AstroChallenge 2018
Multiple Choice Questions
(Junior)

PLEASE READ THESE INSTRUCTIONS CAREFULLY

1. This paper consists of **19** printed pages, including this cover page.

2. Do **NOT** turn over this page until instructed to do so.

3. You have **2 hours** to attempt all questions in this paper. If you think there is more than one correct answer, choose the most correct answer.

4. At the end of the paper, submit this booklet together with your answer script.

5. Your answer script should clearly indicate your name, school, and team.

6. It is your responsibility to ensure that your answer script has been submitted.

1. Consider the following planets and their orbital eccentricities.

Planet	Orbital Eccentricity
A	0.206
B	0.007
C	0.017
D	0.093
E	0.048

Which planet has the **most circular** orbit?

(A) Planet A.

(B) Planet B.

(C) Planet C.

(D) Planet D.

(E) Planet E.

2. Which of the following **best** characterises the movement of a star onto the horizontal branch of a HR diagram?

(A) The onset of helium burning after a helium flash.

(B) The onset of neon burning in an extremely massive star.

(C) The expansion of a low-mass star into a red giant.

(D) The sudden collapse of an iron core into a compact ball of neutrons.

(E) The sudden outpouring of X-rays from a newly formed accretion disk.

3. The following are some neolithic structures portraying the effects of astronomical alignment, as well as an archaeological relic that was thought to be previously used for astronomical purposes.

 I. Khafre's pyramid in Egypt $(29° \, 59')$ was built about 4700 years ago with one of its sides aligned with the direction in which the star 3-Scorpii sets.

 II. The neolithic burial chamber Maeshowe $(59° \, 00')$ was built about 5000 years ago so that the last rays of the setting sun on the winter solstice would travel down the long entrance tunnel to illuminate the interior of the tomb.

 III. The Antikythera mechanism, thought to be built in 100–150 BC, predicted eclipses based on the Saros cycle.

Which of these will still work this year? Ignore any effects of erosion and rusting.

(A) II only.

(B) I and II only.

(C) I and III only.

(D) II and III only.

(E) I, II, and III.

4. A periodic comet in the Solar System with an eccentricity of 0.6216 takes 76.69 years to complete an orbit around the Sun. What is its aphelion distance?

(A) 18 AU.

(B) 29 AU.

(C) 36 AU.

(D) 47 AU.

(E) 59 AU.

5. On the night of 11 November 2018 in Singapore, which star will rise the earliest? You may assume that none of these stars have risen before sunset.

(A) Betelguese (RA: 5h 55min, Dec: $+7° 24'$).

(B) Canopus (RA: 6h 23min, Dec: $-52° 41'$).

(C) Procyon (RA: 7h 39min, Dec: $+5° 13'$).

(D) Rigel (RA: 5h 14min, Dec: $-8° 12'$).

(E) Sirius (RA: 6h 45min, Dec: $-16° 44'$).

6. Which of the following statements about moons in the Solar System is **false**?

(A) The Earth experiences tides twice a day due to the Moon.

(B) The four Galilean moons are in orbital resonance with each other.

(C) Mercury and Venus do not have moons because they are too close to the Sun.

(D) Saturn's shepherd moons are responsible for maintaining the shape of the rings of Saturn.

(E) Due to Phobos' low orbit, it is likely that it will eventually enter its Roche limit and disintegrate.

7. The opposition of Mars in the Gregorian calendar can occur ____.

(A) only in January, March, and August

(B) in all months except February and April

(C) in all months except April and October

(D) in all months except March and September

(E) in all months

8. From Singapore, which of the following constellations **cannot** be seen on October evenings?

(A) Cetus.

(B) Cassiopeia.

(C) Cancer.

(D) Corona Australis.

(E) Cygnus.

9. The data of three G class stars are given in the following table.

Star	Tau Ceti	51 Pegasi	Alpha Centauri A
Spectral type	G8.5V	G5V	G2V
Declination	$-15° 56' 15''$	$+20° 46' 08''$	$-60° 50' 02''$
Apparent magnitude	$+3.50$	$+5.49$	$+0.01$
Distance from Earth	$11.9\,\text{ly}$	$50.9\,\text{ly}$	$4.4\,\text{ly}$
Colour index (B–V)	$+0.71$	$+0.67$	$+0.71$

Which of the following statements is **wrong**?

