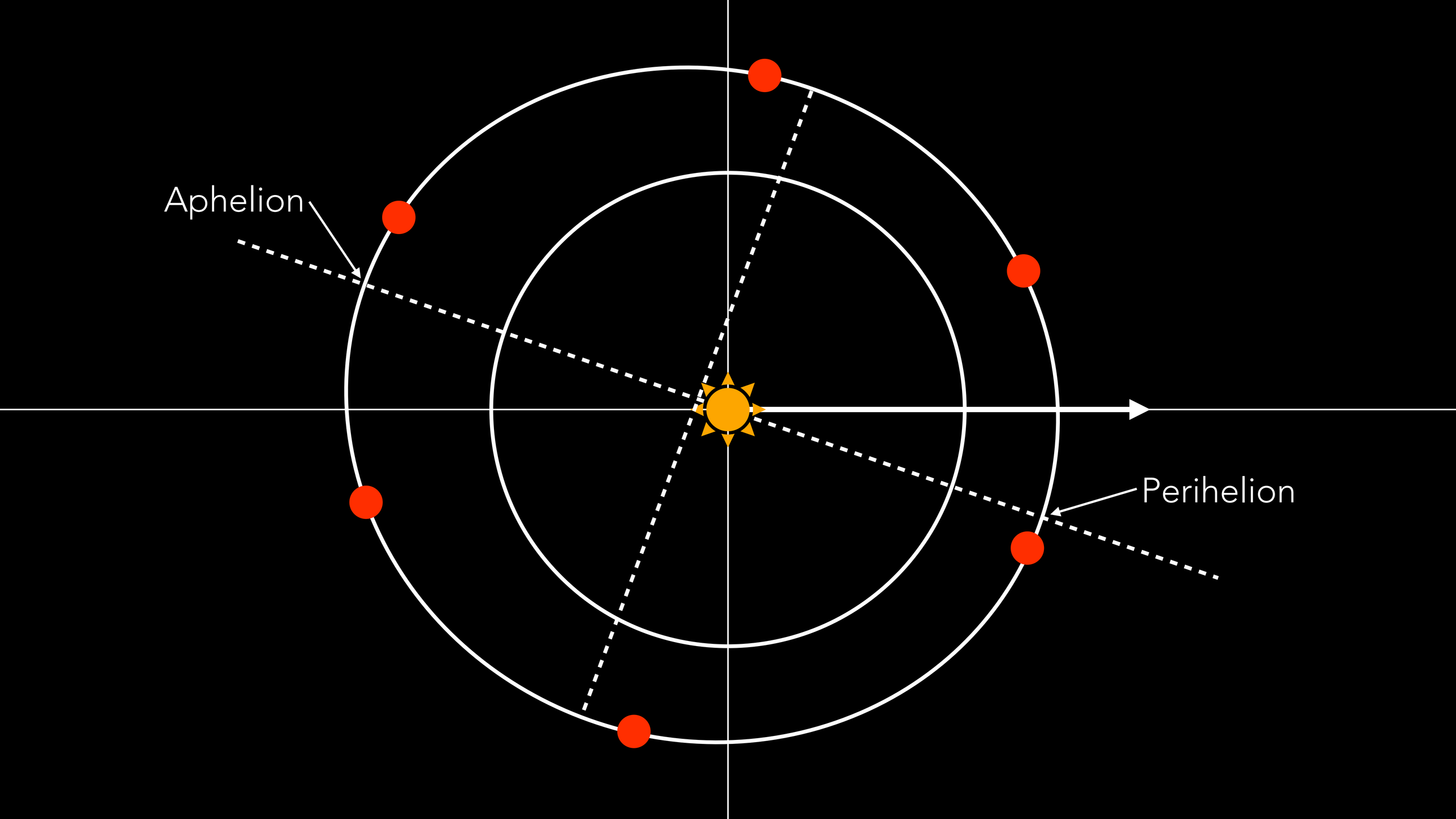



Minor axis
Major axis

QUESTIONS

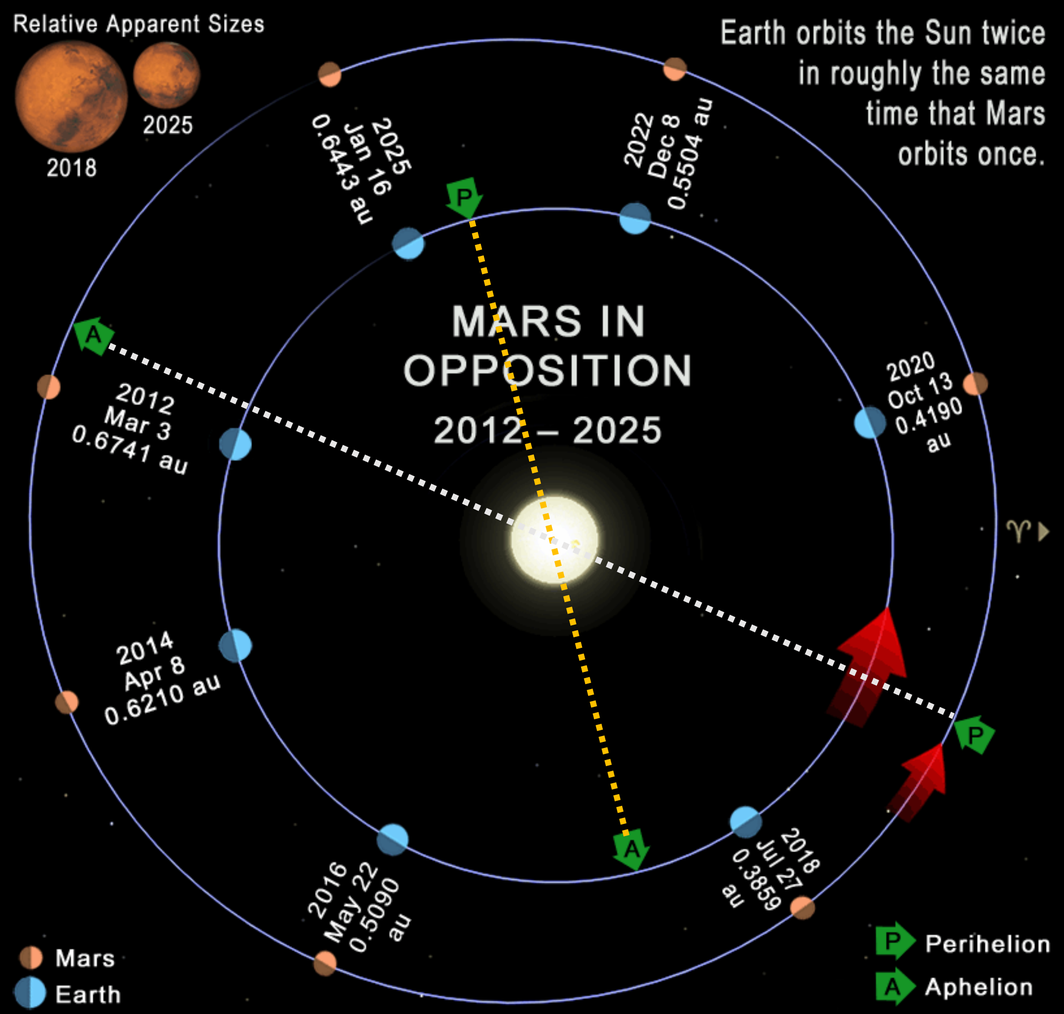
- Q 4: Perihelion distance = closest distance between Mars and Sun.
  Aphelion distance = farthest distance between Mars and Sun.

