Indian National Astronomy Olympiad (INAO) – 2026

Question Paper

Roll Number: □□□□ - □□□□ - □□□□ Date: 31 January 2026
Duration: **Three Hours** Maximum Marks: 100

Please Note:

- Before starting, please ensure that you have received a copy of the question paper containing total 8 pages (4 sheets).
- Please write your roll number in the space provided above.
- There are total 6 questions. Maximum marks are indicated in front of each sub-question.
- For all questions, the process involved in arriving at the solution is more important than the final answer. Valid assumptions / approximations are perfectly acceptable. Please write your method clearly, explicitly stating all reasoning / assumptions / approximations.
- Use of non-programmable scientific calculators is allowed.
- **The answersheet must be returned to the invigilator**. You can take this question paper back with you.

Useful Constants

Mass of Sun	$M_\odot$	=	1.988×10^{30} kg
Radius of Sun	$R_\odot$	=	6.957×10^{8} m
Luminosity of Sun	$L_\odot$	=	3.828×10^{26} W
Solar constant (above atmosphere of Earth)	$S_\odot$	=	$1361\,\mathrm{W\,m^{-2}}$
Mass of Earth	$M_\oplus$	=	5.972×10^{24} kg
Radius of Earth	$R_\oplus$	=	6.378×10^{6} m
Speed of light in vacuum	c	=	$2.998 \times 10^{8}\,\mathrm{m\,s^{-1}}$
Stefan-Boltzmann constant	σ	=	$5.670 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$
Wien's displacement constant	b	=	$2.898 \times 10^{-3}\,\mathrm{m\,K}$
Universal gravitational constant	G	=	$6.674 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$
1 Astronomical Unit	1 au	=	1.496×10^{11} m

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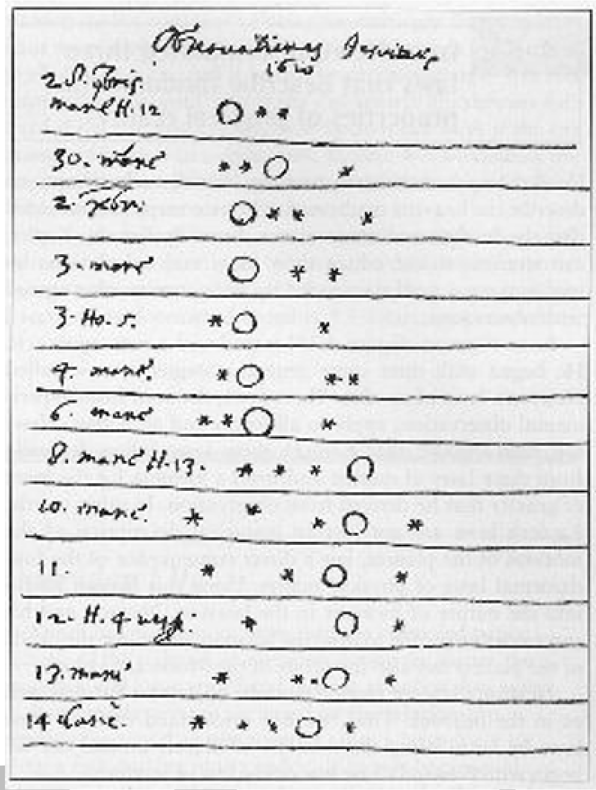
1. One of Galileo's discoveries was the satellites of Jupiter and in his notebook he drew sketches showing the position of the satellites every night. In this picture of his original hand-written notes, the big circle denotes Jupiter and small stars represent the positions of four satellites. The writing on the left is the date.



(a) (10 marks) The following table gives recent measurements of the position of one of the satellites, Europa, with respect to Jupiter at various times. Here, x represents the magnitude of distance between Jupiter and Europa, as measured in a similar image / sketch. Obtain the time period (T) of Europa through a suitable linear plot. (You may assume that the maximum magnitude of x is 3 cm).

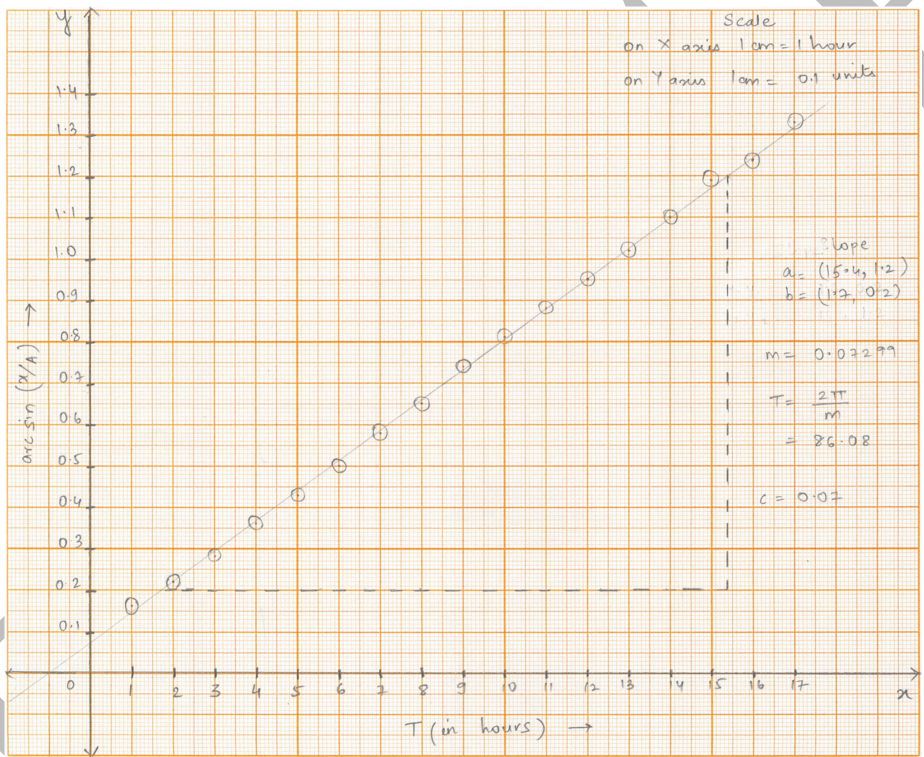
T (in hour)	x (in cm)
0	not seen
1	0.49
2	0.65
3	0.84
4	1.06
5	1.26
6	1.45
7	1.65
8	1.82

T (in hour)	x (in cm)
9	2.02
10	2.18
11	2.32
12	2.45
13	2.56
14	2.67
15	2.78
16	2.84
17	2.91

Solution:

$$
\begin{aligned}
x &= A\sin(\omega t + \phi) \\
x/A &= \sin(\omega t + \phi) \\
\arcsin(x/A) &= (\omega t + \phi) \\
\arcsin(x/A) &= \frac{2\pi}{T} t + \phi
\end{aligned}
$$

On y-axis plot $y = \arcsin(x/A)$ and on x-axis plot T. Then the slope is $m = \dfrac{2\pi}{T}$.



