1. Which one of the following statements best explains why there is not a solar eclipse during every new moon?

    A. The Moon's orbital plane is tilted by about 5° relative to the ecliptic plane
    B. The Moon takes about 27 ⅓ days to complete an orbit relative to the position of distant stars
    C. The Moon takes about 29 1/2 days to complete a cycle of lunar phases
    D. The Moon's diameter is about 4 times smaller than the Earth's
    E. The Moon undergoes axial precession

2. Relative to the Sun, which of the following planets has the highest orbital speed?

    A. Mars
    B. Jupiter
    C. Saturn
    D. Uranus
    E. It depends on the location of the planets along their respective orbits

3. What are the lunar 'seas' made of?

    A. Saltwater over oceanic crust.
    B. Freshwater over oceanic crust.
    C. Ejecta from impactors
    D. Cooled lava.
    E. High albedo intrusive metamorphic rock.

4. In the Northern Hemisphere, where must one point the polar axis of the equatorial mount towards, such that moving the telescope in Right Ascension will most precisely mimic the motion of the sky over the course of a night?

    A. Sirius (Alpha Canis Majoris)
    B. Polaris (Alpha Ursae Minoris)
    C. Capella (Alpha Aurigae)
    D. Alpheratz (Alpha Andromedae)
    E. Rigil Kentarus (Alpha Centauri)

5. What will be the fate of our Sun immediately after it runs out of fuel and ceases all nuclear fusion?

    A. Brown dwarf
    B. Red dwarf
    C. White dwarf
    D. Neutron star
    E. Black hole

6. Based on our current understanding of the history of the solar system, arrange the following statements in chronological order

   i. Planetary migration of the outer planets generates the Late Heavy Bombardment
   ii. A protoplanetary disk forms, with a protostar (the future sun) in the center.
   iii. Planetesimals collide to form the cores of future planets
   iv. A gas cloud becomes unstable and begins gravitational collapse
   v. Orbiting dust grains collide with each other to form larger bodies (planetesimals)
   vi. The gas within the protoplanetary disk is fully dispersed by the Sun's strong stellar wind

   A. ii, iv, v, iii, i, vi
   B. iv, i, ii, iii, v, vi
   C. iv, ii, v, iii, vi, i
   D. ii, iv, iii, v, vi, i
   E. ii, v, iv, vi, i, iii

7. Which of the following planets is not expected to be visible from Singapore at local midnight?

   A. Venus
   B. Mars
   C. Jupiter
   D. Saturn
   E. All the above planets can be visible.

8. The apparent magnitude of the Sun is known to be approximately –26 while the Full Moon is known to have an apparent magnitude of approximately –12, both rounding down to the nearest integer. According to the information given above, how many times is the Sun brighter than the Full Moon? Choose the closest answer.

   A. 1 million times
   B. 400 thousand times
   C. 140 thousand times
   D. 14 times
   E. 35 times

9. For a given comet, when is its gas tail the longest?

   A. When the comet is heading towards the Sun.
   B. When the comet is heading away from the Sun.
   C. When the comet is nearest to the Sun.
   D. When the comet is in the Oort Cloud.

E. The colder it is, the longer the comet gas tail.

10. Which of the following is TRUE about Vega and Altair?

    A. Vega and Altair are only visible in Autumn
    B. The distance between Vega and Altair is the closest on the 7^{th} day of the 7^{th} lunar month in the Chinese calendar, hence resulting in the ancient myth of Vega and Altair being star crossed lovers
    C. Vega and Altair together form a gravitationally bound binary star system
    D. Vega and Altair are part of the "Summer Triangle" asterism, together with Deneb
    E. None of the above

11. Although radio waves are commonly used to measure distance to objects within the solar system, the distance to the sun was first measured using parallax during a Venus transit. Given that two observatories at each of the poles on Earth are measuring the parallax of Venus while it is transiting the Sun, what will be the parallax? Assume Venus to be a point. Hint: calculate the distance from Venus to Earth during the transit.

