GLOBAL ASTRONOMY & ASTROPHYSICS CHALLENGE

ROUND OF 16
QUALIFIER

20 Challenging Multiple-Choice Questions

Time Limit: 30 Minutes

TOPICS

Observational Astronomy · Astrophysics · Planetology
Cosmology · Orbital Mechanics · Space Missions

2026

Round of 16 Qualifier

Instructions

This Qualifier consists of **20 multiple-choice questions** with a time limit of **30 minutes**. Each participant completes the examination individually. The unified Round 1 scoring system (including grade and team-size factors) applies. Select the single best answer for each question.

Physical and Astronomical Constants (Reference)

- Speed of light $c = 3.0 \times 10^8$ m/s
- Gravitational constant $G = 6.674 \times 10^{-11}$ m^3 kg^{-1} s^{-2}
- Solar mass $M_\odot = 1.989 \times 10^{30}$ kg
- Solar luminosity $L_\odot = 3.8 \times 10^{26}$ W
- Solar radius $R_\odot = 6.96 \times 10^8$ m
- Astronomical unit 1 AU $= 1.496 \times 10^{11}$ m
- Parsec 1 pc $= 2.06 \times 10^5$ AU
- Arcseconds per radian 206 265
- Earth's gravitational parameter $\mu_\oplus = 398\,600$ km^3/s^2
- Hubble constant $H_0 = 70$ km/s/Mpc
- CMB temperature today $T_0 = 2.73$ K
- Sun's main-sequence lifetime 10 Gyr

Q1 (Observational Astronomy)

The Astronomy Club receives an old observing sheet containing a measurement of a binary system. The apparent separation of the two components is $0.42''$, and the system is listed at a distance of 24 pc. A later catalogue gives 11 AU as the separation of the two stars. The original observer does not state whether the orbital plane was perpendicular to the line of sight.
Which interpretation is physically possible?

(A) The catalogue must be wrong because $0.42''$ at 24 pc determines a unique three-dimensional separation

(B) The two records can be consistent because the angular observation gives only the projected separation, which may be smaller than the true separation

(C) The stars must be exactly 11 AU apart because the projected separation is always equal to the physical separation

(D) The discrepancy establishes that the system cannot be gravitationally bound

Answer: (B) **Difficulty:** Medium

Solution: At 24 pc, $1''$ corresponds to 24 AU. The observed separation gives

$$s_{\text{proj}} = 0.42 \times 24 = 10.08 \text{ AU}.$$

This is only the component in the plane of the sky. A line-of-sight component can make the true separation larger, allowing a true separation of 11 AU.

Q2 (Astrophysics)

An Arab astronomical manuscript describes the Pleiades as a compact group and Orion as the Hunter following them through the seasonal sky. Centuries later, astrometric observations show that the Pleiades have a bulk proper motion of 19 milliarcseconds per year toward the east, while a selected reference position in Orion shifts 4 milliarcseconds per year toward the west. The old description is being used only as a historical link; the calculation comes from the modern measurements.
If the angular separation between the two reference positions changes by exactly $1.0'$ because of these motions, approximately how long does the change require?

(A) 2.6×10^2 years

(B) 1.3×10^3 years

(C) 2.6×10^3 years

(D) 2.6×10^4 years

Answer: (C) **Difficulty:** Medium

Solution: The motions are opposite in direction, giving a relative rate

$$\mu_{\rm rel} = 19 + 4 = 23 \text{ mas/yr}.$$

One arcminute contains 60 000 mas. The timescale is

$$t = \frac{60\,000}{23} \approx 2.61 \times 10^3 \text{ yr}.$$

Q3 (Observational Astronomy)

The club's imaging team mounts a new CCD camera at the Cassegrain focus of a 1.2 m telescope with focal ratio $f/8$. The detector has 4096×4096 square pixels, each $15\,\mu$m on a side, and no focal reducer is used. Two engineers argue about how much sky the camera actually records. The plate scale is set by the focal length, and the field of view is then the plate scale times the number of pixels.
What is the field of view along one side of the detector, to the nearest 10%?

(A) $11'$

(B) $22'$

(C) $44'$

(D) $88'$

Answer: (B) **Difficulty:** Hard

Solution: The focal length is the focal ratio times the aperture:

$$f = 8(1.2) = 9.6 \text{ m} = 9600 \text{ mm}.$$

The plate scale is

$$\frac{206\,265}{9600} \approx 21.5 \text{ arcsec/mm}.$$

Each pixel is

$$15\,\mu\text{m} = 0.015\text{ mm},$$

so one pixel subtends

$$21.5(0.015) \approx 0.323\text{ arcsec}.$$

Across the full detector,

$$4096(0.323)\text{ arcsec} \approx 1320\text{ arcsec} = 22.0'.$$

A common slip is to use the diameter with the full focal length or to forget that the pixel size must be expressed in millimetres.