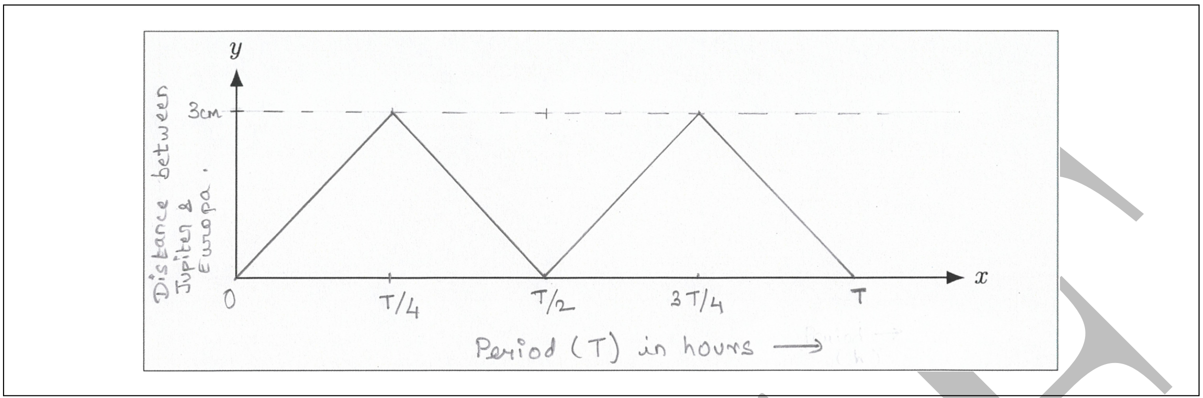
$$\text{slope} = 0.07$$

$$T = \frac{2\pi}{0.07}$$

$$\boxed{T = 89.8\,\text{h} \approx 90\,\text{h}}$$

(b) (2 marks) Draw a rough sketch of the same plot as in part (a), for a full period of Europa.

Solution:



2. (a) (6 marks) An observer is located in the city of Nashik (latitude ≈ 20°N and longitude ≈ 73°E). She observes the rising of the Sun on different days of the year.
The figure in the answersheet depicts the eastern horizon (approximated as a straight line) for the city of Nashik with East cardinal point marked as E. The azimuth range is given to be 60° to 120° with markings at every 10°. In the table below, you are given certain dates alongside alphabets. Mark the approximate rising points of the Sun as seen by the observer for these dates on the image of the horizon given in the answersheet and label them with the corresponding alphabets. Precise calculations are not expected.
Note: For definition of Azimuth refer Appendix.

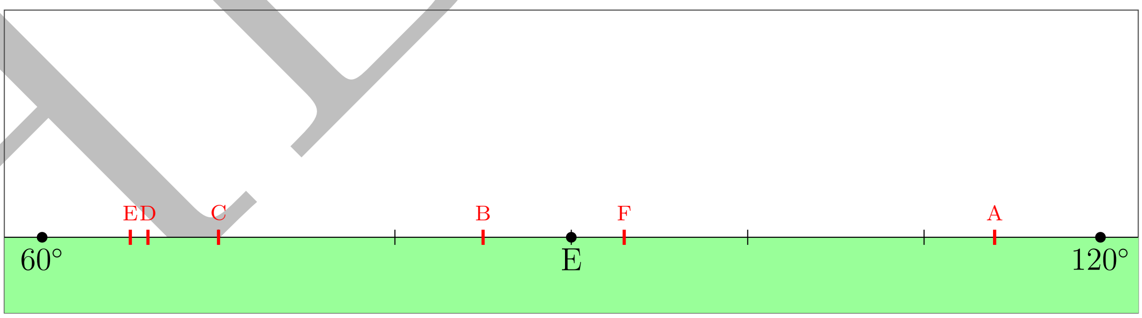
Letter	Date
A	01 Jan 2025
B	01 Apr 2025
C	15 May 2025

Letter	Date
D	01 Jun 2025
E	01 Jul 2025
F	01 Oct 2025

Solution:

Letter	Date	Azimuth
A	01 Jan 2025	114
B	01 Apr 2025	85
C	15 May 2025	70

Letter	Date	Azimuth
D	01 Jun 2025	66
E	01 Jul 2025	65
F	01 Oct 2025	93



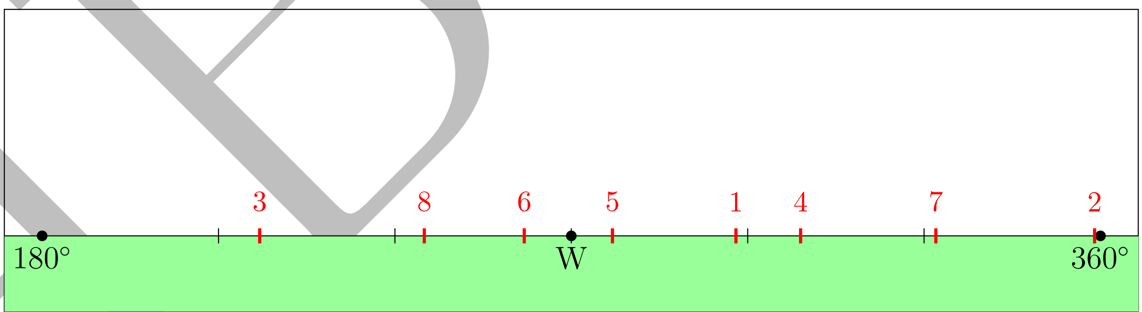
(b) (4 marks) Now consider an observer who is located in a city which lies on the equator of Earth. The figure given in the answersheet is of the horizon (approximated as a straight line) as seen from the equator in the azimuth range 180° to 360°. The cardinal west point is marked with letter W. The azimuths are marked at a separation of 30°.
Mark the approximate setting points of the following stars (by writing their corresponding

Sr. No.), if applicable, on the figure of horizon given in your answersheet.

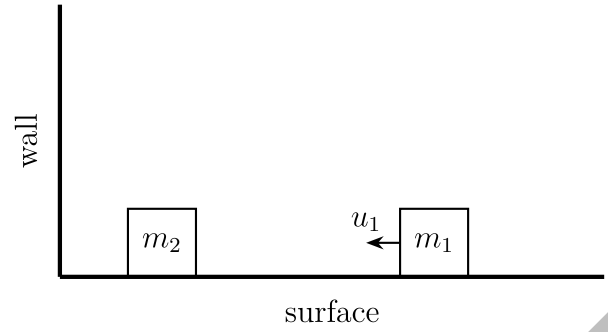
Sr. No.	Star Common Name	Bayer Name
1	Pollux	α Gem
2	Polaris	α UMi
3	Canopus	α Car
4	Vega	α Lyr
5	Revati	ζ Psc
6	Rigel	β Ori
7	Dubhe	α UMa
8	Kaus Borealis	λ Sgr

Solution:

Sr. No.	Star Common Name	Bayer Name	Declination (approx.)
1	Pollux	α Gem	28°
2	Polaris	α UMi	89°
3	Canopus	α Car	−53°
4	Vega	α Lyr	39°
5	Revati	ζ Psc	8°
6	Rigel	β Ori	−8°
7	Dubhe	α UMa	62°
8	Kaus Borealis	λ Sgr	−25°



3. Two blocks, m_1 and m_2, are placed on a frictionless horizontal surface next to a fixed rigid wall. Block m_2 is at rest close to the wall and block m_1 moves towards it with velocity $u_1 = -1\,\mathrm{m\,s^{-1}}$. All collisions (between the blocks and with the wall) are perfectly elastic.



