HOMEWORK 4 SOLUTION

PROBLEM 1

HALLEY'S COMET LAST PASSED THROUGH PERIHELION ON 2/9/86

$e = 0.9671429 \quad a = 17.834144$ AU

DATA FIND ORBITAL PROPERTIES ON THIS DATE

$r = \frac{a(1-e^2)}{1+e\cos\nu}$ $\quad \nu = 0$ SINCE WE'RE AT PERIHELION

$\boxed{r = 0.5859783 \text{ AU}}$ $\quad r = r_p$ @ PERIHELION

$\mathcal{E} = \frac{v^2}{2} - \frac{\mu}{r} = -\frac{\mu}{2a} \Rightarrow \boxed{v = 54.571966 \frac{km}{sec}}$

$1 AU = 1.495978707 \times 10^8 km$ $\quad \mu = \mu_\odot$ SINCE $M_\odot >> M_{COMET}$

$= 1.32712 \times 10^{11} \frac{km^3}{sec^2}$

SINCE WE'RE AT PERIAPSIS $\boxed{\nu = 0}$

FLIGHT PATH ANGLE IS ANGLE BTWN $\bar{V}$ AND $\hat{\theta}$

@ PERIAPSIS $\boxed{\gamma = 0 \text{ ALWAYS}}$

ENERGY $\boxed{\mathcal{E} = -\frac{\mu}{2a} = -24.87153 \frac{km^2}{sec^2}}$

ANG MOMENTUM $h = \sqrt{\mu a(1-e^2)} = \boxed{4.783838 \times 10^9 \frac{km^2}{sec}}$ UNITS

PERIOD $P = 2\pi\sqrt{\frac{a^3}{\mu}} = \boxed{2.3796793 \times 10^9 \text{ sec} \approx 75.316 \text{ yrs}}$

ASSUMING $1 \text{ DAY} = 24 \text{ hr} = 86400 \text{ sec}$

$1 \text{ yr} = 365.25 \text{ days}.$

$r_p = a(1-e) = \boxed{0.5859783 \text{ AU}}$

$r_a = a(1+e) = \boxed{35.08231 \text{ AU}}$

ALREADY KNOW $\boxed{E = r = 0 \text{ @ PERIAPSIS}}$

AT PERIAPSIS $\boxed{(\epsilon - T) = 0}$

PART B

OBSERVERS CAN VIEW THE COMET AT $\boxed{\nu = 260^\circ}$

REGARDLESS OF POSITION IN ORBIT, THE FOLLOWING DO NOT CHANGE

$\mathcal{E}, h, \Pi, r_p, r_a \rightarrow$ CALCULATE THE REST @ $\nu = 260^\circ$

CONIC EQUATION

$$r = \frac{a(1-e^2)}{1 + e\cos\nu} \Rightarrow \boxed{r = 1.3053653 \text{ AU}} \qquad r > r_p$$

VELOCITY

$$V = \sqrt{2\left(\frac{\mu}{r} - \frac{\mu}{2a}\right)} \Rightarrow \boxed{V = 35.08513 \text{ km/sec}}$$

ECCENTRIC ANOMALY

$r = a(1 - e\cos E) \Rightarrow E = 175.51202^\circ, 342.4880$

E, ν IN SAME HALF PLANE

$\boxed{E = 342.4880^\circ}$

FLIGHT PATH ANGLE

$h = rV\cos\gamma \Rightarrow \gamma = \pm 48.85963^\circ \leftarrow$ QUADRANT CHECK

$\boxed{\gamma = -48.85963^\circ}$

PART C

USE KEPLER'S EQN TO FIND TOF.

$\nu_1 = 0 \rightarrow E_1 \rightarrow M_1$

$\nu_2 = 260^\circ \rightarrow E_2 \rightarrow M_2$

$\Delta t = \frac{1}{n}(M_2 - M_1)$

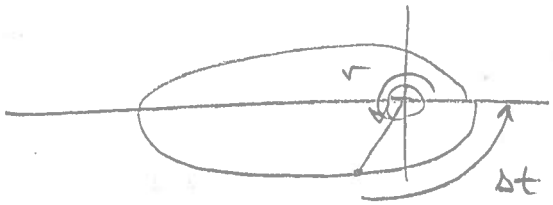
$\Delta t = 75.14$ yrs

NEXT WINDOW 3/21/2061 $\approx$ 2473912.54 JD

AGE 2061 − YR OF BIRTH

PART D

THE NEXT PERIHELION PASSAGE AFTER $\nu = 260^\circ$



$\nu = 260$

$\Delta t = P - (t_{260^\circ} - T) = P - \frac{1}{n}(E_{260} - e \sin E_{260})$

$\Delta t = 64.0246$ DAYS TIME TO PERIHELION

FROM $\nu = 260^\circ$

Properties at Perihelion

Satellite State
Position and Velocity in LVLH frame

r_hat:	87661098.4885525 km	rd_hat:	0 km/sec
t_hat:	0 km	td_hat:	54.5719657203315 km/sec
h_hat:	0 km	hd_hat:	0 km/sec