Q4 (Observational Astronomy)

During a comparison between a ground-based observation and a space-based image, the same crowded stellar field looks completely different. The telescope has a theoretical diffraction limit of $0.05''$, but the atmospheric seeing during the exposure is approximately $0.9''$. Two sources in the space image are known to be separated by $0.2''$.
Which statement is the most defensible interpretation of the ground-based observation?

(A) The sources are automatically resolved because $0.2''$ is larger than the diffraction limit

(B) The sources must be unrelated because their separation is smaller than the seeing

(C) Their individual positions may still be extracted by fitting an appropriate point-spread function, but the raw image cannot be interpreted using the diffraction limit alone

(D) Atmospheric seeing changes their actual physical separation

Answer: (C) **Difficulty:** Hard

Solution: The diffraction limit describes the ideal optical system. Atmospheric turbulence broadens the effective point-spread function to roughly the seeing scale. Two sources separated by $0.2''$ are not simply resolved from the raw image when the seeing is $0.9''$. Model fitting can still recover separate positions under suitable signal-to-noise conditions.

Q5 (Astrophysics)

A comparison exercise in the archive pairs a white dwarf with mass $0.60M_\odot$ and radius $0.0100R_\odot$ against a neutron star with mass $1.40M_\odot$ and radius 12 km. The assistant must convert both radii into the same units and then compare the surface gravitational accelerations. Two drafts are submitted, and they disagree by several orders of magnitude.
Which value is the best estimate of the ratio of the neutron star's surface acceleration to the white dwarf's?

(A) 1.4×10^3

(B) 7.9×10^5

(C) 7.9×10^6

(D) 7.9×10^9

Answer: (B) **Difficulty:** Hard

Solution: The surface acceleration is

$$g \propto \frac{M}{R^2}.$$

The mass ratio is

$$\frac{1.40}{0.60} = 2.33.$$

Convert the radii to metres:

$$R_{\rm WD} = 0.0100 R_\odot = 0.0100(6.96 \times 10^8) = 6.96 \times 10^6 \text{ m},$$

$$R_{\rm NS} = 12 \text{ km} = 1.2 \times 10^4 \text{ m}.$$

The radius ratio is

$$\frac{6.96 \times 10^6}{1.2 \times 10^4} = 580,$$

so

$$\frac{g_{\rm NS}}{g_{\rm WD}} = 2.33(580)^2 = 2.33(3.36 \times 10^5) \approx 7.8 \times 10^5.$$

Replacing the radius ratio by its first power (about 1.4×10^3) is a common slip.

Q6 (Astrophysics)

At the Astronomy Club, Adel and Sami are given a peculiar stellar spectrum by Dr. Hussein. The object is hot, with an effective temperature close to 12 000 K, yet its luminosity is only about $0.003 L_\odot$. The first catalogue entry classified it as an ordinary blue main-sequence star. A radius estimate based on its temperature and luminosity turns out to be far smaller than that expected for a normal main-sequence star at the same temperature.
Which interpretation best fits the evidence?

(A) A compact hot remnant, consistent with a white dwarf

(B) A massive young star whose luminosity has been temporarily suppressed

(C) A cool giant whose temperature was probably overestimated

(D) A planet reflecting light from an unseen companion

Answer: (A) **Difficulty:** Medium

Solution: A high effective temperature combined with a very low luminosity implies a small emitting surface. That combination is characteristic of a compact stellar remnant. White dwarfs can have high surface temperatures while radiating much less total power than ordinary blue main-sequence stars.

Q7 (Astrophysics)

A supernova is discovered in a galaxy whose spectrum contains several recognizable features. One transition known to occur at 600 nm is measured at 900 nm. The observing team marks the host as sufficiently distant that its wavelength shift is handled with cosmological redshift rather

than the low-speed stellar Doppler approximation.
What redshift corresponds to the measured wavelength?

(A) 0.33

(B) 0.50

(C) 1.50

(D) 2.00

Answer: (B) **Difficulty:** Medium

Solution:

$$1 + z = \frac{\lambda_{\rm obs}}{\lambda_{\rm emit}} = \frac{900}{600} = 1.5.$$

The redshift is

$$z = 0.50.$$

Q8 (Astrophysics)

An isolated star is observed through two filters on several nights. Its measured colour changes systematically with altitude: the star appears bluer high in the sky and redder close to the horizon. A space-based observation taken during the same interval shows no corresponding intrinsic change. The ground-based effect becomes stronger at large zenith angles.
Which explanation deserves first attention?