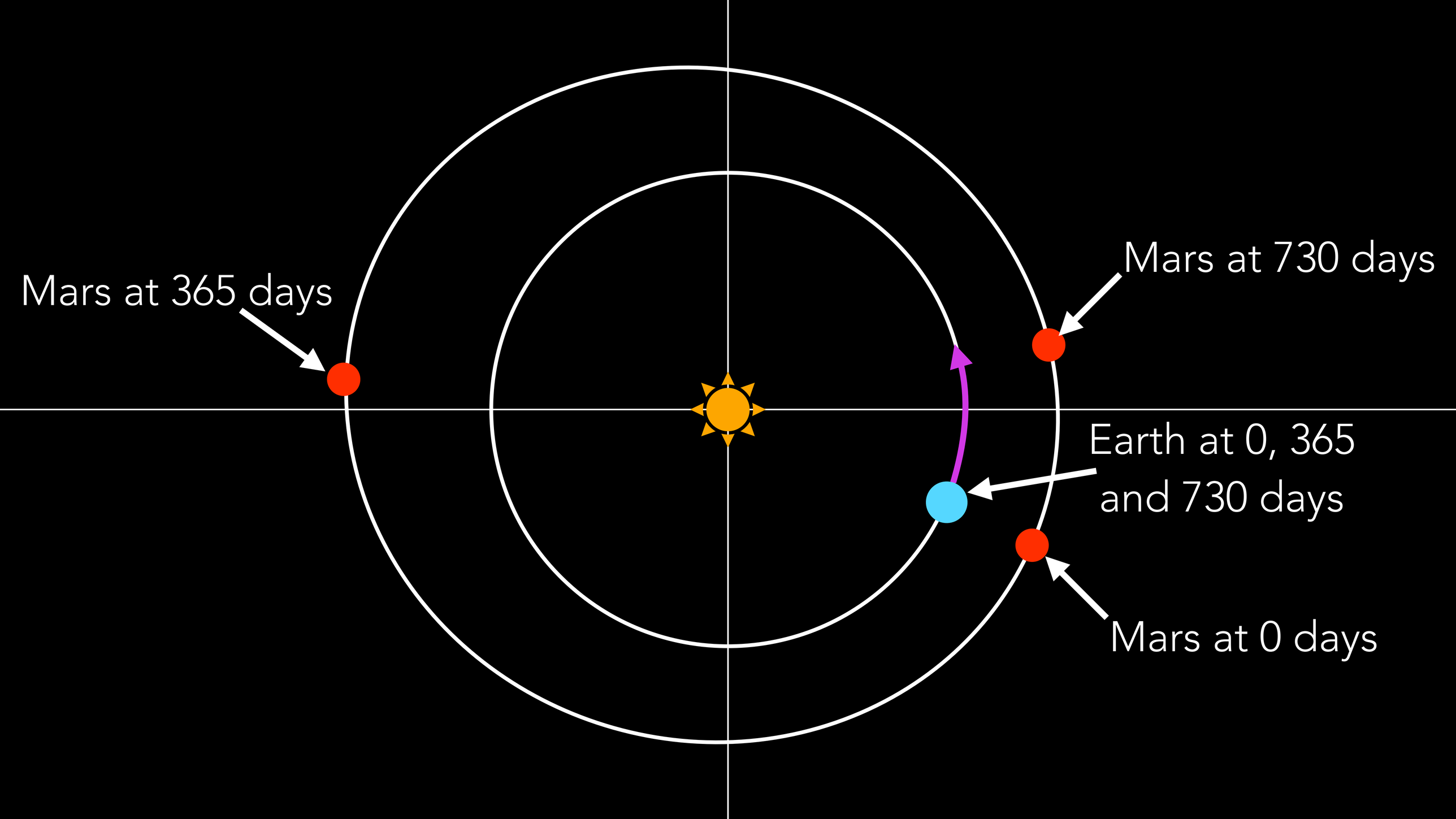



Aphelion
Perihelion

QUESTIONS

- Q 5: Based on their orbits, how often does Earth pass Mars?
- **Hint: P_Earth / P_Mars = ?**




