2nd Japan Astronomy Olympiad
Preliminary Round Questions
Unofficial Translation by Pika

Exam Time: 100 minutes

Instructions

There are 50 questions in total. Since the question order is random, it is recommended to first skim through all questions. Unless otherwise noted, the following symbols in this preliminary round represent the following units.

- pc: Parsec
- au: Astronomical Unit
- $M_\odot$: Solar Mass
- $R_\odot$: Solar Radius

Question 1

There exists a region within a black hole from which not even light can escape. For a non-rotating, non-charged black hole, this region's radius is specifically called the Schwarzschild radius. It is known from general relativity that it can be evaluated with the following formula:

$$r_g = \frac{2GM}{c^2}$$

Here, c is the speed of light in vacuum and G is the gravitational constant. Using this formula, select the most appropriate value for the Schwarzschild radius of Sagittarius A*, which has a mass of $4 \times 10^6 M_\odot$, from choices (1) to (4) below.

- Speed of light in vacuum: $c = 3 \times 10^8\,\mathrm{m/s}$
- Gravitational constant: $G = 7 \times 10^{-11}\,\mathrm{m^3/kg/s^2}$
- Solar radius: $R_\odot = 7 \times 10^8\,\mathrm{m}$
- Solar mass: $M_\odot = 2 \times 10^{30}\,\mathrm{kg}$

(1) $2 \times 10^{-1} R_\odot$

(2) $2 \times 10^{0} R_\odot$

(3) $2 \times 10^{1} R_\odot$

(4) $2 \times 10^{2} R_\odot$

Question 2

Consider bringing a spacecraft close to Earth to change its orbit. Among the following diagrams showing the relationship between Earth's orbital direction and the approach method of the spacecraft, select the one where the spacecraft gains the most acceleration from choices (1) to (4). Assume the orbital plane of the spacecraft is parallel to Earth's orbital plane. Refer to the diagram in the official paper.

Question 3

For the Hayabusa2 asteroid probe to escape the gravitational sphere of the asteroid Ryugu, select the most appropriate value for the minimum required velocity from choices (1) to (4). Assume Hayabusa2 accelerates only at the moment of departure from Ryugu.

Also, assume Ryugu is a uniform density sphere with a mass of $4.5 \times 10^{11}\,\mathrm{kg}$ and a diameter of $9.0 \times 10^{2}\,\mathrm{m}$.

$$\sqrt{2} = 1.4, \quad \sqrt{5} = 2.2, \quad \sqrt{6.7} = 2.6$$

Gravitational constant: $G = 6.7 \times 10^{-11}\,\mathrm{m^3/kg/s^2}$

(1) $0.5 \times 10^{-1}\,\mathrm{m/s}$

(2) $1.9 \times 10^{-1}\,\mathrm{m/s}$

(3) $2.6 \times 10^{-1}\,\mathrm{m/s}$

(4) $3.6 \times 10^{-1}\,\mathrm{m/s}$

Question 4

The absorption wavelength spectrum of a hydrogen atom can be written using the Rydberg constant R_∞ as follows:

$$\frac{1}{\lambda} = R_\infty \left(\frac{1}{n'^2} - \frac{1}{n^2} \right)$$

Here, n' is the principal quantum number before absorption, n is the principal quantum number after absorption, and λ is the wavelength. In observations of hydrogen gas, the line spectrum for $n' = 1, n = 2$ is important. Select the most appropriate wavelength for this line spectrum from choices (1) to (4). Rydberg constant: $R_\infty = 1.10 \times 10^{7}\,/\mathrm{m}$

(1) 103 nm

(2) 122 nm

(3) 486 nm

(4) 656 nm

Question 5

The volume of the universe was half of its current volume at some point in the past. Select the most appropriate temperature for the Cosmic Microwave Background (CMB) radiation at that time from choices (1) to (4). The current CMB temperature is 2.7 K. You may use the following information as needed:

- Relationship about internal energy of the CMB in the universe:

$$\frac{\partial U}{\partial T} = \frac{P}{T} V$$

- Equation of state:

$$P = \frac{U}{3V}$$

- Adiabatic (isentropic) cosmic expansion hypothesis:

$$\frac{1}{T}U + \frac{P}{T}V$$

  is constant.

