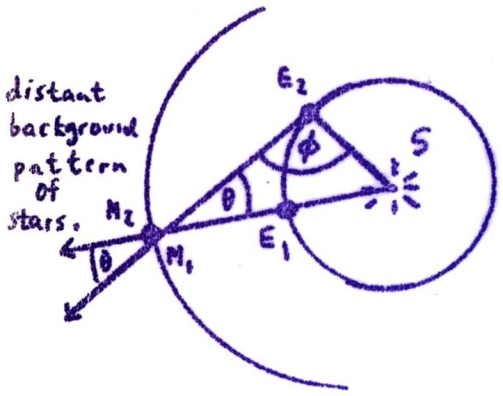
(1)



The angles θ and ϕ, as defined, are measured to be 40·6° and 97·4°, respectively. Determine the distance of Mars from the Sun in Earth units.

(Kepler's method for determining the ratio of the Mars-Sun distance to the Earth-Sun distance. S is the position of the Sun. E_1 and M_1 indicate the positions of the Earth and Mars, respectively, at the first sighting; E_2 and M_2 indicate their positions at the second sighting. Since the second sighting is exactly one "Martian year" after the first, M_1 and M_2 are coincident)

Note that Kepler's method <u>does not assume circular orbits</u>.

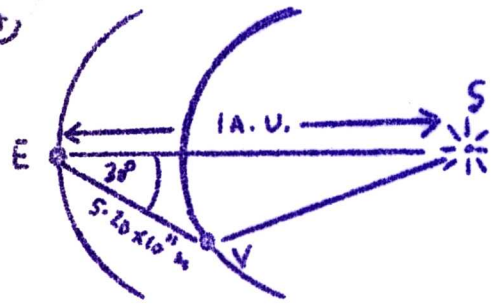
(2) (a) Suppose that the circular orbit approximation <u>can</u> be applied to Mars, and suppose that 2 years 51 days (2·14 years) elapse between two successive oppositions. Estimate the length of one Martian year.

(b) The <u>eighth</u> opposition after the initial opposition occurs after a time interval of 17 years 29 days (17·08 years). Calculate a more accurate value for the Martian year. Is this value still accurate when the ellipticity of the orbit of Mars is recognised?

(3) (a) By sketching a diagram similar to the above, explain how Kepler's method could be used to find the Venus-Sun distance in astronomical units. One "Cytherean year" (please, not "Venusian year") lasts 225 days.

(b) Suppose that the second sighting (taken after the elapse of one Cytherean year) gives a value of 17·4° for the angular difference between the line of sight to the Sun and the line of sight to Venus. By using the sine rule show that the Venus-Sun distance, at this time, is approximately $1{\cdot}1 \times 10^{11}$ m. (Assume that one Astronomical Unit = $1{\cdot}50 \times 10^{11}$ m)

(4)



A radar-ranging experiment gives the distance between the Earth and Venus at a particular time during their motions as $5{\cdot}20 \times 10^{11}$ m. Assuming that the relative Venus-Sun and Earth-Sun distances at this time are 0·72 : 1·00, calculate the value of the Astronomical Unit in metres. (Hint; first determine the angle at V, noting that it is an <u>obtuse</u> angle, and hence deduce the angle at S)

(5) * Explain, qualitatively, why the <u>synodic</u> periods of all the planets from Jupiter to Pluto are almost one year, whereas the synodic periods of Venus and Mars are close to two years. In particular, why is the synodic period of Jupiter almost exactly one year + one month?

Distinguish between the synodic period of a planet and its <u>sidereal</u> period.