Mars at 365 days
Mars at 730 days
Earth at 0, 365
and 730 days
Mars at 0 days

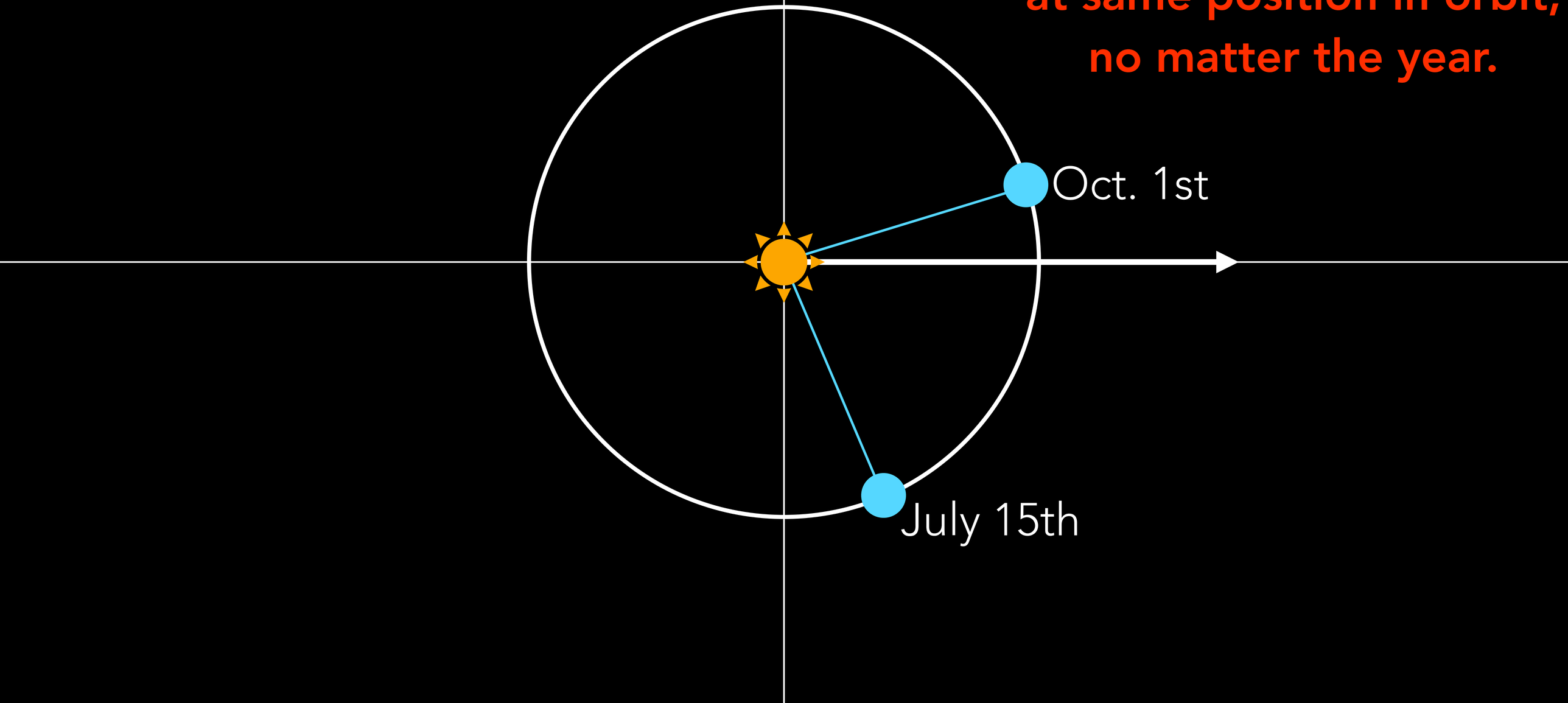
QUESTIONS

- Q 6 & 7: In which month would Mars and Earth be ***closest***? Which month would they be ***farthest***?

- **Hint: Closest/farthest encounters are located when Mars is at perihelion/aphelion. Look at the dates associated with the HL of Earth with respect to Mar's orbit.**

POSITION A:
[HL EARTH: 17 DEG, GL MARS: 290 DEG]
[HL EARTH: 293 DEG, GL MARS: 21 DEG]

Hint:
Earth is in same month at same position in orbit, no matter the year.



QUESTIONS

- Q 8: Calculate ratio between period and semi-major axis using Kepler's 3rd law for both Earth and Mars.
- Remember Kepler's 3rd law: $P^2 = a^3$. Where P = period (in days), and a = semi-major axis (in AU).
- **If calculations for a_Mars is correct, the ratios for Mars and Earth should be the same.**