Homework 10

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of the Requirements of

AE 313
Space Mechanics
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AE 313 Homework 10

1. Draw the Jupiter-centered vector diagram of the fly-by.

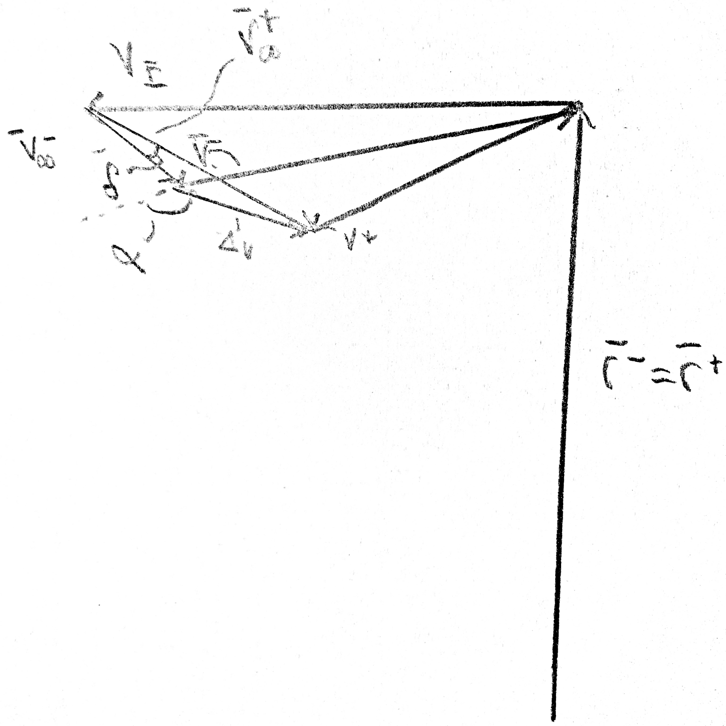

Figure 1: Fly-by diagram

2. Find θ^{*-}

```
ta_clipper1m = atan2d( r_clipper1*v_clipper1m^2/MU('Jupiter') * cosd(
    FPA_clipper1m)*sind(FPA_clipper1m),...
     r_clipper1*v_clipper1m^2/MU('Jupiter') * cosd(FPA_clipper1m) - 1);
```

$\theta^{*-} = 10°$

3. Determine the following: $r_{p/europa}, \alpha$

```
periapsis_europa = a_europa*(1-e_europa);
...
alpha = -alpha;
```

$$\begin{aligned} r_{p/europa} &= 6.6490 \cdot 10^5 \; km \\ r_{p/europa \to clipper} &= 1.3594 \cdot 10^3 \; km \\ \alpha &= -116.1968^\circ \end{aligned}$$

4. Does the spacecraft gain or lose energy? Why?
Geometrically, the spacecraft must lose energy. Observing ‘delta‘ it can be determined that the spacecraft must have lost energy since ‘delta‘ directs the dv vector opposing the initial velocity

5. Does the spacecraft pass "ahead" or "behind"? Prove it with drawings. (Hint: Draw behind pass vs. ahead pass. How does v_{inf} change?)

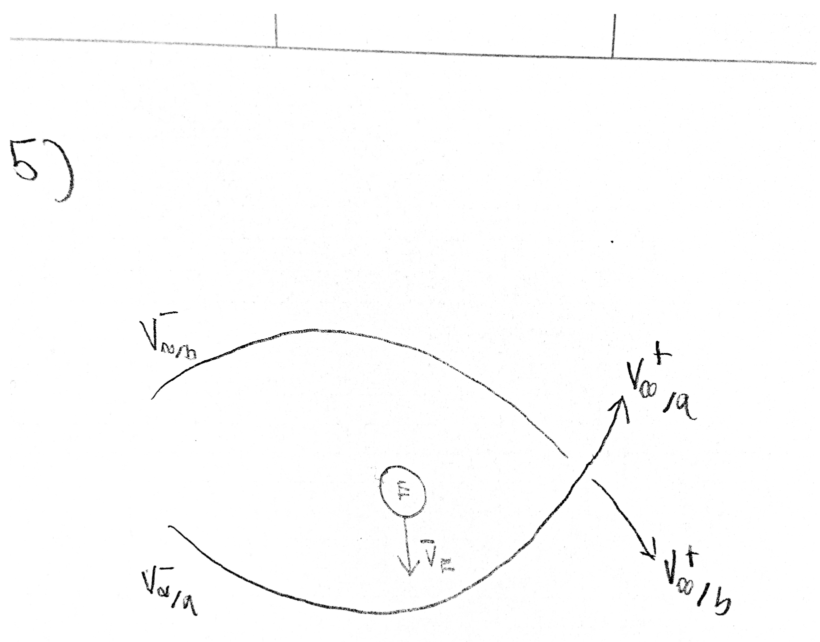

Figure 2: Infinite Diagram

6. Determine the characteristics of the new Jupiter orbit:

```
r_clipper2 = r_clipper1;
...
dAOP = ta_clipper2 - ta_clipper1m;
```

