

**Group competition rules**

1. Teams consisting of three or more students can participate in the group competition.
2. The team will be given a set of 5 problems to solve in 60 minutes.
3. The team's result is decided by the sum total of the points obtained for all 5 problems. Up to 20 points can be obtained for each problem. The team can gain extra points by handing in their solutions to all 5 problems before the end of the allotted 60 minutes, and will lose points for time taken beyond the 60 minutes, as follows:
4. If, at the moment the team's solutions are handed in,  $n$  full minutes are left before the allotted time, then the sum total of the points obtained by the team for their solutions will be multiplied by a factor

$$k = 1 + n/100,$$

thus the team gets an extra 1% of their total result for every minute saved.

5. If the team hand in their solutions  $n$  full minutes after the allotted 60 minutes have passed, the sum total of the points obtained by the team of the team will be multiplied by the factor

$$k = 1 - n/100,$$

thus the team will lose 1% of their result for every minute used beyond the allotted time.

6. The team with the most points after adjustment for time wins.
7. Every student of the winning team will be given a prize and gold medal of the group competition.

**Additional Instructions**

1. You may complete the questions in any order and using any combination of team members working individually or together.
2. Hand your answers in when you have finished working on all of the problems.
3. A team combined from two countries will receive all of the questions in both languages, but should complete and hand in no more than one version of each question.
4. For question 1, mark your answers on the maps provided. For question 3, mark your answers on the question sheet in the appropriate places. For questions 2 and 4 please use the attached answer sheets. For question 5 mark the card.

**Group competition****1. Constellations**

Jan Hevelius (1611–1687) introduced 11 new constellations onto the sky. The International Astronomical Union confirmed 7 of those in 1928:

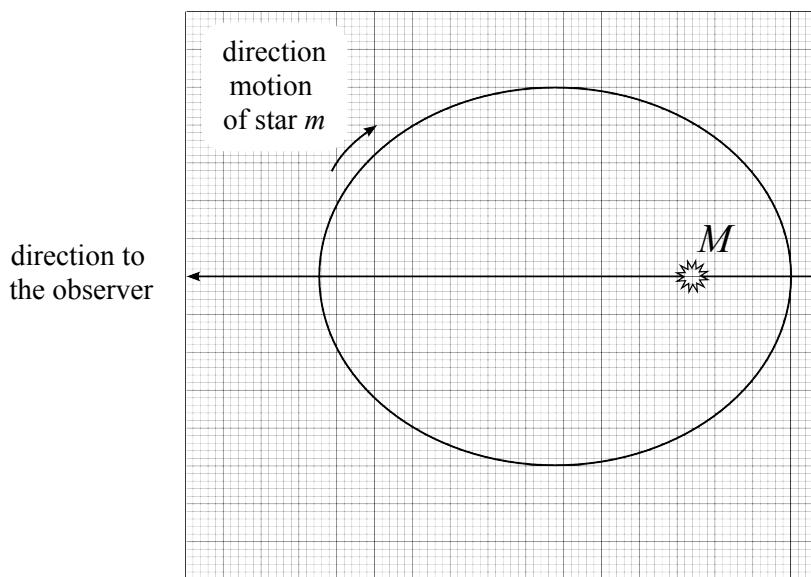
Serial No.	IAU Abbreviation	Latin name	Translation	Equatorial coordinates of the centre of the constellation	
				Right ascension $\alpha$	Declination $\delta$
1	CVn	Canes Venatici	Hunting dogs	13 <sup>h</sup> 00 <sup>m</sup>	+40°
2	Lac	Lacerta	Lizard	22 <sup>h</sup> 30 <sup>m</sup>	+46°
3	LMi	Leo Minor	Smaller Lion	10 <sup>h</sup> 10 <sup>m</sup>	+32°
4	Lyn	Lynx	Lynx	8 <sup>h</sup> 00 <sup>m</sup>	+48°
5	Sct	Scutum	Shield	18 <sup>h</sup> 40 <sup>m</sup>	-10°
6	Sex	Sextans	Sextant	10 <sup>h</sup> 15 <sup>m</sup>	-3°
7	Vul	Vulpecula	(Little) Fox	20 <sup>h</sup> 15 <sup>m</sup>	+24°

- For each of the above constellations, clearly mark on the attached map a point lying anywhere within the constellation, using the appropriate serial number or IAU name.
- On the same map, clearly mark (using a cross or arrow) the positions of any 13 objects from the Messier Catalogue (not necessarily from the constellations above), giving the Messier number (“M xx”) for each.

