Theoretical round. Problems to solve

General note. Maybe not all problems have correct questions. Some questions (maybe the main question of the problem, maybe one of the subquestions) may make no real sense. In this case you have to write in your answer (in English or Russian): «**impossible situation – ситуация невозможна**». Of course, this answer has to be explained numerically or logically.

Data from the tables (Planetary data, stars, constants, etc.) may be used for solving every problem.

The answers «**Да-Yes**» or «**Нет-No**» have to be written in English or Russian.

1. **Transit of Venus.** Recently, on June 6, 2012, an infrequent astronomical phenomenon, transit of Venus across the solar disc, took place. The next transit of Venus will take place only in 2117. Calculate the date of that transit. (Answer without calculations will not be considered even as a partial solution.)

2. **Transit of Pseudovenus.** Recently, on June 6, 2012, an infrequent astronomical phenomenon, transit of Venus across the solar disc took place. Suppose somebody did not understand the phenomenon and ascribed it not to transit of real Venus but of some moon, which we name Pseudovenus, rotating around the Earth in a circular orbit. Find the radius of the orbit of Pseudovenus and diameter of this sky body. Effects due to axial rotating of the Earth should not be taken into account.

3. **Old persons' star.** There is ancient legend in Korea that says, if you managed to see the "Old persons' star" thrice, you are lucky person and will live a long life. The "Old persons' star", now known as Canopus, was seen brighter and better in past times, but even now sometimes one can see this star in Korea. Estimate approximately what visible stellar magnitude Canopus may have when observing it from the southern coast of Jeju island (Korea) in the most favorable conditions. The territory of the island is located at latitudes between 33°12' N and 33°34' N and longitudes between 126°09' E and 126°57' E. Take from the tables and recollect for yourself the necessary additional information.

4. **Stars on Mars.** As you know, last year the Polar Bear (whom you have already met in the texts of many International Astronomy Olympiads) arrived to Mars for astronomical observations. Nowadays his friend Penguin also made a fascinating journey to Mars. At the same instant of time, the Bear and the Penguin observe stars in zenith and see Canopus and Sirius respectively. Estimate roughly, what is the distance (measured on the Martian surface) between the animals? At what height above the horizon does the Bear observe Sirius? The solution has to include a picture with an image of the Bear and the Penguin on Mars. Necessary sizes or angular sizes should be in the picture. Recollect for yourself the necessary information about the Polar Bear and Penguin.

5. **Venus and Earth.** At what maximum distance from the Venus ecliptic the Earth can be visible in the sky from Venus (actually, from a point outside the Venus atmosphere)? Orbits of the planets may be considered circular.

6. **Parallaxes.** In our part of the Galaxy the mean distance between the stars is about 6 light years. Assume that an interferometer can measure parallaxes with an error of ±0.001 arc second. How many stars of our Galaxy could have their parallax determined by this interferometer?

Theoretical round. Problems to solve

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4. **Altair.** Estimate the density of the star Altair.

5. **Venus and Earth.** At what maximum distance from the Venus ecliptic the Earth can be visible at the sky from Venus (actually, from a point outside the Venus atmosphere)? Orbits of the planets may be considered circular.

   Estimate the stellar magnitude of the Earth in this situation.

6. **Remote galaxy.** Astronomers have discovered a distant galaxy that in the Earth's sky, at the first glance looks like ε Eridani, the same in colour, but 1000 times less in intensity. It appears, however, that this galaxy is composed only of stars similar to the Sun in physical characteristics. Find the number of stars in the galaxy.

Элементы орбит.
Физические характеристики некоторых планет, Луны, Солнца и Эриды

Parameters of orbits.
Physical characteristics of some planets, Moon, Sun and Eris

Небесное тело, планета	Среднее расстояние от центрального тела		Сидерический (или аналогичный) период обращения		Наклон орбиты,	Эксцентриситет,	Экваториальн. диаметр	Масса	Средняя плотность	Ускор. своб. пад. у пов.	Наклон оси	Макс. блеск, вид. с Земли **)	Альбедо
	в *астр. ед.*	в *млн. км*	в тропич. годах	в средних сутках	i	e	*км*	10^{24} *кг*	*г/см*^{3}	*м/с*^{2}			
Body, planet	Average distance to central body		Sidereal period (or analogous)		Orbital inclination,	Eccentricity	Equat. diameter	Mass	Av. density	Grav. accelr. at surf.	Axial tilt	Max. magn. From Earth **)	Albedo
	in ***astr. units***	in 10^6 ***km***	in tropical years	in days	i	e	***km***	10^{24} ***kg***	***g/cm***^{3}	***m/s***^{2}			
Солнце Sun	$1,6\cdot10^9$	$2,5\cdot10^{11}$	$2,2\cdot10^8$	$8\cdot10^{10}$			1392000	1989000	1,409			$-26,74^m$	
Меркурий Mercury	0,387	57,9	0,241	87,969	7,00°	0,206	4 879	0,3302	5,43	3,70	0,01°		0,06
Венера Venus	0,723	108,2	0,615	224,7007	3,40	0,007	12 104	4,8690	5,24	8,87	177,36		0,78
Земля Earth	1,000	149,6	1,000	365,2564	0,00	0,017	12 756	5,9742	5,515	9,81	23,44		0,36
Луна Moon	0,00257	0,38440	0,0748	27,3217	5,15	0,055	3 475	0,0735	3,34	1,62	6,7	$-12,7^m$	0,07
Марс Mars	1,524	227,9	1,880	686,98	1,85	0,093	6 794	0,6419	3,94	3,71	25,19	$-2,0^m$	0,15
Юпитер Jupiter	5,204	778,6	11,862	4 332,59	1,30	0,048	142 984	1899,8	1,33	24,86	3,13	$-2,7^m$	0,66
Сатурн Saturn	9,584	1433,7	29,458	10 759,20	2,48	0,054	120 536	568,50	0,70	10,41	26,73	$0,7^m$	0,68
Эрида Eris	68,05			205 029	43,82	0,435	2 326	0,0167	2,52	0,7			0,96

**) Для Луны – в среднем противостоянии.
**) For Moon – in mean opposition.

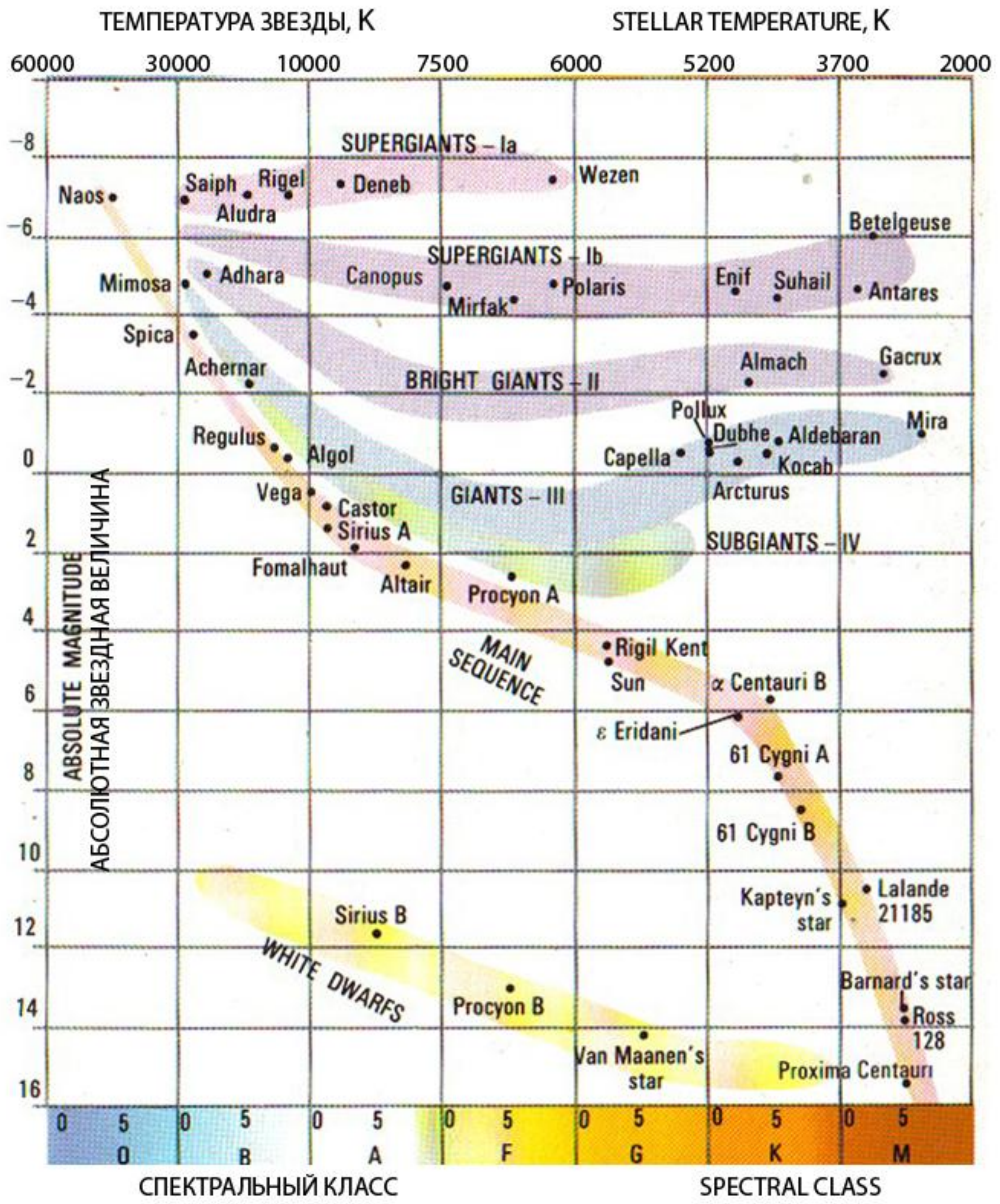
Некоторые константы и формулы
Some constants and formulae