(A) Tau Ceti has the lowest luminosity of the three stars.

(B) Only 51 Pegasi lies north of the celestial equator.

(C) All three are main sequence stars.

(D) Alpha Centauri is the hottest star out of the three stars.

(E) All three stars can be observed at latitude $+30°$ on Earth.

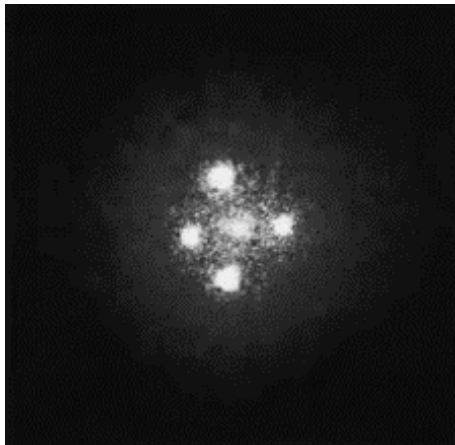10. The following is an image of an active galactic nucleus.

Figure 1: A solitary active galactic nucleus.

The distortion of the image is **most likely** due to _____.

(A) photon noise

(B) image binning

(C) gravitational lensing

(D) chromatic aberration

(E) dark current

11. Brian is new to astronomy and wants to purchase a pair of binoculars for stargazing. He came across the following three binoculars online.

   - Oberwerk Mariner: 8×40 binoculars.
   - Bushnell 8: 16×40 binoculars.
   - Celectron Skymaster: 8×56 binoculars.

   He then makes the following comparisons.

   I. The Celestron Skymaster produces a brighter image as compared to the Oberwerk Mariner.

   II. The Bushnell 8 has a better resolution than the Celestron Skymaster.

   III. The Bushnell 8 has a higher magnification than the Celestron Skymaster.

   Which of the above is/are **correct**?

   (A) II only.

   (B) III only.

   (C) I and III only.

   (D) II and III only.

   (E) I, II, and III.

12. Suppose that you have obtained spectra for three galaxies A, B, and C, and have measured the observed wavelength of a hydrogen emission line that has a rest wavelength of $656.3\,\mathrm{nm}$ for each of these galaxies. Your results are given in the following table.

Galaxy	A	B	C
Observed wavelength	$1.313\,\mu\mathrm{m}$	$984\,\mu\mathrm{m}$	$655.6\,\mu\mathrm{m}$

   Which of the following statements is **most likely correct** with respect to the blueshift data observed for galaxy C?

   (A) The galaxy is moving towards Earth faster than the expansion of the universe at its distance from the Earth.

   (B) This value is derived from the hydrogen emission spectrum of the cosmic microwave background radiation.

   (C) The galaxy must be close to us. However, since galaxy redshift values are always positive, the negative redshift value obtained implies that the data obtained fell within the uncertainty range of the instrument used.

   (D) As this value cannot be obtained through physical means, there must be a measurement error.

   (E) There is a supermassive black hole in the center of galaxy C, which has gravitationally blueshifted the galaxy's emission lines.

13. Consider the following statements about comets and asteroids.

    I. A meteor shower is caused by asteroids only.

    II. Asteroids can cause meteor showers.

    III. Asteroids are common in the Kuiper Belt.

    IV. Asteroids and comets are both formed approximately during the same period in the history of the Solar System.

    Which of the above statements is/are **correct**?

    (A) I only.

    (B) II and III only.

    (C) II and IV only.

    (D) III and IV only.

    (E) II, III, and IV only.

14. The Winter Hexagon (below) is a prominent asterism in the Northern Hemisphere, observable between December and March.

    Figure 2: The Winter Hexagon.

    Starting from the bottom star and proceeding in a **clockwise** direction, name the stars that make up the asterism.

    (A) Capella, Procyon, Pollux, Canopus, Aldebaran, Rigel.

    (B) Sirius, Procyon, Pollux, Capella, Aldebaran, Saiph.

    (C) Canopus, Procyon, Pollux, Capella, Aldebaran, Rigel.

    (D) Sirius, Procyon, Pollux, Capella, Aldebaran, Rigel.

    (E) Canopus, Procyon, Pollux, Capella, Aldebaran, Saiph.

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15. During full moon, the difference between the right ascension of the moon and the sun is approximately _____.