Here, U is the total energy of the CMB in the universe, σ is the Stefan-Boltzmann constant, V is the volume of the universe, T is the CMB temperature, and P is the CMB radiation pressure.

$$\sqrt[3]{2} = 1.26$$

Stefan-Boltzmann constant: $\sigma = 5.67 \times 10^{-8}\,\mathrm{J/s/m^2/K^4}$

① 2.4 K

② 3.4 K

③ 4.4 K

④ 5.4 K

Question 6

Approximately how many billion years ago was the volume of the universe half its current volume? Select the most appropriate value from choices to . Assume the universe began from a single point and has been expanding at a constant speed. Also, assume 13.8 billion years have passed since the birth of the universe.

$$\sqrt[3]{2} = 1.26$$

① About 2.8 billion years ago

② About 4.0 billion years ago

③ About 6.9 billion years ago

④ About 11.0 billion years ago

Question 7

Select the most appropriate statement about atoms, photons, and electrons from choices ① to ④.

① A gamma-ray burst is an astronomical phenomenon where electrons are emitted at the speed of light.

② Line spectra have discrete wavelengths, which helps in identifying redshift.

③ X-rays have longer wavelengths and greater energy per photon than visible light.

④ No matter how small the frequency of light, if the amount of light is increased, electrons in atoms can be excited.

Question 8

The peak wavelength in the spectrum of a certain star is 580 nm. Select the most appropriate surface temperature for this star from choices ① to ④. Assume the radiation from the star can be approximated as blackbody radiation. The peak wavelength in the Sun's spectrum is 500 nm, and the Sun's surface temperature is 5800 K.

① 4000 K

② 5000 K

③ 6000 K

④ 7000 K

Question 9

By what factor is the wavelength of electromagnetic waves stretched when they reach Earth from a galaxy 50 million light-years away? Select the most appropriate value from choices ① to ④. Assume the distance between Earth and the galaxy is sufficiently close that the universe can be considered to be expanding at a constant speed, and also that the expansion velocity of the universe is sufficiently larger than the galaxy's peculiar motion velocity.

- Hubble constant: $H_0 = 75\,\mathrm{km/s/Mpc}$
- Speed of light in vacuum: $c = 3.0 \times 10^8\,\mathrm{m/s}$
- 1 light-year = 0.31 pc

① 1.4

② 1.04

③ 1.004

④ 1.0004

Question 10

The following text explains how to find the North Celestial Pole. Select the most appropriate combination of terms to fill in blanks (a), (b), and (c) from options ① to ④.

> A famous method for finding (a) (the North Star) uses the two constellations Cas (Cassiopeia) and (b). When using Cas, place point A at the intersection of the line connecting ϵ Cas and δ Cas and the line connecting α Cas and β Cas. Connect point A and (c), and extend this line in the direction of (c) for approximately 5 times the distance between point A and (c). (a) is located there.

	(a)	(b)	(c)
①	α UMa	UMi	γ Cas
②	α UMa	UMi	μ Cas
③	α UMi	UMa	γ Cas
④	α UMi	UMa	μ Cas

Question 11

Among the following combinations of constellation abbreviations defined by the International Astronomical Union (IAU) and their common Japanese names, select the one that is **incorrect** from choices ① to ④. The rest of the contents are not translatable.

Question 12

Consider "the brightness of the night sky" as the sum of the brightness of stars visible in the night sky. Let's call a spherical shell with negligible thickness an "infinitesimally thin shell."
Denote an infinitesimally thin shell centered on the observer with radius r and thickness

Δh as $B(r;\Delta h)$.

If the number density of stars is ρ and their average luminosity is L, then the total luminosity of the entire shell $B(r;\Delta h)$ can be expressed as (a). The apparent brightness of a single star is inversely proportional to the square of its distance. Therefore, the total apparent brightness $F_{\Delta h}(r)$ from the entire shell $B(r;\Delta h)$ is proportional to (a). Assuming the universe is infinitely large, it can be considered as the superposition of shells $B((n-1)\Delta h;\Delta h)$ for all natural numbers n. Thus, the brightness of the night sky is the sum of $F_{\Delta h}((n-1)\Delta h)$ over all natural numbers n. This sum results in (c) (infinity or finiteness).

Select the most appropriate combination for (a), (b) (the exponent for the inverse proportionality of apparent brightness), and (c) from choices (1) to (8).