Position and Velocity in EPH/PQW frame

e_hat:	87661098.4885525 km	ed_hat:	-0 km/sec
p_hat:	0 km	pd_hat:	54.5719657203315 km/sec
h_hat:	0 km	hd_hat:	0 km/sec

Position and Velocity in IJK frame

i_hat:	49555952.980993 km	id_hat:	-42.7288952576909 km/sec
j_hat:	-67895779.5124715 km	jd_hat:	-33.4030287751889 km/sec
k_hat:	24876471.5496224 km	kd_hat:	-6.0480262302854 km/sec

RAD_MAG :	87661098.4885525 km =		0.5859782528224 AU
VEL_MAG :	54.5719657203315 km/sec		

Orbital Elements

sma:	2667949955.67328 km	raan:	58.4200809765684 deg
ecc:	0.9671429	arg_p:	111.332485104518 deg
inc:	162.262690579161 deg	nu:	0 deg

Elliptic Orbital Parameters

:	172441907.497957 km =		1.15270295959399 AU
ANG MOM :	4783838461.7239 km^2/sec		
PERIOD :	2376792617.19159 sec =		660220.171442109 hr
ENGERGY :	-24.871530989139 km^2/sec^2		
RAD_PER :	87661098.4885525 km =		0.585978252822399 AU
RAD_APO :	5248238812.85801 km =		35.0823097471776 AU

VEL_CIRC :	38.9091409861444 km/sec		
VEL_ESC :	55.0258348828922 km/sec		
TRUE_ANOM :	0 deg		
FPA :	0 deg		
ECC_ANOM :	0 deg		
MEAN_ANOM :	0 deg		
MEAN_MOT :	1.51464623962596e-07 deg/sec		

T_PAST_PER:	0 sec =		0 hr

Properties at Next OBS window

Satellite State
Position and Velocity in LVLH frame

r_hat:	207247610.488273 km	rd_hat:	-26.4226148823327 km/sec
t_hat:	0 km	td_hat:	23.0827195085783 km/sec
h_hat:	0 km	hd_hat:	0 km/sec

```
Position and Velocity in EPH/PQW frame
e_hat:        -35988169.8871145 km ed_hat:        27.3202800561662 km/sec
p_hat:        -204099053.602106 km pd_hat:        22.0129238127155 km/sec
h_hat:                        0 km hd_hat:                       0 km/sec

Position and Velocity in IJK frame
i_hat:         139461413.392241 km id_hat:       -1.79122682858017 km/sec
j_hat:          152801032.38902 km jd_hat:       -34.6341813537965 km/sec
k_hat:          12406882.307302 km kd_hat:        5.31333280838711 km/sec

RAD_MAG   :     207247610.488273 km =     1.38536471467323 AU
VEL_MAG   :     35.0851324228906 km/sec

Orbital Elements
sma:           2667949955.67328 km raan:          58.4200809765684 deg
ecc:                 0.9671429    arg_p:         111.332485104518 deg
inc:           162.262690579161 deg nu:                       260 deg

Elliptic Orbital Parameters
P         :     172441907.497957 km =     1.15270295959399 AU
ANG MOM   :      4783838461.7239 km^2/sec
PERIOD    :     2376792617.19159 sec =     660220.171442109 hr
ENGERGY   :     -24.871530989139 km^2/sec^2
RAD_PER   :     87661098.4885525 km =    0.585978252822399 AU
RAD_APO   :     5248238812.85801 km =     35.0823097471776 AU

VEL_CIRC  :       25.30523245408 km/sec
VEL_ESC   :     35.7870029355638 km/sec
TRUE_ANOM :                  260 deg
FPA       :    -48.8596318737455 deg
ECC_ANOM  :     342.487976680015 deg
MEAN_ANOM :      359.16213891027 deg
MEAN_MOT  : 1.51464623962596e-07 deg/sec

T_PAST_PER:     2371260889.26853 sec =      658683.58035237 hr

Time to go nu=260 to perihelion: [ 5531726.31671964] sec = [ 64.02461015] days
Next obs window: 2061.0/3/29.0
```

HOMEWORK SOLUTION

PROBLEM 2

HYPERBOLIC DEPARTURE FROM EARTH

$r_p = 1000 \text{ km} + R_\oplus \qquad e = 1.05$

PART A DETERMINE a, P, V_∞, AIM RADIUS, $\mathcal{E}, \delta, \nu_\infty$

$r_p = |a|(e-1)$

$\boxed{a = -147\,562.9 \text{ km}}$ $\quad a<0$ FOR HYPERBOLA

SEMI-LATUS RECTUM

$p = |a|(e^2-1) = \boxed{15125.19 \text{ km}}$

ENERGY $\mathcal{E} = -\frac{\mu}{2a} = \boxed{1.350611 \frac{\text{km}^2}{\text{sec}}}$ $\quad \mathcal{E}>0$ FOR HYPERBOLA