   (A) 0h

   (B) 9h

   (C) 12h

   (D) 15h

   (E) 24h

16. NASA scientists found an extrasolar planetary system around a M8V star named TRAPPIST-1 in early 2016. The system has seven terrestrial planets orbiting it, three of which lie in the habitable zone. Consider the following statements.

   I. In the habitable zone, water exists in a liquid state on the surface.

   II. The main component of the planets are rocks.

   III. TRAPPIST-1 lies in the bottom right part of the Hertzsprung-Russell diagram.

   IV. The peak emission of the TRAPPIST-1 spectrum lies in the blue region of the visible light spectrum.

   Which of the above statements are **correct**?

   (A) I and III only.

   (B) II and III only.

   (C) II and IV only.

   (D) I, II, and III only.

   (E) I, II, III, and IV.

17. Consider the following statement.

   The major meteor showers peak at the same few days every year.

   Is this statement true? If it is true, why?

   (A) The statement is true. They only occur when Earth is at the right place in its orbit to intersect a meteor trail.

   (B) The statement is true. Poor weather prevents them from being observed at other times of year.

   (C) The statement is true. The meteor trail is depleted and requires time to recharge.

   (D) The statement is true. The constellations that they appear to originate from lie too close to the Sun to be observed.

   (E) The statement is false. The peak date of a meteor shower cannot be predicted with any accuracy.

18. From Singapore, stars appear to rise four minutes later each night. This is largely because _____.

(A) changes in Earth's axial tilt change the orientation of Earth relative to the stars

(B) the motion of stars through interstellar space causes them to shift in position over time

(C) the motion of the Sun through interstellar space causes stars to rise later over time

(D) Earth's rotation is gradually slowing down due to the tidal effects of the Moon

(E) Earth's orbital motion means that the Sun drifts relative to the stars

19. Which of the following statements is **false**?

(A) From our perspective, Perseus lies within the plane of the Milky Way.

(B) Traditionally, Algol (Beta Persei) has been regarded as one of the unluckiest stars in the sky, causing it to be known colloquially as the "Demon Star".

(C) Algol dims sharply at regular intervals because it is a multiple star system in which two stars periodically eclipse each other from our perspective.

(D) The heart of the Algol paradox is that the more massive star in this binary star system has turned into a red giant, while the less massive star is still on the main sequence.

(E) Mass transfer between both stars is the cause of the Algol paradox.

20. From Singapore, which of these objects are **impossible** to see at 5.30 AM in December? Assume clear skies and a wholly unobstructed horizon.

(A) The Great Square of Pegasus.

(B) The Big Dipper.

(C) Sirius.

(D) The Orion Nebula.

(E) The Southern Cross.

21. Consider the following statement.

We do not see a lunar eclipse every full moon, or a solar eclipse every new moon.

Is this statement true? If it is true, why?

(A) The statement is true. Poor weather prevents us from observing them all the time.

(B) The statement is true. The fast motion of the Moon means these eclipses are extremely brief.

(C) The statement is true. The orbit of the Moon is inclined relative to the Earth's orbit around the Sun.

(D) The statement is true. Solar and lunar eclipses are only visible from a small fraction of Earth's surface area, making them rare when observing from a fixed location.

(E) The statement is false. We do indeed observe a lunar eclipse every full moon and a solar eclipse every new moon.

22. Below are some statements about the life-cycle of stars.

    I. Hydrogen fusion commences, and the protostar moves onto the main sequence.

    II. The star forms an iron core, and subsequently goes supernova.

    III. The star ejects its outer layers and becomes a white dwarf surrounded by a planetary nebula.

    IV. Hydrogen runs out in the centre of a main sequence star, and the star turns into a red giant.

    V. A gas cloud collapses on itself and forms a protostar surrounded by a protoplanetary disk.

    VI. Helium runs out in the centre of the red giant, and the star becomes unstable and highly variable.

Five of these describe the life-cycle of a sun-like star. For such a star, arrange the relevant statements in chronological order, **starting with the earliest**.

(A) I, IV, VI, III, II.

(B) V, I, VI, III, II.

(C) V, I, IV, VI, III.

(D) I, V, IV, VI, II.

(E) V, IV, VI, II, III.