Скорость света в вакууме, c (м/с)	299 792 458	Speed of light in vacuum, c (m/s)
Гравитационная постоянная, G (Н·м²/кг²)	$6.674 \cdot 10^{-11}$	Constant of gravitation, G (N·m²/kg²)
Солнечная постоянная, A (Вт/м²)	1367	Solar constant, A (W/m²)
Параметр Хаббла, H_0 (км/с/МПк) — среднее значение	71	mean value — Hubble parameter, H_0 (km/s/Mpc)
Параметр Хаббла, H_0 (км/с/МПк) — диапазон значений	50-100	diapason of values — Hubble parameter, H_0 (km/s/Mpc)
Постоянная Планка, h (Дж·с)	$6.626 \cdot 10^{-34}$	Plank constant, h (J·s)
Заряд электрона, e (Кл)	$1.602 \cdot 10^{-19}$	Charge of electron, e (C)
Масса электрона, m_e (кг)	$9.109 \cdot 10^{-31}$	Mass of electron, m_e (kg)
Соотношение масс протона и электрона	1836.15	Proton-to-electron ratio
Постоянная Фарадея, F (Кл/моль)	96 485	Faraday constant, F (C/mol)
Магнитная постоянная, μ_0 (Гн/м)	$1.257 \cdot 10^{-6}$	Magnetic constant, μ_0 (H/m)
Универсальная газовая постоянная, R (Дж/моль/К)	8.314	Universal gas constant, R (J/mol/K)
Постоянная Больцмана, k (Дж/К)	$1.381 \cdot 10^{-23}$	Boltzmann constant, k (J/K)
Постоянная Стефана-Больцмана, σ (Вт/м²/К⁴)	$5.670 \cdot 10^{-8}$	Stefan-Boltzmann constant, σ (W/m²/K⁴)
Константа смещения Вина, b (м·К)	0.002897	Wien's displacement constant, b (m·K)
Лабораторная длина волны H**α** (Å)	6562.81	Laboratory wavelength of H**α** (Å)
Длина тропического года, T (сут)	365.242199	Tropical year length, T (days)
Стандартная атмосфера (Па)	101 325	Standard atmosphere (Pa)
Ослабление видимого света земной атмосферой в зените (минимально)	19%, 0.23^m	Visible light extinction by the terrestrial atmosphere in zenith (minimum)
Показатель преломления воды при 20°C, n	1.334	Refractive index of water for 20°C, n
Момент инерции шара	$I = {}^2/_5\, MR^2$	Moment of inertia of a solid ball
Площадь сферы	$S = 4\pi R^2$	Area of sphere
π	3.14159265	π
e	2.71828183	e
Золотое сечение, φ	1.61803399	Golden ratio, φ

Данные о некоторых звёздах
Data of some stars

			RA	DEC	p	m	S C	масса mass
Солнце	Sun	ʘ	0^h – 24^h	-23°26' +23°26'	8".794	$-26^m.74$	G2	1 $M_\odot$
Альдебаран	Aldebaran	α Tau	$04^h\ 35^m\ 55^s$	16° 30' 33"	0".048	$0^m.85^v$	K5	2.5 $M_\odot$
Альтаир	Altair	α Aql	$19^h\ 50^m\ 47^s$	08° 52' 06"	0".195	$0^m.77$	A7	1.7 $M_\odot$
Антарес	Antares	α Sco	$16^h\ 29^m\ 24^s$	-26° 25' 55"	0".006	$0^m.96$	M1+B4	22.4 $M_\odot$
Арктур	Arcturus	α Boo	$14^h\ 15^m\ 40^s$	19° 10' 57"	0".089	$-0^m.04^v$	K1	1.1 $M_\odot$
Ахернар	Achernar	α Eri	$01^h\ 37^m\ 43^s$	-57° 14' 12"	0".026	$0^m.46$	B3	
зв.Барнарда	Barnard's star	Oph	$17^h\ 57^m\ 48^s$	04° 41' 36"	0".545	$9^m.54$	M4	
Бетельгейзе	Betelgeuse	α Ori	$05^h\ 55^m\ 10^s$	07° 24' 25"	0".005	$0^m.5^v$	M1	
Вега	Vega	α Lyr	$18^h\ 36^m\ 56^s$	38° 47' 01"	0".129	$0^m.03$	A0	
Денеб	Deneb	α Cyg	$20^h\ 41^m\ 26^s$	45° 16' 49"	0".002	$1^m.25$	A2	
Канопус	Canopus	α Car	$06^h\ 23^m\ 57^s$	-52° 41' 45"	0".010	$-0^m.72$	F0	
Капелла	Capella	α Aur	$05^h\ 16^m\ 41^s$	45° 59' 53"	0".073	$0^m.08$	G5+G0	
Полярная	Polaris	α UMi	$02^h\ 31^m\ 49^s$	89° 15' 51"	0".0076	$1^m.97^v$	F7	
Процион	Procyon	α CMi	$07^h\ 39^m\ 18^s$	05° 13' 30"	0".288	$0^m.38$	F5	
Ригель	Rigel	β Ori	$05^h\ 14^m\ 32^s$	-08° 12' 06"	0".013	$0^m.12$	B8	
Сириус	Sirius	α CMa	$06^h\ 45^m\ 09^s$	-16° 42' 58"	0".375	$-1^m.46$	A1	
Спика	Spica	α Vir	$13^h\ 25^m\ 12^s$	-11° 09' 41"	0".023	$0^m.98$	B1	
Альфа Центавра	Alpha Centauri	α Cen	$14^h\ 39^m\ 36^s$	-60° 50' 07"	0".751	$-0^m.01$ $1^m.33$	G2 K1	2.0 $M_\odot$
Бета Центавра	Beta Centauri	β Cen	$14^h\ 03^m\ 49^s$	-60° 22' 23"	0".009	$0^m.61$	B1	21 $M_\odot$
Эпсилон Эридана	Epsilon Eridani	ε Eri	$03^h\ 32^m\ 56^s$	-09° 27' 30"	0".311	$3^m.74$	K2	0.82 $M_\odot$

Диаграмма Герцшпрунга-Рассела Hertzsprung-Russell diagram



Practical round. Problem 7 to solve

Note. If you find somewhere in the problems an impossible situation, write in English «**impossible situation**».

7. **Fireball.** A fireball was observed from three different observing sites I, II, III. The position of the observing sites, the altitude and azimuth of start and end points of the fireball's trajectory are given in Table 1. Azimuth is measured eastward from the North direction, and altitude measured above the horizon, and both the angular measurements are in degrees. Following the steps below, find true trajectory and location on the surface of Earth of fallen debris of the fireball (meteorite).

Table 1. Observational Data for a Fireball

observing position			starting point (**A**)		end point (**B**)	
	longitude	latitude	azimuth	altitude	azimuth	altitude
I	127.3°E	+35.7°	17°	35°	77°	10°
II	128.5°E	+37.0°	235°	-	139°	-
III	128.5°E	+35.4°	325°	-	48°	-

7.1. You are provided by a scaled marked graph paper. Mark the 3 observing positions (I, II, III) and draw a projected trajectory of the fireball as seen on the surface of Earth.
7.2. Calculate the longitude and latitude of start (λ_A, φ_A) and end (λ_B, φ_B) points of the fireball and total length **L** of the trajectory projected on the earth surface.
7.3. Find the heights of starting point $\mathbf{h_A}$ and end point $\mathbf{h_B}$. of the fireball's trajectory above the surface of Earth.
7.4. Where can you find a meteorite, if it survives passage through the atmosphere and hits the ground? Calculate the longitude and latitude (λ_C, φ_C) of the location of the meteorite on the surface of Earth's.

Finally, redraw the table below to your answer-book and fill the empty cells with you results.

point	longitude λ	latitude φ	L (km)	h_A (km)	h_B (km)	You may find the meteorite at	
						longitude λ	latitude φ
A							
B							

Practical round. Problem 8 to solve

Note. If you find somewhere in the problems an impossible situation, write in English «**impossible situation**».

8. Moon. The Korean Astronomy and Space Science Institute (KASI) publishes the Korean Astronomical Almanac every year. You have been provided with an astronomical table extracted from the Korean Astronomical Almanac of 2012 showing the Korean local time of Moon culmination. (See separate sheet, and you may fill the empty cells by necessary content.)

Date	Culmination of Moon		Date	Culmination of Moon		Date	Culmination of Moon	
Mar 2			April 1			May 1		

Also you are provided with a scaled marked graph paper to plot graphs.

8.1. Find the date in April 2012 when the Moon is closest to the Earth.
8.2. Find the date in March 2012 when the Moon is remotest from the Earth.
8.3. The scaled marked graph paper (a) shows the eccentric orbit of the Moon, the Earth being located at the center. Mark the positions of the Moon by the symbol **x** on April 19 and April 23 (with labels A19 and A23).
8.4. Calculate the ratio of the apparent angular sizes of the Moon (α_{Moon}) and the Sun (α_{Sun}) on July 1.
8.5. Draw on the scaled marked graph paper the geostationary orbit around the Earth in the given scale.

Practical round. Problem 8 to solve

Note. If you find somewhere in the problems an impossible situation, write in English «**impossible situation**».

8. **Clusters.** Using the moving cluster method, the Hyades cluster is known to be 45 pc away. This open cluster is important as a standard candle, because we can use it to determine the distances of other clusters. However, the interstellar medium absorbs light making a star appear fainter and redder, which is called the interstellar extinction A_V and reddening $E_{(B\text{-}V)}$, both measured in stellar magnitudes. The true distance modulus can be computed using the relation

$$m - M = 5\log\mathbf{d} - 5 + A_V.$$

The empirical relation between A_V and $E_{(B\text{-}V)}$ is

$$A_V = 3\cdot E_{(B\text{-}V)}.$$

In Tables I and II, you are provided with photometric data of the stars of the two open clusters, Hyades and NGC 2682.

