Observation Examination
Telescope Round
Instructions

- You are given an envelope marked B. Please verify the Contestant Code printed on it.
- The Question Paper, a Sky Map, and Summary Answersheets are kept inside the smaller envelope S. **You are allowed to open this envelope (S) only when the whistle is blown to mark the start of the examination.** The exam time (1 hour) starts from this point.
- **Setup**:
  - You are assigned one telescope "station", where you will find a six-inch Newtonian telescope with equatorial (EQ3) mount. You must always remain in the vicinity of your telescope during the exam.
  - The telescope is balanced along both the axes and is also polar-aligned. There is no finder scope attached to the telescope.
  - There is a large projection screen mounted near the ceiling diagonally across the hall. During the exam, you have to point your telescope at this screen.
  - At the station, there is a writing board and an Equipment Box placed beside the telescope, containing the following items:
    1. Two eyepieces: 25 mm and 10 mm (with crosshair)
    2. A head torch
    3. A green pen
    4. A stopwatch

    You should leave these items at the station after use.
  - An Examiner is assigned to your telescope station. Please provide your Contestant Code to the Examiner for verification.
  - The flow of the exam will be as follows:

Lights ON	**20 min**	Question reading and planning observations – At the Table
Lights OFF:	**25 min**	Projection Sequence – At the Telescope
Time (min:sec)	**Duration**	**Projection**
00:00 – 01:10	70 sec	Welcome message (**Use to point the telescope**)
01:10 – 03:10	2 min	Sample Sky (for darkness adaptation, pointing and focusing)
03:10 – 03:20	10 sec	Countdown for Question OT01
03:20 – 09:20	6 min	Sky for Question OT01
09:20 – 09:40	20 sec	Blurred image (**You should move away from the telescope**)
09:40 – 10:40	1 min	Evaluation time for the Examiner for Question OT01
10:40 – 14:40	4 min	Break (You may continue working on your sheet)
14:40 – 15:00	20 sec	Countdown for Question OT02
15:00 – 25:00	10 min	6 runs of Question OT02
Lights ON	**15 min**	Calculations and finalization – At the Table

  - At the start of the exam, you will have 19 minutes to read the question paper, and make any preliminary plans for your observation. During this time, lights in the hall will be on. At the end of this time, a whistle will be blown, and you must leave the table and approach the telescope.
  - For the next 1 minute, you are expected to familiarize yourself with the contents of the Equipment Box, and the telescope, but **you are not allowed to change its orientation from the zenith pointing**.

- At the 20th minute, the whistle will blow again and the hall will go dark. You can now begin your observations with the telescope. The hall will remain dark for the next 25 minutes. During this time you will see different projections on the screen.
- The Examiner will **not** help you in any way during the first question (OT01) to orient or point the telescope towards the screen.
- In the first question (OT01), you have to point at a certain object on the screen using the telescope. After 6 minutes, the screen will be blurred for 20 seconds during which you must move away from the telescope.
- After 20 seconds, the sky projection will be restored to exactly the same view as before. The Examiner will now check the pointing.
- At the end of the first question, there will be a break for 4 minutes. **If you were unable to point the telescope correctly for the first question, you may use this time to point the telescope to the screen. Alternatively, you can ask the Examiner to point the telescope at the screen for the second question at the beginning of the break. This, however, will have a penalty of 1 mark.**
- At the end of Question OT02, the lights in the hall will be switched on and you should go back to the table. You will have 15 minutes to finish your calculations.

- **At the end of the examination:**
  - Check that you have correctly written your Contestant Code and page numbers on all used sheets.
  - Arrange your sheets in the following order:
    Summary Answersheet of (OT01), the sky map Map-OT01, Working Sheet(s) used for (OT01), Summary Answersheet of (OT02), Working Sheet(s) used for (OT02).
  - Place the bunch of the above sheets inside the smaller envelope [S]. Both Summary Answersheets must be placed inside the envelope [S] irrespective of whether you have used them or not.
  - **Only the contents of the smaller envelope [S] will be evaluated. Any sheet that is not placed inside this envelope will not be evaluated.**
  - Place the smaller envelope [S] inside the bigger envelope [B].
  - All other sheets, namely, Instruction Sheet(s), Question Paper(s), Data Sheet(s) and unused Working Sheet(s) should be placed directly inside the bigger envelope [B].
  - Tie the thread seal on the envelope [B].
  - Hand over the envelope [B] to the examiner. Make sure that no sheet is left on the table.

