Homework Assignment #06 (Sun and the Orbit)
[Answer, Code]

```
%constants
mu = 3.986004415*10^14;
ae = 6378136.3;
we = 7.292115*10^-5;
g=9.81;
j2=1.082*10^-3;

%%Preallocations
n = zeros(1,4);
bigWbar = zeros(1,4);
wbar = zeros(1,4);
Mbar = zeros(1,4);
T_kepler = zeros(1,4);
T_anomalistic = zeros(1,4);
u = zeros(1,4);
T_nodal = zeros(1,4);
bigW = zeros(4,361);
beta = zeros(4,361);
```

Problem 1.

Index: [Topex Grace ERS-1 Lageos]

a. **Precession Rates:**

Node_Precession_Rate =

[-2.0912e+000 -134.7252e-003 995.4267e-003 342.0030e-003]

Perigree_Precession_Rate =

[-442.4410e-003 -3.9328e+000 -2.9563e+000 -214.0469e-003]

Mean_Anomaly_Precession_Rate =

[4.6198e+003 5.5452e+003 5.1599e+003 2.2989e+003]

```
%% Problem 1
% a. Calculate Precession rates in units of degrees/day
```

```
%       1       2       3       4
%   [Topex   Grace   ERS-1   Lageos]
a = [7705    6820    7156    12271]*1000; % m
e = [0.001   0.0016  0.001   0.004]; %
i = [65.99   89.02   98.6    109.83]*pi/180; % rad

for j=1:4
n(j) = sqrt(mu/a(j)^3);
bigWbar(j) = -1.5*n(j)*(ae/a(j))^2*j2/sqrt(1-e(j)^2)*cos(i(j));
wbar(j) = -0.75*n(j)*(ae/a(j))^2*j2/(1-e(j)^2)^2*(1-5*(cos(i(j)))^2);
Mbar(j) = n(j)*(1-(0.75*(ae/a(j))^2*j2/(1-e(j)^2)^(3/2)*(1-3*(cos(i(j)))^2)));
end
%convert from rad/s to deg/day
Node_Precession_Rate = (bigWbar)*180/pi*60*60*24
Perigree_Precession_Rate = (wbar)*180/pi*60*60*24
Mean_Anomaly_Precession_Rate = (Mbar)*180/pi*60*60*24
```

b. Periods:

```
Keplerian_Period =

  [112.1808e+000    93.4192e+000   100.4073e+000   225.4653e+000]


Anomalistic_Period =

  [112.2122e+000    93.4855e+000   100.4677e+000   225.4976e+000]


Nodal_Period =

  [112.2230e+000    93.5519e+000   100.5253e+000   225.5186e+000]
```

```
% b. Calculate the Kepler, Anomalistic, and Draconitic/Nodal Periods
for j=1:4
   T_kepler(j) = 2*pi/n(j);
   T_anomalistic(j) = 2*pi/Mbar(j);
   u(j) = wbar(j) + Mbar(j);
   T_nodal(j) = 2*pi/u(j);
end
Keplerian_Period = T_kepler/60
Anomalistic_Period = T_anomalistic/60
```

```
Nodal_Period = T_nodal/60
```

c. **Sun-cycle duration:**

```
SunCycle_Duration =

  -117.0038e+000  -321.3220e+000    36.8082e+003  -559.3160e+000
```

```
% c.Calculate the Sun-Cycle Duration in units of days
bigWs = (360/365.2426); %deg/day
for j=1:4
Cs(j) = 360/(Node_Precession_Rate(j) - bigWs);
end
SunCycle_Duration = Cs
```