VELOCITY V_∞ → ENERGY IS ALWAYS CONSERVED

$\mathcal{E} = \frac{V_\infty^2}{2} \Rightarrow \boxed{V_\infty = 1.643540 \text{ km/sec}}$

FINAL TRUE ANOMALY

$\cos \nu_\infty = -\frac{1}{e} \Rightarrow \boxed{\nu_\infty = 162.2472^\circ}$

FLYBY ANGLE $\nu_\infty = 90^\circ + \frac{\delta}{2} \Rightarrow \boxed{\delta = 144.4944^\circ}$

AIMING RADIUS $b = |a|\sqrt{e^2-1} = \boxed{47243.15 \text{ km} = b}$

PART B

WHEN S/C REACHED $\nu = 90^\circ$ FIND

$r_1, V_1, H_1, \gamma_1, (t_1 - t_p)$

↖ HYPERBOLIC ANOMALY

CONIC EQUATION $r_1 = \dfrac{|a|(e^2-1)}{1+e\cos\nu_1}$ $\boxed{r_1 = 15125.19 \text{ km}}$

$r_1 = p$ @ $\nu = 90^\circ$ ← CHECK

VELOCITY $V_1 = \sqrt{2\left(\dfrac{\mu}{r_1} + \dfrac{\mu}{2|a|}\right)} = \boxed{7.443656 \dfrac{\text{km}}{\text{sec}}}$

FOR A HYPERBOLA

$r = |a|(e\cosh(H) - 1) \Rightarrow \boxed{H_1 = 0.3149248} = 18.0438^\circ$

FLIGHT PATH ANGLE

$r_1 V_1 \cos\gamma = h \Rightarrow \gamma = 46.39718^\circ, -46.39718^\circ$

$\boxed{\gamma_1 = +46.39718^\circ}$ ENSURE CORRECT QUADRANT

KEPLER'S EQ. FOR HYPERBOLIC ORBITS

$(t_1 - t_p) = \dfrac{1}{n}(e\sinh(H) - H)$

$= 1906.936 \text{ sec} = \boxed{0.5297045 \text{ hr}}$

CONVERT TO LVLH + PERIFOCAL FRAMES $\hat{r}, \hat{\theta}$, $\hat{p}$ $\hat{q}$

$$\bar{r}_1 = r_1 \hat{r} = r_1 \cos\nu_1 \hat{p} + r_1 \sin\nu_1 \hat{q}$$

$$= 15125.19 \hat{r} = 0\hat{p} + 15125.19 \hat{q} \text{ km} = \bar{r}_1$$

$$\bar{v}_1 = v_1 \left[\sin\gamma_1 \hat{r} + \cos\gamma_1 \hat{\theta}\right] = v_1 \sin\gamma_1 \left[\cos\nu_1 \hat{p} + \sin\nu_1 \hat{q}\right]$$
$$+ v_1 \cos\gamma_1 \left[-\sin\nu_1 \hat{p} + \cos\nu_1 \hat{q}\right]$$

$$\bar{v}_1 = 5.390233 \hat{r} + 5.133556 \hat{\theta} \text{ km/sec}$$
$$= -5.133556 \hat{p} + 5.390233 \hat{q} \text{ km/sec}$$