    A. 1.11 arc minutes
    B. 1.62 arc minutes
    C. 1.06 arc minutes
    D. 0.554 arc minutes
    E. 0.843 arc minutes

12. An observer notices that star A culminates (in other words, crosses the meridian) at local midnight on January 1st. Two days later, he notices that star B (rather than star A) now culminates at local midnight. Which of the following statements are definitely true?

    A. Both stars share the same declination
    B. Both stars share the same right ascension
    C. Both stars are separated by around 8 minutes of declination
    D. Both stars are separated by around 8 minutes of right ascension
    E. Culmination time depends on location, and thus there is insufficient information to answer the question

13. Post processing images is an essential part of astrophotography. Which of the following isn't a purpose of post processing?
    A. To remove certain wavelengths of light to reduce light pollution
    B. Adding colour and/or adjusting the colour balance of the image
    C. Crop and framing the image
    D. Adjusting exposure and contrast to bring out details
    E. Combining colour data from separate exposures to build an image

14. Three friends are arguing over the positions of sunrise and sunset at different latitudes and seasons.

    Alni Tak: The sun rises due east and sets due west. Differences in latitude only changes the angle of the sun's path in the sky.

    Alni Lam: No, the point of sunrise and sunset can be anywhere between 0 degree and 180 degree from North on the East and West sides respectively depending on latitude and season.

    Min Taka: Both of you are wrong. While it is true the point of sunrise and sunset varies according to latitude and season, it can only vary between 30 degrees and 120 degrees from due north.

    Who is right?

    A. Alni Tak
    B. Alni Lam
    C. Min Taka
    D. None of them.
    E. All of them are correct according to their own unique subjective view of the universe.

15. On June 21st, an observer in the Northern hemisphere notices that the maximum and minimum length of shadow of a 1.0 m pole is 16.3 m and 1.05 m respectively. What is the latitude of the observer?

    A. 10 degrees N
    B. 25 degrees N
    C. 40 degrees N
    D. 55 degrees N
    E. 70 degrees N

16. The vast majority of globular clusters no longer appear to produce any new stars today. This is mainly because

    A. Gravitational interactions over billions of years have ejected gas out of the cluster.
    B. The strong solar winds of the stars have pushed out gas.
    C. Most globular clusters formed very early in the history of the universe and have long since exhausted their gas reserves.
    D. The production of new stars is outshadowed by the light of the cluster.

E. This is a trick question: Many new stars are still being born in most globular clusters.

17. Copernicus was known for introducing the Heliocentric System which placed the Sun, rather than the Earth, at the center of the universe. What were some advantages of the Copernican model over the then prevailing Ptolemaic geocentric model?

i. The Copernican model had removed the need for epicycles.
ii. The Copernican model provided a simpler account of retrograde motion.
iii. The Copernican model could predict eclipses.
iv. The Copernican model explains the orbit of comets.

A. i, ii
B. ii only
C. i,ii,iii
D. i,ii,iv
E. i only

Refer to the following passage for Q18-19

This Week's Planet Roundup

Mercury, Venus, and Mars remain deep in the glare of the Sun.

Jupiter (magnitude –2.0, in the feet of Ophiuchus) is the white dot low in the southwest as twilight fades. Can you still spot Antares, one sixteenth as bright at magnitude +1.0, 10° to Jupiter's lower right?

Saturn (magnitude +0.5, in Sagittarius) is the steady yellow "star" in the south-southwest during and after dusk. It's 25° upper left of Jupiter. Below Saturn is the handle of the Sagittarius Teapot. Barely above it is the dimmer, smaller bowl of the Sagittarius Teaspoon.

Uranus (magnitude 5.7, in Aries) is well up in the east by 10 p.m. daylight saving time. It's highest in the south around 1 or 2 a.m.

Neptune (magnitude 7.8, in Aquarius) is in the southeast after dark and highest in the south by 10 or 11.