d. **Identify Sun-synchronous orbit:**

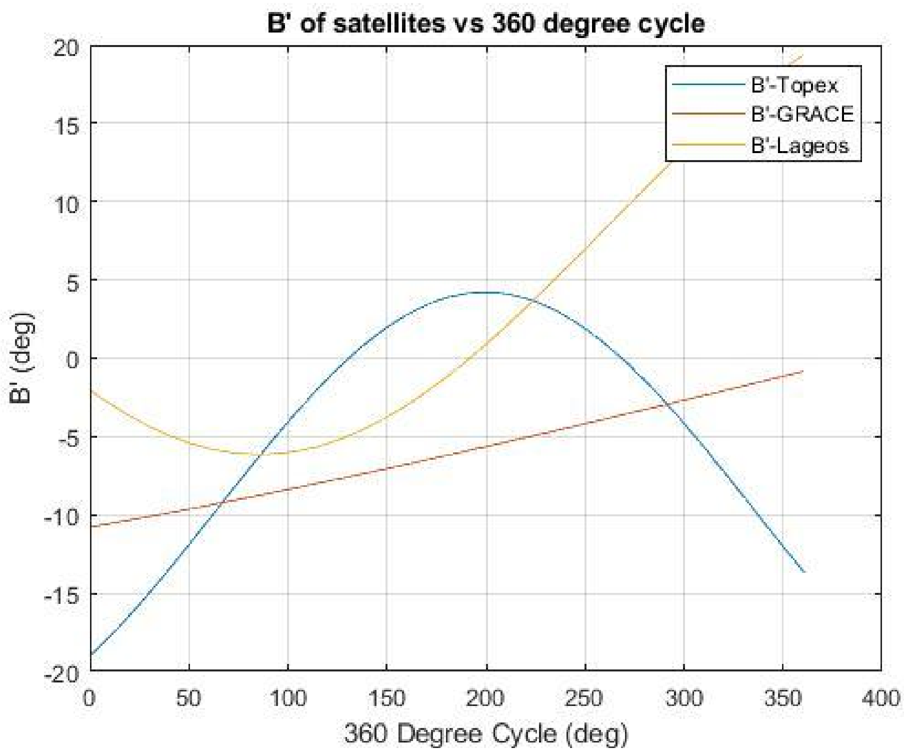
Only the satellite ERS-1 (Satellite #3) is nearly sun-synchronous because its mean sun and nodal precession rate difference is near zero.

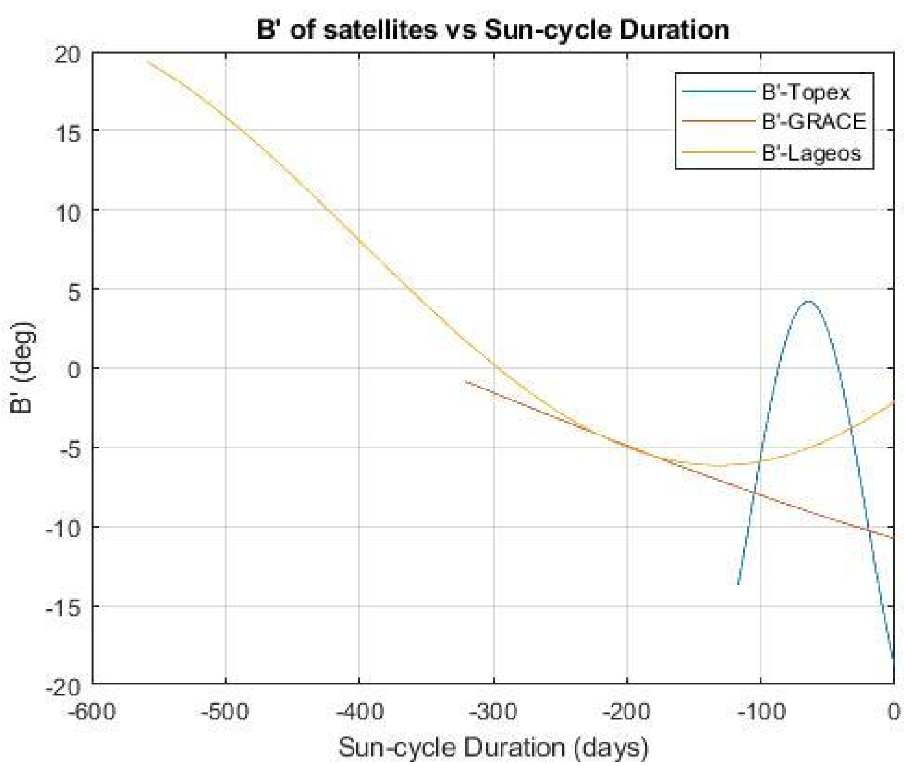
```
SunSyncTest =

    -3.0768e+000    -1.1204e+000     9.7804e-003  -643.6433e-003
```

```
% d. Identify if Satellite is in sun-synchronous orbit
SunSyncTest = Node_Precession_Rate - bigWs
```