PART C ATTACHED

PART D

FIND TIME OF FLIGHT FROM $\nu_1 = 90°$ TO $\nu_2 = 150°$

$\nu_1 \to H_1 \to M_1$
$\nu_2 \to H_2 \to M_2$
$\Big\} \Delta t$

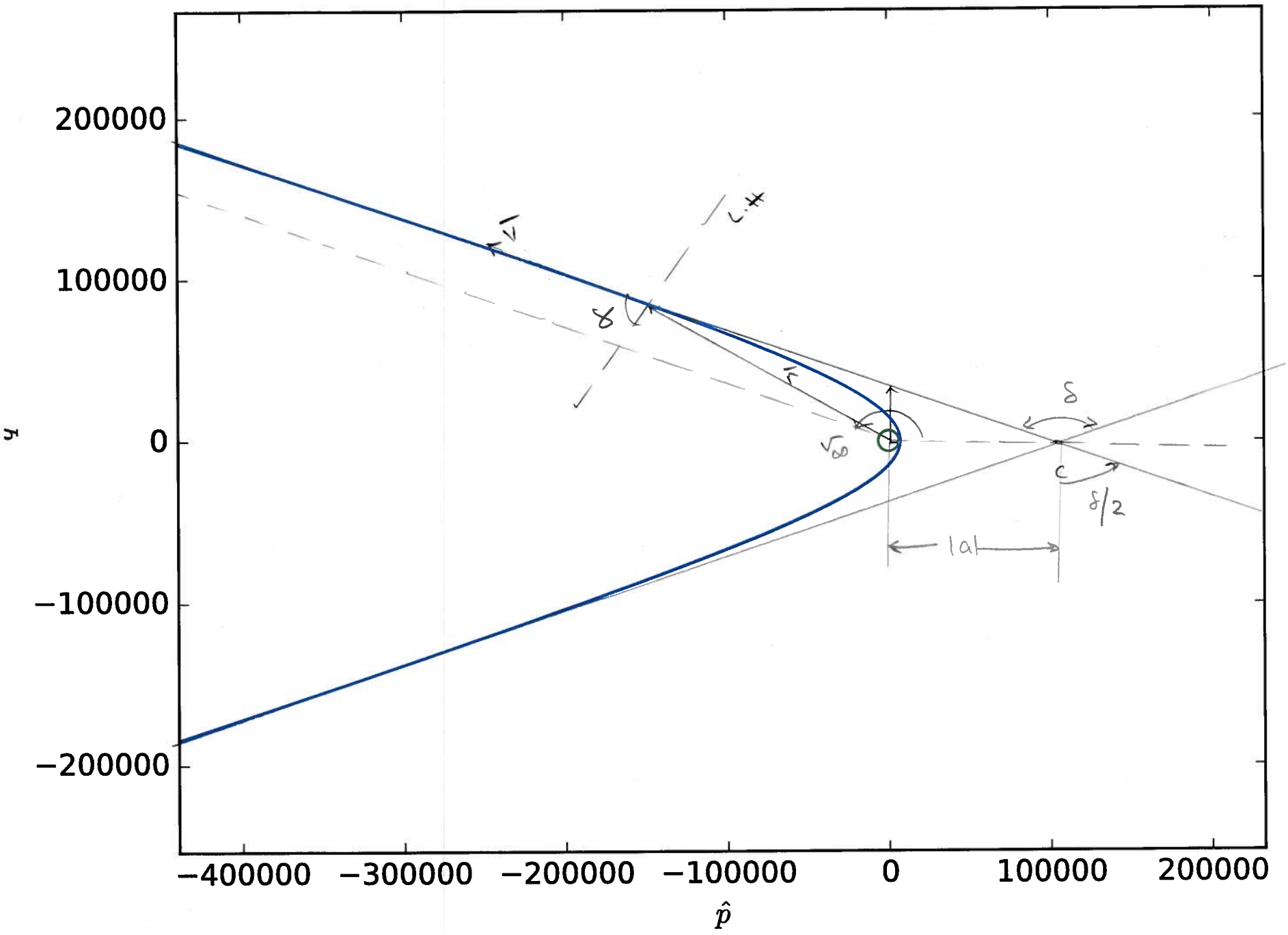
$$\tanh\frac{H_2}{2} = \tan\frac{\nu_2}{2}\left(\frac{e-1}{e+1}\right)^{1/2} \Rightarrow H_2 = 1.333532$$

$$(t_2 - t_p) = \frac{1}{n}\left(e\sinh H_2 - H_2\right) = 46703.41 \text{ sec}$$

$$\Delta t = \frac{1}{n}(M_2 - M_1) = 44796.48 \text{ sec} = 12.44347 \text{ hr}$$