(a) (5 marks) In the first case, we consider two identical blocks, each of mass 1 kg. Calculate total number of collisions (block-block or block-wall), n_1, that will occur in this system.

Solution:

To begin with we have,

$$u_1 = -1\,\mathrm{m\,s^{-1}}$$
$$u_2 = 0\,\mathrm{m\,s^{-1}}$$

Conservation of Energy tells us:

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$
$$1 = v_1^2 + v_2^2$$

In an elastic collision, relative velocity reverses sign,

$$(u_1 - u_2) = -(v_1 - v_2)$$
$$\therefore (-1 - 0) = -(v_1 - v_2)$$
$$v_1 - v_2 = 1$$

By conservation of linear momentum

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$
$$v_1 + v_2 = -1$$

Solving for velocities, we get:

$$v_1 = 0\,\mathrm{m\,s^{-1}}$$
$$v_2 = -1\,\mathrm{m\,s^{-1}}$$

Now, m_1 is stationary, m_2 is moving towards the wall. After collision of m_2 with the wall i.e. the block - wall collision, (elastic collision, no energy lost in friction, wall is massive), velocities are:

$$v_1 = 0\,\mathrm{m\,s^{-1}}$$
$$v_2 = 1\,\mathrm{m\,s^{-1}}$$

Repeating the same procedure, now again for the block-block collision, the velocities after collision are:

$$v_1 = 1\,\mathrm{m\,s^{-1}}$$
$$v_2 = 0\,\mathrm{m\,s^{-1}}$$

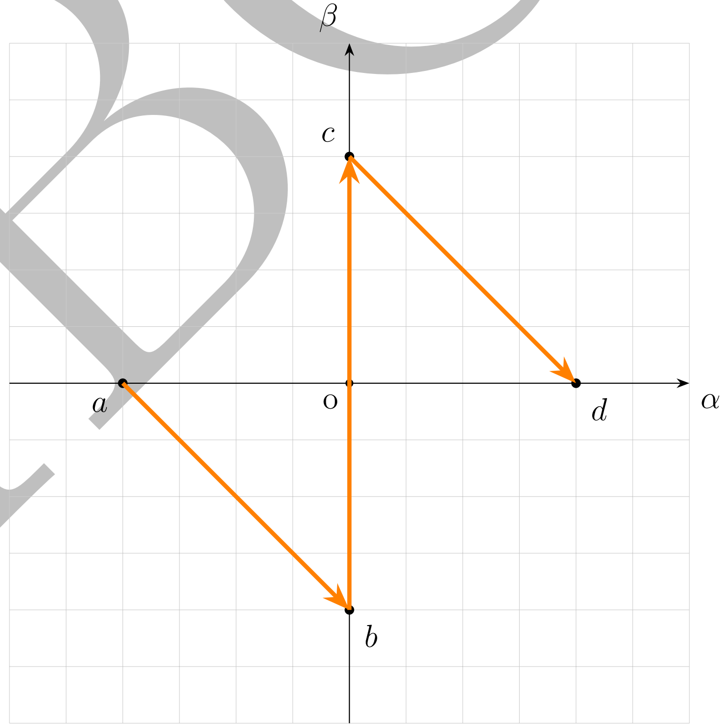
Block m_1 keeps moving along the positive x axis while block m_2 remains stationary. No further collisions.

$$\boxed{n_1 = 3}$$

(b) (2 marks) Now, we will attempt to describe this motion in velocity space by drawing an appropriate figure but for a more general problem.
In the coordinate grid given in the answersheet, we redefine the two axes as, $\alpha = v_1\sqrt{m_1}$ and $\beta = v_2\sqrt{m_2}$.
Plot the values of α and β that depict the velocities between successive collisions during each phase and connect them with straight line arrows depicting the transition at the instance of each collision.

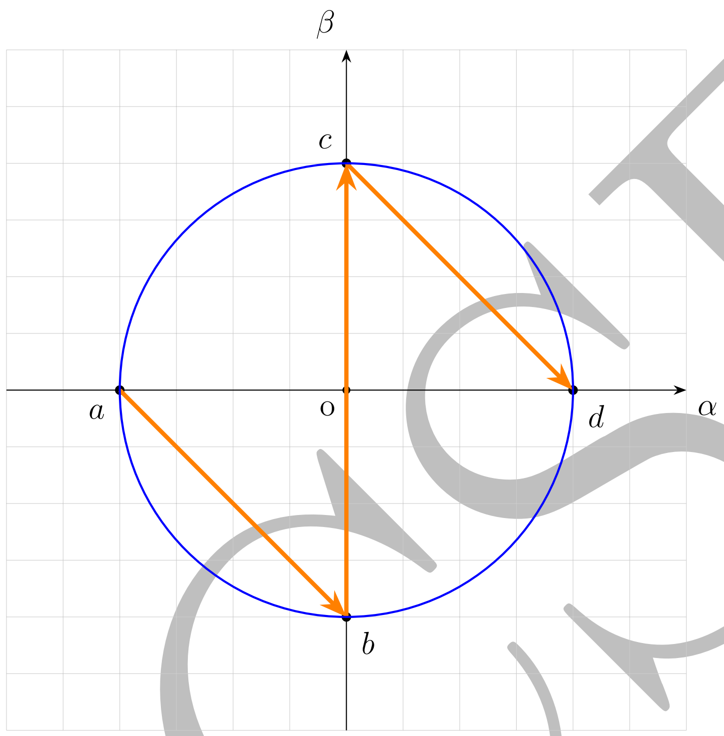
Solution:

Instance	α	β
Start	-1	0
Phase 2	0	-1
Phase 3	0	1
Phase 4	1	0



(c) (3 marks) On this phase diagram, we can plot several constant energy contours. Draw the constant energy contour, on the same grid given in part (b), that passes through the phase points that you have plotted.

Solution:



The circle's equation is given by,

$$\alpha^2 + \beta^2 = 1$$
$$m_1 v_1^2 + m_2 v_2^2 = 1$$
$$\therefore \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 = \frac{1}{2} = \text{constant}$$

The circle represents the mathematical set of all points where total kinetic energy is conserved. Since, the collisions are elastic and instantaneous, there is no change in potential energy throughout the motion. Hence the circle represents the set of points where total energy is conserved.