Problem 2. Calculate and plot B' for all satellites not in sun-synchronous orbit





Where "negative" days indicates westward propagation, assuming eastward direction is positive.

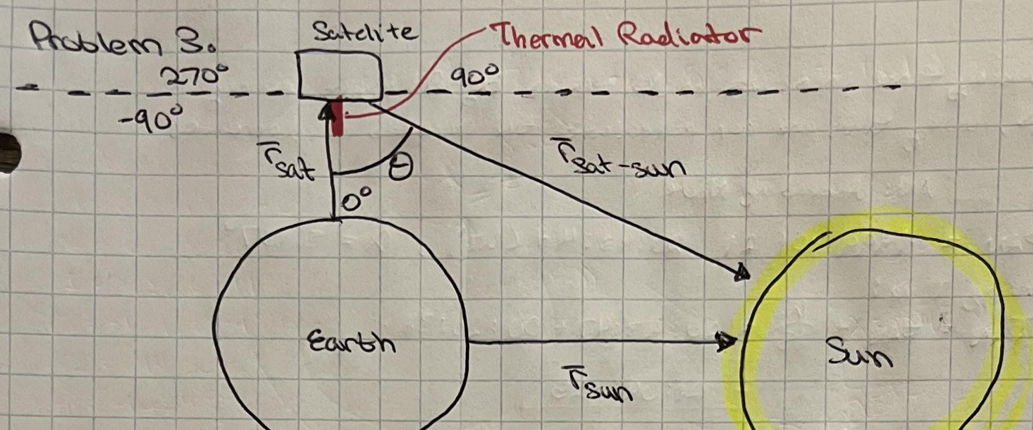
```
%% Problem 2.
% Calculate the B' angle at 1-day intervals and plot its variaton within
% one complete cycle of 360 degrees.
% Epoch Noon Jan 1, 2000
P2epoch = [2000 1 1 12 0 0];
%A. (10) Calculate the mean longitude of the sun (L)
JD = juliandate(P2epoch);
D = JD - 2451545.0; %in units of days
%Mean Longitude of Sun:
L = (pi/180)*(280.460 + 0.9856474*D); % rad
Ldeg = rad2deg(L);
%B. Calculate the RA and Dec of the Sun
%Mean Anomaly:
g = pi/180*(357.528 + 0.9856003*D); % rad
%ecliptic longitude:
lambda = L + deg2rad(1.915)*sin(g) + deg2rad(0.020)*sin(2*g);
%Ecliptic Obliquity:
eps = (pi/180)*(23.439 - (4e-7)*D);
%Right Ascension:
RA = atan(cos(eps)*tan(lambda));
RAdeg = rad2deg(RA)
Dec = asin(sin(eps)*sin(lambda));
Decdeg = rad2deg(Dec)
%C. Calculate GMST
GMST = 15*(pi/180)*(18.697374458 + 24.06570982*D); %in units of rad

% Use RA and Dec to calculate e_sun (remains constant)
e_sun = [sin(pi/2 - Dec)*cos(RA),
       sin(pi/2 - Dec)*cos(RA),
       cos(pi/2 - Dec)];

% To calculate e_h, need the change in RAAN
%   Change in time = sun cycle duration
bigWo = 0;
%Topex B'
dt1 = 0:(Cs(1)/360):Cs(1);
bigW(1,:) = bigWo + Node_Precession_Rate(1)*(dt1); % degrees
for j=1:361
eh_Topex = [sind(bigW(1,j))*sin(i(1)),
      -1*cosd(bigW(1,j))*sin(i(1)),
```

```
    cos(i(1))];
beta(1,j) = 90 - acosd(dot(e_sun,eh_Topex)); % in degrees
end
%GRACE B'
dt2 = 0:(Cs(2)/360):Cs(2);
bigW(2,:) = bigWo + Node_Precession_Rate(2)*(dt2); % degrees
for j=1:361
eh_Grace = [sind(bigW(2,j))*sin(i(2)),
    -1*cosd(bigW(2,j))*sin(i(2)),
    cos(i(2))];
beta(2,j) = 90 - acosd(dot(e_sun,eh_Grace)); % in degrees
end
%Lageos B'
dt4 = 0:(Cs(4)/360):Cs(4);
bigW(4,:) = bigWo + Node_Precession_Rate(4)*(dt4); % degrees
for j=1:361
eh_Lageos = [sind(bigW(4,j))*sin(i(4)),
    -1*cosd(bigW(4,j))*sin(i(4)),
    cos(i(4))];
beta(4,j) = 90 - acosd(dot(e_sun,eh_Lageos)); % in degrees
end
Cycleof360 = 1:361;
figure(1)
plot(Cycleof360,beta(1,:),Cycleof360,beta(2,:),Cycleof360,beta(4,:))
title("B' of satellites vs 360 degree cycle")
legend("B'-Topex","B'-GRACE","B'-Lageos")
xlabel("360 Degree Cycle (deg)")
ylabel("B' (deg)")
grid on
figure(2)
plot(dt1,beta(1,:),dt2,beta(2,:),dt4,beta(4,:))
title("B' of satellites vs Sun-cycle Duration")
legend("B'-Topex","B'-GRACE","B'-Lageos")
xlabel("Sun-cycle Duration (days)")
ylabel("B' (deg)")
grid on
```