AT THIS TIME

$$r = \frac{|a|(e^2-1)}{1 + e\cos\nu_2} = 166809.66 \text{ km}$$


200000
100000
0
−100000
−200000
−400000
−300000
−200000
−100000
0
100000
200000
$\hat{p}$
$\hat{q}$
r_1
γ
r_2
r_∞
δ
c
$\delta/2$
$|a|$

```
Properties at nu=90 deg

Satellite State
Position and Velocity in LVLH frame
r_hat:              15125.18085 km rd_hat:        5.39023786539628 km/sec
t_hat:                         0 km td_hat:        5.13355987180598 km/sec
h_hat:                         0 km hd_hat:                       0 km/sec

Position and Velocity in EPH/PQW frame
e_hat:     9.26150215723867e-13 km ed_hat:       -5.13355987180598 km/sec
p_hat:              15125.18085 km pd_hat:        5.39023786539628 km/sec
h_hat:                         0 km hd_hat:                       0 km/sec

Position and Velocity in IJK frame
i_hat:     9.26150215723867e-13 km id_hat:       -5.13355987180598 km/sec
j_hat:              15125.18085 km jd_hat:        5.39023786539628 km/sec
k_hat:                         0 km kd_hat:                       0 km/sec

RAD_MAG   :           15125.18085 km = 0.000101105589604986 AU
VEL_MAG   :     7.44366181411867 km/sec

Orbital Elements
sma:                  147562.74 km raan:                          0 deg
ecc:                       1.05    arg_p:                         0 deg
inc:                          0 deg nu:                          90 deg

Hyperbolic Orbital Parameters
          :           15125.18085 km = 0.000101105589604986 AU
ANG MOM   :     77646.0214653682 km^2/sec
ENGERGY   :      1.3506136440676 km^2/sec^2
RAD_PER   :             7378.137 km = 4.93197998073101e-05 AU

V_INF     :     1.64354108197368 km/sec
RAD_AIM   :     47243.1278518001 km
FLYBY     :     144.494419676107 deg
NU_INF    :     162.247209838053 deg

VEL_CIRC  :     5.13355987180598 km/sec
VEL_ESC   :      7.2599499939623 km/sec
TRUE_ANOM :                   90 deg
FPA       :     46.3971810272964 deg
HYP_ANOM  :     18.0438594175852 deg
MEAN_ANOM :     1.21692029381318 deg
MEAN_MOT  : 0.000638155454781177 deg/sec

T_PAST_PER:     1906.93393701454 sec =    0.529703871392928 hr
Properties at nu=150 deg

Satellite State
Position and Velocity in LVLH frame
r_hat:         166809.595642343 km rd_hat:        2.69511893269814 km/sec
t_hat:                         0 km td_hat:       0.465476947931996 km/sec
```

```
h_hat:                          0 km hd_hat:                          0 km/sec

Position and Velocity in EPH/PQW frame
e_hat:        -144461.347421279 km ed_hat:       -2.56677993590299 km/sec
p_hat:         83404.7978211714 km pd_hat:       0.944444604563914 km/sec
h_hat:                          0 km hd_hat:                          0 km/sec

Position and Velocity in IJK frame
i_hat:        -144461.347421279 km id_hat:       -2.56677993590299 km/sec
j_hat:         83404.7978211714 km jd_hat:       0.944444604563914 km/sec
k_hat:                          0 km kd_hat:                          0 km/sec

RAD_MAG   :     166809.595642343 km =  0.00111505328011918 AU
VEL_MAG   :     2.73502008227436 km/sec

Orbital Elements
sma:                  147562.74 km raan:                           0 deg
ecc:                       1.05    arg_p:                          0 deg
inc:                          0 deg nu:                          150 deg

Hyperbolic Orbital Parameters
P         :          15125.18085 km = 0.000101105589604986 AU
ANG MOM   :     77646.0214653682 km^2/sec
ENGERGY   :      1.3506136440676 km^2/sec^2
RAD_PER   :             7378.137 km = 4.93197998073101e-05 AU

V_INF     :     1.64354108197368 km/sec
RAD_AIM   :     47243.1278518001 km
FLYBY     :     144.494419676107 deg
NU_INF    :     162.247209838053 deg

VEL_CIRC  :     1.54581815914888 km/sec
VEL_ESC   :     2.18611700563095 km/sec
TRUE_ANOM :                  150 deg
FPA       :     80.2010512739565 deg
HYP_ANOM  :      76.405734006518 deg
MEAN_ANOM :     29.8040001869942 deg
MEAN_MOT  : 0.000638155454781177 deg/sec

T_PAST_PER:     46703.3541180244 sec =     12.9731539216734 hr
Time of flight from 90 to 150 deg: 44796.420181009846 sec = 12.44345005 hrs
```

HOMEWORK SOL

PROBLEM 3

SATELLITE STATE

$a = 3R_\oplus$ $\quad \Omega = 45°$

$e = 0.4$ $\quad \omega = 90°$

$i = 28.5°$ $\quad \nu = 235°$

FIND: $\bar{r}, \bar{v}, r, v, \gamma, M, E, (t-T)$ $\quad \bar{r}, \bar{v}$ IN LVLH / PERIFOCAL / ECI

I'VE COMPUTED THESE THINGS MANY TIMES.

I'LL LIST THE EQUATIONS FOLLOWED BY ANSWERS

$r_p = a(1-e)$

$r_a = a(1+e)$

$p = a(1+e)$

$h = \sqrt{\mu p}$

$r = \dfrac{p}{1 + e\cos\nu}$

$\mathcal{E} = \dfrac{v^2}{2} - \dfrac{\mu}{r} = -\dfrac{\mu}{2a}$

$h = rv\cos\gamma$

$r = a(1 - \cos E)$

$n(t_1 - T) = E - e\sin E = M$

CONVERTING BETWN FRAMES

$$\left.\begin{aligned} \bar{r} &= r\hat{r} \quad \text{km} \\ \bar{v} &= v_r\hat{r} + v_\theta\hat{\theta} \quad \frac{\text{km}}{\text{sec}} \end{aligned}\right\} \text{LVLH}$$

LVLH $\rightarrow$ PQW

$$\bar{r}_{PQW} = \begin{bmatrix} C\nu & -S\nu & 0 \\ S\nu & C\nu & 0 \\ 0 & 0 & 1 \end{bmatrix} \bar{r}_{LVLH}$$