The map is prepared for epoch J 2000.0 and uses a polar projection with a linear scale in declination. It includes stars brighter than about 5th magnitude.

## 2. Orbital motion

The scale diagram below represents the relative orbit of a physically double star:



A star of mass  $m$  moves around a star of mass  $M$  in the indicated direction, where  $m \ll M$ . The major axis of the ellipse is aligned with the direction to the observer, and the motion of the star is in the plane of the diagram.

- (a) Find the part of the ellipse where the angular velocity  $\omega$  of star  $m$  is less than its mean angular velocity  $\langle\omega\rangle$ , and indicate this as accurately as possible on the scale diagram on the answer sheet.

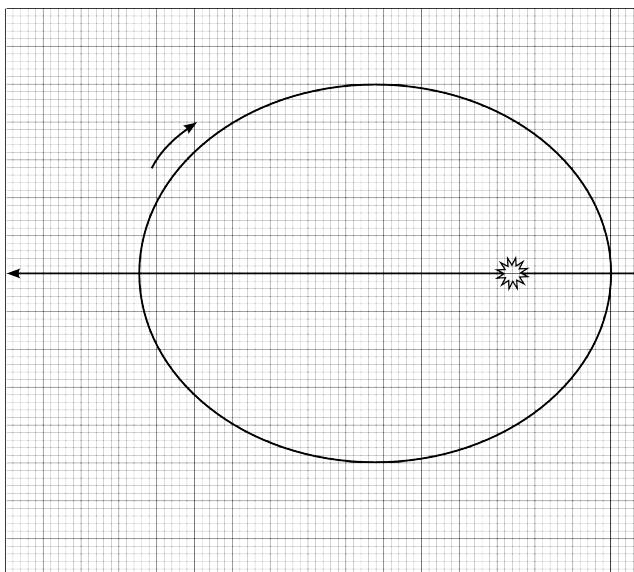
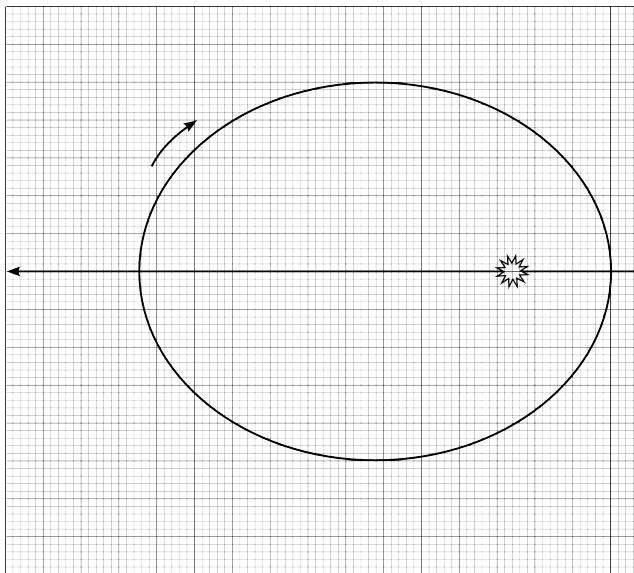
Note: The instantaneous angular velocity  $\omega$  of star  $m$  is equal to the mean angular velocity  $\langle\omega\rangle$  when the distance between stars  $r = \sqrt{ab}$ , where  $a$  and  $b$  are the semi-axes of the orbit.

Also mark those places on the ellipse for which the observer will see:

- (b) extreme tangential (perpendicular to line of sight) velocity:  $v_{t\max}$  and  $v_{t\min}$ ,  
(c) extreme radial (parallel to line of sight) velocity:  $v_{r\max}$  and  $v_{r\min}$ .