23. Consider the following objects.

    I. M7, Ptolemy Cluster.

    II. Betelgeuse (a star of spectral classification M).

    III. Ring Nebula.

    IV. Eta Carinae.

Rank these objects in order of **descending** mass.

(A) I, III, IV, II.

(B) IV, I, II, III.

(C) I, IV, II, III.

(D) IV, III, I, II.

(E) III, I, IV, II.

24. Which of the following objects **cannot** be found within constellations along the ecliptic?

(A) M8, the Lagoon Nebula.

(B) Jupiter.

(C) M44, the Beehive Cluster.

(D) M45, the Pleiades Cluster.

(E) C49, the Rosette Nebula.

25. Consider the following astronomical events.

    I. Lunar eclipse.

    II. Blue moon.

    III. Solar eclipse.

    IV. Full moon.

Rank these events according to how often they occur globally, **from the most frequent to the rarest**.

(A) IV, III, I, II.

(B) IV, III, II, I.

(C) IV, II, III, I.

(D) IV, II, I, III.

(E) IV, I, III, II.

26. It is known that the moon has a synodic month of approximately 29.5 days, and a sidereal month of 27.3 days. This, in combination with the rotation of Earth about its axis, as well as the moon's orbit, causes the moon to rise approximately _____ later every day.

On a winter evening in Singapore, the local sidereal time is found to be 1h 30min. The star Aldebaran has an hour angle (HA) of 20h 54min. That evening, the moon rose 4h 57min before Aldebaran.

To the nearest minute, the right ascension (RA) of the moon 24h from this moment is _____.

(A) 49min; 22h 50min

(B) 49min; 00h 28min

(C) 50min; 00h 29min

(D) 53min; 22h 46min

(E) 53min; 00h 32min

27. Which of the following statements about the cosmos is the **most accurate**?

(A) There is a point in the universe where the Big Bang originated from, albeit not necessarily from the centre of our galaxy.

(B) The number of young stars in any direction is approximately equal.

(C) There is certainty that our universe will collapse into a black hole in the future.

(D) Under the standard λCDM Cosmological Model, the universe is expanding with a decelerating rate due to dark energy.

(E) The standard λCDM Cosmological Model suggests that matter can be created out of nothingness.

28. Before the recombination epoch, nuclei, free protons, and free electrons interacted strongly with the ambient radiation and kept the constituents in the cosmological brew thermalised at constant temperature. The universe was therefore quite opaque to light in the beginning. Which of the following statements is **incorrect**?

   (A) Gravitational wave astronomy is a technique that could possibly allow us to probe beyond the recombination epoch, as gravitational waves interact very weakly with the constituents.

   (B) Observation of neutrinos from this time and beyond is a technique that could possibly allow us to look further into the past as neutrinos interact very weakly with the other constituents.

   (C) The cosmic microwave background radiation originates from the radiation that leaked out from before the recombination epoch due to the early thermal fluctuations.

   (D) The expansion of the universe resulted in a lower rate of reaction between matter and radiation, which led to their decoupling at the beginning of the recombination epoch.

   (E) The weak nuclear interaction between electrons and protons allowed for the formation of bound states of hydrogen.

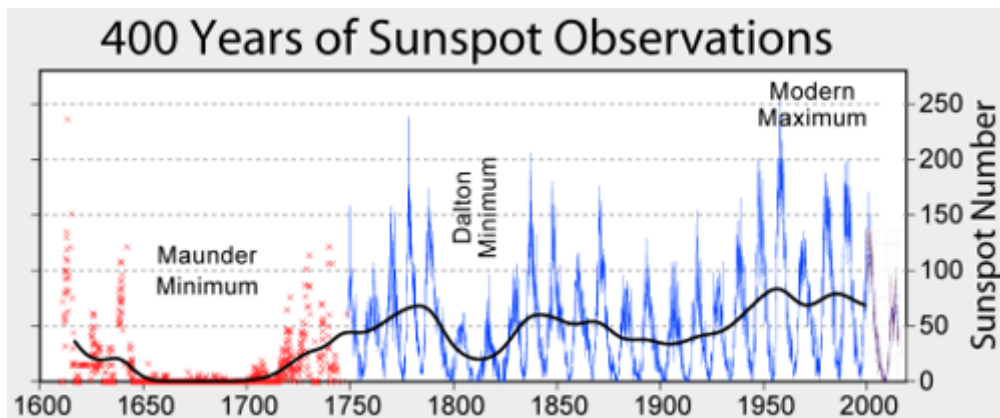29. The figure below shows a record of 400 years of sunspot observation.