18. This passage is written from the perspective of North American observers at a certain point in time. Suppose we keep the time fixed, but allow the observer’s

location to change. Which of the following statements are still valid from an observer stationed ANYWHERE ELSE on Earth? Exclude the geographic North and South Poles from consideration

A. Jupiter is the white dot low in the southwest as twilight fades
B. Antares is 10° to Jupiter's lower right
C. Saturn is in the south-southwest during and after dusk
D. Uranus is highest in the south around 1-2 a.m
E. None of the above

19. This passage is written for the first week of a certain month. This month is most probably:

A. January
B. March
C. July
D. October
E. Insufficient information to determine the answer

20. Benjamin is attempting to view M31, the Andromeda Galaxy through a pair of binoculars in Singapore. At the position where M31 should be, he sees a dim fuzzy elliptical blob. Unfortunately, he could not see the spiral arms of M31. What is the most likely explanation?

A. The surface brightness of M31 is too low to be seen in Singapore. Benjamin is most likely looking at M110, a dwarf elliptical galaxy near M31 which has a much higher surface brightness.
B. Binoculars do not have sufficient magnification and resolution to resolve the spiral arm structure, thus the whole galaxy appears as a fuzzy elliptical blob.
C. No galaxies can be seen in Singapore. Benjamin is most likely hallucinating.
D. Benjamin is only seeing the bright center core of M31, while its spiral arms are too dim to be visible.
E. M31 does not have spiral arms as it is actually a globular cluster.

21. The crescent moon was photographed to have the “dark part” of the moon bright enough such that the lunar features are visible to the naked eye. Which of the following best explains this?

    A. The “dark side” of the moon is a misnomer -all areas of the moon receive about equal sunlight when averaged out throughout a year
    B. The dark area is not in total shadow and hence some light still reaches it from the Sun.
    C. This phenomenon can be observed a few days before a lunar eclipse. The “dark part” is Earth’s shadow on the moon
    D. The ‘“dark part” of the moon receives reflected light off Earth to be illuminated.
    E. This phenomenon occurs when 2 conditions are met -the moon is in syzygy with Earth and the Sun, and the moon is at its perihelion

22. Consider the following three pairs of binoculars.

    I. Pentax 8.5×21 U-series Papilio II
    II. Vixen 10×50 Ascot
    III. Orion 20×80 Astronomy

    Which of the above would NOT be recommended for astronomy via handheld binocular viewing?

    A. I only.
    B. I and II only.
    C. I and III only.
    D. II and III only.
    E. All of the above would not be recommended

23. While a superior planet is experiencing apparent retrograde motion, the planet _____.

    A. Rises in the west and sets in the east
    B. Rises and sets earlier than expected
    C. Moves backwards in its orbit around the Sun
    D. Appears to stop its westward motion, and then drifts eastwards relative to the stars
    E. Appears to stop its eastward motion, and then drifts westwards relative to the stars

24. Hindu cosmology (c 1700 to 1100 BCE) states that one cycle of existence is approximately 311 trillion years, and the life of one universe is approximately 8 billion years. The universal cycle is preceded by an infinite number of universes and is to be followed by an infinite number of universes. This concept is most similar to the concept of…

A. the Big Bang
B. steady state
C. the Big Crunch
D. accelerating expansion
E. negative pressure

25. I want to take a color image of the Great Dark Spot (6600 km across), using individual 10s exposures in 3 different wavelengths. My setup enjoys clear skies in the Australian outback and uses a Schmidt-Cassegrain telescope and tracking equatorial mount only.

    Suppose I only can vary the aperture of my telescope. What is the minimum diameter my telescope needs to have, such that all exposures satisfy my technical requirements?

    You are given that Neptune will be 4.4 billion kilometres away at the time of the shot and the exposures will be taken in red (650nm), green (550nm) and blue (450 nm)

    A. 0.05 cm
    B. 37 cm
    C. 45 cm
    D. 53 cm
    E. Not possible given the current setup.

For Questions 26-28, refer to the image below

26. Which of the following is the star Canopus

    A. A
    B. B
    C. C
    D. D
    E. None of the above

27. Which of the below Asterisms is not in the field of view

    A. The W of Cassiopeia
    B. Winter Triangle
    C. Winter Hexagon
    D. False Cross
    E. All of the above Asterisms are in

28. Can you see the plane of the Milky Way in the above field of view? If so, state which section of the Milky Way is visible

    A. Yes, the section between Crux and Auriga
    B. Yes, the section between Cancer and Taurus
    C. Yes, the section between Scutum and Crux
    D. Yes, the section between Orion and Perseus
    E. No I cannot see the Milky Way in this field of view even if viewed from a dark sky site.