(A) Differential atmospheric extinction

(B) A sudden change in the star's nuclear reaction rate

(C) Proper motion of the star

(D) Gravitational waves altering the star's colour

Answer: (A) **Difficulty:** Medium

Solution: The light path through the atmosphere becomes longer toward the horizon. Atmospheric extinction is wavelength dependent, with shorter wavelengths affected more strongly. The observed reddening with increasing zenith angle is a direct signature of differential extinction.

Q9 (Astrophysics)

A research team builds a simple structural model of a prestellar core. They suppose the density falls off away from the centre as a power law, so the profile is written as a function of radius

$$\rho(r) = \rho_0 \left(\frac{R}{r}\right)^n,$$

where ρ_0 is the density at the reference radius R and n is a free index. The mass enclosed inside a radius r follows from adding spherical shells:

$$M(<r) = \int_0^r 4\pi r'^2 \rho(r')\, dr'.$$

The team wants to test the idea that the mass in the core keeps growing in direct proportion to the radius, so that $M(<r) \propto r$.
Which index n makes the enclosed mass scale linearly with radius?

(A) 1
(B) 3/2
(C) 2
(D) 3

Answer: (C) **Difficulty:** Hard

Solution: Insert the profile into the shell integral:

$$dM = 4\pi r^2 \rho(r)\, dr = 4\pi \rho_0 R^n\, r^{2-n}\, dr.$$

Integrating from 0 to r, excluding only the special case $n = 3$, gives

$$M(<r) = \frac{4\pi \rho_0 R^n}{3-n}\, r^{3-n}.$$

For the enclosed mass to grow in direct proportion to the radius,

$$3 - n = 1 \qquad \Longrightarrow \qquad n = 2.$$

The resulting profile $\rho \propto r^{-2}$ is the singular isothermal sphere, a standard idealized description of prestellar cores.

Q10 (Astrophysics)

A new hot Jupiter is discovered with the transit method: the planet passes directly in front of its Sun-like host star. Its radius is measured as $R_p = 0.10 R_\odot$, essentially equal to the radius of eleven Earths. During mid-transit the planet covers a circular patch of the stellar disk, blocking the light from that area.
What fractional decrease in the star's apparent flux should the astronomers expect?

(A) 0.01%
(B) 0.1%
(C) 1%
(D) 10%

Answer: (C) **Difficulty:** Medium

Solution: The transit depth is the ratio of the blocked disk area to the stellar disk area:

$$\delta = \frac{\pi R_p^2}{\pi R_\star^2} = \left(\frac{R_p}{R_\star}\right)^2 = \left(\frac{0.10 R_\odot}{1 R_\odot}\right)^2 = 0.010$$

$$\delta = 1\%.$$

The dip is small because the area covered scales with the square of the radius.

Q11 (Cosmology)

A member of the team studies two twin galaxies in the archive. They have identical true size, luminosity, and orientation, and both are seen face-on with no dust along the line of sight. One is nearby, with a small redshift, and the other is far away, with $z \approx 1$. In a static, Euclidean universe, two identical galaxies would show the same surface brightness, meaning the same flux per square arcsecond of the telescope image. In the expanding universe this equality quietly breaks.
Which scaling describes how the surface brightness of the identical distant galaxy compares with the nearby one?

(A) It is $1 + z$ times fainter

(B) It is $(1 + z)^2$ times fainter

(C) It is $(1 + z)^4$ times fainter

(D) It is unchanged, independent of z

Answer: (C) **Difficulty:** Hard

Solution: Three separate effects each take one factor of $1+z$, and a fourth emerges from geometry. A photon carries energy $E = h\nu$. As the universe stretches, each photon loses a factor $1 + z$ of its energy. Expansion also dilates time, so photons arrive at a lower rate, another factor $1 + z$. Finally, the solid angle subtended by the galaxy grows: the angular size dilates, making the apparent area in square arcseconds about $(1 + z)^2$ larger.
Multiplying the three effects,

$$F_{\rm sb} \propto (1 + z)^{-(1+1+2)} = (1 + z)^{-4}.$$

The surface brightness dims as $(1 + z)^4$, far faster than the $(1 + z)^2$ naive geometric guess. This deep dimming is one of the cleanest signatures that separates a genuinely expanding universe from a static one, and it is part of the reason the sky is dark and the far universe looks so faint.