	(a)	(b)	(c)
(1)	$8\pi\rho L\pi\Delta h$	2	finite, consistent with reality
(2)	$8\pi\rho L\pi\Delta h$	2	infinite, contradicts reality
(3)	$8\pi\rho L\pi\Delta h$	3	finite, consistent with reality
(4)	$8\pi\rho L\pi\Delta h$	3	infinite, contradicts reality
(5)	$4\pi\rho Lr^2\Delta h$	2	finite, consistent with reality
(6)	$4\pi\rho Lr^2\Delta h$	2	infinite, contradicts reality
(7)	$4\pi\rho Lr^2\Delta h$	3	finite, consistent with reality
(8)	$4\pi\rho Lr^2\Delta h$	3	infinite, contradicts reality

Question 13

Galaxies exhibit various morphologies. Elliptical galaxies are classified as En (e.g., E1, E5), where n represents the flatness of the ellipse. Select the diagram that most appropriately represents an E4 galaxy from choices (1) to (4). The flatness n is expressed using the semi-major axis a and semi-minor axis b of the ellipse as $n = 10\left(1-\frac{b}{a}\right)$.

Question 14

Generally, the speed of sound v [m/s] in Earth's atmosphere is expressed using the air temperature t [°C] as $v = 331.5 + 0.6t$. This is actually an approximation of the following formula.

$$v = \sqrt{\frac{\gamma RT}{M}}$$

Here, R is the gas constant, T is the absolute temperature, is the specific heat ratio, and M is the average molar mass. Saturn's moon Titan is famous for having an atmosphere

composed mostly of N_2 at about $-180°C$. Select the most appropriate value for the speed of sound near Titan's surface from choices (1) to (4).

- Atomic weight of N: 14
- For diatomic molecules, $\gamma = \frac{7}{5}$
- Gas constant: $R = 8.31\,\mathrm{J/mol/K}$

(1) 150 m/s

(2) 200 m/s

(3) 270 m/s

(4) 390 m/s

Question 15

The photo below shows an equatorial mount telescope correctly set up in the Northern Hemisphere. Select the most appropriate direction for the North Celestial Pole from choices (1) to (4).

Question 16

When using a telescope, a small auxiliary telescope called a finder scope is often used to locate stars. During telescope setup, it is necessary to align the centers of the main telescope tube and the finder scope.
The figure below is a photo of a finder scope fixed by six screws. The left photo "Finder Scope Diagram" shows the view from the eyepiece side. The right photo "Exploded View of Finder Scope" shows the finder scope detached from its mount, placed with the objective side up in the image. Among the six screws, the three screws on the eyepiece side are labeled as screws a, b, c as shown in the right photo.
After attaching this finder scope to the telescope and viewing a terrestrial landscape, the field of view shown in the schematic diagram below was obtained. Using only screws a, b, and c to align the finder scope, select the most appropriate method from choices (1) to (4).

Question 17

A meteor shower is a phenomenon where dust (meteoroid stream) released by comets or asteroids collides with Earth, and the meteoroids entering Earth's atmosphere emit light.

The direction from which the meteoroids enter Earth is parallel. Assuming all meteoroids are the same size and have the same luminous conditions, with a luminous point at 120 km altitude and an extinction point at 60 km altitude, select the most realistically expected path for a meteor in the shower from choices (1) to (4). In the diagrams, the red cross marks the radiant point, and the yellow arrows represent meteors.

$$\tan 19.1^\circ = \frac{\sqrt{3}}{5}$$

Question 18

A fireball was observed from two locations, A and B, 120 km apart, yielding the observation data below. Select the most appropriate combination of the fireball's approximate entry angle and geocentric velocity from choices (1) to (4).

$$\tan 18^\circ = \frac{1}{\sqrt{10}}, \quad \tan 35^\circ = \frac{1}{\sqrt{2}}$$

Location	Latitude (N)	Longitude (E)	Start Time	End Time	Start Dir.	Start Alt.	End Dir.	End Alt.
A	34.7°	133.9°	23h31m10.03s	23h31m15.00s	N (0°)	45°	SE (135°)	35°
B	34.7°	135.2°	23h31m10.03s	23h31m15.00s	NW (315°)	35°	SW (225°)	35°

(1) Entry angle: 18°, Geocentric velocity: 40 km/s

(2) Entry angle: 18°, Geocentric velocity: 80 km/s

(3) Entry angle: 35°, Geocentric velocity: 40 km/s

(4) Entry angle: 35°, Geocentric velocity: 80 km/s

Question 19

Atoms in the universe always contain an atomic nucleus, which is formed by N neutrons and Z protons bound together by binding energy. The total binding energy E_B within a single nucleus is semi-empirically known to be

$$E_B = E_V - E_O - E_C - E_S + E_P$$

Choices (1) to (4) represent possible formulas (all in MeV) for E_V, E_O, E_C, or E_S. Select the one that corresponds to E_C from choices to . Descriptions for each term are below.