(d) (6 marks) Consider a general case with arbitrary values of m_1 and m_2. In the phase diagram for this general case, let points a, b, c be the first three phase points. Let $\angle abc = \theta$. Find expression for θ in terms of m_1 and m_2.

Solution:
The line ab represents the first collision. We recall that the linear momentum is conserved in the collision.

$$\therefore m_1 v_1 + m_2 v_2 = \text{constant}$$
$$\sqrt{m_1}\alpha + \sqrt{m_2}\beta = \text{constant}$$

$$\therefore \text{slope} = \frac{d\beta}{d\alpha} = -\sqrt{\frac{m_1}{m_2}}$$

When there is a collision with the wall, the velocity of m_2 just reverses. So the line representing that collision (line bc) will be exactly vertical.

$$\angle abc = \theta$$

$$\theta = \tan^{-1}\left(\frac{1}{\text{slope}}\right)$$

$$\boxed{\theta = \tan^{-1}\left(-\sqrt{\frac{m_2}{m_1}}\right)}$$

(e) (3 marks) Using this information from part (d) draw a complete phase diagram for $m_1 = 4m_2$.

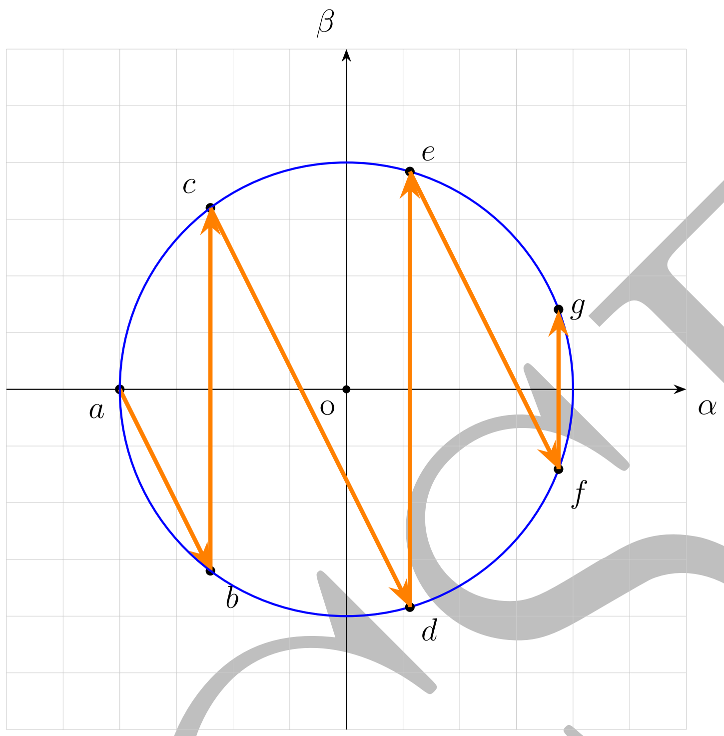
Solution:

Here it is important to notice following points:

- At all collisions between the blocks, the momentum transfer ratio is exactly the same. Hence all lines representing those collisions will be exactly parallel.
- During each phase, the point must be on the circumference of the circle (energy conservation). Hence we are looking for intersections between the lines and the circle.
- The x coordinate of the path will either remain constant or will increase. Thus, at some point we will reach a place, where we cannot draw the next line following the rules above. That would be the last collision.

One should realise that the slope of the inclined line is exactly -2. Then it would be easier to draw the lines on the graph and find the points.

Instance	α	β
Start	-2	0
Phase 2	-1.2	-1.6
Phase 3	-1.2	1.6



Point g will be the last phase as the next inclined line will go outside the circle. The number of collisions are same as the number of lines, i.e. 6.

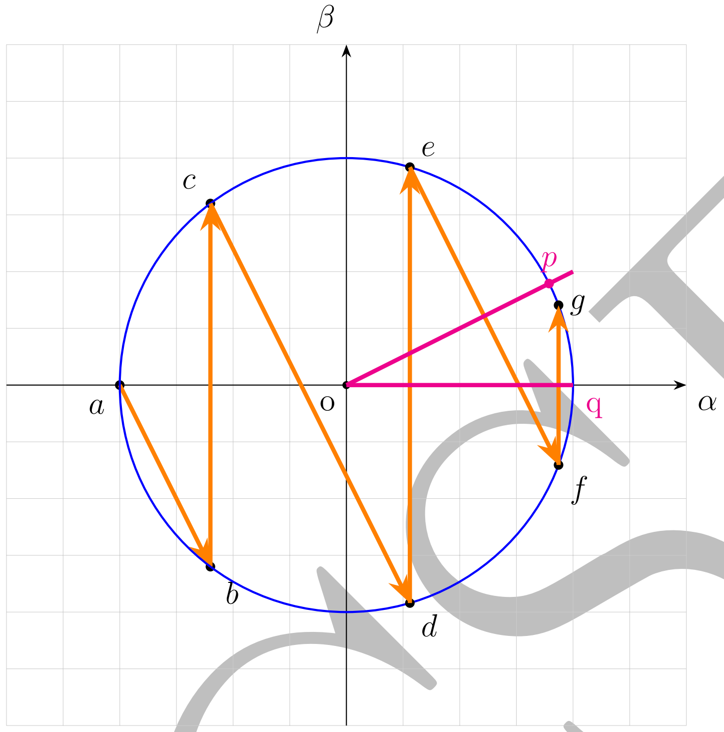
(f) (3 marks) You may have realised, in a general case, i.e. for an arbitrary ratio m_1/m_2, you will be able to define a region of this curve in which the last phase point must lie. If p and q are the end points of that region on the curve and o is the origin, find equations of lines op and oq.
Draw these lines for $m_1/m_2 = 4$ case in the diagram of part (e).
Hint: In one of the two equations, you will be using the ratio $\dfrac{m_2}{m_1}$.

Solution:
The upper end of the arc will be the point p, where the inclined line starting from p will be a tangent to the circle. The line op, being the radial line, will be exactly perpendicular to the inclined line. Thus,

$$\text{Slope}_{\text{op}} = -\tan\theta = \sqrt{\frac{m_2}{m_1}} = \frac{1}{2}$$

For point q, one should realise that the lower end of the arc can go upto x-axis, but not below. Having the last point below x-axis is a contradiction, as then you will always be able to draw a vertical line from it and get the next point. Thus,

$$\text{Slope}_{\text{oq}} = 0$$



(g) (5 marks) Write an inequality showing bounds on n, where n is the total number of collisions, in terms of m_1 and m_2.
Hint: Find an inequality between θ and n.