(OT01) Discovery of 'Z' [25 marks]

You are given a sky map "Map-OT01" along with the question paper. This map shows only stars but no diffuse objects.

Four known stars (S1, S2, S3 and S4), which are present in the map above, are given in the table below with their Common names, Bayer designations and Equatorial coordinates.

Sr. No.	Common Name	Bayer Name	RA	Dec
S1	Alpheratz	α Andromedae	00h 08m 24s	$29°5'16''$
S2	Markab	α Pegasi	23h 04m 46s	$15°12'17''$
S3	Scheat	β Pegasi	23h 03m 47s	$28°4'58''$
S4	Algenib	γ Pegasi	00h 13m 14s	$15°10'59''$

Complete the tasks (OT01.1) and (OT01.2) while you are planning the observations.

(OT01.1) Your first task is to mark these 4 stars (with a circle around each star) and label them as S1, S2, S3 and S4 on the sky map "Map-OT01" provided to you. **6**

(OT01.2) An astronomer has discovered a new diffuse object 'Z' at the following coordinates – RA: 21h 36m 10.6s, Dec: $-26°10'24.4''$
Mark the position of this diffuse object on the same sky map "Map-OT01" with a $\oplus$ sign and label it as 'Z'. Assume that a linear rectangular grid for equatorial coordinates is valid in the relevant region of the map. **7**

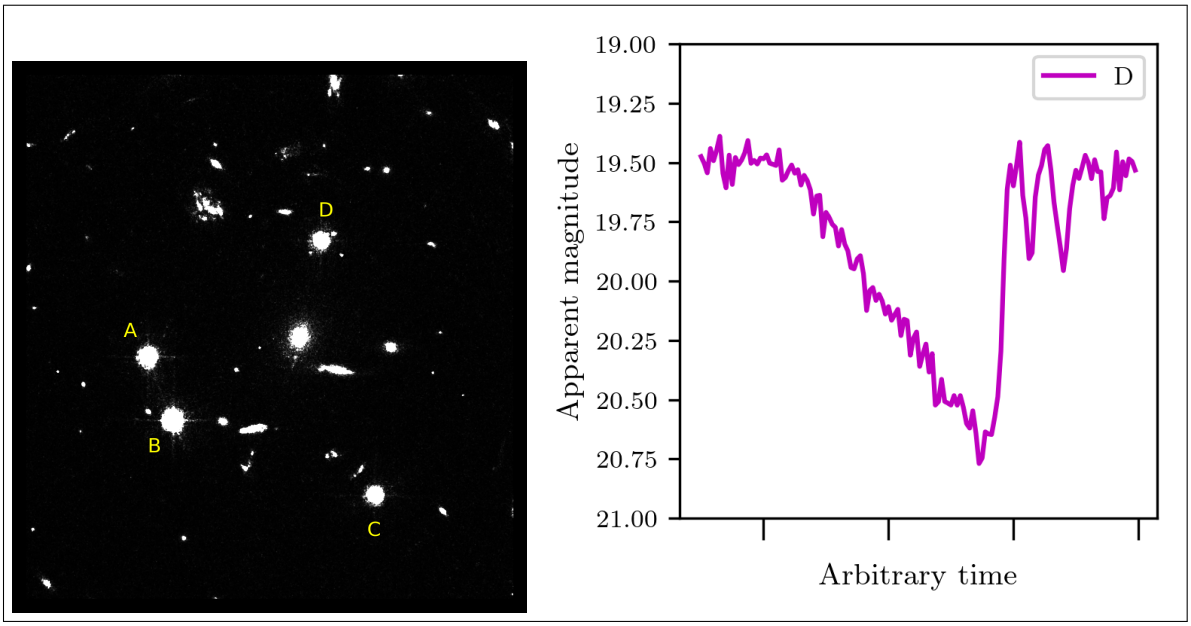
The following task is to be performed once you reach the telescope station.

On the screen diagonally opposite to your station, initially a welcome message, followed by a sample sky (sky unrelated to the question) will be displayed along with a countdown timer. You may use this time to orient the telescope towards the screen and familiarize yourself with other equipment provided at the station. At the end of this time a part of the sky given in the map "Map-OT01" will be projected on the screen for the next 6 minutes. Note that the scale of the projection shown on the screen is different from the actual scale seen in the sky.