- E_V: Binding energy dependent on the volume of the nucleus, which depends on the number of nucleons.
- E_O: Because the number of bonds at the nuclear surface is less than that considered for the nuclear volume, the actual binding energy is smaller than the sum considered for the nuclear volume.
- E_C: Protons have a repulsive Coulomb force due to their charge. This repulsion energy depends on the average distance between nucleons and is proportional to the number of bonds between one proton and the others.
- E_S: Quantum mechanically, nuclei are more stable when neutron and proton numbers are symmetric. A difference in numbers leads to instability and reduces binding energy.
- E_P: Pairing term: $E_P = \begin{cases} 11.2(N+Z)^{-\frac{1}{2}} & \text{(N, Z both even)} \\ -11.2(N+Z)^{-\frac{1}{2}} & \text{(N, Z both odd)} \\ 0 & \text{(otherwise)} \end{cases}$

(1) $0.714Z(Z-1)(N+Z)^{-\frac{1}{2}}$

(2) $15.67(N+Z)$

(3) $23.28(N-Z)^2(N+Z)^{-1}$

(4) $17.23(N+Z)^{\frac{2}{3}}$

Question 20

The figure below shows part of an optical planetarium projector known as the Zeiss type. Generally, the Zeiss type can represent the motion of stars due to diurnal motion, annual motion, precession, and changes in latitude. It projects stars using a sphere called the "star ball" and projects planets and their motions using a "planet cage." The rotation plane of the planet cage is roughly orthogonal to the central axis of the planetarium projector shown in the figure. Select the most appropriate statement about Polaris from choices (1) to (4). Do not consider the bright star projector.

(1) The central axis corresponds to Earth's rotation axis, so Polaris is projected from direction A.

(2) The central axis corresponds to Earth's precession axis, so Polaris is projected from direction B.

③ The central axis is based on the horizon, so based on Japan's average latitude, Polaris is projected from direction C.

④ The central axis is based on the galactic coordinate system to easily project the Milky Way, and Polaris is projected from direction D.

Question 21

The graph below shows, for a certain planet A in the solar system and seven other planets (1-7), the closest approach distance (blue symbols) and farthest separation distance (orange symbols) between each planet 1-7 and planet A. Select the appropriate planet for A from choices ① to ④. Ignore differences due to orbital inclination in the graph.

Question 22

The figure below shows the possible region traced by the tip of the shadow of a vertical pole of length 1 over the course of a year in Akashi City, Hyogo Prefecture (E135°00'05.3", N34°38'57.8"). Similarly, select the most appropriate region for the possible shadow tip over a year at Syowa Station in Antarctica (E39°35'01.5", S69°00'25.1") from choices ① to ④.

Question 23

Planet B and planet C orbit star A. Consider viewing inner planet B from planet C. Planet B's orbital period is 1.75×10^7 s, and planet C's orbital period is 3.00×10^7 s. Both orbits are circular, and planet B's orbital plane is inclined by 4° relative to planet C's orbital plane. At a certain time, a transit of planet B across the star's disk was observed from planet C. Select the **incorrect** statement from the following.

① The orbital radius of planet B is about 0.70 times that of planet C.

② Planet B and planet C undergo closest approach every 4.20×10^7 s.

③ Planet C passes through the penumbra of planet B every 2.10×10^8 s.

④ A transit of planet B across the star's disk is observed from planet C every 2.10×10^9 s.

Question 24

Observing the Sun on a certain day, sunspots A and B were observed. Setting latitude and longitude on the solar surface relative to the rotation axis resulted in the positional relationship between the coordinate system and the sunspots as shown in the figure. Assume the Sun's rotation direction is counterclockwise when viewed from above the rotation axis (top of image). Select the most appropriate positional relationship between the coordinate system and sunspots A, B when the Sun is observed again 5 days later from choices ① to ④.