8.1. Make the colour-magnitude diagrams of the Hyades cluster and NGC 2682 using the provided scaled marked graph paper (A). In the diagrams, draw the main sequence line of each cluster.
8.2. Plot the colour-colour diagrams of the Hyades cluster and NGC 2682 using the provided scaled marked graph paper (B).
8.3. Assuming that the interstellar reddening of Hyades cluster is negligible, derive the interstellar reddening, $E_{(B\text{-}V)}$ of NGC 2682.
8.4. Determine the distance to NGC 2682.
8.5. Find the absolute magnitude and colour index (B-V) of the main sequence turn-off star in each cluster, approximately.
8.6. Which cluster is older? (Write in English «**Hyades**» or «**NGC 2682**».)

Практический тур. Таблица к задаче 8

Practical round. Table for Problem 8

Дата	Кульминация Луны		Дата	Кульминация Луны		Дата	Кульминация Луны	
Date	Culmination of Moon		Date	Culmination of Moon		Date	Culmination of Moon	
Mar 2	19 40		April 1	20 02		May 1	20 20	
3	20 31		2	20 52		2	21 10	
4	21 22		3	21 42		3	22 02	
5	22 14		4	22 33		4	22 57	
6	23 05		5	23 25		5	23 56	
7	23 56		6	-		6	-	
8	-		7	0 19		7	0 57	
9	0 48		8	1 16		8	2 01	
10	1 41		9	2 16		9	3 03	
11	2 36		10	3 17		10	4 04	
12	3 32		11	4 19		11	5 00	
13	4 31		12	5 19		12	5 52	
14	5 30		13	6 15		13	6 40	
15	6 29		14	7 08		14	7 26	
16	7 26		15	7 57		15	8 09	
17	8 20		16	8 43		16	8 52	
18	9 11		17	9 28		17	9 35	
19	9 59		18	10 10		18	10 18	
20	10 45		19	10 53		19	11 02	
21	11 29		20	11 36		20	11 48	
22	12 12		21	12 19		21	12 36	
23	12 55		22	13 04		22	13 24	
24	13 38		23	13 51		23	14 14	
25	14 22		24	14 39		24	15 03	
26	15 08		25	15 27		25	15 52	
27	15 54		26	16 17		26	16 40	
28	16 43		27	17 06		27	17 27	
29	17 32		28	17 55		28	18 14	
30	18 22		29	18 43		29	19 02	
31	19 12		30	19 31		30	19 51	

Практический тур. Таблицы к задаче 8

Practical round. Tables for Problem 8

Таблица 1. Данные о Гиадах
Table 1. Hyades data

m_V	(B-V)	(U-B)	m_V	(B-V)	(U-B)
7.78	+0.62	+0.16	6.62	+0.42	-0.01
7.14	+0.51	+0.05	5.65	+0.28	+0.08
8.46	+0.72	+0.31	3.61	+0.99	+0.84
7.47	+0.57	+0.08	4.80	+0.16	+0.12
4.22	+0.14	+0.12	3.85	+0.96	+0.74
6.02	+0.34	+0.04	4.27	+0.12	+0.11
5.13	+0.21	+0.12	9.05	+0.84	+0.53
9.99	+1.06	+0.95	8.06	+0.64	+0.17

Таблица 2. Данные о NGC 2682
Table 2. NGC 2682 data

m_V	(B-V)	U-B	m_V	(B-V)	(U-B)
12.80	+0.79	+0.27	13.66	+0.55	+0.03
12.67	+0.68	+0.19	12.55	+0.41	+0.03
12.93	+0.93	+0.59	14.00	+0.61	+0.11
15.64	+0.89	+0.53	16.38	+1.00	+0.70
15.19	+0.80	+0.30	14.96	+0.76	+0.28
17.33	+1.19	+0.97	14.23	+0.64	+0.12
12.16	+1.02	+0.81	13.14	+0.45	+0.01
12.22	+0.42	+0.03	13.25	+0.52	+0.01

Code of participant

Вопросы наблюдательного тура. Чистое небо

Observational round. Questions. Clean sky

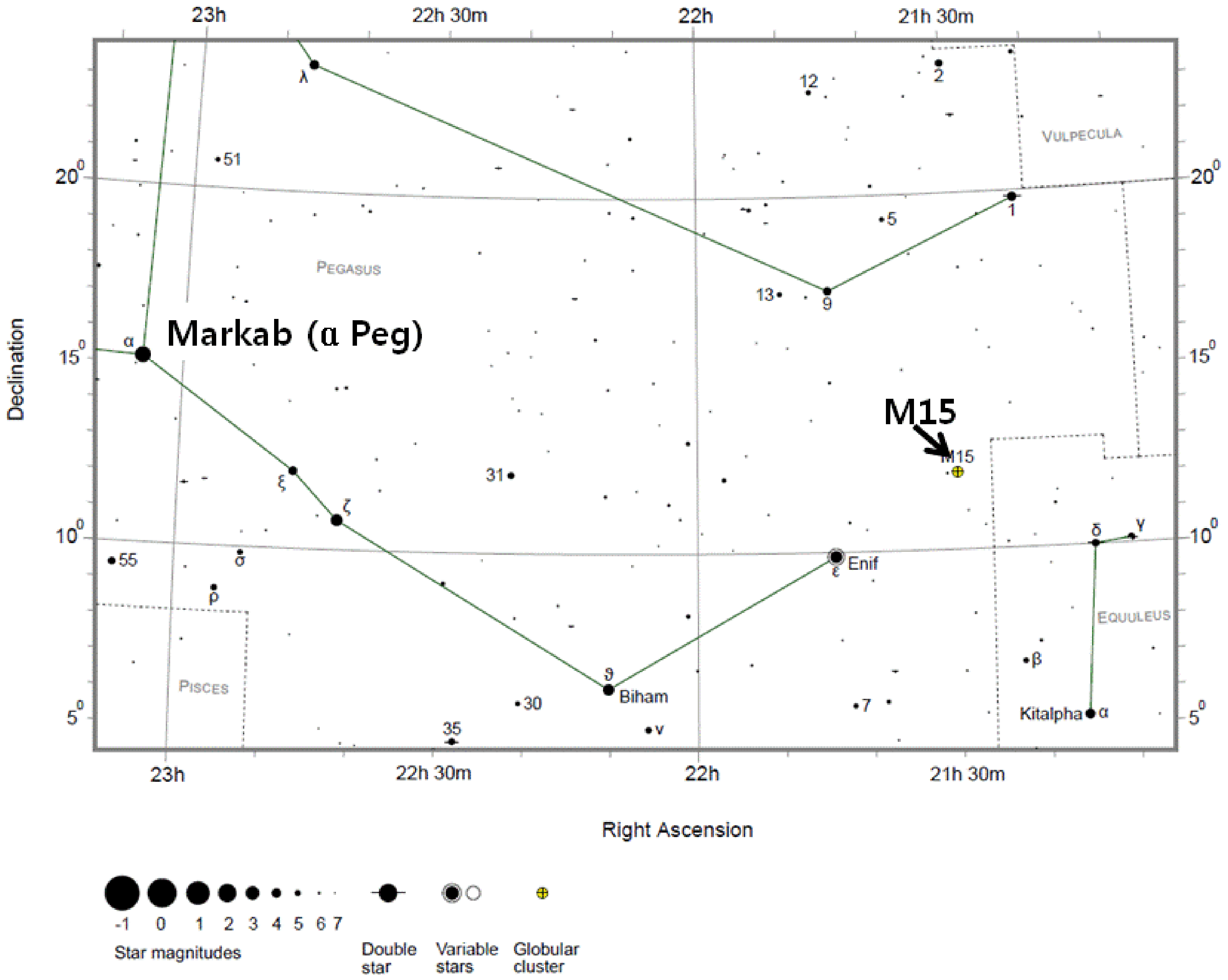
Русский	English
В Вашем распоряжении **фонарик**	You are provided with a **light**
9. Покажите экзаменатору направление на следующие объекты. **9.1.** Полярную звезду, **9.2.** Эклиптику (проведите рукой вдоль линии эклиптики). **10.** Расположите NGC 869 и NGC 884 в поле зрения телескопа. После нахождения объектов покажите их экзаменатору. **10.2.** Оцените часовой угол этих объектов (с точностью ± 10 градусов). Ответ в градусах: **11.** Расположите M15 в поле зрения телескопа. Карта прилагается. После нахождения объекта покажите его экзаменатору. **12.** Приблизительно оцените зенитное расстояние Меркурия. Ответ:	**9.** Point the direction of the following objects (show it to examiner): **9.1.** the Polaris, **9.2.** the Ecliptic (draw the line following the ecliptic). **10.** Place NGC 869 and NGC 884 in the field of view of the telescope. After identifying the objects, show them to the examiner. **10.2.** Estimate the current hour angle of them (to ± 10 degree accuracy). Answer in degrees: **11.** Place M15 in the field of view of the telescope. The finding chart is given. After identifying the object, show it to the examiner. **12.** Estimate the approximate zenith distance of Mercury. Answer:
Максимальное время выполнения задания – **17 минут**.	The maximum total time for all tasks is **17 minutes**.

Наблюдательный тур.
Чистое небо

Observational round.
Clean sky

Карта поиска M15

Messier Finder Chart for M15



Theoretical round. Sketches for solutions

Note for jury and team leaders. The proposed sketches are not full; the team leaders have to give more detailed explanations to students. But the correct solutions in the students' papers (enough for 8 pts) may be shorter.