(You may use one or both of the diagrams on the answer sheet to show your answer.)

Answer sheet for Question 2



Answer sheet for Question 2

**3. Identifying telescope components**

- (a) Look at the pictures of the telescope and match the names of the items with the corresponding letters. Write your answers in the table below:

Item name	Letter	Points
(example) Tripod	M	0
1. Counterweight		
2. Right Ascension Setting Circle (R.A. Scale)		
3. Declination Setting Circle (Declination Scale)		
4. Right Ascension locking knob		
5. Declination locking knob		
6. Geographical latitude scale		
7. Finder scope		
8. Focuser tube		
9. Focuser knob		
10. Eyepiece		
11. Declination Axis		
12. Right Ascension Axis (Polar Axis)		
13. Right Ascension slow motion adjustment		
14. Declination flexible slow motion adjustment		
15. 90° diagonal mirror		
16. Azimuth adjustment knobs		
17. Altitude adjustment screws		
18. Lock screw		
19. Spirit level bubble		
20. Eyepiece reticle light – on/off switch & brightness control		

(b) Select and circle the correct answer for each of the questions below:

21. Mount design :

- a. Fork      b. Transit      c. Dobsonian Alt-Azimuth      d. German Equatorial

22. Optical type :

- a. Newtonian      b. Cassegrain      c. Keplerian      d. Galilean

23. Objective aperture :

- a. 60 mm      b. 80 mm      c. 90 mm      d. 100 mm

and objective lens focal length :

- a. 400 mm      b. 500 mm      c. 600 mm      d. 800 mm

24. Eyepiece focal length :

- a. 4 mm      b. 6 mm      c. 12.5 mm      d. 25 mm

25. Used for visual observations of the sky, the finder scope gives a picture which is :

- a. normal      b. rotated by 180°      c. reflected in one axis      d. rotated by 90°

26. Used for visual observations **with** the diagonal mirror, the instrument gives a picture which is :

- a. normal      b. rotated by 180°      c. reflected in one axis      d. rotated by 90°

(c) Determine the following theoretical instrument parameters

27. Magnification : \_\_\_\_\_

28. Focal ratio : \_\_\_\_\_

29. Resolution : \_\_\_\_\_  
(in arcseconds)

30. Limiting magnitude: \_\_\_\_\_

#### 4. Minimum of an eclipsing binary

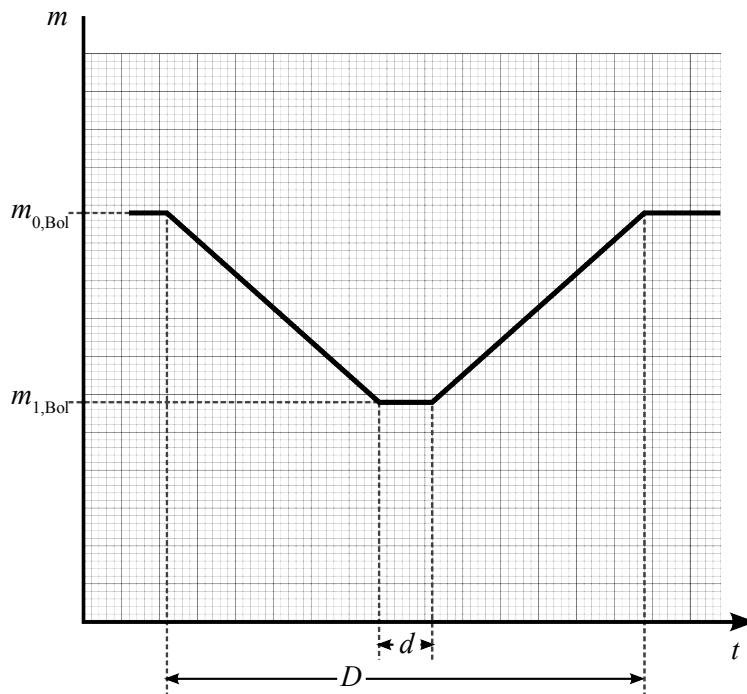
The figure shows the secondary (shallower) minimum of the bolometrically - corrected light curve of an eclipsing binary star. The difference between magnitudes  $m_{1,\text{Bol}} - m_{0,\text{Bol}} = 0.33$  magnitude.