$$\begin{aligned} r^+ &= 6.6490 \cdot 10^5 \; km & v^+ &= 16.8374 \; km/s \\ \gamma^+ &= -7.8811^\circ & \theta^{*+} &= -23.1067^\circ \\ a^+ &= 1.2976 \cdot 10^6 \; km & e^+ & \quad 0.5021 \\ \Delta\omega &= -10.7848^\circ \end{aligned}$$

7. In GMAT, plot the new and old Clipper orbits and the orbit of Europa. Draw the orbit properties.

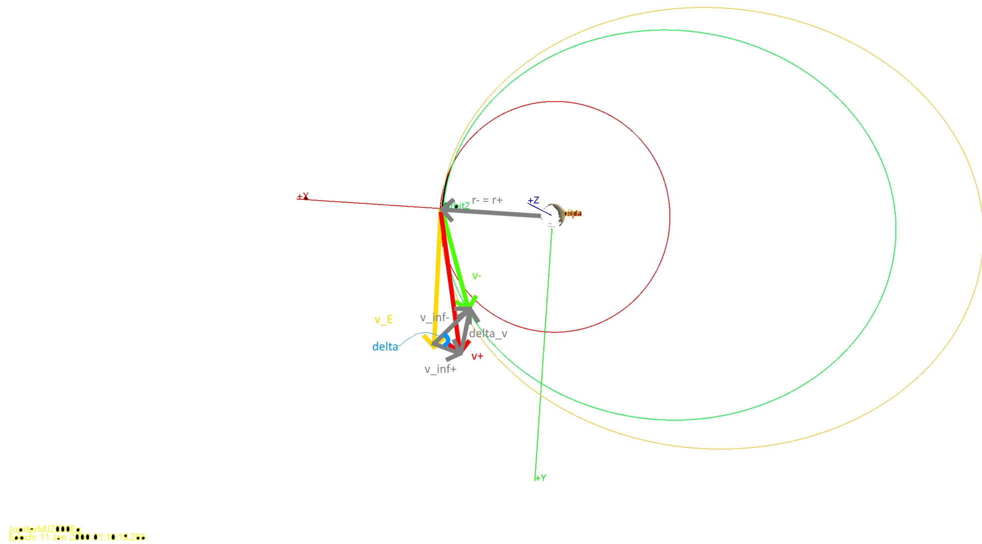

Figure 3: GMAT with orbital properties

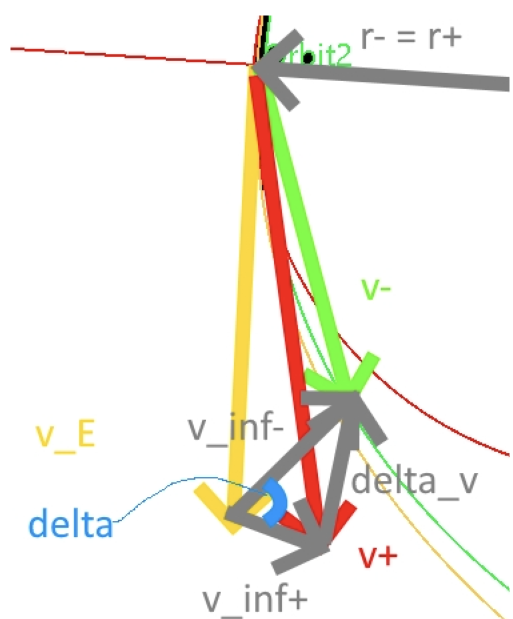

Figure 4: Detailed View

8. Clipper's mission could involve over 45 fly-bys of Europa. If the goal is to return to Europa, would you have the spacecraft perform the fly by?
I would not have the spacecraft perform this fly-by. The radius of clipper at periapsis around Europa is 1359km while the radius of Europa is 1561km. This is an impact trajectory. Another path would need to be chosen to avoid clipper impact with Europa.

