Solve the problems listed below, and write up your answers clearly and completely. Do not turn in rough work – instead, make a clean copy after checking your calculations. Use English sentences and phrases to explain your solution and describe key equations. Show your work!

1. We observe planetary transits across a star with the same mass $M_*$ and radius $R_*$ as the Sun. The period between transits is $P = 10$ day, and during the transit the star appears to have 99% of its normal brightness. Assume the transiting planet has a circular orbit.

(a) What is the radius of the planet?
(b) What is the maximum amount of time a transit can last? Under what circumstances would we observe this maximum duration?
(c) Suppose the transit is observed to last 2 hour (measured from the instant when the brightness falls to 99.5% to the instant when it returns to that level). What is the planet’s orbital inclination $i$?

2. A single planet on a circular orbit produces a sinusoidal radial velocity curve. However, we also observe radial velocity curves which are not sinusoidal; a hypothetical example is shown in Fig. 1.

(a) What is the orbital period of this planet?
(b) Why is this curve not sinusoidal?
(c) What can you say about the shape and orientation of the planet’s orbit?

![Figure 1: Radial velocity as a function of time for a hypothetical star with a single orbiting planet.](image-url)
3. A meteor entering a planet’s atmosphere is slowed by aerodynamic drag; if it slows down enough, it may survive impact and later be found on the surface. A simple condition for a meteor to slow down may be derived by comparing its mass \( m \) to the mass \( m_a \) of atmosphere it displaces before reaching the surface; drag is significant only if \( m_a > m \).

(a) Consider a spherical meteor of radius \( r \) and density \( \rho \) which falls vertically. Let the planet have surface gravity \( g \) and surface atmospheric pressure \( P \). Assuming the meteor displaces a cylindrical column of atmosphere of radius \( r \) as it falls, find an expression for the ratio \( m_a/m \) in terms of \( g \), \( P \), \( r \), and \( \rho \).

(b) Is atmospheric drag more significant for big meteors or for small ones? Explain your answer.

(c) Assuming the meteor has the density of iron (\( \rho \simeq 8000 \text{ kg m}^{-3} \)), and that it falls vertically through the Earth’s atmosphere (\( P \simeq 1.0 \times 10^5 \text{ kg m}^{-1} \text{s}^{-2} \)), evaluate the critical radius \( r \) for a meteor which yields \( m_a = m \).

(d) Repeat (c) for the atmospheres of (i) Venus (\( P \simeq 95 \times 10^5 \text{ kg m}^{-1} \text{s}^{-2} \)), and (ii) Mars (\( P \simeq 0.0064 \times 10^5 \text{ kg m}^{-1} \text{s}^{-2} \)). Don’t forget to use the appropriate values of \( g \) for these planets.