Solution:
We notice there are two sets of parallel lines. Lines ab, cd, and ef are parallel to each other. Lines bc, de, and fg are parallel to each other. Thus, using the opposite angle property,

$$\measuredangle abc = \measuredangle bcd = \measuredangle cde = \measuredangle def = \measuredangle efg = \theta$$

Now, these angles have their apex on the circumference of the circle and the cut an arc of the circle. Thus, by the property of the circle,

$$\measuredangle aoc = 2\measuredangle abc = 2\theta$$

Note that all arcs except the last one (total $n-1$ arcs) subtend this same angle at the origin. And the last angle, i.e. $\measuredangle fog \leq \theta$. (It will be exactly equal to θ, if the last two points are exactly p and q.) Thus,

$$2\theta \times (n-1) < 2\pi$$
$$2\theta \times n \geq 2\pi$$
$$\therefore \frac{\pi}{\theta} \leq n < \frac{\pi}{\theta} + 1$$
$$\frac{\pi}{\tan^{-1}\left(-\sqrt{\frac{m_2}{m_1}}\right)} \leq n < \frac{\pi}{\tan^{-1}\left(-\sqrt{\frac{m_2}{m_1}}\right)} + 1$$

(h) (3 marks) Lastly, use the information above to estimate the total number of collisions, n_{total}, for the case $m_1 = 10^{10} m_2$.

Solution:

For such a large ratio of $\frac{m_1}{m_2}$, each arc and the angle subtended by it becomes very small.

Using a small angle approximation,

$$\frac{\pi}{\left(-\sqrt{\frac{m_2}{m_1}}\right)} \leq n < \frac{\pi}{\left(-\sqrt{\frac{m_2}{m_1}}\right)} + 1$$

$$\therefore -\pi\sqrt{\frac{m_1}{m_2}} \leq n < -\pi\sqrt{\frac{m_1}{m_2}} + 1$$

$$\pi\sqrt{\frac{m_1}{m_2}} \geq n > \pi\sqrt{\frac{m_1}{m_2}} - 1$$

$$3.1415926 \times 10^5 \geq n > 3.1415926 \times 10^5 - 1$$

$$314159.26 \geq n > 314158.26$$

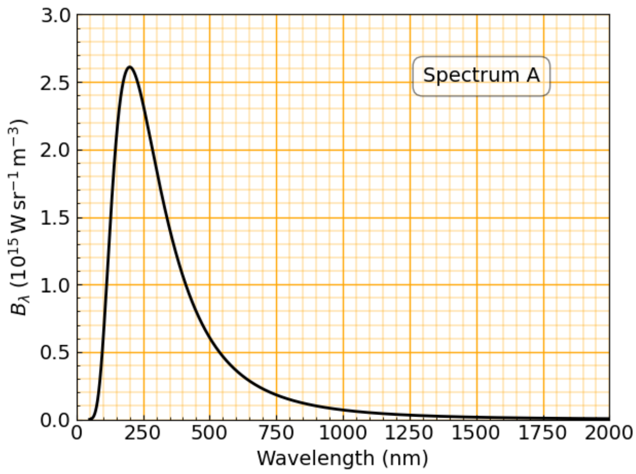
As the number of collisions is always an integer, we get

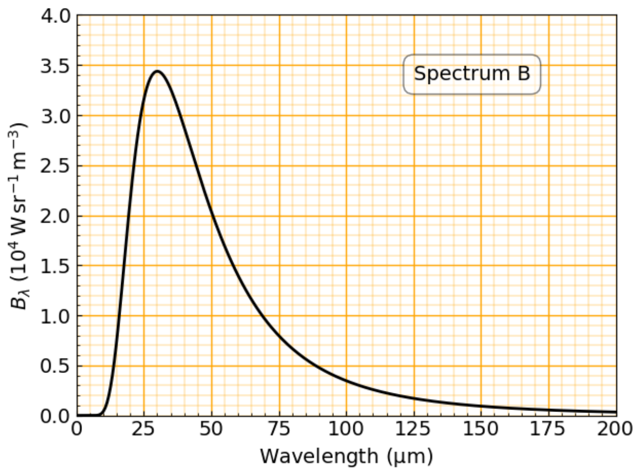
$$\boxed{n_{\text{total}} = 314159}$$

4. **Blackbody Radiation**

(a) (4 marks) Consider a star of radius $R_s = 3\,\mathrm{R}_\odot$ and a gas cloud of radius R_g at a distance d from the star. Assume that the gas cloud doesn't contain any source of radiation and there are no other stars in the vicinity of this system. Both the star and the gas cloud can be assumed to be blackbodies.

You are given two spectra (A and B) below. Determine which spectra corresponds to the star and which corresponds to the gas cloud. Justify your answer. Also, calculate the effective temperature for the star, T_s, and for the gas cloud, T_g.





Solution:
From the above graphs, we get
$\lambda_{\text{max, A}} = 200\,\text{nm}$ and $\lambda_{\text{max, B}} = 30\,\mu\text{m}$.
Since, $\lambda_{\text{max, A}} << \lambda_{\text{max, B}}$,
spectrum A corresponds to that of a star and
spectrum B corresponds to that of the gas cloud.
From Wien's law,

$$\lambda_{\text{max}}\, T = 2.898 \times 10^{-3}\,\text{m K}$$

$$\text{for spectrum A, } T_{\text{s}} = \frac{2.898 \times 10^{-3}}{\lambda_{\text{max, A}}}$$

$$\boxed{T_{\text{s}} = 14\,490\,\text{K} \approx 14\,500\,\text{K}}$$

$$\text{for spectrum B, } T_{\text{g}} = \frac{2.898 \times 10^{-3}}{\lambda_{\text{max, B}}}$$

$$\boxed{T_{\text{g}} = 96.6\,\text{K} \approx 97\,\text{K}}$$

(b) (4 marks) Calculate the distance, d, of the gas cloud from the star.

Solution:
The luminosity of the star is given by,

$$L_{\text{s}} = 4\pi R_{\text{s}}^2 \sigma T_{\text{s}}^4$$

The flux at a distance d from the star is given by $L_{\text{s}}/(4\pi d^2)$. Since the gas cloud is assumed to be a blackbody the energy absorbed per unit time by a cross-sectional area of πR_{g}^2 is -

$$\text{Energy absorbed per unit time } = \frac{4\pi R_{\text{s}}^2 \sigma T_{\text{s}}^4}{4\pi d^2} \times \pi R_{\text{g}}^2$$

The luminosity or energy emitted per unit time by the gas cloud is given by,

$$\text{Energy emitted per unit time } = 4\pi R_{\text{g}}^2 \sigma T_{\text{g}}^4$$

In equilibrium, the energy absorbed and emitted per unit time is the same, therefore,

$$d^2 = \frac{T_{\text{s}}^4}{4T_{\text{g}}^4} R_{\text{s}}^2$$

$$d = \frac{T_{\text{s}}^2}{2T_{\text{g}}^2} R_{\text{s}}$$

$$\boxed{d = 2.348 \times 10^{13}\,\text{km} \approx 2.3 \times 10^{13}\,\text{km}}$$

$$\boxed{d = 156.9\,\text{au} \approx 1.6 \times 10^{2}\,\text{au}}$$

5. (10 marks) **Observing the ISS**
The International Space Station (ISS) is sometimes visible in the sky, during the morning and evening twilight, as a bright moving object. One day, Kundan sees the ISS rising at the horizon, then passing near the zenith, and then setting in the opposite direction.