Q12 (Cosmology)

A compact-object merger is detected in a distant galaxy. The gravitational-wave signal indicates two compact bodies with masses of only a few solar masses. An optical transient appears in follow-up observations, and spectroscopy of the host provides a substantial cosmological redshift. The research group has to decide whether the event can reasonably be identified as a neutron-star merger rather than an ordinary stellar supernova.
Which combination of evidence is most decisive?

(A) The host galaxy's apparent size together with the transient's apparent colour

(B) The gravitational-wave waveform, inferred component masses, and an electromagnetic counterpart

(C) The host galaxy's redshift alone

(D) The apparent brightness of the optical transient alone

Answer: (B) **Difficulty:** Hard

Solution: A neutron-star merger leaves a characteristic gravitational-wave signal, and the waveform constrains the component masses. An electromagnetic counterpart supplies an independent signature of the post-merger event. The host redshift contributes the cosmological distance scale, but it cannot identify the transient by itself.

Q13 (Cosmology)

A cosmology worksheet asks for a rough measure of the age of the universe from the expansion rate alone. The student is given $H_0 = 70$ km/s/Mpc and the conversion facts 1 pc $= 2.06 \times 10^5$ AU and 1 AU $= 1.496 \times 10^{11}$ m, with 1 yr $= 3.156 \times 10^7$ s. The inverse of the expansion rate has units of time and is called the Hubble time.
What is the Hubble time to two significant figures?

(A) 1.4 Gyr
(B) 14 Gyr
(C) 140 Gyr
(D) 1400 Gyr

Answer: (B) **Difficulty:** Hard

Solution: Convert the megaparsec into kilometres:

$$1 \text{ Mpc} = 10^6(2.06 \times 10^5)(1.496 \times 10^{11}) \text{ m} \approx 3.08 \times 10^{22} \text{ m} = 3.08 \times 10^{19} \text{ km}.$$

The Hubble time is the reciprocal of the Hubble constant:

$$t_H = \frac{1}{H_0} = \frac{3.08 \times 10^{19} \text{ km}}{70 \text{ km s}^{-1}} \approx 4.40 \times 10^{17} \text{ s}.$$

Converting to years and then to billions of years,

$$t_H = \frac{4.40 \times 10^{17}}{3.156 \times 10^7} \text{ yr} \approx 1.39 \times 10^{10} \text{ yr}$$

$$t_H \approx 14 \text{ Gyr}.$$

Skipping the AU conversion shifts the answer by several orders of magnitude.

Q14 (Cosmology)

A cosmology report contains the following chain of reasoning. A galaxy is observed at redshift $z = 3$, and the report correctly states that its emitted light corresponds to a cosmic scale factor one quarter of today's value. The author then concludes that the galaxy is now exactly four times farther from us than it was when the light was emitted. The sentence looks convincing because the numerical factor four appears in both steps.
What invalidates the final conclusion?

(A) Redshift has no relation to the scale factor
(B) A scale-factor ratio does not by itself determine the ratio of emission-time and present

distances, because cosmic distances depend on the evolving geometry and on the distance definition being used

(C) The galaxy must be closer now because the universe is expanding

(D) A galaxy at $z = 3$ cannot be observed directly

Answer: (B) **Difficulty:** Very Hard

Solution: The redshift relation gives

$$1 + z = \frac{a_0}{a_{\text{emit}}},$$

so $a_{\text{emit}} = 1/4$ when $a_0 = 1$ and $z = 3$.
That result does not imply

$$d_{\text{now}} = 4d_{\text{emit}}.$$

The source participates in the cosmic expansion, and distances in cosmology are defined in several ways, including proper, comoving, luminosity, and angular-diameter distance. Their relations involve the expansion history rather than a single scale-factor ratio. The numerical factor four identifies the scale-factor change, not a universal distance ratio.

Q15 (Planetology)

Adel and Sami are assigned a fictional rocky planet whose mass is measured as $0.64M_\oplus$. Its radius turns out to be $0.80R_\oplus$, and rotational effects are negligible. Before the lander activates its gravimeter, the team wants a prediction for the surface acceleration.
What fraction of Earth's surface gravity should the lander expect?

(A) 0.64

(B) 0.80

(C) 1.00

(D) 1.25

Answer: (C) **Difficulty:** Medium

Solution: Surface gravity scales as

$$g \propto \frac{M}{R^2}.$$

The planetary ratio is

$$\frac{g}{g_\oplus} = \frac{0.64}{(0.80)^2} = \frac{0.64}{0.64} = 1.$$

The surface gravity matches Earth's in this idealized model.

Q16 (Planetology)

Radar mapping of a fictional lunar-polar crater shows a floor extending 58 km from its centre. One section of the rim rises 1.7 km above the floor. During the critical season, sunlight arrives from that side at an elevation of only 1.6° above the local horizon.