29. Which of the following is TRUE about an emission nebula?

    A. It emits hundreds to millions of stars and gravitationally binds them together tightly
    B. It appears to have spiral arms that are emitted from its center
    C. It does not appear to interact with observable electromagnetic radiation
    D. It is made up of ionized gases that emit light of various wavelengths
    E. It only emits light of a single wavelength.

30. Suppose there is a planet beyond Neptune, moving in a orbit about 20 times larger than Neptune's orbit on average. What would be its approximate orbital period?

    A. 740 years
    B. 3,300 years
    C. 14,700 years
    D. 4.5 million years
    E. 10.9 million years

31. What is light trespass in astronomy?

    A. It is when unwanted and uncontrolled light enters people's property and affects them.
    B. It is when light pollution lights up and trespasses into the night sky.
    C. It is when light from a reflection nebula affects the emission nebula that you are trying to photograph.
    D. It is when light from a star shines through a dark nebula, causing the dark nebula to glow.
    E. It is when you trespass a private observatory, but just slightly.

32. The Winter Hexagon is an asterism that contains 7 extremely bright stars from The Bull, The Hunter, The Great Dog, The Lesser Dog, The Charioteer and The Twins. Which of these stars is not part of the Winter Hexagon?

    A. Capella
    B. Procyon
    C. Sirius
    D. Castor
    E. Arcturus

33. The classification of stars is primarily based on their temperatures. The Harvard spectral classification scheme assigns each star a spectral type. If there are 3 stars which are blue, yellow and red in colour respectively, what can be a possible combination of their spectral types in that specific sequence (ie. Blue, yellow, red)?

    A. O,G,M
    B. B,M,A
    C. A,M,K
    D. M,K,G
    E. A,B,O

34. At 4am on 3rd August, you notice that Alpheratz, the Alpha star in Pegasus, is right on the meridian. On which date would Alpheratz rise at approximately 6pm?
    A. 2nd September
    B. 2nd October
    C. 2nd November
    D. 2nd December
    E. 2nd January

35. The luminosity of the Sun, $L_{\odot}$, is $3.828*10^{26}$W. Polaris has a mass of $7.5M_{\odot}$and a diameter 30 times that of the Sun. The difference between their absolute magnitudes is 8.47. What is the surface temperature on Polaris?

    A. 7600K
    B. 7400K
    C. 7200K
    D. 7000K
    E. 6800K

36. Consider the following two scenarios:

    Scenario A: The Earth is orbiting around the Sun in the anti-clockwise direction as viewed vertically above from its North Pole.

    Scenario B: The Earth is orbiting around the Sun in the clockwise direction as viewed vertically above from its North Pole. Which of following corresponds to the approximately best local time in each scenario to observe as many sporadic meteors

as possible? Note that in both scenarios, Earth is rotating in the anti-clockwise direction.

	Scenario A	Scenario B
A	6 PM – 12 MN	6 PM – 12 MN
B	6 PM – 12 MN	12 MN – 6 AM
C	12 MN – 6 AM	6 PM – 12 MN
D	12 MN – 6 AM	12 MN – 6 AM
E	The best time is season dependent	

37. Tides are the rise and fall of sea levels caused by the combined effects of gravitational forces exerted by the moon and the sun, and the rotation of the earth. A spring tide is when the tide is at its maximum. Generally, when does a spring tide occur?

    A. The moon and the sun is on the same side of the earth
    B. The moon and the sun is on the opposite side of the earth
    C. Neither. It occurs during spring when the moon is closest to the earth
    D. Both a) and b)
    E. Whenever the angular distance between the Moon and Sun reaches 90 degrees, as measured from earth.