We also know from simultaneous spectroscopy that the star with the smaller radius was totally eclipsed by the larger star during the secondary minimum (since only one spectrum was observable during the minimum).

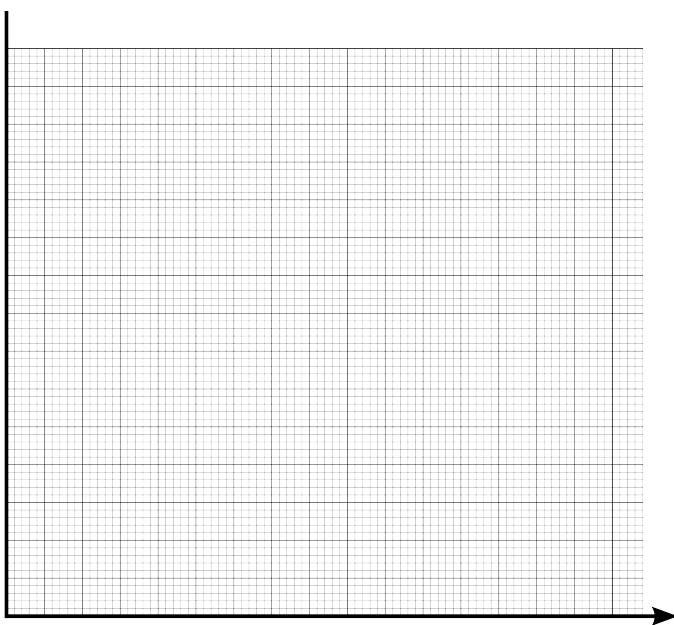
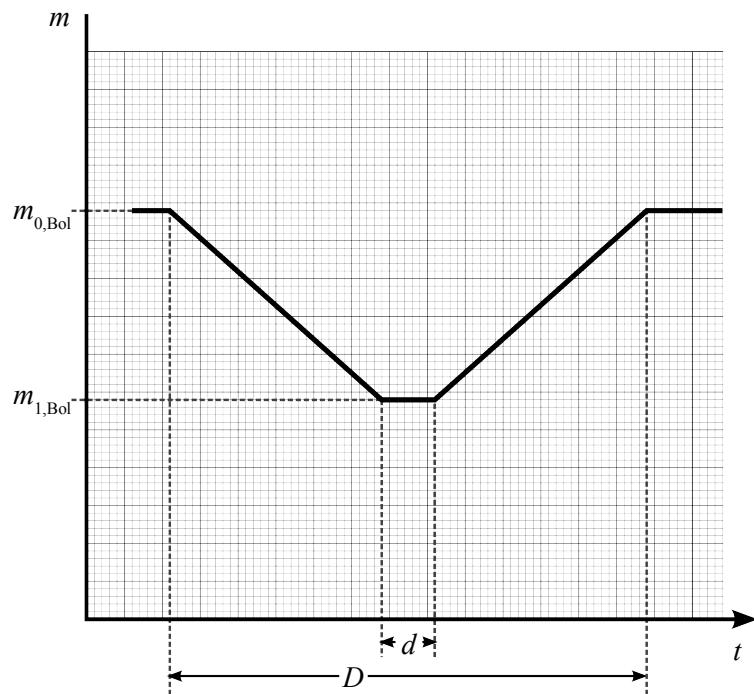
Determine the change of brightness of this binary during the primary minimum and draw the shape of the primary minimum using the same scale as the secondary minimum. Label the graph with all appropriate parameters.

Use the answer sheets (one blank, one with the light curve plots) for your final answers.

You may assume that the eclipses are central, that the stars are spheres of constant surface brightness, and that the distance between the stars does not change.