Figure 3: 400 years of sunspots.

   Which of the following statements about the Sun is **incorrect**?

   (A) The sun has an absolute bolometric magnitude of 4.7554.

   (B) The next maximum in the solar cycle should occur approximately in early 2020.

   (C) The frequency of auroras is unaffected by the solar cycle.

   (D) Sunspots are cooler regions on the photosphere of the Sun.

   (E) The corona lies above the photosphere of the Sun.

30. Which of the following statements about the equinoxes and solstices is **correct**?

  (A) The autumnal equinox occurs at the same time all over the world.

  (B) Equinoxes and solstices are unaffected by the gyroscopic precession of the earth.

  (C) Equinoxes are spaced approximately three months apart.

  (D) In the southern hemisphere, the summer solstice occurs in December.

  (E) The Sun crosses the celestial equator during the solstices.

31. Consider the following five objects.

  a. Elliptical galaxies.

  b. Irregular galaxies.

  c. Spiral galaxies.

  d. Active galactic nuclei.

  e. Dwarf elliptical galaxies.

  Below are descriptions of the five objects above, in no particular order.

  I. Often have radio jets aligned with their minor axes extending from their cores.

  II. Disks with central bulges surrounded by spherical halos of old stars.

  III. Giant spheroidal galaxies typically having no apparent structure.

  IV. Thought to be remnants of the original building blocks of all galaxies.

  V. Have very chaotic structure with no apparent symmetry.

  Match the five descriptions to their respective objects.

  (A) I–c; II–d; III–b; IV–e; V–a.

  (B) I–c; II–a; III–d; IV–e; V–b.

  (C) I–d; II–b; III–c; IV–e; V–a.

  (D) I–b; II–c; III–a; IV–e; V–d.

  (E) I–d; II–c; III–a; IV–e; V–b.

32. Which of the following statements about neutron stars is **false**?

  (A) Newly formed neutron stars are thought to have an active phase making them "blink" as pulsars.

  (B) Neutron stars spin very fast.

  (C) If a person could survive this experiment, a scientist would weigh more standing on a white dwarf than standing on a neutron star.

  (D) Neutron stars are supported by neutron degeneracy pressure.

  (E) Neutron stars are as massive as the Sun, but only about 10 km across.

33. Three different star clusters A, B, and C with different ages are plotted separate diagrams shown below.
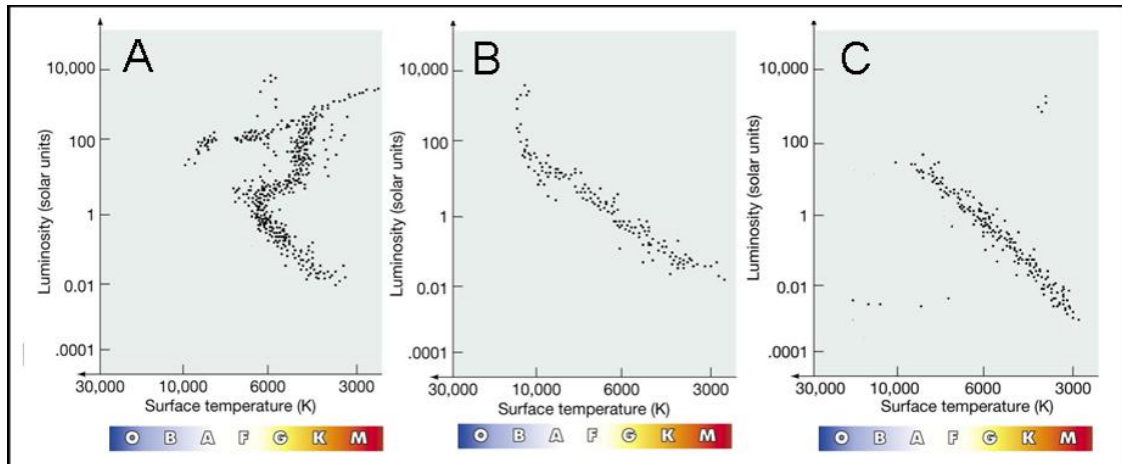

Figure 4: Profiles of three different star clusters.