38. Suppose we are currently at Tokyo (35°41’22’’ N). Which of the stars will always be seen?

    I. Alderamin (RA/DEC: 21h 19min/+62°40’18”)
    II. Antares (RA/DEC: 16h 21min/-26°28’29”)
    III. Betelgeuse (RA/DEC: 5h 26min/+7°24’31”)
    IV. Capella (RA/DEC: 5h 18min/+46°00’57’’)
    V. Shedar(RA/DEC: 0h 41min/+56°38’54’’)

    A. II only

B. I and V only
C. II and III only
D. I, IV and V only
E. I, III, IV and V only

39. Enceladus, a moon of Saturn, is known to possess cryovolcanoes near its south pole. These cryovolcanoes are observed to constantly eject jets of water vapour and other volatiles into space. Which of these CANNOT possibly be reasons why Enceladus exhibits cryovolcanic activity?

A. Enceladus contains a subsurface water ocean under the south pole, providing a source of water for these jets.
B. Tidal friction exerted upon Enceladus heats up the interior of Enceladus, helping to sustain these jets.
C. Dark albedo features preferentially absorb sunlight, generating warm spots on Enceladus that create jet activity.
D. The decay of radioactive elements within Enceladus heats the ocean and helps to power these jets.
E. All the options above are possible reasons for cryo-volcanism on Enceladus

Read the following passage to answer questions 40 to 42.

The circumstellar habitable zone (CHZ), commonly called the Goldilocks Zone, is the region surrounding a star where the insolation on any planet within is sufficiently high that ice melts into liquid water, but not high enough that the water boils away, given an atmospheric pressure of 1 atm.

A binary measure of the 'habitability' of a planet is to check if it is within the CHZ or not.

Contrary to popular belief, the CHZ is not the be-all, end-all of planetary habitability, as there are several other factors and nuances that need to be considered when determining how habitable a certain planet is.

In fact, the very definition of the CHZ itself is subject to much controversy, including that of our own Sun's. Ranges for the Sun's CHZ vary widely. The most lenient estimates place individual inner bounds at0.38 AU and outer bounds at3 AU. More conservative ranges are0.725–1.24 AU and 0.95–1.37 AU, which place Venus and Mars respectively, almost within the Sun's CHZ.

The strictest estimate barely fits Earth:0.99–1.01 AU. This estimate has been frequently cited.

40. The passage mentions: 'the CHZ is not the be-all, end-all of planetary habitability, as there are several other factors and nuances that need to be taken into account...'.Below are some statements that either corroborate or contradict the clause above.

I. Earth sustains life even in conditions typically considered to be inhospitable to life, such as around black smokers on the ocean floors, highly corrosive lakes filled with acid around volcanoes, and in the highly radioactive walls of nuclear reactors.

II. In each star system, the parent star is not necessarily the only source of energy able to generate liquid water, and this might mean that life could possibly be found well outside a star's CHZ.

III. Even within the CHZ of a star, conditions may not be suitable for life, and hence the CHZ.

IV. The causal relationship cited between the CHZ and likelihood of finding life, is flawed because the premise of the CHZ focuses on Earth-like biochemistry including carbon- and water-based life; there might be other forms that rely on alternate biochemical models including ammonia or silicon.

V. The CHZ is useful in concluding that a planet is likely to host sentient and advanced multi-cellular life with technology; such planets are good candidates for SETI missions.

Which of the above statements are valid?

A. I, II, and III only
B. II, III, and V only
C. II, IV, and V only
D. I, II, III, IV only
E. All the statements are valid.

41. Consider your pre-existing knowledge of Venus and Mars, including their evolution over the solar system's lifetime, and this excerpt from the passage: '*More conservative ranges ... place Venus and Mars almost within the Sun's CHZ*'.

Which of the following options best explains why these estimates place Venus and Mars *almost* within the Sun's CHZ, but not quite inside it?

A. The mass and diameter of Venus are like those of Earth
B. Mars has nearly the same axial tilt as Earth.
C. Mars has a day approximately as long as Earth's sidereal day.
D. Venus and Mars may once have been as habitable as Earth is today, but certain factors led to their divergence from habitability, and thence to their present appearance.
E. Venus has a thick atmosphere just like Earth does, and Mars has polar ice caps just like Earth does.