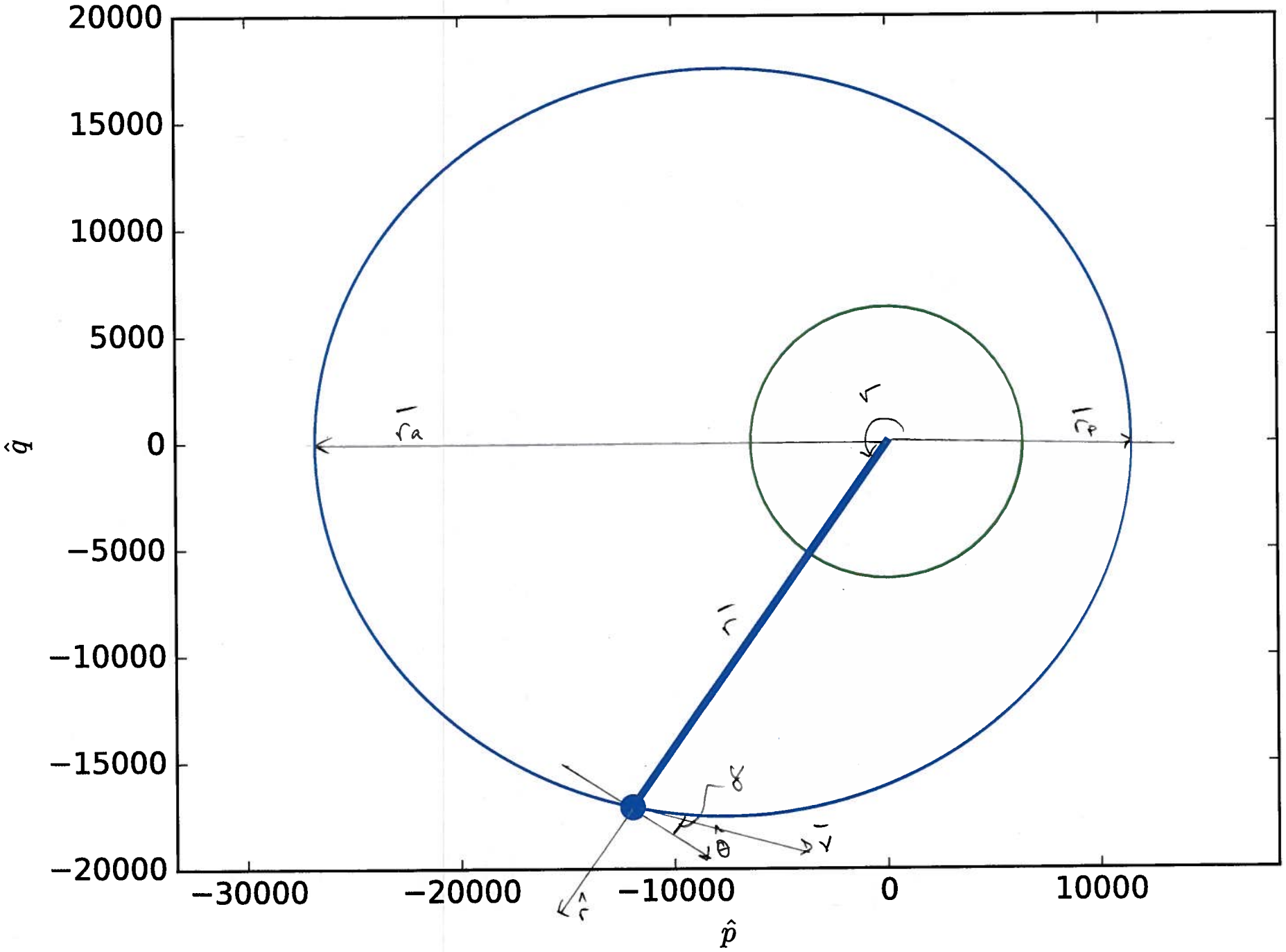
SAME FOR $\bar{v}_{PQW}$

PQW → ECI

$$\bar{r}_{ECI} = ROT_3(\Omega)\, ROT_1(i)\, ROT_3(\omega)\, \bar{r}_{PQW}$$

$$\bar{r}_{ECI} = \begin{bmatrix} c\Omega c\omega - s\Omega s\omega ci & -c\Omega s\omega - s\Omega c\omega ci & s\Omega si \\ s\Omega c\omega + c\Omega s\omega ci & -s\Omega s\omega + c\Omega c\omega ci & -c\Omega si \\ s\omega si & c\omega si & ci \end{bmatrix} \bar{r}_{PQW}$$

SAME AS $\bar{V}_{PQW} \rightarrow \bar{V}_{ECI}$


20000
15000
10000
5000
0
−5000
−10000
−15000
−20000
−30000
−20000
−10000
0
10000
$\hat{q}$
$\hat{p}$
$\bar{r}_a$
$\bar{r}$
$\bar{r}_p$
$\bar{r}$
γ
θ
$\bar{v}$
$\hat{r}$

atellite State
Position and Velocity in LVLH frame

r_hat:	20858.4777814326 km	rd_hat:	-0.206406913822747 km/sec
t_hat:	0 km	td_hat:	0.485413111351423 km/sec
h_hat:	0 km	hd_hat:	0 km/sec

Position and Velocity in EPH/PQW frame

e_hat:	-11963.9313535816 km	ed_hat:	0.516017284556866 km/sec
p_hat:	-17086.2647154171 km	pd_hat:	-0.109342877153738 km/sec
h_hat:	0 km	hd_hat:	0 km/sec