Arrange the clusters **from youngest to oldest**.

(A) B, A, C.

(B) C, A, B.

(C) B, C, A.

(D) C, B, A.

(E) A, B, C.

34. In this question, you may assume the following facts.

- Mars has a diameter of 6794 km. It has an angular size of 5.5×10^{-3} degrees when viewed from Earth this week.

- The planet Uranus has a period of 84 years.

Consider the following statements.

I. It takes radio signals from the Opportunity rovers on the surface of Mars 236 s to reach the scientists on Earth.

II. Kepler's second law notes that a planet should move fastest at perihelion.

III. The semi-major axis of Uranus's orbit is 19.1 AU. Assuming that Uranus's orbit has zero eccentricity, the centripetal acceleration of Uranus in its orbit is $0.107 \, \text{AU} \, \text{year}^{-2}$.

Which of the above statements is/are **true**?

(A) I only.

(B) I and II only.

(C) I and III only.

(D) II and III only.

(E) I, II, and III.

35. The lithium test for brown dwarfs is sometimes used to determine if an object is a star or a brown dwarf. The test involves measuring the spectrum of the object in question, searching for lithium. While the test admits some ambiguity, it nevertheless provides a degree of surety past certain thresholds. Why does this test work?

(A) Stars and brown dwarfs naturally contain lithium from formation, but cooler brown dwarfs are too cool for lithium to undergo fusion.

(B) Brown dwarfs do not contain lithium since they are not sufficiently hot for hydrogen fusion. Conversely, young stars contain lithium due to hydrogen fusion.

(C) Both stars and brown dwarfs contain lithium from formation. However, the intensity of lithium spectral lines for stars is higher due to lithium produced via fusion.

(D) Both young stars and brown dwarfs contain lithium lines in their spectra. However, temperature warping changes the position of these lines for stars.

(E) Both young stars and brown dwarfs contain lithium lines in their spectra. However, gravitational redshifting changes the position of these lines more significantly for stars.

36. How was Edwin Hubble able to use his discovery of a Cepheid in Andromeda to prove that "spiral nebulae" (like Andromeda) were actually located outside the Milky Way?

(A) From the period-luminosity relation for Cepheids, he was able to determine the distance to Andromeda and show that it was far outside the Milky Way Galaxy.

(B) Since a Cepheid is a type of luminous galaxy, when he found it in Andromeda he was able to prove that Andromeda was a separate galaxy from the Milky Way.

(C) He used main-sequence fitting to determine the distance to Andromeda and show that it was far outside the Milky Way Galaxy.

(D) There are no Cepheids in the Milky Way, so his discovery proved that it has to be in another galaxy.

(E) He measured the stellar parallax of the Cepheid in Andromeda, was able to determine the distance to it and showed that it was far outside the Milky Way.

37. Orion is visible on winter evenings for most observers in the northern hemisphere, but not during summer evenings because of _____.

(A) the precession of the Earth's axis

(B) the tilt of the Earth's axis

(C) interference from the full moon

(D) the rotation of Earth around its own axis

(E) the location of the Earth in its orbit

38. Assuming circular and coplanar orbits, what is the angle of maximum elongation for Venus from Mars?

(A) 19°.

(B) 22°.

(C) 25°.

(D) 28°.

(E) 31°.

39. What is the apparent magnitude of a binary star which has two stars of apparent magnitude 4.11 and 5.01 respectively?

(A) 0.90

(B) 3.21

(C) 3.72

(D) 4.56

(E) 9.12

40. Which Messier object is **most easily observed** with the naked eye on a clear night in Singapore?

(A) Crab Nebula (M1).

(B) Butterfly Cluster (M6).

(C) Andromeda Galaxy (M31).

(D) Beehive Cluster (M44).

(E) Pleiades (M45).

41. The Celestron C8 is a Schmidt-Cassegrain reflective telescope with a focal ratio of 10 and a diameter of 203.2 mm. Using an objective lens (eyepiece) with a focus of 25 mm, a circular squirrel with a diameter of 25 cm fills the field of view completely. Assuming an apparent field of view of 50°, which of the following statements are **correct**?

   I. The focal length of the telescope is 203.2 cm.

  II. The true field of view of the telescope assembly is approximately 37'.

 III. The distance from the squirrel to the observer is 2328 cm.

 IV. The resolving power of the telescope is 0.68'.

(A) I and II only.