αβ-1. Transit of Venus. Any transit of Venus may occur only in configuration of inferior conjunction of Venus. To calculate next inferior conjunctions we need first to find the synodic period T_S of Venus:

$$1/T_S = 1/T_V - 1/T_E,$$

where T_V and T_E are the sidereal periods of Venus and Earth respectively,

$$T_S = T_E \cdot T_V / (T_E - T_V) = 583.92^d.$$

January 1, 2117 will be in 105·365 + (26-1) – (5+31+30+31+28+31) = 38194 days after June 6, 2012. December 31, 2017, respectively, will be in 38194+364 = 38558 days after that date.

$$38194 / 583.92 = 65.41.$$
$$38558 / 583.92 = 66.03.$$

It means that the close approach of Venus in 2117 will be after 66 synodic periods of Venus.

$$66 \times 583.92 = 38538.7.$$

38538 days are 20 days earlier than the date 38558 that we calculated for December 31, 2117. Thus, 38538 days after June 6, 2012 corresponds to December 11, 2117.
Answer: The next transit of Venus will take place on December 11, 2117.

αβ-2. Transit of Pseudovenus. Visible motion of Venus depends on the synodic motion of the planet. During the Venus transit we see just synodic velocity of Venus. The synodic angular speed of Venus is:

$$\omega = \omega_V - \omega_E,$$

where ω_V and ω_E are angular sidereal velocities of Venus and Earth respectively. If R_V and R_E are the radii of the orbits, the velocity of Venus in this system is,

$$V = \omega \cdot R_V = (\omega_V - \omega_E) \cdot R_V,$$

and its visible angular speed on the Earth's sky,

$$u = V / (R_E - R_V) = (\omega_V - \omega_E) \cdot R_V / (R_E - R_V).$$

But the synodic motion of the Pseudovenus has the direction opposite to that of planet's rotation around the Sun. So the relation between the synodic **u** and sidereal ω_P angular velocities of Pseudovenus will be

$$u = \omega_P + \omega_E$$

(opposite to formula $u = \omega_P - \omega_E$ for the same direction). So

$$\omega_P = u - \omega_E,$$
$$\omega_P = (\omega_V - \omega_E) \cdot R_V / (R_E - R_V) - \omega_E,$$
$$\omega_P = \omega_V \cdot R_V / (R_E - R_V) - \omega_E \cdot (R_V / (R_E - R_V) + 1) = \omega_V \cdot R_V / (R_E - R_V) - \omega_E \cdot R_E / (R_E - R_V) =$$
$$= (\omega_V \cdot R_V - \omega_E \cdot R_E) / (R_E - R_V) = 2\pi \cdot (R_V/T_V - R_E/T_E) / (R_E - R_V).$$

For a body rotating around the Earth (mass M) in a circular orbit we may write,

$$\omega^2 R = GM/R^2,$$
$$R^3 = GM_E/\omega^2,$$
$$R_P = [GM_E(R_E - R_V)^2 / 4\pi^2 \cdot (R_V/T_V - R_E/T_E)^2]^{1/3}.$$

Calculations give us,

$$R_P = 2.92 \cdot 10^9 \text{ m} = 2.92 \text{ mln.km (approx. 7.60 radii of lunar orbit).}$$

There is also an other way to get the result after we have ω_P. It is to compare the motion of Pseudovenus with the motion of Moon. Since according to III Kepler law, T is proportional to $R^{3/2}$, ω is proportional to $R^{-3/2}$,

$$(\omega_P/\omega_M) = (R_P/R_M)^{-3/2},$$
$$R_P = R_M \cdot (\omega_M/\omega_P)^{2/3},$$
$$R_P = R_M \cdot (2\pi/T_M\omega_P)^{2/3}.$$

And calculations give us,

$$R_P = 7.62\ R_M = 2.93 \text{ mln.km.}$$

Note for jury. Additional point may be given for the students who note that this distance is out of the Hill sphere for the Earth and so this situation is impossible.

We may find the size (diameter) of Pseudovenus using this distance R_P and the angular size of the object that is equal to:

$$\alpha = r_V/(R_E - R_V),$$

where r_V is the diameter of the real Venus.

$$r_P = \alpha \cdot R_P = r_V \cdot R_P/(R_E - R_V).$$

Calculations give us,

$$r_P = 8.55 \cdot 10^5 \text{ m} \approx 850 \text{ km (approx. 0.25 diameters of the Moon).}$$

αβ-3. Old persons' star. Canopus is a star of the southern sky; if it is visible in Korea, it should be close to the horizon. Absorption and scattering of light play an important role under such conditions of observations. Therefore, the most favorable conditions for the observation are at the southern point of the island Jeju, and Canopus is at upper culmination. The latitude of this point is the smallest of the given range, i.e. 33°12' N. At this latitude Canopus culminates at the altitude

$$\mathbf{h} = 90° - \varphi + \delta = 90° - 33°12' + -52°42' = 4°06'.$$

Atmospheric absorption and scattering are significant for observations at such a low altitude. The depth of atmosphere which a beam of light from the star passes is 1/sin**h** times larger than the depth that the light from a star located in zenith passes. $1/\sin 4°06' \approx 14$. (Otherwise, one may use the formal formula using the zenith angle $1/\cos z = 1/\cos 85°54' \approx 14$.) It is known that under the most favorable conditions, the loss of light when it passes one atmosphere (due to absorption and scattering) is about 20% (or 19% as it is written in the supplement table), or (in magnitudes) $0^m.23$. Since the magnitudes of stars in the table ($\mathbf{m_0} = -0^m.72$ for Canopus) are given with the zenith absorption and scattering ($+0^m.23$ to the magnitude visible from space), the additional absorption of light at a height of 4°06 'will be $(1/\tan 4°06' - 1) \approx 13$ times more than in zenith. Thus,

$$\Delta\mathbf{m} = 0^m{,}23\ (1/\sin 4°06' - 1) \approx 3^m.0.$$
$$\mathbf{m_1} = \mathbf{m_0} + \Delta\mathbf{m} = -0^m{,}72 + 3^m{,}0 \approx 2^m.3.$$

Note for jury. This problem is to estimate. So the exact values are not too important, especially knowledge the exact value of 20% (15% – 30% may be reasonable), or (in magnitudes) $0^m.23$ ($0^m.15$ – $0^m.4$ may be reasonable). And the reasonable answers are from $1^m.5$ to 4^m.

α-4. Stars on Mars. As we may see from the "Data of some stars", Canopus and Sirius have almost the same RA (Earth based coordinates) while the difference in DEC is significant. It means that the distance between these stars in the Earth sky is approximately equal to the difference in DEC,

$$\beta = \delta_1 - \delta_2 = (-16°42'58'') - (-52°41'45'') \approx 35°59' \approx 36°.$$

After moving the observer to Mars, this angle will not change, although the coordinates in the Martian sky will be different. It means, the distance measured, by along Martian surface, between the points where Canopus and Sirius are in zenith is:

$$\beta(\text{rad})\times R = \beta(°)\times\pi R/180 \approx 2130 \text{ km}.$$

where R = 3397 km is the radius of Mars.

If the Bear sees Canopus in zenith, the zenith angle of Sirius will be $\beta \approx 36°$, and its height above horizon

$$\mathbf{h} = 90° - \beta \approx 90° - 36° = 54'.$$

Answers: ~2300 km, 54°.

β-4. Altair. All necessary data may be taken from tables and the Hertzsprung-Russell diagram. Distance to Altair is

$$D_{\mathbf{A}} = 1 \text{ pc} / \boldsymbol{p} = 206265 \text{ a.u.} / 0.195 \approx 1\,060\,000 \text{ a.u.}$$

Our Sun being moved to this distance will have the magnitude

$$\mathbf{m_1} = -26^{\mathbf{m}}.74 + 5^{\mathbf{m}} \lg 1\,060\,000 \approx -26^{\mathbf{m}}.74 + 30^{\mathbf{m}}.12 \approx 3^{\mathbf{m}}.38.$$

So the difference in absolute stellar magnitudes of Sun and Altair is:

$$\Delta\mathbf{m} = 3^{\mathbf{m}}.38 - 0^{\mathbf{m}}.77 = 2^{\mathbf{m}}.61.$$

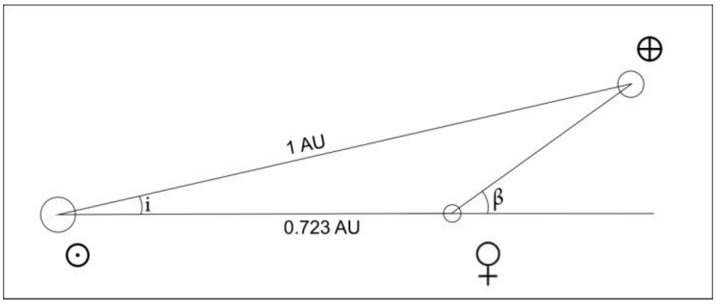
Thus, the ratio of luminosities of Altair $L_{\mathbf{A}}$ and the Sun $L_{\mathbf{0}}$ is

$$L_{\mathbf{A}} / L_{\mathbf{0}} = 100^{\mathbf{2{,}61/5}} \approx 11.1.$$

The luminosity of a star L is proportional to its surface area and the fourth power of surface temperature, i.e. $L \sim R^{\mathbf{2}}T^{\mathbf{4}}$. Density of a star is equal to its mass divided by its volume, i.e. it is proportional to $M/R^{\mathbf{3}}$. Thus, $\rho \sim MT^{\mathbf{6}}/L^{\mathbf{3/2}}$. Temperatures of Altair and Sun may be found using the Hertzsprung-Russell diagram from their spectral types, A7 and G2, 8100 K and 5800 K respectively. So by comparing the densities of Altair and Sun (see table, $\rho_0 \approx 1410$ kg/m$^{\mathbf{3}}$), we may find that the density of Altair is

$$\rho_{\mathbf{P}} = \rho_{\mathbf{0}}\cdot(M_{\mathbf{A}}/M_{\mathbf{0}})\cdot(T_{\mathbf{A}}/T_{\mathbf{0}})^6\cdot(L_{\mathbf{0}}/L_{\mathbf{A}})^{3/2} \approx 480 \text{ kg/m}^{\mathbf{3}}.$$

α-5. Venus and Earth. The maximum space distance from the Earth to the Venus ecliptic is (see figure)



$$H = R_{\mathbf{0}} \times \sin \boldsymbol{i},$$

where $R_{\mathbf{0}}$ is radius of the Earth orbit (1 AU), and $\boldsymbol{i}$ is the orbital inclination of the terrestrial orbit to the plane of Venus ecliptic, which is evidently equal to the orbital inclination of the Venus orbit to the plane of the Earth's ecliptic, i.e. 3.4°.

$$H = 1 \text{ AU} \times \sin 3.4° = 0.0593 \text{ AU},$$

In the Venetian sky, the Earth in such position can be visible at the maximum distance at the configuration of opposition, when the distance between Venus and Earth is minimal and equals to

$$L = R_{\mathbf{0}} - R_{\mathbf{V}} = 1 \text{ AU} - 0.723 \text{ AU} = 0.277 \text{ AU}$$

(all angles are small and we do not take into account the inclination in these calculations). The maximal distance in the sky (angle $\boldsymbol{\beta}$) may be found from the equation

$$H = L \times \tan \boldsymbol{\beta},$$
$$\text{tg } \boldsymbol{\beta} = H / L = 0.0593 \text{ AU} / 0.277 \text{ AU} = 0{,}214,$$
$$\boldsymbol{\beta} = 12{,}1°.$$

β-5. Venus and Earth. First part of the solution, see solution of problem **α-5**.