Would direct sunlight from that direction reach the crater centre?

(A) Yes, because any positive solar elevation produces illumination

(B) No, because the geometric shadow extends slightly beyond the crater radius

(C) Yes, because the Moon has no atmosphere

(D) No, because sunlight cannot travel nearly horizontally across lunar terrain

Answer: (B) **Difficulty:** Hard

Solution: The geometric shadow length is approximately

$$L = \frac{h}{\tan\alpha} = \frac{1.7}{\tan 1.6^\circ} \approx 60.8 \text{ km}.$$

The floor radius is 58 km. The shadow reaches beyond the centre, leaving the centre geometrically dark from that direction.

Q17 (Planetology)

A robotic mission studies an airless world whose surface is covered by impact craters. One broad region contains densely overlapping craters, while an adjacent region is comparatively smooth and contains rock units that cut across older terrain. No substantial atmosphere is present, and no active erosion mechanism has been detected.
Which interpretation best fits the sequence visible in the terrain?

(A) The smooth region must be older because its surface contains fewer scars

(B) The smooth region is likely younger, with later resurfacing reducing the visible record of earlier impacts

(C) Crater counts carry no information about relative age on airless worlds

(D) Dense crater fields can form only after volcanic activity has stopped everywhere on the planet

Answer: (B) **Difficulty:** Medium

Solution: Airless surfaces accumulate impact scars over time. A younger resurfaced region can erase or bury much of the older crater record. The cross-cutting relation described in the question supports the smooth region being younger than the heavily cratered terrain.

Q18 (Orbital Mechanics)

The Artemis navigation team receives a trajectory update after the spacecraft has entered a highly eccentric lunar orbit. The new objective is to push the high point of the orbit outward as efficiently as possible, but the propellant budget cannot be increased. The low point of the orbit is the part of the trajectory where the spacecraft moves fastest, reaching 8.0 km/s, while the high point is traversed at only 2.0 km/s.
Two candidate maneuvers use exactly the same small tangential prograde impulse Δv. One is executed at the low point and the other at the high point. The guidance engineer says the first

maneuver produces a much larger change in orbital energy even though the engines deliver the same Δv.
What is the ratio of the first-order changes in specific orbital energy?

(A) 1 : 4
(B) 2 : 1
(C) 4 : 1
(D) 16 : 1

Answer: (C) **Difficulty:** Hard

Solution: For a small tangential prograde impulse,

$$\Delta\epsilon = \frac{(v+\Delta v)^2 - v^2}{2} \approx v\Delta v.$$

The two impulses have equal Δv, giving

$$\frac{\Delta\epsilon_{\text{low}}}{\Delta\epsilon_{\text{high}}} = \frac{8.0}{2.0} = 4.$$

The high-speed maneuver changes the orbital energy four times as much to first order.

Q19 (Orbital Mechanics)

A second Artemis correction is scheduled near the high point of the transfer orbit. The spacecraft is moving at 2.0 km/s when a small prograde impulse of 50 m/s is applied. The navigation software states that terms of order $(\Delta v)^2$ may be neglected.
What increase in specific orbital energy is produced by this maneuver?

(A) $0.01\ \text{km}^2/\text{s}^2$
(B) $0.05\ \text{km}^2/\text{s}^2$
(C) $0.10\ \text{km}^2/\text{s}^2$
(D) $1.0\ \text{km}^2/\text{s}^2$

Answer: (C) **Difficulty:** Medium-Hard

Solution: The speed increment is

$$50\ \text{m/s} = 0.050\ \text{km/s}.$$

For a small tangential impulse,

$$\Delta\epsilon \approx v\Delta v.$$

The energy change is

$$\Delta\epsilon = (2.0)(0.050) = 0.10\ \text{km}^2/\text{s}^2.$$

Q20 (Space Science)

The final transmission received by the expedition concerns a short-lived high-energy transient first detected by an orbiting observatory. Seconds later, an optical counterpart appears in approximately the same region of the sky. The high-energy detector cannot localize the source well enough to identify a host galaxy by itself, while the optical telescope can obtain a much more precise position.
Which follow-up observation provides the strongest combination of physical identification and distance information?

(A) A precise optical position followed by spectroscopy of the transient and its host galaxy

(B) A second measurement of apparent brightness alone

(C) A single colour measurement without accurate localization

(D) A repeat exposure in the same high-energy band without optical spectroscopy

Answer: (A) **Difficulty:** Medium

Solution: A precise optical position allows the transient to be associated with a host galaxy. Spectroscopy can provide the host redshift and reveal characteristic features of the transient. The combination supplies both a distance scale and information about the physical nature of the event.