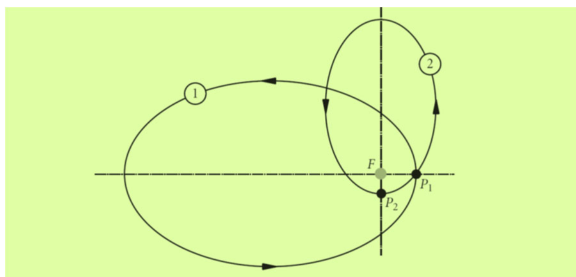
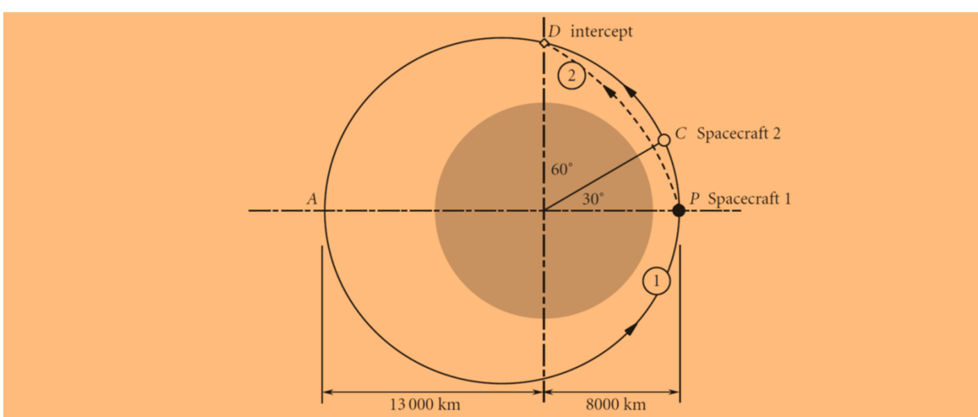
1) The space shuttle weighs approximately 12.5 tons whose thrusters can simultaneously produce a total thrust of 53400 Newtons for orbital maneuvers. Assuming that the shuttle is initially in a 300 Km (altitude) circular Earth orbit, it is desired to use a single impulse to transfer the shuttle to a 250x300 Km elliptical orbit.
   - 1-1 Determine the required ΔV .
   - 1-2 Use elementary physics and determine the **burn time** of the engine thrusters for the maneuver.
   - 1-3 Calculate the approximate **distance travelled** during the burn time.
   - 1-4 Determine the ratio of your answer to 1-2 to the period of the initial and final orbit.
   - 1-5 Determine the ratio of your answer to 1-3 to the circumference of the initial and final orbit.

2) A satellite in orbit 1 undergoes an ΔV impulsive maneuver at its perigee P_1 such that the new orbit has the same eccentricity e, but its apse line is rotated 90^0 clockwise from the original one. Compute the angular momentum of orbit 2 (h_2) in terms of that of orbit 1 (h_1) and the eccentricity.



3) Two spacecrafts are in the same 8000x13000 Km (radius) elliptical Earth orbit. Spacecraft 1 one is at the perigee while spacecraft 2 is 30º ahead. Calculate the total ΔV required for spacecraft 1 to intercept and rendezvous with spacecraft 2 when spacecraft 2 has traveled 60º .
   Hint: This is a chasing maneuver and requires Lamberts formulas as well.



4) The vector connecting the apogee to perigee of an Earth orbiting satellite is given. The radial velocity component of the satellite at point C on the orbit is also provided. Given these information:

   1-1 Find the satellite orbit equation in polar coordinates (2D).

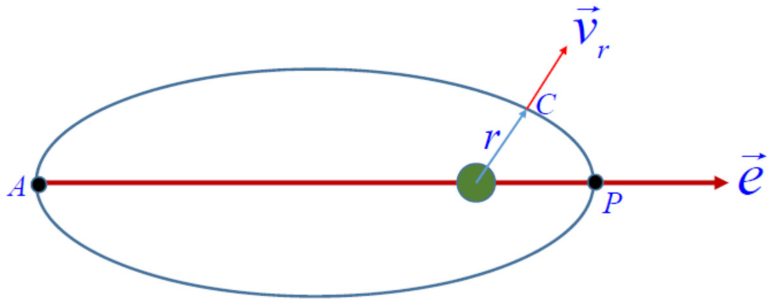
   1-2 The satellite current position, velocity and flight path angle.

   Hint1: $\vec{r}_{PA}$ is the direction of eccentricity vector.

   Hint2: $\vec{v}_{r_C}$ also lies in the orbital plane.

$$[\vec{r}_{PA}]^{ECI} = [\ 9798 \quad 5657 \quad 11314]^T \ km$$

$$[\vec{v}_{r_C}]^{ECI} = [-0.1 \quad 0.2 \quad 0.3]^T \ km/s$$

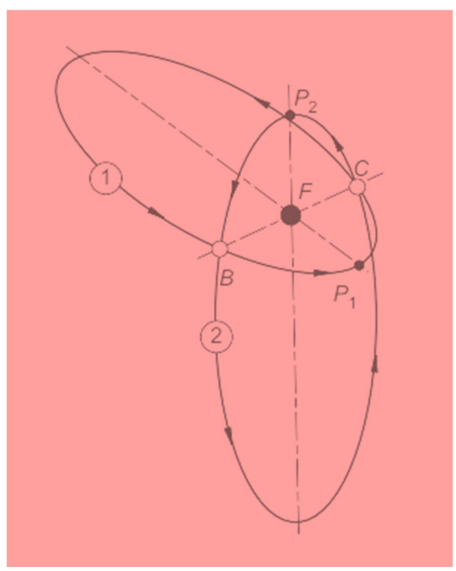


5) **Orbit 1** has an angular momentum h and an eccentricity of e. The direction of motion is shown. Find a relation for the required impulse ΔV (as a function known parameters: h, e, μ) to rotate the **Orbit 1,** 90 ° about its latus rectum BC without changing h and e to transfer to **Orbit 2**. That means the orbit shape will remain the same.

   Hint1: The impulse is made at point B.

   Hint2: True anomalies at B are not the same on both orbits.

   Hint3: $\Delta v = \sqrt{(v_{r2} - v_{r1})^2 + v_{\perp 1}{}^2 + v_{\perp 2}{}^2 - 2 v_{\perp 1} v_{\perp 2} \cos\delta}$



Bonus Problems: (Optional)

B1: Consider the problem of transferring between two coplanar orbits 1 to 2 whose polar equations are given: $r_1 = \dfrac{7200}{1+0.5\cos\theta_1}$, $r_2 = \dfrac{8064}{1+0.4\cos\theta_2}$ using a single impulse.

a- Find the range of possible values of θ_1 for which the transfer to r_2 is possible.

b- Find a functional relation for $\Delta V = f(\theta_1)$ that can be utilized to find the optimum θ_1 that yields the minimum the required impulsive velocity for transfer to orbit 2 .

c- Determine the optimum value of θ_1 and its corresponding ΔV_{min} .