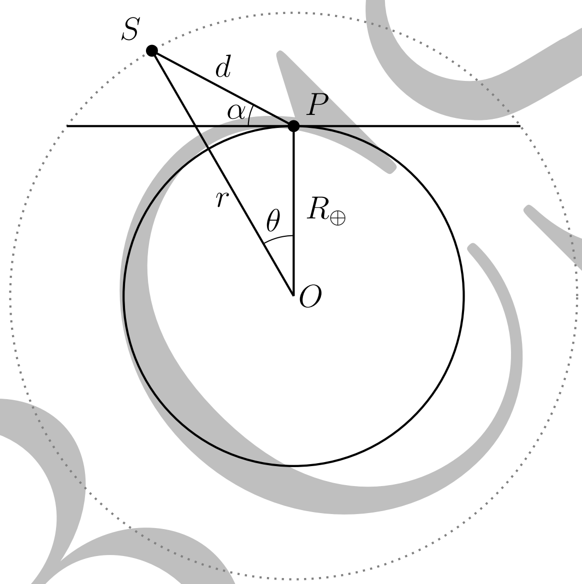
Consider the ISS to be w metre across and orbiting the Earth in a circular orbit at a height x metre above the Earth's surface.

Derive an expression for its apparent angular size, ϕ, measured by Kundan as a function of its altitude from Kundan's location.

Solution:

Let us first draw the diagram and mark the quantities of interest:

here, $r = R_\oplus + x$



Expressing the central angle (θ) in terms of the ISS's altitude (α):
Applying the Law of Sines to sides $R_\oplus$ and r :

$$\frac{\sin(\angle SPO)}{r} = \frac{\sin(\angle OSP)}{R_\oplus}$$

Substitute $\angle SPO = 90^\circ + \alpha$ and $\angle OSP = 90^\circ - (\theta + \alpha)$:

$$\frac{\sin(90^\circ + \alpha)}{r} = \frac{\sin(90^\circ - (\theta + \alpha))}{R_\oplus}$$
$$\frac{\cos(\alpha)}{r} = \frac{\cos(\theta + \alpha)}{R_\oplus}$$

Rearranging for θ we get,

$$\theta = \arccos\left(\frac{R_\oplus}{r}\cos(\alpha)\right) - \alpha$$

Expressing the distance to the ISS (d) in terms of θ and α:
Applying the Law of Sines to sides r and d

$$\frac{\sin(\angle SPO)}{r} = \frac{\sin(\angle SOP)}{d}$$

Substitute $\angle SPO = 90^\circ + \alpha$ and $\angle SOP = \theta$:

$$\frac{\cos(\alpha)}{r} = \frac{\sin(\theta)}{d}$$
$$d = \frac{r}{\cos\alpha}\sin\theta$$

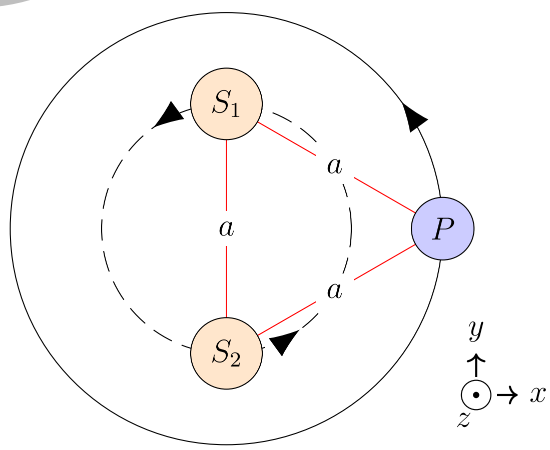
Now substituting θ, we get,

$$d = \frac{r}{\cos(\alpha)}\sin\left(\arccos\left(\frac{R_\oplus}{r}\cos(\alpha)\right) - \alpha\right)$$

Expressing the apparent angular size (ϕ) in terms of its size (w) and distance (d)

$$\phi = \frac{w}{d}$$
$$\boxed{\phi = \frac{w}{\frac{r}{\cos(\alpha)}\sin\left(\arccos\left(\frac{R_\oplus}{r}\cos(\alpha)\right) - \alpha\right)}}$$

6. **Planet's Orbit around a Binary Star System:**
Dhananjay, an exoplanet researcher, wanted to explore the prospects of life on an Earth like planet in a binary star system. More specifically he wanted to look into the following configuration: two identical stars S_1, S_2 and a planet P have circular orbits about the center of mass of the system and at every point in time, the three bodies form a equilateral triangle with side of length $a = 2\,\mathrm{au}$ as shown in the figure below. (Note that at the instance shown in this figure, the radius vector from the centre of mass of the system to P is exactly along the x-axis).



The period t_P of such a system is known to be:

$$t_\mathrm{P} = \sqrt{\frac{4\pi^2 a^3}{G(m_1 + m_2 + m_3)}}$$

You can take the mass and radius of the planet P to be exactly that of Earth and the two stars are Sun like. The sidereal period of rotation of P is $1\,\mathrm{d}$ and the angle made by the P's axis of rotation with the z-axis in the diagram above, called the axial tilt, is $\epsilon = 30^\circ$.

Help Dhananjay answer the following questions about the planet:

(a) (3 marks) Taking the albedo of the planet P to be $A = 0.15$, estimate its average surface temperature (T_P).

Solution:

The flux at the planet due to each of the stars is

$$f_{\mathrm{S}_1} = f_{\mathrm{S}_2} = \frac{L_\odot}{4\pi a^2}$$

In equilibrium, the energy absorbed is the energy radiated,

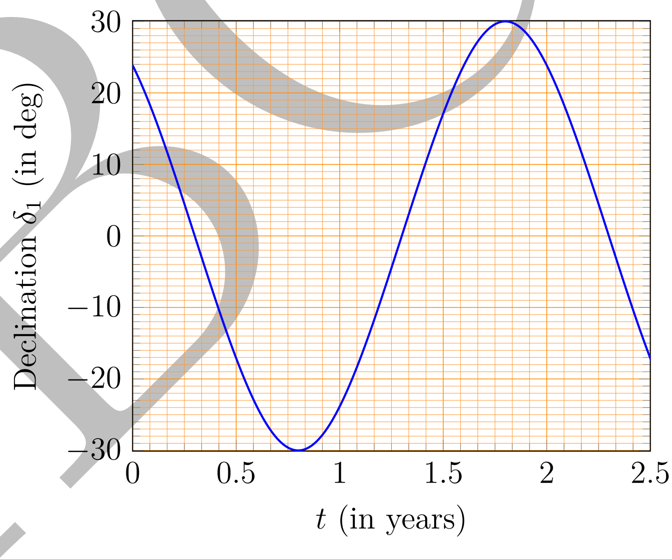
$$\sigma(4\pi R_\mathrm{P}^2)T_\mathrm{P}^4 = (1-A)f_{\mathrm{S}_1}(\pi R_\mathrm{P}^2) + (1-A)f_{\mathrm{S}_2}(\pi R_\mathrm{P}^2)$$