To estimate stellar magnitude of the Earth visible from vicinities of Venus in opposition we may compare it with Mars visible from the Earth in opposition (below α is albedo, D are diameters of the bodies and R are distances, indices E, V, M and S correspond to Earth, Venus, Mars and Sun).

The flux to Venus from Earth $\qquad F_{\mathbf{V}} \sim \alpha_{\mathbf{E}}\cdot D_{\mathbf{E}}^{\mathbf{2}}\cdot(1/R_{\mathbf{V\text{-}E}})^{\mathbf{2}}\cdot(1/R_{\mathbf{S\text{-}E}})^{\mathbf{2}}.$

The flux to Earth from Mars $F_M \sim \alpha_M \cdot D_M^2 \cdot (1/R_{E\text{-}M})^2 \cdot (1/R_{S\text{-}M})^2$.

The ratio of fluxes $F_E/F_M = (\alpha_E/\alpha_M)\cdot(D_E^2/D_M^2)\cdot(R_{E\text{-}M}\cdot R_{S\text{-}M})^2/(R_{V\text{-}E}\cdot R_{S\text{-}E})^2$.

Taking the necessary values from the table of Solar system, we may calculate:

$$F_E/F_M = (0.36/0.15)\cdot(12756/6794)^2\cdot(0.524\cdot 1.524)^2/(0.277\cdot 1)^2.$$
$$F_E/F_M \approx 70.$$

So the Earth visible from vicinities of Venus at opposition is brighter than Mars visible from Earth at opposition, and the difference in stellar magnitudes is equal

$$\Delta m = -2^m.5\cdot \lg(F_E/F_M) \approx -4^m.6.$$

Stellar magnitude of the Earth

$$m = -2^m.0 + \Delta m \approx -6^m.6.$$

Of course it is not the only possible correct way for solution.

α-6. Parallaxes. 6 light years is equal to (6/3.26) pc ≈ 1.84 pc.

A parallax of 0.001" corresponds to a distance of 1000 pc.

So the interferometer cannot measure the parallaxes of the stars that are more distant than 1000 pc with any reasonable accuracy.

If we had a uniform distribution of stars in space, the volume of space with these stars could be considered a sphere with radius of 1000 pc. For the number of stars one would write:

$$N = 4\pi/3\ (1000\text{ pc} / 1.84\text{ pc})^3 \approx 6.7\cdot 10^8.$$

or, with reasonable accuracy to one significant digit, $7\cdot 10^8$ stars, i.e. seven hundred million stars.

However, the stars of our Galaxy are distributed not evenly in all directions. In our part of the Galaxy the thickness of the Galaxy is less than 1000 pc, but is only about 400 pc. Therefore, the volume of space with these stars could be considered a cylinder with a radius of 1000 pc and a height of 400 pc. The number of stars in this volume:

$$N = \pi\ (1000\text{ pc} / 1.84\text{ pc})^2(400\text{ pc} / 1{,}84\text{ pc}) \approx 2\cdot 10^8$$

or two hundred million stars.

Note for jury. This problem is to estimate. So the exact values are not too important, especially knowledge of the exact value of the thickness of Galaxy. In this point the most important is simple understanding that this effect should be taken into account, and reasonable order of value of the thickness of Galaxy.

β-6. Remote galaxy. The fact that the galaxy, consisting of yellow stars like the Sun, looks like the orange star **ε** Eridani indicates redshift. $z = (\lambda_1 - \lambda_0)/\lambda_0$. According to Wien's displacement law $\lambda T = \text{const}$. $\lambda_1 T_1 = \lambda_0 T_0$. Therefore, $z = (T_0 - T_1)/T_1$.

The approximate temperatures of the stars may be found from the Hertzsprung-Russell diagram,

$T_0 \approx 5800$ K, $T_1 \approx 4900$ K.

Hence $z \approx (5800 - 4900)/4900 \approx 0.18$.

The galaxy is receding from us with a speed $V = zc$. $V = 0.18\cdot 300000$ km/s = 54000 km/s.

According to Hubble's law, $V = R\cdot H$, $R = V/H$ = 54000 km/s / 71 km/s/Mpc ≈ 760 Mpc.

Thus, the galaxy is located at the distance 760 Mpc, and the fact that it looks like **ε** Eridani ($3^m.74^m$), weakened in brightness by factor 1000 ($3^m.74^m + 7^m.5^m = 10^m.24^m$) allow us to conclude that (excluding the effect of the redshift) the absolute magnitude of the galaxy is:

$M = m - 5^m\cdot\log(R/10\text{ pc}) = 3^m.74 + 7^m.5 - 5^m\cdot\log(76\,000\,000) \approx -28^m.2$.

Redshift leads to the fact that every photon coming to us loses some of the energy, $E = h\nu = hc/\lambda$, $\Delta E = h\Delta\nu = hc(1/\lambda_0 - 1/\lambda_1)$, $\Delta E/E = \Delta T/T_0 \approx 0.16$, $E_1/E_0 = T_1/T_0 \approx 0.84$. This change the magnitude by $\Delta m = -2^m.5\cdot\lg(0.84) \approx 0^m.2$.

Thus, taking into account the effect of redshift, absolute magnitude of the galaxy is

$M = -28^m.2^m + -0^m.2^m \approx -28^m.4^m$.

The absolute magnitude of the Sun is $4^m.8$, the difference is $\Delta M = 33^m.2$.

Using this value we can conclude that the total number of stars is $10^{\Delta M/2.5} \approx 10^{13.28} \approx 1.9\cdot 10^{13}$ or about 20 trillion stars.

Theoretical round. Basic criteria. For work of Jury

Note. The given sketches are not full; the team leaders have to give more detailed explanations to students. But the correct solutions in the students' papers (enough for 8 pts) may be shorter.

αβ-1. Transit of Venus.

Transit of Venus may occur only in configuration of inferior conjunction of Venus – 2 pt.
Will be after integer number of synodic period of Venus – 1 pt.
Formula and calculation of synodic period of Venus – 2 pt.
Calculation of number of days till the inferior conjunction of Venus in 2117 – 1 pt.
Final answer – 2 pt.

αβ-2. Transit of Pseudovenus.

Understanding that synodic motion should be used – 1 pt.
Formulae and result for synodic motion – 3 pt.
Using Gravitation law or III Kepler law, formulae and result for Pseudovenus orbit radius – 2 pt.

Note for jury. Additional point may be given for the students who note that this distance is out of the Hill sphere for the Earth and so this situation is impossible.

Calculation of Pseudovenus size (diameter) – 2 pt.

αβ-3. Old persons' star.

Understanding that φ = 33°12' should be used – 1 pt.
Calculation of the altitude on which Canopus culminates at – 2 pt.
Calculation of the depth of atmosphere to pass (like 1 / tg 4°06' ≈ 14) – 2 pt.
Calculation of the loss of light in atmosphere in stellar magnitudes (Δ**m** ≈ ... or similar) – 2 pt.
Final result – 1 pt.

Note for jury. This problem is to estimate. So the exact values are not too important, especially knowledge the exact value of 20% (15% – 30% may be reasonable), or (in magnitudes) $0^m.23$ ($0^m.15$ – $0^m.4$ may be reasonable). And the reasonable answers are from $1^m.5$ to 4^m.

α-4. Stars on Mars.

Angular distance at Earth sky – 2 pt.
Understanding angular distance at Earth sky = angular distance at Martian sky – 1 pt.
Understanding angular distance at = angular distance at planet's surface – 1 pt.
Calculation of the distance between Bear and Penguin – 2 pt.
Calculation of the height of Surius if Canopus in zenith – 1 pt.
Necessary picture with Bear and Penguin (artistic type) – 1 pt.

β-4. Altair.

The distance to Altair – 1 pt.
Finding the ratio of luminosities of Altair and Sun – 2 pt.
Realization that $L \sim R^2T^4$, $\rho \sim M/R^3$, and so $\rho \sim MT^6/L^{3/2}$ – 2 pt.
Taking correct temperatures of the stars – 1 pt.
Final result – 2 pt.

α-5. Venus and Earth.

Understanding the configuration, picture (maybe not drawn but explained) – 3 pt.
Taking for solution correct values from tables – 1 pt.
Calculation of necessary distances – 2 pt.
Final result – 2 pt.

β-5. Venus and Earth.

First part of the solution – 4 pt, (see criteria for problem **α-5** and divide number of points by factor 2).
Second part of the solution – 4 pt, including:

Formula for flux – 2 pt

(including 0.5 pt for each correct dependence on α, D, R(obs-planet), R(sun-planet)).