Question 25

Regarding events I-III below, select the correct chronological order from oldest to newest from choices ① to ⑥.

I. Edmond Halley's calculation of Halley's Comet's orbit.

II. The International Astronomical Union's (IAU) establishment of the 88 constellation names.

III. Johannes Kepler's announcement that planetary orbits are elliptical.

① I $\longrightarrow$ II $\longrightarrow$ III

② I $\longrightarrow$ III $\longrightarrow$ II

③ II $\longrightarrow$ I $\longrightarrow$ III

④ II $\longrightarrow$ III $\longrightarrow$ I

⑤ III $\longrightarrow$ I $\longrightarrow$ II

⑥ III $\longrightarrow$ II $\longrightarrow$ I

Question 26

Among the following constellations, select the one **not** included in the 88 constellations defined by the International Astronomical Union (IAU) from choices ① to ④.

① Indus (Indii)

② Vulpecula (Vul)

③ Antlia (Ant)

④ Quadrans Muralis (Quadrantids)

Question 27

Regarding stellar atmospheres, select the **incorrect** statement from choices ① to ④.

① When observing the Sun in visible light, the center of the photosphere appears darker.

② Sudden brightening due to flares has been observed in stars other than the Sun.

③ In massive main-sequence stars, hydrogen absorption lines are primarily easy to observe.

④ Charged particles are emitted from the outer layers of a star's atmosphere, called stellar wind.

Question 28

Select the most appropriate schematic diagram for the internal structure of a star with an initial main-sequence mass of $1M_{\odot}$ just before it becomes a planetary nebula from choices to . The symbols inside ①④ indicate the elements abundant in that layer. The ratios of layer thicknesses are not accurate.

① Layers (from center out): C, O / He / H

② Layers (from center out): H / He / C, O

③ Layers (from center out): Fe / Si, Mg / O, Ne, Mg / He / H

④ Layers (from center out): H / He / C, O / Si, Mg / Fe

Question 29

The figure below is a schematic showing the evolutionary path on the HR diagram for a star of about $1M_{\odot}$ until it becomes a main-sequence star. What is the general term for stars in the stage just before becoming a main-sequence star, as shown in this evolutionary process? Also, what is the ratio of the stellar radius at point A in the figure to the stellar radius at point B, to one significant figure? Select the most appropriate combination of the general term and the radius ratio from choices ① to ④.

	General Term	Radius Ratio (A/B)
	T Tauri Star	1×10^2
	T Tauri Star	1×10^1
	Protostar	1×10^2
	Protostar	1×10^1

Question 30

The supernova explosion that created the supernova remnant M1 (Crab Nebula) is believed to have been observed in 1054 AD. Select the most appropriate value for the average expansion speed of M1 from the time of the explosion to the present from choices (1) to (6). The current angular diameter of M1 is 6 arcminutes, and its distance from Earth is 2.4×10^3 pc. Ignore the size of the star just before the explosion.

$$1\,\mathrm{pc} = 3.1 \times 10^{16}\,\mathrm{m}, \quad 1\,\mathrm{year} = 3.2 \times 10^7\,\mathrm{s}$$

(1) 2×10^2 km/s

(2) 4×10^2 km/s

(3) 2×10^3 km/s

(4) 4×10^3 km/s

(5) 2×10^4 km/s

(6) 4×10^4 km/s

Question 31

Right ascension and declination are coordinate systems based on the vernal equinox and the celestial equator. Similarly, galactic longitude and latitude are coordinate systems based on the direction of the galactic center and the plane of the Milky Way's disk. Select the constellation that does **not** contain the galactic latitude $b = 0°$ within its area from choices (1) to (2).

(1) Orion

(2) Sagittarius

(3) Cygnus

(4) Coma Berenices

Question 32

The following image groups and graph groups are images and color-magnitude diagrams of two different types of star clusters. Select the most appropriate combination of the image of a globular cluster and its corresponding HR diagram from choices (1) to (4).

Question 33

It is known that the rotation speeds of many disk galaxies are nearly constant regardless of radius. Here, we model the Milky Way as a sufficiently thin disk, assuming the rotation speed is constant independent of radius and the density distribution is isotropic within the disk plane. For an isotropic density distribution within a certain radius, the magnitude of gravitational force on an object of mass m at radius r is given by

$$\frac{GmM_r}{r^2}$$

where M_r is the total mass contained within radius r, and G is the gravitational constant. Considering the balance between centrifugal force and gravitational force at each radius, select the graph that most appropriately shows the radius dependence of M_r from choices (1) to (4). The graphs use relative values on both axes.