HW9.m

```
clc; clear;
% Constants
planets = {'Sun', 'Moon', 'Mercury', 'Venus', 'Earth', 'Mars', 'Jupiter', 'Saturn', 'Uranus', 'Neptine', 'Pluto'};
rad_list = [695990.0, 1739.2, 2439.7, 6051.9, 6378.0, 3397.0, 71492.0, 60268.0, 25559.0, 25269.0, 1162.0];
mu_list = [132712440000.0, 4902.8, 22032.0, 324860.0, 398600.0, 42828.0, 126713000.0, 37941000.0, 5794500.0, 6836500.0, 981.6];
sma_list = [0.0, 384400.0, 57910000.0, 108210000.0, 149600000.0, 227920000.0, 778570000.0, 1433530000.0, 2872460000.0, 4495060000.0, 5906380000.0];
R = containers.Map(planets,rad_list);
MU = containers.Map(planets,mu_list);
r = containers.Map(planets,sma_list);
%%%%%%%

MU_europa = 3202.7;
a_europa = 671200;
R_europa = 1561.0;
e_europa = 0.00938;

a_clipper = 21.6*R('Jupiter');
e_clipper = 0.5731;

% Europa conditions
r_europa = 664904.144;
v_europa = sqrt(2*MU('Jupiter')/r_europa - MU('Jupiter')/a_europa);
FPA_europa = 0; %periapsis


% 2. Find ta_clipper1m
periapsis_europa = a_europa*(1-e_europa);
r_clipper1 = periapsis_europa;

v_clipper1m = 17.294;
FPA_clipper1m = -4.5205; %deg | from worksheet 4-3-19

ta_clipper1m = atan2d( r_clipper1*v_clipper1m^2/MU('Jupiter') * cosd(FPA_clipper1m)*sind(FPA_clipper1m),...
    r_clipper1*v_clipper1m^2/MU('Jupiter') * cosd(FPA_clipper1m) - 1);

% 3. determine periapsis_clipper_europa, alpha1
delta = 17.4; % deg | from worksheet 4-3-19
```

```matlab

% inf vel rel to europa
v_inf = sqrt(v_europa^2 + v_clipper1m^2 - 2*v_europa*v_clipper1m*cosd(FPA_clipper1m));
a_clipper_europa1m = -MU_europa/v_inf^2;
e_clipper_europa1m = 1/sind(delta/2);
periapsis_clipper_europa1m = a_clipper_europa1m * (1-e_clipper_europa1m);

dv = 1.1; % km/s | from problem statement
nu = acosd( dv/(2*v_inf) ); % positive by inspection
offset_angle = acosd( (v_europa^2 - v_inf^2 - v_clipper1m^2)/(-2*v_inf*v_clipper1m) ); % positive by inspection
alpha = 180 - nu + offset_angle;
if alpha > 0
    alpha = -alpha; %we are told alpha is negative
end

% 4. Does the spacecraft lose energy?
% Geometrically, the spacecraft must lose energy. Observing `delta` it can
% be determined that the spacecraft must have lost energy since `delta`
% directs the dv vector opposing the initial velocity

% 5. Ahead or behind
% Observing the same diagram from problem one we can see that the v_inf
% after the gravity assist is directed more towards jupiter. This implies
% that it is an ahead pass. It is not necessary to draw a diagram in the
% europa centered view because all information is included in the jupiter
% centered view.

% 6. find r_clipper2 v_clipper2 FPA_clipper2 ta_clipper2 a_clipper2
% e_clipper2 dAOP
r_clipper2 = r_clipper1;
new_nu = 180 - alpha;
v_clipper2 = sqrt( dv^2 + v_clipper1m^2 - 2*dv*v_clipper1m*cosd(new_nu) );
FPA_clipper2 = acosd( (v_inf^2 - v_europa^2 - v_clipper2^2)/(-2*v_europa*v_clipper2) );
% dFPA = FPA_clipper2 - FPA_clipper1m not correct

FPA_clipper2 = abs(FPA_clipper2)*sign(alpha);

ta_clipper2 = atan2d(r_clipper2*v_clipper2^2/MU('Jupiter')*cosd(FPA_clipper2)*sind(FPA_clipper2),...
    r_clipper2*v_clipper2^2/MU('Jupiter')*cosd(FPA_clipper2)-1);
if sign(FPA_clipper2) > 0
```

```
    ta_clipper2 = ta_clipper2 + 180;
end

energy = v_clipper2^2/2 - MU('Jupiter')/r_clipper2;
a_clipper2 = -MU('Jupiter')/(2*energy);

e_clipper2 = sqrt( (r_clipper2*v_clipper2^2/MU('Jupiter') - 1)^2*cosd(
    FPA_clipper2)^2 + sind(FPA_clipper2)^2 );

dAOP = ta_clipper2 - ta_clipper1m;
```