Rev. 0a
30 September 2025

Earth Orbital Mechanics and Solar Irradiance: Part I – Theoretical Model (MATLAB Programming Assignment)

Experiment 3

Part I: Numerical Modeling: Solar Irradiance and Earth/Sun Orbital Mechanics

A. Earth/Moon-Sun distance [R]: Write a MATLAB code to **calculate the Sun to Earth/Moon distance** *for an entire year* using the equations of Earth/Moon to Sun orbital mechanics provided in the lecture notes and summarized below.

   1. Plot time (Julian Day) vs. R (include axis labels and a title)
   2. Place an X symbol on this curve for noon on the date of your birthday.

B. Write a MATLAB code to **calculate the solar declination angle** [δ_s] **and cosine of the solar zenith angle** [$\cos(\Theta_o)$] for the day of the year (Julian Day) *during the data window specified by the instructor* using the equations of Earth/Moon to Sun orbital mechanics provided in the lecture notes and summarized below.

   1. Use the `subplot` command to plot these variables in two panels on one page.

C. Write a MATLAB code to **calculate** the top of the atmosphere **(**TOA) **solar irradiance** (S_{TOA}) *during the data window specified by the instructor*, given the solar constant and the equations of Earth/Moon to Sun orbital mechanics provided in the lecture notes and summarized below.

   1. Use the `plot` command to create a time-series plot of TOA SWR on one page.

Part I calculations of solar irradiance are for a single location – the Rooftop Radiation Laboratory. The latitude for this location is (remember: convert to radians): 41° 24' 06" N

Deliverables: Tasks #1, #2, #3, #4 are electronic submittals; Task #5 is hardcopy

1. One M-file (with a format consistent with the formatting instruction guidelines).
2. Figure 1: a time-series plot of time vs. R, consistent with instruction A above.
3. Figure 2: two time-series panels, consistent with instruction B above.
   a. one of solar declination angle
   b. cosine of the solar zenith angle (only the positive values please)
4. Figure 3: a time-series of time vs. S_{TOA}, consistent with instruction C above.
5. Hand-written answers to the questions, written on the question handout sheet.

Part I: MATLAB comments

Equations for this project are in the lecture notes, repeated here for your convenience:

1. The instantaneous distance between the Sun and the center of mass of the Earth/Moon system and solar declination angle both depend only on orbital position, *i.e.*, time of year:

$R = a(1 - e^2)/\{1+e\cos(M)\}$		Sun to Earth/Moon distance
where	$a = 149.457 \times 10^9$ m	semi-major axis
	$e = 0.0167$	orbit eccentricity
	$M = 2\pi\{(\text{time} - 3.0)/T_{orbit}\}$	orbital angle (mean anomaly)
$\delta_s = \Phi_r \cos[2\pi(\text{time} - 173.0)/T_{orbit}]$		Solar Declination Angle (SDA)
where	$T_{orbit} = 365.25463$ days	orbital period
	$\Phi_r = 23.45^o$	maximum declination angle

2. Cosine of the solar zenith angle [$\cos(\Theta_o)$] is given by:

$$\cos(\Theta_o) = \sin(\phi)\sin(\delta_s) - \cos(\phi)\cos(\delta_s)\cos[2\pi(fracday + t\_offset)]$$

where ϕ is latitude; *fracday* is the decimal fraction of a day – see below. For Part I t_offset = 0; however, for Part II it will be based on longitude.

   a. Use MATLAB command "`linspace`" to create the Julian Day time variable in **ten-minute** increments: `time = linspace(timeStart,timeEnd,Nt).` A time window will be specified by the instructor & Nt = 24(SamplePerHour)Δt+1.

   To create the variable *fracday*, use: `fracday = time - floor(time);`

   b. To eliminate values of the cosine of the solar zenith angle (CSZA) which are less than zero, consider the following code:

```
for n = 1:Nt;
     if CSZA(n) <= 0.0;
          CSZA(n) = 0.0;
     end
end
```

3. The Solar Irradiance at the Top Of Atmosphere (TOA) for a location on Earth depends upon the time of year (*i.e.*, orbital trajectory & solar declination effects) and latitude:

$$S_{TOA} = S_o\{R_{AVE}/R\}^2 \cos(\Theta_o)$$

where $S_o = 1368 \pm 7$ W m^{-2}

$R_{AVE} = 149.2 \times 10^9$ m