Question 34

An Active Galactic Nucleus (AGN) is an object where energy equivalent to the brightness of the galaxy itself is radiated from the central region of a galaxy. It is thought to be powered by a supermassive black hole at the galaxy's center. Regarding AGNs and black holes, select the **least** appropriate statement from choices (1) to (4).

(1) AGNs shining at various wavelengths, such as radio and X-rays, have been discovered.

(2) AGNs are thought to shine using gravitational potential energy released when matter falls into the black hole.

(3) All supermassive black holes at galactic centers are thought to have masses around $10^6 M_\odot$.

(4) AGNs that change brightness over short periods have been discovered.

Question 35

Nebulae are classified into various types based on the cause of their observed emission. Select the most appropriate statement about nebula classification from choices ① to ④.

① An emission nebula is a nebula where gas atoms are ionized by light from stars, often seen around low-mass stars.

② A reflection nebula is a molecular cloud containing many molecules that shines by reflecting light from stars.

③ A dark nebula is a nebula mainly composed of dark matter. It cannot be observed directly but is detected by blocking background light.

④ A planetary nebula is formed when a star with about the Sun's mass ends its life and expels gas. A neutron star is often seen at its center.

Question 36

Observations of a certain Cepheid variable showed an apparent magnitude of 8.5 mag. Its absolute magnitude, derived from the period-luminosity relation, was -4.0 mag. However, multi-wavelength observations revealed this Cepheid suffers from 2.5 magnitudes of interstellar extinction. Considering the extinction, select the most appropriate distance to this Cepheid from choices ① to ④.

① 1.0 kpc

② 3.2 kpc

③ 10 kpc

④ 32 kpc

Question 37

In astronomy, combining multi-wavelength observations to obtain various information about celestial objects is extremely important. Electromagnetic waves are classified into several types based on their wavelength (frequency). Select the **incorrect** statement regarding the types of electromagnetic waves and their uses from choices ① to ④.

① Although individual differences exist, the wavelength of visible light is roughly from 400 nm to 800 nm.

② Infrared light has longer wavelengths than visible light, making it less affected by interstellar extinction. It is used to observe objects like protostars embedded in dust.

③ X-rays are used to observe low-temperature objects but are difficult to observe from the ground due to atmospheric absorption.

④ Observations using interferometers combining multiple radio telescopes enable high spatial resolution.

Question 38

The brightness (energy received per unit time, area, and wavelength) of a certain star was measured using filters for various wavelength bands, yielding the results in the table below. Ignoring effects like interstellar extinction, and assuming each filter's sensitivity is constant within its band, select the most appropriate spectral type for this star from choices ① to ④.

Filter Wavelength Band [nm]	Brightness (Relative Value)
300 - 400	1.00
400 - 550	1.32
550 - 700	1.17
700 - 850	0.86
850 - 950	0.64
950 - 1100	0.48

① O-type star

② A-type star

③ G-type star

④ M-type star

Question 39

Select the most appropriate combination of major telescopes around the world and the wavelengths they primarily observe from choices ① to ④.

	Major Telescope	Observing Wavelength
①	Subaru Telescope	1 nm
②	ALMA Telescope	1 m
③	Hubble Space Telescope	1 m
④	James Webb Space Telescope	1 mm

Question 40

Select the most appropriate statement about binary star systems from choices ① to ④.

① About 1% of stars are in binary systems.

② When observing the spectrum of a binary system with an intrinsic wavelength λ_0, two spectral lines are always seen.

③ All eclipsing variable stars are part of binary systems.

④ All double stars are binary systems.

Question 41

Consider an eclipsing variable star with a light curve as shown in the figure below. This variable star is a binary system consisting of two main-sequence stars. An observer on Earth is in the orbital plane of the binary. Select the diagram that most appropriately represents the positional relationship between the two main-sequence stars and the direction to Earth at the time t marked on the figure from choices ① to ④.