Calculation of the ratio of fluxes – 1 pt.

Final result – 1 pt.

α-6. Parallaxes.

Realization that interferometer can measure the parallaxes of the stars distanced <1000 pc – 3 pt
Calculating number of stars in sphere <1000 pc – 3 pt
Taking into account that Galaxy has thickness less than 1000 pc and calculating number of stars for this model – 2 pt

Note for jury. This problem is to estimate. So the exact values are not too important, especially knowledge the exact value of the thickness of Galaxy. In this point the most important simple understanding that this effect should be taken into account, and reasonable order of value of the thickness of Galaxy.

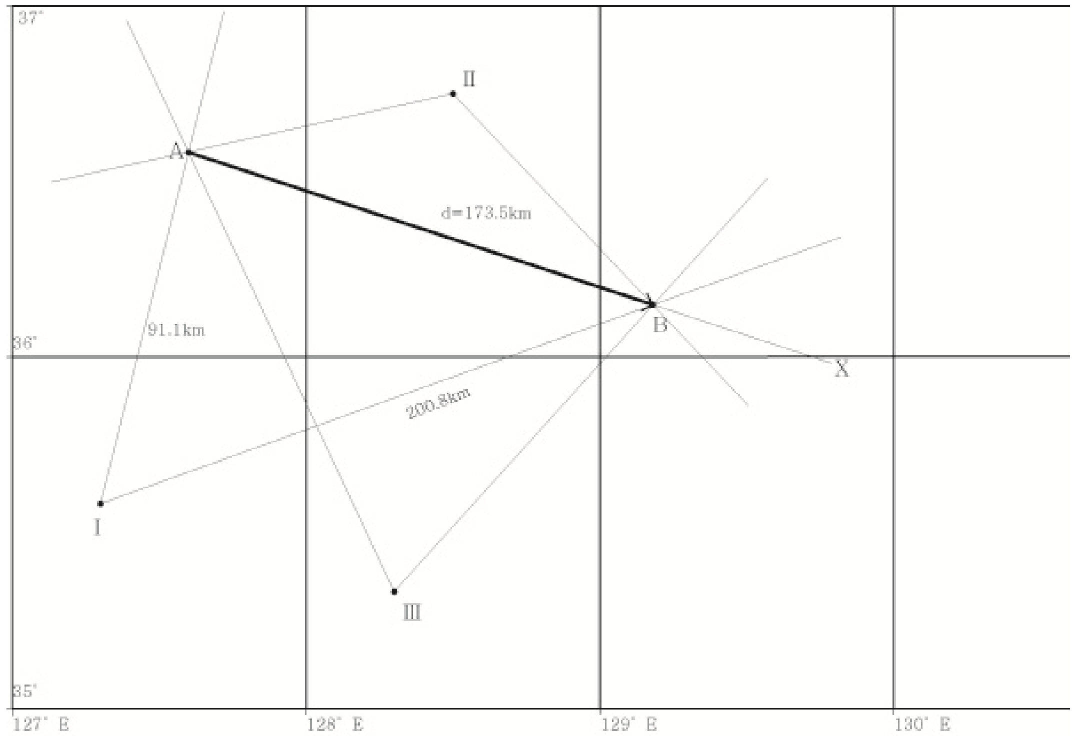
β-6. Remote galaxy.

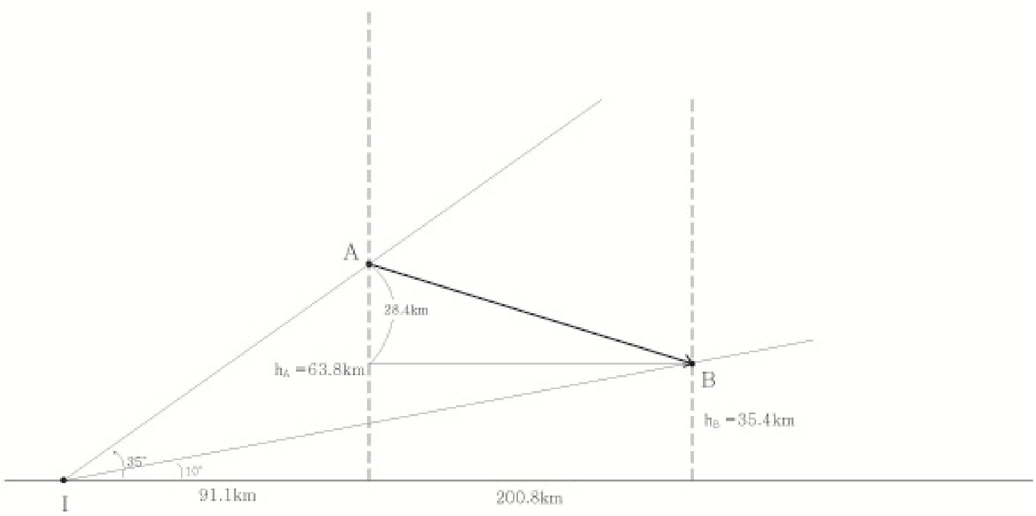
Understanding about redshift, taking temperatures from Hertzsprung-Russell diagram, finding the receding us with a speed, and the distance to the galaxy according Hubble law – 3 pt
Calculating necessary difference in stellar magnitudes – 3 pt
Taking into account effect of red shift that gives correction $\Delta m \approx 0^{\mathbf{m}}.2$ – 1 pt
Final result of number of stars – 2 pt

Practical round. Sketches for solutions

αβ-7. Fireball.

7.1. Observing points I, II and III are plotted as in the figure (point II is not correctly plotted below, but when plotted correctly on the gridded paper, the answer becomes clear). Then by drawing only using azimuthal angles, projected points A and B can be obtained, as intersecting points.





7.2. Read off from the grid, and coordinates (λ_A, φ_A, λ_B, φ_B) can be easily obtained as (127.60°E, 36.47°N) for point A, and (129.45°E, 36.10°N) for point B.

Then one should first convert the differences in angle into distance, and then use Pythagorean principle, such that

$$L = [\{(129.45\text{-}127.60) \times 110) \times (4.8/5.8)\}^2 + \{(36.47\text{-}36.10) \times 110\}^2]^{1/2},$$

where the conversion factor 4.8/5.8 for longitudinal distance per one degree longitude can be read off from the correctly scaled gridded paper or using ~sin(90°-36°), and one can use 110 km / (latitude degree). Then L = 173.5 km.

7.3. Once points I, A & B are correctly marked, the distance $\mathbf{I_A}$ and $\mathbf{I_B}$ can be calculated using Pythagorean principle just as in problem 2, which are 91.1 km and 200.8 km. And using altitudes observed from point I, one can get

$$\mathbf{h_A} = 91.1 \text{ km} \times \tan 35° = 63.8 \text{ km, and } \mathbf{h_B} = 200.8 \text{ km} \times \tan 10° = 35.4 \text{ km.}$$

7.4. If the fireball hits the surface, the full projected trajectory from point **A** to the hitting point (let's call it **C**), **AC**, is the multiple of the projected distance **AB** by a factor of 63.8/(63.8-35.4)=2.2465. The same multiplication factor can be used to get the trajectory on the longitude and latitude separately, such that

$$\lambda_C = 127.6 + 2.2465\ (129.45\text{-}127.6) = 131.76°$$
$$\varphi_C = 36.49 + 2.2465\ (36.11\text{-}36.49) = 35.64°$$

point	longitude λ	latitude φ	L (km)	h_A (km)	h_B (km)	You may find the meteorite at	
						longitude λ_C	latitude φ_C
A	127.60° E	+36.49° N	173.5	63.8 km	35.4 km	131.76°E	35.64°N
B	129.45° E	+36.11° N					

α-8. Moon.

Date	Culmination of Moon	ΔT (min)	Date	Culmination of Moon	ΔT (min)	Date	Culmination of Moon	ΔT (min)
Mar 2	19 40	51	April 1	20 02	50	May 1	20 20	50
3	20 31	51	2	20 52	50	2	21 10	52
4	21 22	52	3	21 42	51	3	22 02	55
5	22 14	51	4	22 33	52	4	22 57	59
6	23 05	51	5	23 25	54	5	23 56	61
7	23 56	52	6	-		6	-	
8	-		7	0 19	57	7	0 57	65
9	0 48	53	8	1 16	57	8	2 01	62
10	1 41	55	9	2 16	60	9	3 03	61
11	2 36	56	10	3 17	61	10	4 04	56
12	3 32	59	11	4 19	62	11	5 00	52
13	4 31	59	12	5 19	60	12	5 52	48
14	5 30	59	13	6 15	56	13	6 40	46
15	6 29	57	14	7 08	53	14	7 26	43
16	7 26	54	15	7 57	49	15	8 09	43
17	8 20	51	16	8 43	46	16	8 52	43
18	9 11	48	17	9 28	45	17	9 35	43
19	9 59	46	18	10 10	43	18	10 18	42
20	10 45	44	19	10 53	46	19	11 02	46
21	11 29	43	20	11 36	43	20	11 48	48
22	12 12	43	21	12 19	45	21	12 36	48
23	12 55	43	22	13 04	47	22	13 24	50
24	13 38	44	23	13 51	48	23	14 14	50
25	14 22	46	24	14 39	48	24	15 03	49
26	15 08	46	25	15 27	50	25	15 52	48
27	15 54	49	26	16 17	50	26	16 40	47
28	16 43	49	27	17 06	49	27	17 27	47
29	17 32	50	28	17 55	48	28	18 14	48
30	18 22	50	29	18 43	48	29	19 02	49
31	19 12	50	30	19 31	49	30	19 51	

8.1. In the table above, we compute the difference in culmination times of two neighboring days. On average it is about 48 minutes, but differs every day due to the elliptical nature of the lunar orbit. Figure 1 shows the variation of culmination time for the three months. When the moon is at the perigee, the difference in culmination is the largest. Therefore, the moon is at the perigee on Mar 13, April 11, May 7. Therefore, the answer is 11.

