HOMEWORK PROBLEMS 2
ASTR 350

Celestial Mechanics and Binary Stars
Due date: Friday, 9/26/25 — 6pm

Submission protocol: By the deadline, please submit a scanned PDF copy (always as a single file) of your homework by email to the TA, Moira Venegas at *Moira.Venegas@rice.edu*, CCing Prof. Baring. Retain your original.

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1. The transit of Venus across the face of the sun occurs four times every 243 years, and approximately twice during every epoch half that long (121.5 years), in pairs of transits separated by around 8 years. The last one was June 5th, 2012. The rarity of the transits is primarily due to inclination (of angle α_V) of Venus' orbit around the sun relative to the ecliptic.

(a) Draw a diagram to illustrate the geometry that describes the Venus and Earth orbit configuration required to generate a transit of Venus.

(b) Assuming that both Venus' and Earth's orbits around the sun are circular, use your geometrical picture as a guide to derive an equation for the approximate average time between Venus transit pairs in terms of the orbital inclination angle α_V. Estimate the maximum possible value of this inclination using the observed 121.5 year quasi-period.

(c) Approximately how long does a transit last for an observer on Earth? *Hint:* assume that the transit takes Venus approximately in a straight line passing through the line of sight from the Earth to the center of the sun (a rare case for such transits that maximizes the duration).

(d) For two observers at the opposite extremities of the Earth, the start of the Venus transit (at the solar limb) occurs at different times separated by an interval δt. Using some convenient assumptions, to be stated, simplify the considerations to derive an equation for δt in terms of Venus' and Earth's orbital periods, the Earth's radius $R_\oplus$, and the distance (1 AU) to the sun.

Invert your result to express the *astronomical unit* in terms of these orbital periods and $R_\oplus$. What value of δt yields the known value for 1 AU?

At this stage, you should realize that Venus transits served as a tool for astronomers for measuring the distance to the sun. A prominent case in point includes Captain James Cook's voyage to Tahiti in 1769.

[46 points credit]

2. Carroll and Ostlie problems 2.9 and 2.10.

[28 points credit]

3. Carroll and Ostlie problem 7.3, and a bit.

Assume that two stars are in circular orbits about a mutual center of mass, and are separated by a distance a. Assume that the angle of inclination of the orbits to our line of sight is i, and that their stellar radii are r_1 and r_2.

(a) Sketch the geometry and find an expression for the smallest angle of inclination that will just barely produce an eclipse.

(b) If $a = 2\,\text{AU}$, $r_1 = 10R_\odot$ and $r_2 = R_\odot$, what will be this minimum value of i for an eclipse to arise?

(c) For general values of $r_2 < r_1$ and a, obtain an expression for the maximum fraction of the orbital period that a system can undergo a *total* eclipse. Does this fraction depend on the mass of either companion?

[26 points credit]