Question 42

Regarding the following statements a, b, c about planets in the solar system, select the most appropriate combination of their truth values from choices ① to ⑧.

a The orbital period of terrestrial planets is shorter than that of Jovian planets.

b The flattening (oblateness) of terrestrial planets is smaller than that of Jovian planets.

c The number of satellites of terrestrial planets is fewer than that of Jovian planets.

	a	b	c
①	True	True	True
②	True	True	False
③	True	False	True
④	True	False	False
⑤	False	True	True
⑥	False	True	False
⑦	False	False	True
⑧	False	False	False

Question 43

The figure below shows the equation of time for the year 2023. The equation of time is obtained by subtracting mean solar time (based on a fictitious "mean sun" moving at constant speed along the celestial equator) from apparent solar time (based on the actual observed motion of the Sun). For a location in Japan on the 135°E meridian today (February 18th), select the time closest to when the Sun will transit the meridian (south) from choices ① to ④.

① 11:25

② 11:55

③ 12:05

④ 12:35

Question 44

In the 18th century, the English astronomer William Herschel systematically investigated the distribution of stars. At that time, there was no method to measure distances to stars, so he assumed

> The absolute magnitude of all stars is equal, and their apparent brightness is inversely proportional to the square of their distance.

Based on this assumption, he arrived at the concept of a disk-shaped "Galactic System" with the solar system nearly at its center. If Herschel's assumption were correct, select the most appropriate statement about stars from choices ① to ④.

① The distance to a star of apparent magnitude 6 is about 10 times that to a star of apparent magnitude 1.

② When the observable magnitude limit increases by 1 magnitude, the number of observable stars increases by about 10 times.

③ Stars with larger apparent magnitudes have smaller absolute magnitudes.

④ Stars with smaller apparent magnitudes have smaller annual parallaxes.

Question 45

The universe is expanding uniformly. Galaxies A to D are distributed on the same plane as shown in the figure. Select the most appropriate statement about galaxies A to D from choices ① to ④. Assume the peculiar motions of galaxies A to D are sufficiently small compared to their recession velocities due to cosmic expansion and can be ignored.

① When viewed from galaxy A, among galaxies BD, galaxy C has the largest recession velocity.

② When viewed from galaxy B, the angular separation between galaxy A and galaxy D on the celestial sphere appears to be increasing.

③ When viewed from galaxy C, the recession velocity of galaxy D is twice that of galaxy B.

④ When viewed from galaxy D, the recession velocity of galaxy A is equal to that of galaxy C.

Question 46

Regarding the following statements a, b, c about the motion of planets in the solar system, select the most appropriate combination of their truth values from choices to .

a Planets revolve around the Sun in elliptical orbits with the Sun at one focus.

b Kepler's laws cannot be applied to trans-Neptunian objects or periodic comets.

c At perihelion, the distance between a planet and the Sun is minimal, so it is summer in Earth's Northern Hemisphere.

	a	b	c
①	True	True	True
②	True	True	False
③	True	False	True
④	True	False	False
⑤	False	True	True
⑥	False	True	False
⑦	False	False	True
⑧	False	False	False

Question 47

Suppose there is a hypothetical planet X inside Earth's orbit. The maximum elongation of planet X as observed from Earth is 30°. Select the most appropriate orbital period for planet X from choices ① to ④. Assume both Earth's and planet X's orbits are circles centered on the Sun, and their orbital planes coincide.

$$\sqrt{2} = 1.41, \quad \sqrt[3]{2} = 1.26$$

① 100 days

② 130 days

③ 160 days

④ 190 days

Question 48

Regarding the following statements a, b about distances to stars, select the most appropriate combination of their truth values from choices ① to ④.

a Distances to stars can be determined using annual parallax up to about 0.001 arcseconds.

b Hubble's law can be used to measure the distance to the center of our Milky Way galaxy.

	a	b
①	True	True
②	True	False
③	False	True
④	False	False

Question 49

Regarding the following statements a, b, select the most appropriate combination of their truth values from choices ① to ④.

a There are years when no solar eclipse occurs anywhere on Earth.

b There are years when no lunar eclipse occurs anywhere on Earth. (Penumbral lunar eclipses are not included.)

	a	b
①	True	True
②	True	False
③	False	True
④	False	False

Question 50

For a telescope with an objective lens focal length of 800 mm, an eyepiece focal length of 20 mm, and an objective lens effective aperture of 80 mm, select the most appropriate combination of the telescope's magnification and f-number from choices ① to ④.

	Magnification	f-number
①	10	F4
②	10	F10
③	40	F4
④	40	F10