$$T_\mathrm{P} = \left(\frac{(1-A)L\odot}{8\pi\sigma a^2}\right)^{\frac{1}{4}}$$

$$= \left(\frac{(1-0.15)\times 3.828\times 10^{26}}{8\pi\times(5.670\times 10^{-8})\times(2\times 1.496\times 10^{11})^2}\right)^{\frac{1}{4}}$$

$$\boxed{T_\mathrm{P} = 224.73\,\mathrm{K} \approx 225\,\mathrm{K}}$$

Dhananjay calculated the variation of declination, δ_1, of star 1 with time as seen from the planet. This variation is plotted in the figure below.

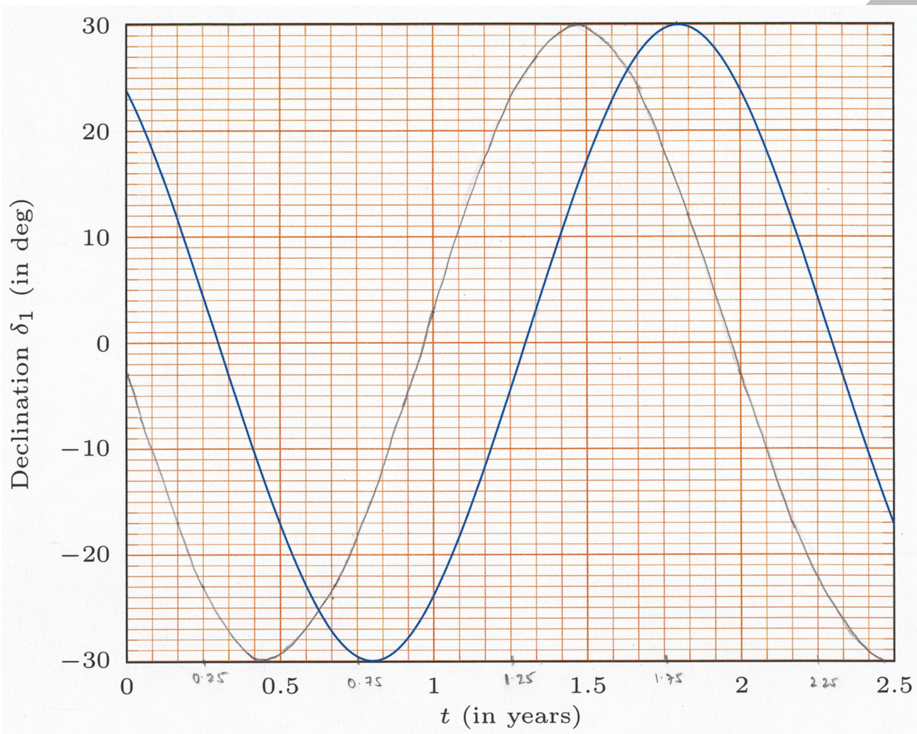


Note that declination is defined in the usual sense - the angle made by the object with the celestial equator of the planet.

(b) (4 marks) Plot the declination, δ_2, of star S_2 vs time in the plot provided in answersheet.

Solution:

The plot for δ_2 vs t should be ahead of δ_1 by 60° in phase ($\frac{1}{6}^{\text{th}}$ of period). To reason about this, imagine a distant star in the direction of x-axis. Clearly PS_1 aligns along x-axis $\frac{1}{6}^{\text{th}}$ period after PS_2



(c) (6 marks) The configuration of the two stars and planet system shown in the figure given in the preamble of the question is the orientation of the system corresponding to time $t = 0$ in the declination vs time plot.
In the figure given in the answersheet, mark the direction of the equinoxes, as seen from the planet, with respect to the x-axis on the orbit of planet. Mark the equinox after which the days get longer, in the northern hemisphere of the planet, with a × and write VE beside it and the other one with Δ and write AE beside it.
Note that the equinox is the day corresponding to the median day length.

Solution:
Using Kepler's 3rd law:

$$t^2 \propto R^3$$

$$\frac{t_{\text{p}}^2}{t_{\oplus}^2} = \left(\frac{4\pi^2}{G(m_1 + m_2 + m_3)} \times (2\,\text{au})^3\right) \times \left(\frac{GM_{\odot}}{4\pi^2} \times \frac{1}{(1\,\text{au})^3}\right)$$

$$t_{\text{p}} = t_{\oplus} \times \sqrt{\frac{M_{\odot}}{2M_{\odot} + m_{\text{p}}}} \times 2^{\frac{3}{2}}$$