Problem 3.



$$\hat{e}_{sat-sun} = \frac{\bar{r}_{ss}}{r_{ss}}$$

$$\hat{e}_r = \frac{\bar{r}}{r}$$

$\cos\theta = -\hat{e}_r \cdot \hat{e}_{sat-sun}$, solve for θ to determine if sun is shining on thermal radiator

- The Sun is not shining on the thermal Radiator when it is blocked by or behind the Earth

- The sun shining on the Thermal Radiator is significant, because energy from the Sun will impact the ~~sens~~ instrument's heat / temperature readings

Problem 4.

Problem 4.

- The crossing time increases or decreases by 24 hours every C_s Days, using this one can calculate the increases or decreases

TRMM: AN: Ascending Node

$t_{AN} = 1999 \cdot 01\ 21 \quad 20{:}43{:}47$ (UT), $\lambda = 5.157°$

LMT Crossing Time:

$T_{AN} = t_{AN} + \frac{\lambda}{15} = 20{:}43{:}47 + 00{:}20{:}38$

$\boxed{= 21{:}04{:}25}$

$C_s = -\frac{365.25}{7.89} = -46.29$ days

Daily Drift: $\frac{1440}{C_s} = -31.02$ min

Time Difference: 21:04 on 21 Jan 1999 (J = 21)

$22{:}20 - 21{:}04 \approx 76$ min

Passage of TRMM occurs with shift of $-76/31 = -2.45$ days

- This translates to 2 days earlier on

19 Jan 1999 (J = 21)

Therefore ascending node crossing about 22:20 occurs on the days J_K given by...

$$\boxed{J_K = 19 + k\,|C_s| \ldots \quad \text{where } C_s = -46.29 \text{ days}}$$