(OT01.3) Find the new object 'Z' with the telescope using any appropriate eyepiece. Then centre the object properly in the field of view of the eyepiece with the crosshair, and show it to the examiner at your station. **12**
At the end of 6 minutes, the projection will be blurred for 20 seconds. At this point you must step away from the telescope. The projection will be restored for the examiner to check the view through the telescope. This marks the end of the first task.

(OT02) **Lensing Time Delay** **[25 marks]**

Gravitational lensing can result in multiple images of a background source if the source, the lensing object and the observer are nearly aligned. These multiple images take different times to reach the observer, and if the background source is variable, each image shows the same feature in its variability after specific time delays. These time delay measurements are extremely useful to estimate the current expansion rate of the Universe, the Hubble constant.



We will consider the gravitational lens system shown in the above figure. The left hand panel shows a galaxy cluster (lens) together with 4 images of a background quasar formed due to gravitational lensing. The 4 images, labelled A, B, C and D, have different fluxes as each image is magnified by a different amount. For any given image the magnification does not change with time. Light takes the largest time to travel for the image labelled D.

The light coming from this quasar is variable, and astronomers have monitored this system for more than a decade now. The right hand panel of the figure shows the light curve for the image D.

On the screen opposite to your station you will see a movie of the gravitational lens system. This movie is 28 s long and will loop 6 times with a breaks of 1 minute or 2 minutes between runs. Every second on the watch corresponds to 250.0 days in the actual lens system.

(OT02.1) Let the time delays of image D with respect to images A, B and C be given as $t_{DA} = t_D - t_A$, $t_{DB} = t_D - t_B$, and $t_{DC} = t_D - t_C$, respectively. Find these time delays, taking any necessary steps to reduce the uncertainty in your results. **25**

Map-OT01

Contestant Code | | | | | - | | |

Summary Answersheet

FRONT

Contestant Code				–		

Q. No.	OT01	Page No.	SA-1

Final answers

(OT01.1)	Use "Map-OT01"	**Marks (6.0)**
(OT01.2)	Use "Map-OT01"	**Marks (7.0)**
(OT01.3)	Pointing telescope to 'Z'	**Marks (12.0)**

Total:

End of Summary Answersheet

18th IOAA MUMBAI, INDIA - 2025

Summary Answersheet

BACK

Contestant Code				–		

Q. No.	OT01	Page No.	SA-2

Final answers

(OT02.1) **Marks (25.0)**

Run	t_A	t_B	t_C	t_D

t_{DA} =

t_{DB} =

t_{DC} =

Total:

End of Summary Answersheet

18th IOAA MUMBAI, INDIA - 2025

Summary Answersheet

BACK

Contestant Code				–		

Q. No.	OT02	Page No.	SA-4

(OT01) **Discovery of 'Z'** **[25 marks]**

You are given a sky map "Map-OT01" along with the question paper. This map shows only stars but no diffuse objects.

Four known stars (S1, S2, S3 and S4), which are present in the map above, are given in the table below with their Common names, Bayer designations and Equatorial coordinates.

Sr. No.	Common Name	Bayer Name	RA	Dec
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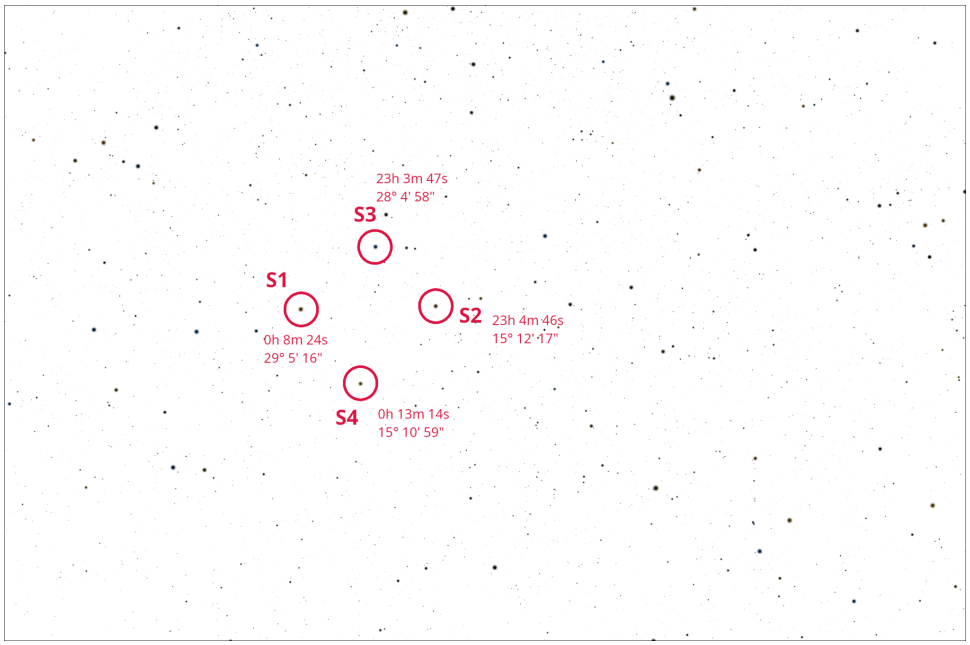
Complete the tasks (OT01.1) and (OT01.2) while you are planning the observations.