42. Consider the last paragraph of the passage. Which of the following options is the most likely reason why the strictest estimate of 0.99–1.01 AU has been '*frequently cited*'?

A. Articles discussing habitability typically only ever consider multi-cellular, *sentient* life, which has very strict conditions for habitability, like liquid water, molecular oxygen in the atmosphere, etc.
B. Even if articles discuss microbial life or other extremophile organisms, there is only one data point to work with, i.e. Earth, and it is statistically incorrect to extrapolate from this; hence, it makes sense to be strict with estimates of the Sun's chz.
C. The strictest bounds of the chz make it easy to classify other exoplanets as habitable or otherwise.
D. The looser estimates of the Sun's chz were when extrasolar planets had not been discovered yet; discovery of such planets have cast these estimates in doubt as new information about habitable planets has been received.
E. Earth's perihelion and aphelion are at 0.99 and 1.01 AU respectively.

43. Two days before a full moon, you wish to observe a meteor shower. At approximately what time would the moon rise? You are given that sunset occurred around 1900 and that you are in Singapore.

A. 0517
B. 0913
C. 1654
D. 1734
E. 2041

44. You are currently on holiday in Svalbard, Norway (78° 13'N, 15° 39'E). You observe that the sun rises northeast, and sets northwest. Which direction will the sun be at local noon?

A. North
B. South
C. East
D. West
E. Zenith

45. Which of these statements about the night sky is factually accurate? You are given that these statements are written for an observer in Singapore.
A. One can easily see the Orion Nebula at midnight in May
B. As it is circumpolar, Polaris is easily visible above the horizon for all Singaporeans.
C. A line drawn from Sirius to Canopus points approximately due South towards the South Celestial Pole
D. During the June holidays, Andromeda is above the horizon immediately after sunset.
E. One can use the Big Dipper to find Polaris by following the arc of its handle.

46. Why is the sky blue?

    A. The ocean reflects light to the atmosphere, causing it to appear blue
    B. Blue light scatters more than red light in sunlight due to its shorter wavelength, causing the sky to appear blue as the atmosphere scatters blue light more effectively than red light
    C. The atmosphere absorbs other colours of light more than blue due to its shorter wavelength, causing the sky to appear blue
    D. Both a) and b)
    E. The upper atmosphere of the earth emits blue light due to ionisation when solar radiation interacts with the particles in the sky.

47. The fastest-spinning neutron star is known as PSR J1748-2446ad. Given that its radius is 16km and it spins at a rate of 43000 revolutions per minute, find the greatest speed at which its surface is moving in terms of the speed of light.

    A. 0.12c
    B. 0.24c
    C. 0.36c
    D. 0.48c
    E. 0.80c

48. Which option correctly depicts the sequence of events detailing how a solar mass star evolves over time?
    1. A nebula collapses, forming a protostar
    2. Hydrogen runs out in the core, leading to expansion into a red giant star
    3. Hydrogen fusion begins, leading to a main sequence star
    4. Outer layers are expelled into space, leaving behind a white dwarf.
    5. Core helium fusion begins, producing carbon. Helium eventually runs out.
    6. The core of the star commences fusion of carbon and heavier elements.
    7. Core collapse leads to a supernova

    A. 1>2>4
    B. 1>3>2>5>4
    C. 1>3>6>7
    D. 1>5>3>2>6>7
    E. 1>5>3>4

49. You have recently bought a new 254mm aperture F/5 Dobsonian reflector from Astroshop Science Centre Singapore and it came with a standard 25mm 52°eyepiece. Calculate the magnification and true field of view of the set up
    A. 50.8 times, 1.63°

B. 10.2 times, 5.12°
C. 102 times, 0.512°
D. 50.8 times, 1.02°
E. 312 times, 0.182°

50. Why do star trails appear in long exposure astrophotos?

A. Stars have ‘tails’ like comets
B. Internal camera defects/errors/miscalibration.
C. The camera’s tripod is loose and the camera is slowly tilting.
D. Due to the rotation of the Earth, causing the stars to move across the sky.
E. The stars in the sky are orbiting around the Earth.