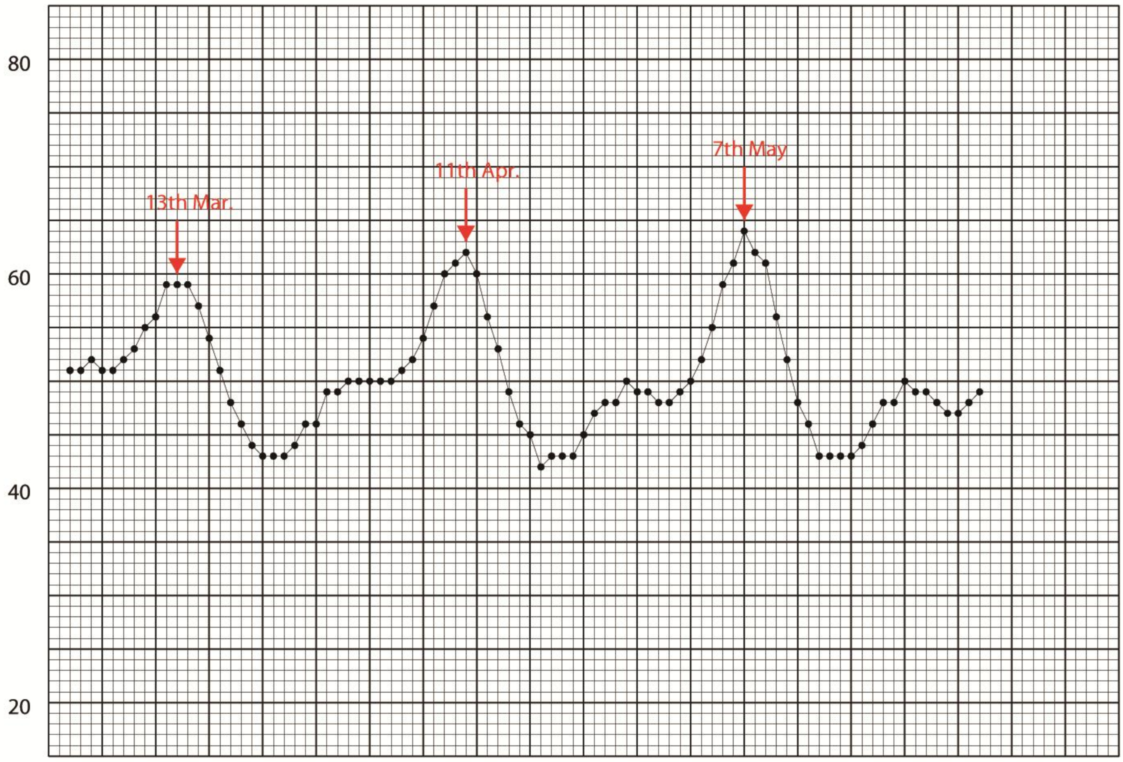
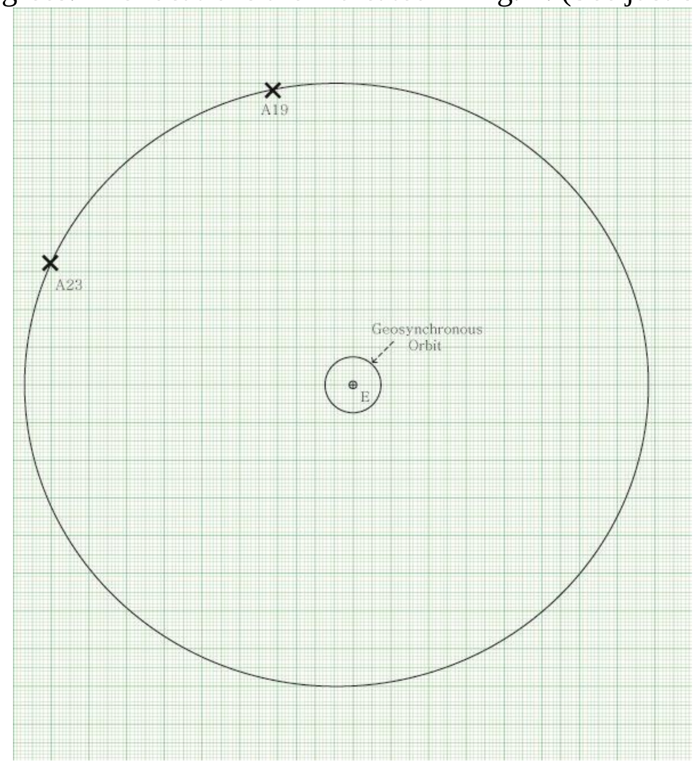


Fig 1. Culmination time difference in minutes.
On the dates marked by the red arrows the moon is at perigee.

8.2. 14 days after Mar 13 (or 14 days before April 11) the moon is located on the opposite side of the perigee. Therefore, the answer is Mar 27.

8.3. There are 8 days between April 11 and April 19, which correspond to 8/27.3 of the lunar orbital period. The angle from the perigee is 105.5 degrees. There are 12 days corresponding to 12/27.3 × 360=158.2 degrees. The locations are indicated in Fig. 2. (See just below.)

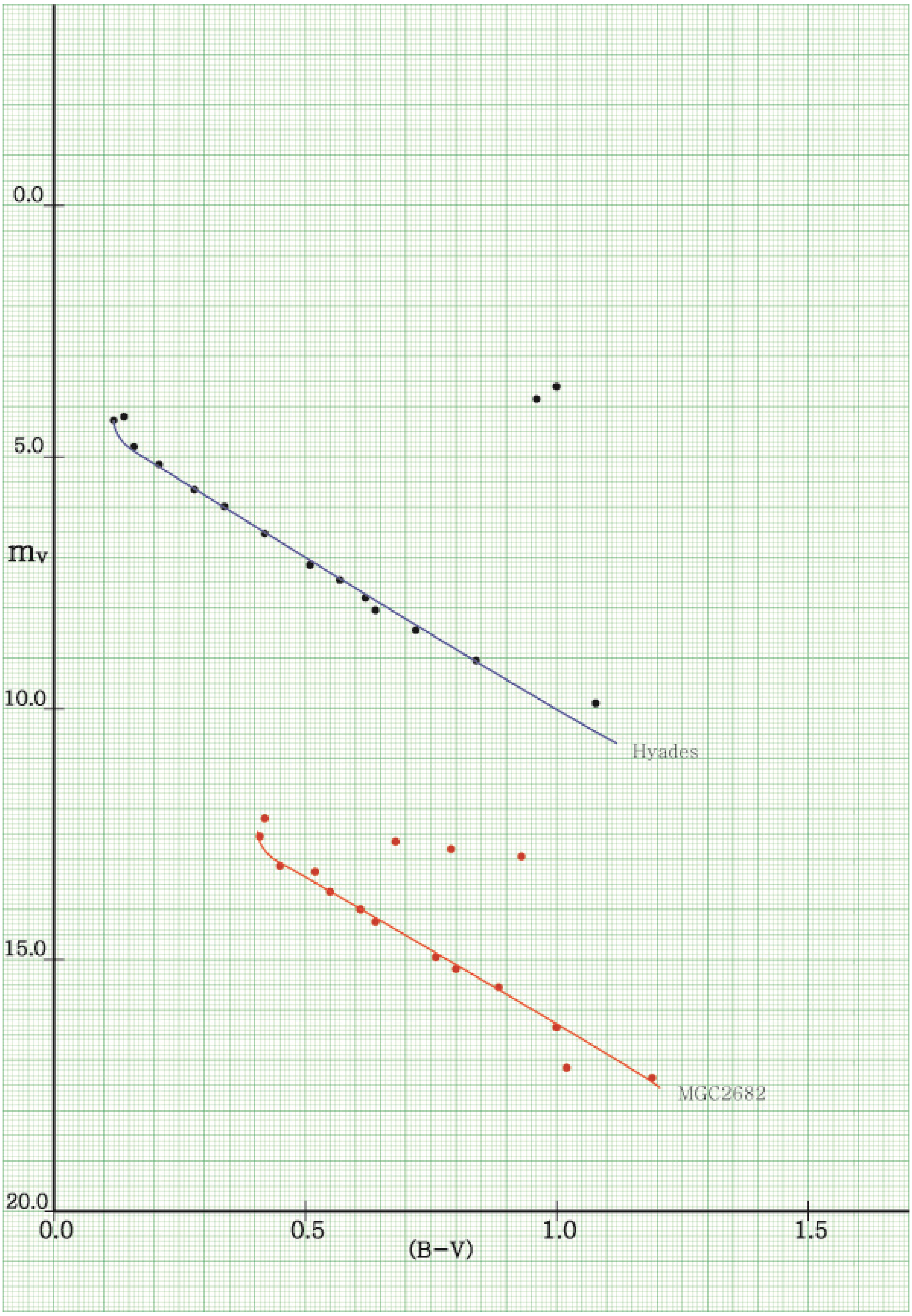


8.4. July 1 is 54 days after May 7th, where the Moon is at perigee. The Sun is near aphelion, whereas the Moon is near perigee. Therefore the sun's apparent angular diameter is 31'59" × 0.983 = 31'27". The real diameter of the moon is D = 3476.4 km. The distance is 384400" × (1 – 0.055) = 362900 km. Hence the apparent angular size is 3476/362900 × 180/3.14 × 60 = 32'54". Therefore, the moon appears 1.05 larger than the Sun.