Position and Velocity in IJK frame

i_hat:	19516.4104333318 km	id_hat:	-0.243345101546554 km/sec
j_hat:	4647.21685750787 km	jd_hat:	0.397979281366266 km/sec
k_hat:	-5708.69465250606 km	kd_hat:	0.246222167771684 km/sec

RAD_MAG : 20858.4777814326 km = 0.000139430312620311 AU
VEL_MAG : 0.527474836125573 km/sec

Orbital Elements

sma:	19134.411 km	raan:	45 deg
ecc:	0.4	arg_p:	90 deg
inc:	28.5 deg	nu:	235 deg

Elliptic Orbital Parameters

P	:	16072.90524 km = 0.000107440735887483 AU
ANG MOM	:	10124.9785979397 km^2/sec
PERIOD	:	208235.895040777 sec = 57.8433041779937 hr
ENGERGY	:	-0.166666666666667 km^2/sec^2
RAD_PER	:	11480.6466 km = 7.67433827767735e-05 AU
RAD_APO	:	26788.1754 km = 0.000179067893145805 AU
VEL_CIRC	:	0.552975151376187 km/sec
VEL_ESC	:	0.782024958731518 km/sec
TRUE_ANOM	:	235 deg
FPA	:	-23.0361228508524 deg
ECC_ANOM	:	256.981987543938 deg
MEAN_ANOM	:	279.311282630493 deg
MEAN_MOT	:	0.0017288085703452 deg/sec

T_PAST_PER: 161562.874815412 sec = 44.8785763376144 hr

HOMEWORK SOL

PROBLEM 4

OTV WITH STATE

$$\bar{r}_1 = 3R_\oplus \hat{x} + 5R_\oplus \hat{y}$$

$$\bar{v}_1 = -3.2\hat{x} + 2\hat{y} + 2.5\hat{z} \ \text{km/sec}$$

} INERTIAL FRAME

FIND: $a, e, i, \omega, \Omega, r, v, \gamma, r, M, E, (t-T)$

AGAIN THIS PROBLEM IS VERY STRAIGHTFORWARD. JUST APPLY THE EQNS + CHECK QUADRANTS!!

↳ ALSO YOU SHOULD HAVE A PROJECT THAT DOES THIS!

$r = |\bar{r}_1|$

$v = |\bar{v}_1|$

$\varepsilon = \frac{v^2}{2} - \frac{\mu}{r} = -\frac{\mu}{2a} \rightarrow a$

$\bar{h} = \bar{r}_1 \times \bar{v}_1 \qquad h = |\bar{h}_1|$

$p = \frac{h^2}{\mu}$

$p = a(1-e^2)$

$h = rv\cos\gamma$ ← QUADRANT CHECK $\quad \dot{r} = \hat{r}_1 \cdot \hat{v}_1$ ← DESCENDING/ASCENDING

$r = \frac{p}{1+e\cos\nu}$

$r = a(1-e\cos E)$

$M = n(t-T) = E - e\sin E$

CLASSICAL ORBITAL ELEMENTS

$$\bar{e} = \frac{1}{\mu}\bar{v} \times \bar{h} - \frac{\bar{r}}{r}$$

$$\bar{n} = \hat{z} \times \bar{h}$$

$$i = \cos^{-1} \hat{h} \cdot \hat{z} \qquad 0 < i < \pi$$

$$\Omega = \tan^{-1}\left(\frac{\hat{y} \cdot \hat{n}}{\hat{x} \cdot \hat{n}}\right)$$

$$\omega = \tan^{-1}\left(\frac{\hat{h} \cdot (\hat{n} \times \hat{e})}{\hat{n} \cdot \hat{e}}\right)$$

$$\nu = \tan^{-1}\left(\frac{\hat{h} \cdot (\hat{e} \times \hat{r})}{\hat{e} \cdot \hat{r}}\right)$$

atellite State
Position and Velocity in LVLH frame
r_hat: 37190.6100257329 km rd_hat: 0.0685994340569952 km/sec
t_hat: 0 km td_hat: 4.52606828468673 km/sec
h_hat: 0 km hd_hat: 0 km/sec

Position and Velocity in EPH/PQW frame
e_hat: 37171.8346408868 km ed_hat: -0.0752352531258094 km/sec
p_hat: 1181.60209745587 km pd_hat: 4.52596284305197 km/sec
h_hat: 0 km hd_hat: 0 km/sec

Position and Velocity in IJK frame
i_hat: 19134.411 km id_hat: -3.20000000000001 km/sec
j_hat: 31890.685 km jd_hat: 1.99999999999999 km/sec
k_hat: 2.95585778076202e-12 km kd_hat: 2.5 km/sec