Since, $M_{\odot} >> m_{\text{p}}$

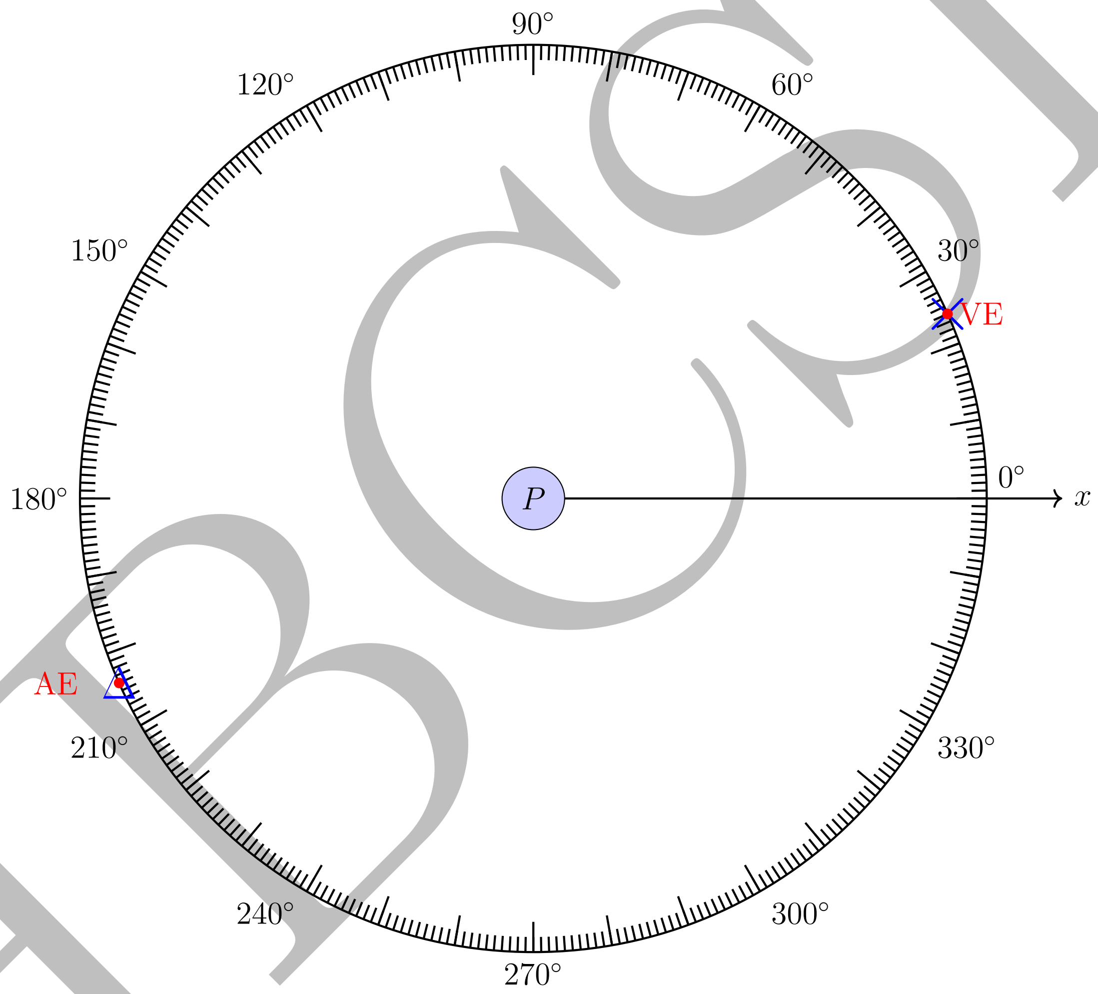
$$t_{\text{p}} = \frac{1}{\sqrt{2}} \times 2^{1.5}$$

$$t_p = 2\,\text{yr}$$

One can estimate the period of the system to be approximately 2 years.
From the figure in declination vs time plot given in the question, $\delta_1 = 0°$ at $t = 0.3\,\text{yr}$ and the declination is decreasing hence star S_1 must be close to AE equinox. This is after $0.3/2 = 0.15$ of period.
At $t = 0$, star S_1 is at an angle 150° to the x-axis. So, AE would be at

$$150° + 0.15 \times 360° = 204°$$

Hence, VE would be at $204° - 180° = 24°$.



(d) (10 marks) We define the effective flux at a point on the planet as the energy per unit area per unit time falling on a tangential plane at that point. Plot the effective flux on the planet's North Pole from $t = 0\,\text{yr}$ to $t = 2.5\,\text{yr}$.

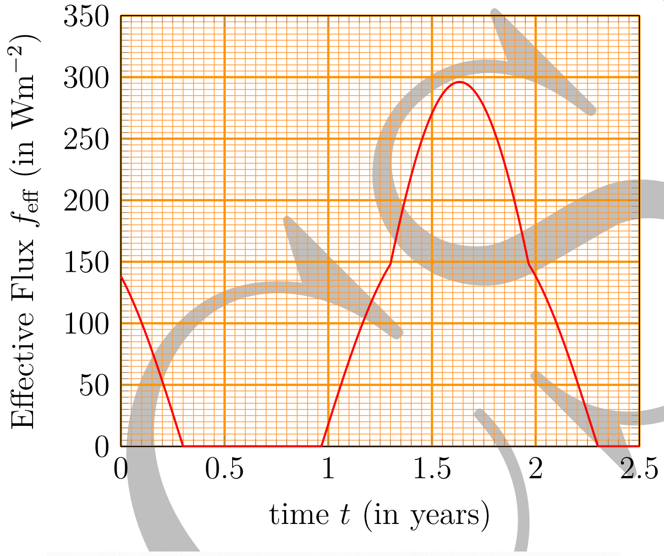
Solution:
Altitude of any star S_i at North pole is equal to its declination,

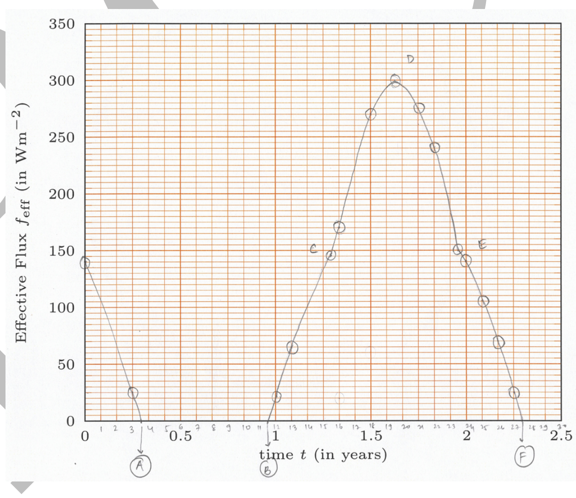
$$\text{alt } S_i = \delta_i$$

Effective flux is simply (except during star rising or setting of a star when part of the star's disc will be blocked)

$$
\begin{aligned}
f_{\text{eff}} &= f_{S_1} \max\{0, \cos(90^\circ - \delta_1)\} + f_{S_2} \max\{0, \cos(90^\circ - \delta_2)\} \\
&= \frac{L_\odot}{4\pi a^2} \times (\max\{0, \sin\delta_1\} + \max\{0, \sin\delta_2\}) \\
f_{\text{eff}} &= 340.3\,\mathrm{W\,m^{-2}} \times (\max\{0, \sin\delta_1\} + \max\{0, \sin\delta_2\})
\end{aligned}
$$

Read off from your own declination vs time plot for a few data points and plot them.





(e) (4 marks) What will be the typical day length at the equator, $t_{\text{day, eq}}$, and the pole, $t_{\text{day, pole}}$? Explain your answer.

Solution:
The angular difference between the two stars as seen from the planet is 60°. So after one star sets, another one will take 4 h to set.
Hence, the day length at the equator will be

$$\boxed{t_{\text{day, eq}} = 16\,\text{h}}$$

On the pole, as seen in the figure in the solution for the earlier part, the effective flux is non-zero for around 1.35 yr.
Hence the typical day length at the pole is

$$\boxed{t_{\text{day, pole}} = 1.35\,\text{yr}}$$

(f) (3 marks) What is/are the number of zero shadow days, N_{ZSD} for an observer on the planet in one period of the system for the following two cases -
Case 1: Latitude $> 30°$
Case 2: Latitude $< 30°$
Explain your answer in brief.

Solution:
Zero shadow days are NOT possible, so the answer is 0.

$$\boxed{N_{\text{ZSD}} = 0}$$

For zero shadow we need to have both stars at the zenith of the observer, or one at zenith and the other below the horizon. The angular separation between the two stars S_1 and S_2 is always $60°$. So, if one star is at the zenith, the other star is bound to be above the horizon. Hence, zero shadow is impossible.