Answer sheet for Question 4

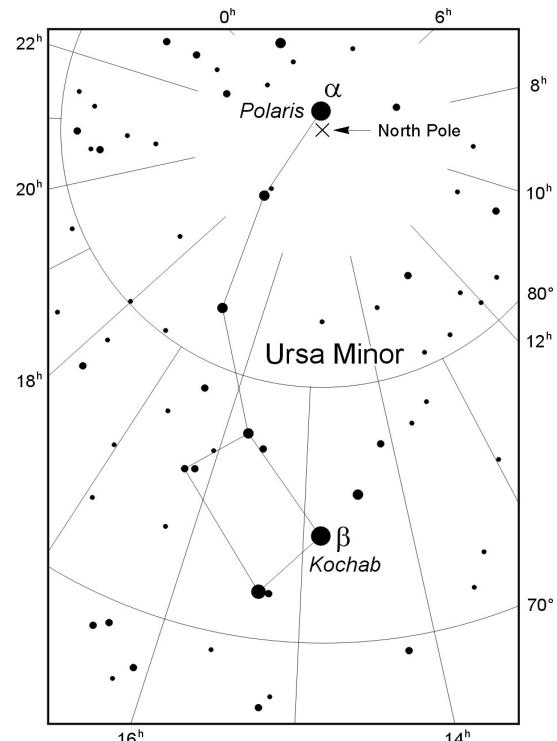
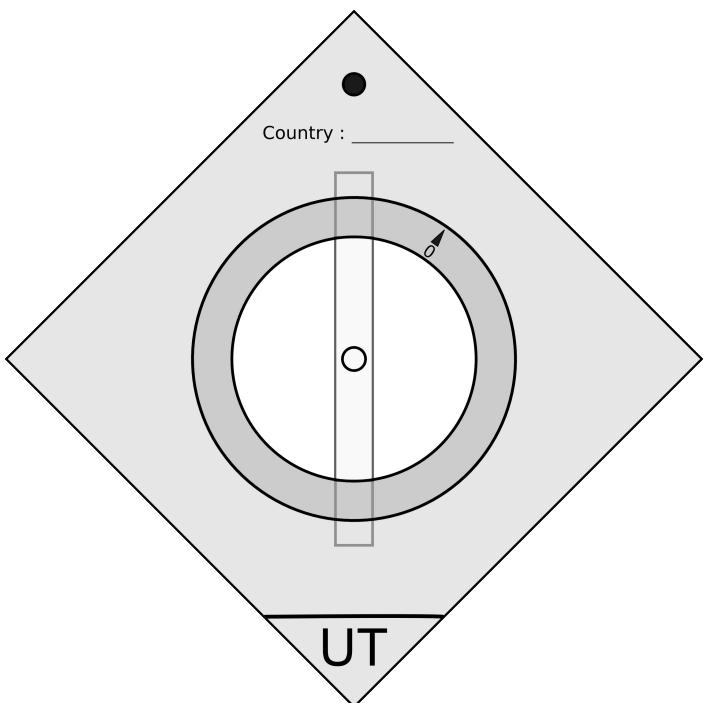


Answer sheet for Question 4

## 5. Nocturnal

Circumpolar stars describe a full circle around the Celestial Pole over 24 hours. This can be used to make a simple clock.

You are given a blank card with a movable ring, along with a clear strip with a centre circle. If the card has a suitable scale, the clear strip is attached as in the diagram below and the Pole Star is visible through the centre circle, then the position of the star Kochab ( $\beta$  UMi) on the inner edge of the ring will give the current time.



Design and mark on the card and ring suitable inner and outer scales (as required) such that, in Katowice for any night of the year, the side of the clock marked "UT" can be used to show current Universal Time, and the other side (marked "ST") can be used independently to show current Local Sidereal Time.

For 27 August in Katowice, the lower culmination of Kochab is at 05:15 Central European Summer Time (UT+2). The coordinates of Kochab ( $\beta$  UMi) are :  $\alpha$ :  $14^{\text{h}} 51^{\text{m}}$ ,  $\delta$ :  $+74.2^{\circ}$ .

Notes: – The blank card is marked with a line which should be held horizontally when the device is used.

- The clear strip will be attached later, after you have finished and handed in the card. For now it is left off so that it does not get in your way when making the scale.