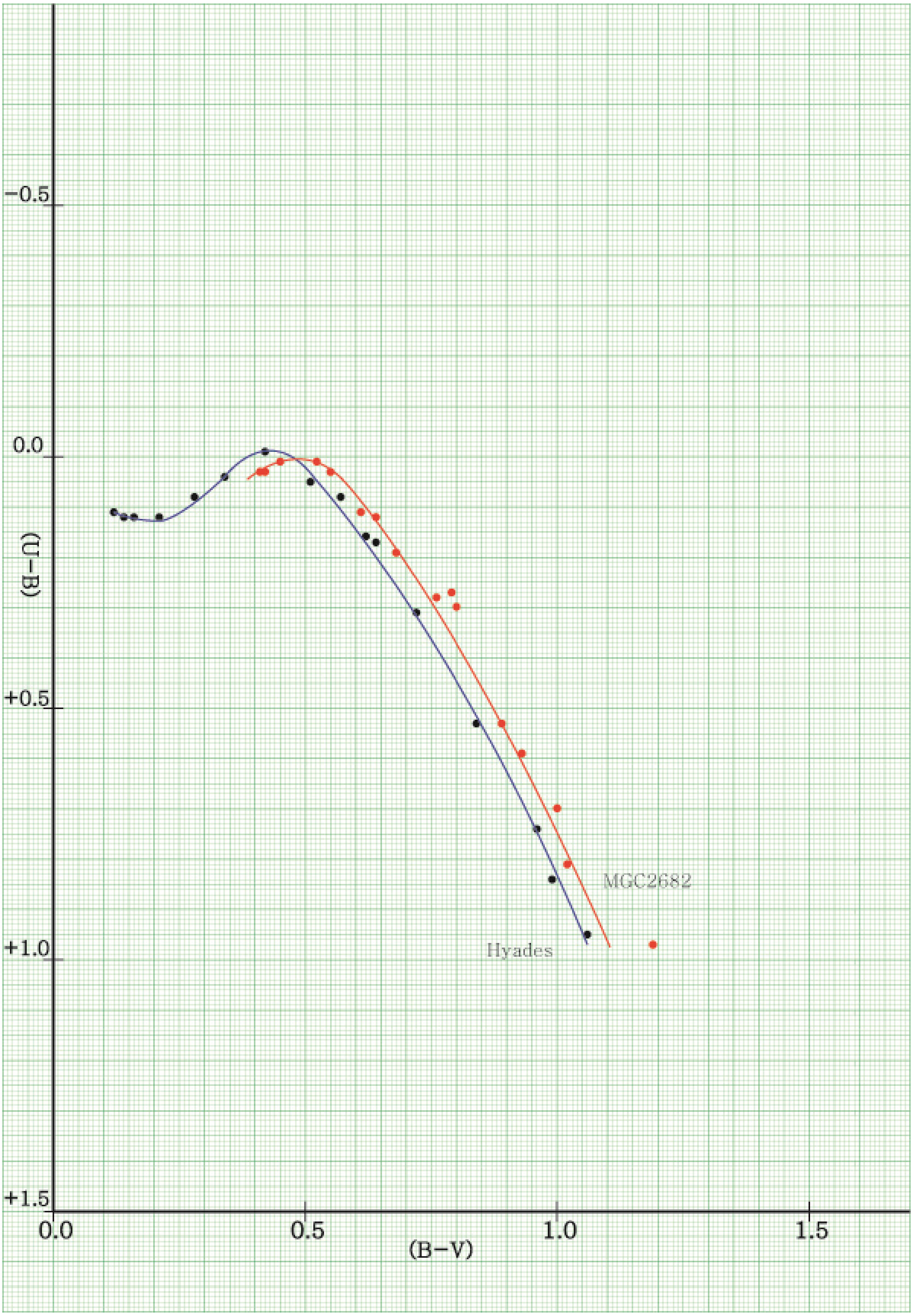
8.5. The approximate size of the geostationary orbit may be found using the Kepler's III law, with the additional fact that geostationary orbit has 27.3 times shorter period. The ratio or the orbital sizes is $27.3^{2/3}$, or approximately 9. The answer is shown in Fig. 2.

β-8. Clusters. All necessary data may be taken from tables and the Hertzsprung-Russell diagram.

8.1. Color-Magnitude Diagrams (blue dots and line for Hyades cluster, red dots and line for NGC2682).



8.2. Color-Color Diagram (blue dots and line for Hyades cluster, red dots and line for NGC6282):



8.3. On the color-color diagram (problem 8-2), the reddening line is E(U-B) / E(B-V) = 0.67. However, data points for two clusters are not sufficient to get such detailed reddening, we accept the difference (B-V) between two main-sequence lines on the color-color diagram as reddening E(B-V), which is E(B-V) ~ 0.06 (+- 0.02 acceptable).

8.4. On the color-magnitude diagrams in Problem 8-1, the magnitude difference Δm_V between the main sequence line of Hyades and the main sequence line of NGC 2686, which is Δm_V = -6.3 (±0.2 acceptable).

$$m_V(\text{Hyades}) - m_V(\text{NGC 2682}) = 5 \log 45 - 5\log \mathbf{d} - 3\cdot E(B\text{-}V),$$
$$-6.3 = 5 \log 45 - 5\log d - 0.18,$$
$$d = 741 \text{ pc } (660 \text{ pc} - 851 \text{ pc ; acceptable}).$$

8.5. Find the absolute magnitude and colour index (B-V) of the main sequence turn-off star in each cluster, approximately.

On the color-magnitude diagram of Hyades, MT (main sequence turn off point) is (B-V) ~ 0.12 (acceptable ±0.02) and m_V ~ 4.3 (acceptable ±0.2).

$$m_V - M_V = 5\cdot\log 45 - 5 - 0.18 \quad ==> \quad M_V = 0.75 \text{ (acceptable } \pm 0.2).$$

Ans: (B-V) = (B-V)o = 0.12, M_V = 0.75.

On the color-magnitude diagram of NGC2682, MT (main sequence turn off point) is (B-V) ~ 0.42 (±0.02 acceptable) and m_V = 12.6 (±0.2 acceptable).
Intrinsic color of the turn off star is (B-V)o = (B-V) - E(B-V) = 0.36 (acceptable : 0.32 - 0.40)

$$===> m_V - M_V = 5\cdot\log d - 5 + A \quad ==> \quad Mv = 3.41 \text{ (acceptable } 3.09 - 3.73).$$

Ans : (B-V) = 0.42, (B-V)o = 0.36 M_V = 3.41

8.6. NGC2682.

Practical round. Basic grading criteria

αβ-7. Fireball.

7.1. Marking points I, II, III correctly. Marking and drawing the fireball trajectory correctly – 3 pts.

7.2. Getting longitude and latitude of Points A, B correctly. Getting distance with correct scaling over longitude and latitude – 2 pts.

7.3. Getting the right geometry. Final values of heights within 10 percent of error – 3 pts.

7.4. Getting the right geometry. Final values of the correct position within 10 percent of error – 2 pts.

α-8. Moon.

8.1. April (11 ± 1) – 2 pts, ± 2days – 1 pt.

8.2. Mrch (27 ± 1) – 2 pts, ± 2days – 1 pt.

8.3. Similar to the Figure in the answer sheet – 2 pts, ± 10 degrees – 1 pt.

8.4. Correct ratio ± 0.01 – 2 pts, ± 0.04 – 1 pts.

8.5. Similar to the figure in the solutions – 2 pts, radius less than 1 cm – 1 pts.

β-8. Clusters.

8.1. (2.0 point),
correct plot with main sequence line : 2.0 point,
plots without main sequence line : deduction of 0.1 point.

8.2. (2.0 point),
correct plot with different marks for each cluster : 2.0 point,
plots without identifying each cluster : deduction of 0.1 point.

8.3. (2.0 point),
E(B-V) ~ 0.06 ±0.02, get 2.0 point (±0.03, get 1.5 point; ±0.04, get 1.0 point; ±0.05, get 0.5 point).

8.4. (2.0 point),
Δm_V ~ -6.3 ±0.2 ➔ distance ~741pc
Correct method to get distance with wrong Δm_V values : deduction of 0.2 point

8.5. . (1.8 point),
only (B-V) value for main sequence turn off stars of each cluster (Hyades and NGC 2682) : get 0.9 point, only absolute magnitude of it get 0.9.

8.6. (0.2 point) NGC2682.

Observational round. Basic grading criteria

9. Pointing objects in the sky (the Polaris and the Ecliptic): **4 pt**.

9-1. If pointed correctly, **2 pt**, if not, 0 pt.
9-2. If pointed correctly, **2 pt**, if not, 0 pt.

10. NGC869/884 (The Perseus double cluster): **6 pt**.

10-1. If the cluster is in the field of view of the telescope, **3 pt**. If not, 0 pt
10-2. Hour angle of the double cluster

Time	Hour angle
21:00	-60 or 300 degree
22:00	-45 or 315 degree
23:00	-30 or 330 degree

4 min shift = 1 degree shift
The end time of the exam for each group was recorded.
If the hour angle at the end time and the answer agree within ±10 degree, **3 pt**.
If the difference is more than ±10 degree, -1 pt for each interval of an additional difference of 0 degree < hour angle ≤5 degree. This means that 0 pt for the answer with more than ±20 degree offset.
If two answers were given for each object with separation more than 1 degree, 0 pt.

11. M15: **5 pt**.

If the target was within the field of view of the telescope, **5 pt**.
If not, 0 pt.

12. Zenith distance of Mercury: **5 pt**.

Mercury always stays close to the Sun, but RA of it is about $15^h\,04^m$, while RA of the Sun is $13^h\,38^m$. The combination of the knowledge of the latitude of the site, and the location of the Sun, and at the time when the observation started, it was already well below the horizon.

On October 19, the Zenith distance of Mercury was the following.

Time	Zenith distance (degree)
21:00	116
21:15	120
21:30	123
21:45	126
22:00	129
22:15	132
22:30	135
22:45	138
23:00	140
23:15	143

If the zenith distance at the time closest to the above table and the answer agree within 15 degree, **5 pt**.
For the additional difference at intervals of 0 degree < difference ≤ 5 degree beyond the ±15 degree, -1 pt was taken off. This means that 0 pt was given if the difference is more than 35 degree.