(OT01.1) Your first task is to mark these 4 stars (with a circle around each star) and label them as S1, S2, S3 and S4 on the sky map "Map-OT01" provided to you. **6**

Solution:



Circle around each correct star	0.5
Correct identification as S1–S4 of each star	1.0

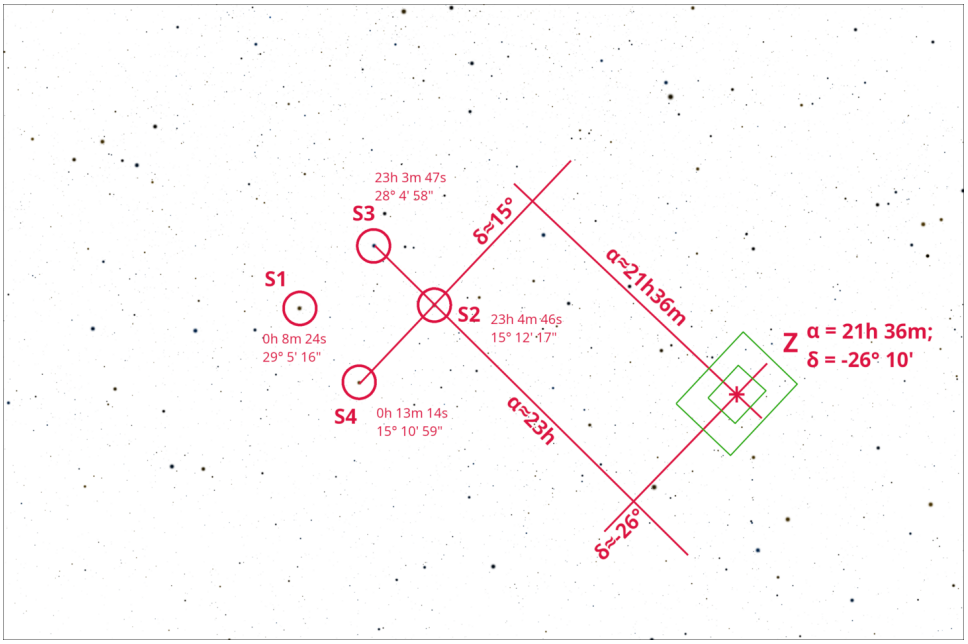
(OT01.2) An astronomer has discovered a new diffuse object 'Z' at the following coordinates – RA: 21h 36m 10.6s, Dec: $-26°10'24.4''$ **7**

Mark the position of this diffuse object on the same sky map "Map-OT01" with a $\oplus$ sign and label it as 'Z'. Assume that a linear rectangular grid for equatorial coordinates is valid in the relevant region of the map.

Solution:

- Realize that two stars have almost the same RA and two of them have almost same declination.

- We draw a line through them indicating constant RA and constant Declination.
- Given the scale of the map and the separation between the 4 stars and the new object we can assume that the celestial grid will be almost linear.
- We can thus mark 'Z' at its given coordinates.



Object marked within inner rectangle	7.0
Object marked between outer and inner rectangles	4.0

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(OT01.3) Find the new object 'Z' with the telescope using any appropriate eyepiece. Then centre the object properly in the field of view of the eyepiece with the crosshair, and show it to the examiner at your station. **12**

At the end of 6 minutes, the projection will be blurred for 20 seconds. At this point you must step away from the telescope. The projection will be restored for the examiner to check the view through the telescope. This marks the end of the first task.