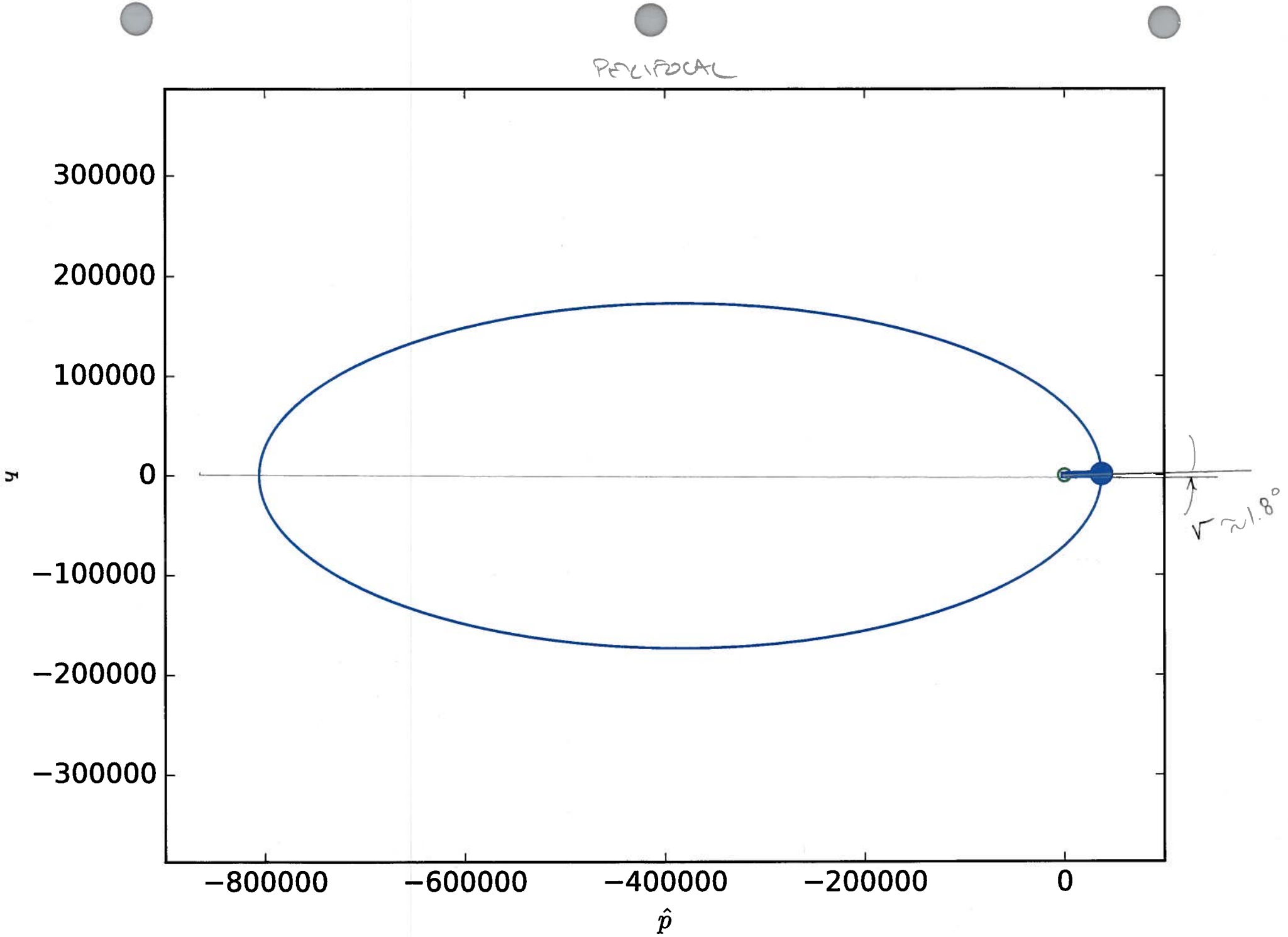
RAD_MAG : 37190.6100257329 km = 0.000248603874010592 AU
VEL_MAG : 4.52658811910251 km/sec

Orbital Elements
sma: 421556.288571242 km raan: 59.0362434679265 deg
ecc: 0.911799072999493 arg_p: 358.179319773404 deg
inc: 33.5287802479313 deg nu: 1.82068022659575 deg

Elliptic Orbital Parameters
P : 71083.854392984 km = 0.000475166219899949 AU
ANG MOM : 168327.240525622 km^2/sec
PERIOD : 2723919.74136792 sec = 756.644372602199 hr
ENGERGY : -0.472772570124567 km^2/sec^2
RAD_PER : 37181.6554348768 km = 0.00024854401626759 AU
RAD_APO : 805930.921707608 km = 0.005387315485893 AU

VEL_CIRC : 3.2738009362398 km/sec
VEL_ESC : 4.62985368454006 km/sec
TRUE_ANOM : 1.82068022659575 deg
FPA : 0.868338008711285 deg
ECC_ANOM : 0.391096552536914 deg
MEAN_ANOM : 0.0344978476757372 deg
MEAN_MOT : 0.000132162484280544 deg/sec

T_PAST_PER: 261.026023107344 sec = 0.072507228640929 hr


PERIFOCAL
300000
200000
100000
0
−100000
−200000
−300000
−800000
−600000
−400000
−200000
0
$\hat{p}$
$\hat{q}$
$\gamma \approx 1.8°$