(B) II and IV only.

(C) I, II, and III only.

(D) II, III, and IV only.

(E) None of the above.

42. A star has an average density of $1.08\,\mathrm{g\,cm^3}$. Find the approximate period of a planet orbiting at six times the radius of the star.

(A) 47 hours.

(B) 58 hours.

(C) 69 hours.

(D) 70 hours.

(E) 81 hours.

43. In 7.4×10^{11} years, the mass of the Sun will have dropped by 5%. This is caused by the Sun's fusion reaction that changes mass into energy. Assuming that Earth has a circular orbit, that the orbital speed of Earth remains constant, and that the Earth moves closer to the Sun to compensate, what is the length of a year in this future Earth?

(A) 0.91 years.

(B) 0.92 years.

(C) 0.93 years.

(D) 0.94 years.

(E) 0.95 years.

44. A binary system with two stars has a head-on inclination of $90°$. The first star has an effective temperature of T_1 and radius R_1. The second star has an effective temperature of $T_2 = 2.5T_1$ and radius of $R_2 = 0.75R_1$. When the larger star eclipses the smaller one, what is the **change** in bolometric magnitude?

(A) 0.7

(B) 1.4

(C) 2.8

(D) 3.4

(E) 4.1

45. The Celestron Advanced VX Y Go-To Reflector Telescope has an Y'' optical tube assembly with specification $f/5$, where Y is an unknown value. The focal length of the optical tube is 1016 mm. Two eyepieces, one with diameter 8 mm and another with diameter 25 mm were provided. Determine the **minimum** size of a crater on the Moon that can be resolved by this telescope. Assume light of wavelength 550 nm.

(A) 1.27 km.

(B) 2.54 km.

(C) 10.2 km.

(D) 31.7 km.

(E) 72.7 km.

46. The Islamic calendar is an example of a lunar calendar consisting of 12 lunar (synodic) months. Each month has approximately 29.6 days.

Eid al-Fitr, also known as Hari Raya Puasa, refers to the start of the next Islamic month, after the month of Ramadan (commonly known as the fasting month). In 2018, Hari Raya Puasa will fall on 15 June 2018 on the Gregorian calendar. Which day on the Gregorian calendar will the start of the month of Ramadan most probably be in 2019?

(A) 10 April 2019.

(B) 15 April 2019.

(C) 5 May 2019.

(D) 10 May 2019.

(E) 25 June 2019.
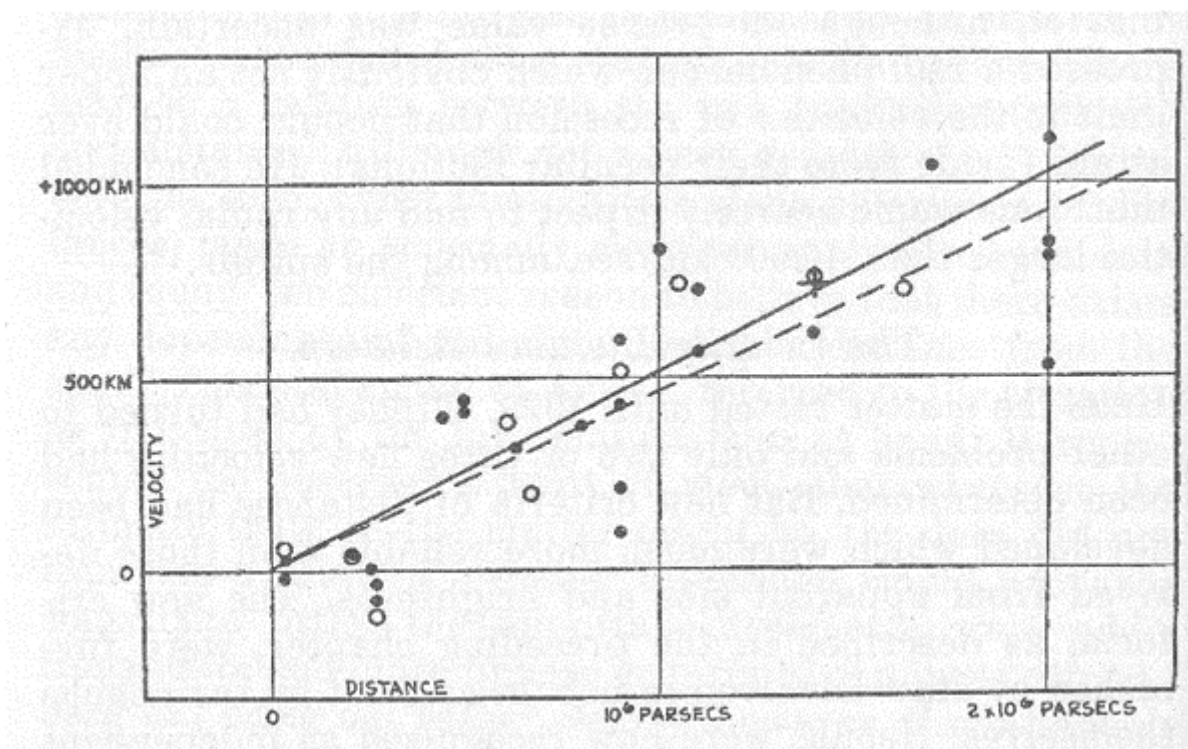
Use the diagram below to answer questions 47 and 48.