Solution:

- After marking the new object on the given sky map, we carefully look at its position and the star pattern surrounding it
- Using the 25 mm focal length eyepiece we try to locate it

- By doing some fine adjustments, we try to bring the same pattern in the 10 mm focal length eye piece (which has a crosshair)

Pointing towards the screen	1.0

If 10mm objective is used:

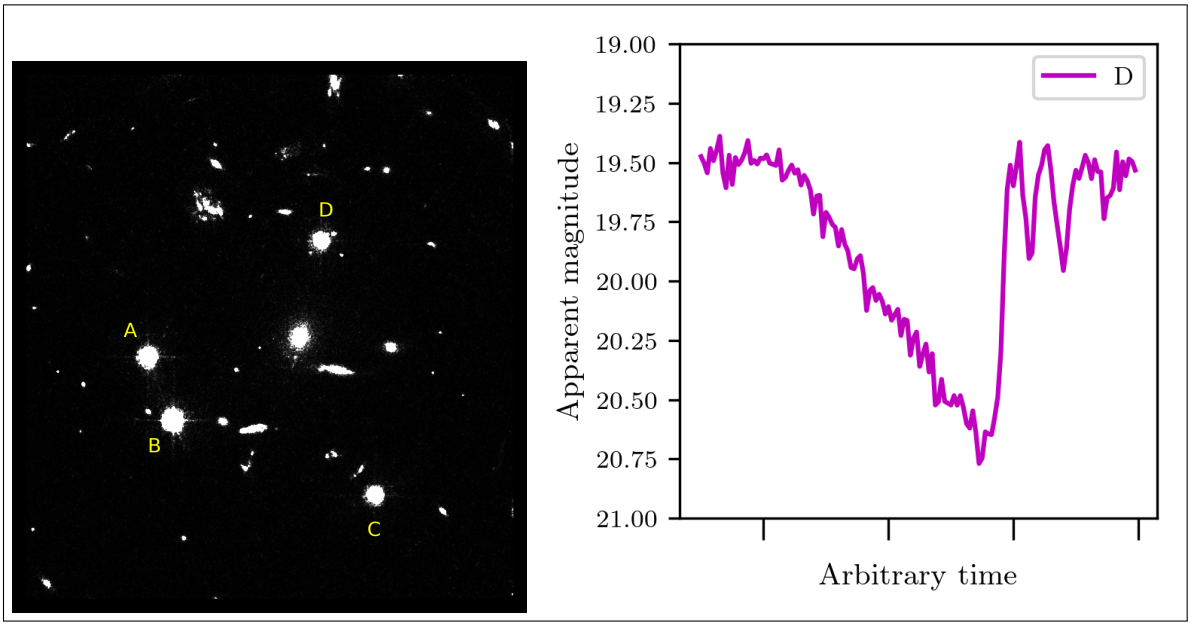
Correct choice of eyepiece	2.0
Object is anywhere in FOV	3.0
Any part of the object is touching the origin of crosshair	6.0

If 25mm objective is used:

Object is anywhere in FOV	3.0

(OT02) **Lensing Time Delay** **[25 marks]**

Gravitational lensing can result in multiple images of a background source if the source, the lensing object and the observer are nearly aligned. These multiple images take different times to reach the observer, and if the background source is variable, each image shows the same feature in its variability after specific time delays. These time delay measurements are extremely useful to estimate the current expansion rate of the Universe, the Hubble constant.



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Solution:

The solution is $t_{DA} = 1694\,\mathrm{d}$, $t_{DB} = 1651\,\mathrm{d}$ and $t_{DC} = 2485\,\mathrm{d}$.

Pointing towards the screen	1.0
Choice of correct eyepiece	1.0

For each of images A, B, C, D

Timings of image	2.0

At least one reading	1.0
Extra reading (0.5 each, maximum 1.0)	1.0

Calculation of time differences

Calculation each of t_{DA}, t_{DB} and t_{DC}	3.0

Half credit lower limit	Full credit range	Half credit upper limit
Value -50 d	Value -25 d to Value $+25$ d	Value $+50$ d

Scaling from seconds to days for each interval	1.0

Correct order ($t_{DC} > t_{DA} > t_{DB}$)	3.0

Map-OT01

Contestant Code | | | | | - | | |