Figure 5: Hubble's plot to determine the Hubble constant.

47. The value of the Hubble Constant published in 1936 is **most probably** _____.

(A) $20.8 \, \text{km} \, \text{s}^{-1} \, \text{Mly}^{-1}$

(B) $76.7 \, \text{km} \, \text{s}^{-1} \, \text{Mly}^{-1}$

(C) $153 \, \text{km} \, \text{s}^{-1} \, \text{Mly}^{-1}$

(D) $815 \, \text{km} \, \text{s}^{-1} \, \text{Mly}^{-1}$

(E) $1630 \, \text{km} \, \text{s}^{-1} \, \text{Mly}^{-1}$

48. The following are statements that attempt to account for this difference between Hubble's estimate of the Hubble constant versus its modern value today.

   I. When Hubble first published this paper in 1929, he did not account for interstellar extinction in his calculations.

   II. The Hubble Constant is not actually a constant. Its value changes with time. Hence, the value today is different from the value in 1929.

   III. The distinction between Type I and Type II Cepheid variables was only discovered after Hubble's observations, which would have affected the distance measurement between Earth and the Cepheid variable stars.

   Which of the above statements could possibly account for this difference?

   (A) I only.

   (B) II only.

   (C) I and III only.

   (D) II and III only.

   (E) I, II, and III.

49. Refer to the following table for this question.

Star	Right Ascension	Declination
Aldebaran	4h 36min	$16° \, 31'$
Antares	16h 29min	$-26° \, 26'$
Deneb	20h 41min	$45° \, 20'$
Miaplacidus	9h 13min	$-69° \, 42'$
Spica	13h 25min	$-11° \, 09'$

An observer at St. Petersburg ($59° \, 56'$ N, $30° \, 16'$ E) attempts to observe all five stars listed in the table above, and notes their proximity to the zenith when then culminate (i.e. reaches the meridian). Let the star closest to the zenith during its culmination be A. When A culminates above St. Petersburg, around which city will Arcturus (14h 16min, $19° \, 11'$) be undergoing its culmination?

   (A) San Juan, Puerto Rico ($18° \, 24'$ N, $66° \, 04'$ W).

   (B) Chiang Mai, Thailand ($18° \, 48'$ N, $99° \, 00'$ E).

   (C) Belo Horizonte, Brazil ($19° \, 55'$ S, $43° \, 56'$ W).

   (D) Antananarivo, Madagascar ($18° \, 56'$ S, $47° \, 31'$ E).

   (E) Mexico City, Mexico ($19° \, 26'$ N, $99° \, 08'$ W).

50. The coordinates of the stars making up Northern Cross is given below.

Star	Right Ascension	Declination
Deneb	20h 41min	45° 20′
Gienah	20h 46min	33° 58′
Delta Cygni	19h 45min	45° 08′
Sadr	20h 22min	40° 15′
Albireo	19h 31min	27° 58′

According to an observer, all stars in the Northern Cross are always above the horizon. Assuming that atmospheric refraction can change the coordinate of a star up to 35′, what is the **southernmost (lowest) possible latitude** of that observer?

(A) 28° 33′.

(B) 44° 05′.

(C) 45° 15′.

(D) 61° 27′.

(E) 62° 37′.