

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 $27 \frac{1}{3}$ days to complete an orbit relative to the position of distant stars
 - C. The Moon takes about $29 \frac{1}{2}$ 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. Suppose it takes twice as many days for Earth to completely orbit the Sun, while its axis tilt and rotational velocity remain unchanged. Which of the following statements is true?
- A. The time taken for a star to rise and set at night would double.
 - B. Days would be 48 hours long instead of 24 hours long
 - C. Each of the four seasons would be twice as long as they currently are
 - D. Earth would not have seasons
 - E. None of the above statements are true
8. A Dyson sphere is a hypothetical megastructure that completely encompasses a star and captures a large percentage of its power output. Suppose we observe a Dyson sphere with a radius of 200AU and temperature of 3400K. At what wavelength of EM radiation does it emit most intensely? Assume that the sphere is a black body.
- A. 760 nm
 - B. 820 nm
 - C. 850 nm
 - D. 920 nm
 - E. None of the above
9. The Event Horizon telescope utilizes the concept of very long baseline interferometry to image the SMBH in M87. Assuming M87 spans 25 microarcseconds in the sky and the baseline of the telescopes spans the earth's diameter, what is the wavelength of light that was used to image the black hole?
- A. 1mm
 - B. 1nm
 - C. 1m
 - D. 1km
 - E. 1pm

10. Which of the following statements is correct?
- A. "This telescope introduces chromatic aberration since I see red and blue on opposite edges of the moon"
 - B. "This image of the deep sky has dimmer stars towards the edges due to coma"
 - C. "Astigmatism causes the stars in an image to look like comets"
 - D. "We should use spherical lenses or mirrors in telescopes because they reduce spherical aberration"
 - 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?

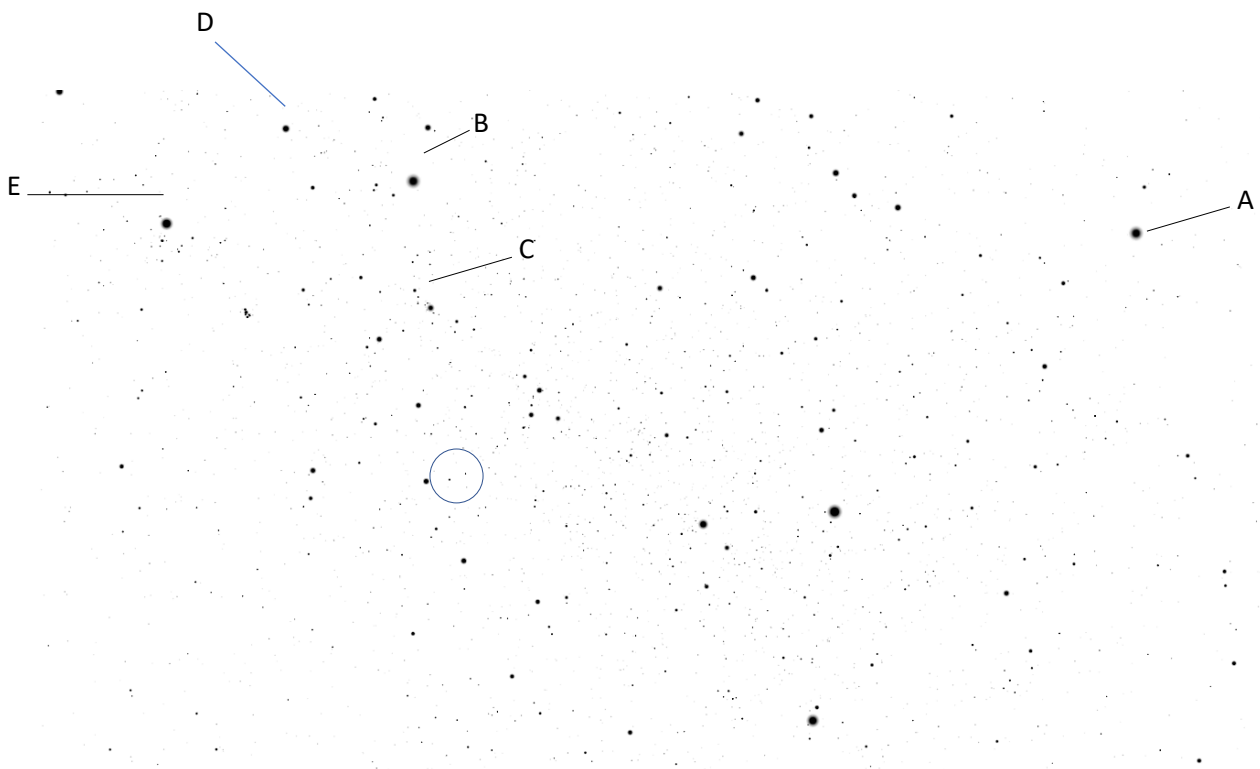
- A. Alni Tak
 - B. Alni Lam
 - C. Min Taka
 - D. None of them.
 - E. All of them are correct according to their own unique subjective view of the universe.
15. On June 21st, an observer in the Northern hemisphere notices that the maximum and minimum length of shadow of a 1.0 m pole is 16.3 m and 1.05 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. Achernar (alpha Eridani) is the brightest star in the constellation Eridanus. It is the primary component of a binary star system, with a secondary star orbiting it at a distance of 12 AU. Achernar has an oblate spheroid shape (flattened sphere) and is the least spherical star to date in the Milky Way.

What is the most likely explanation for Achernar's extreme shape?

- A. Achernar has a high rotational velocity.
 - B. Achernar has a rapidly rotating spheroid magnetic field which confines its plasma atmosphere.
 - C. Achernar experiences great tidal forces due to its companion star.
 - D. Achernar is accreting gas from its companion star.
 - E. Achernar is experiencing post-partum mass gain.
18. Eris has an aphelion and perihelion distance of 97.5AU and 38AU respectively. What is its orbital period?
- A. 8 years
 - B. 26 years
 - C. 340 years
 - D. 558 years
 - E. 1578 years
19. For an observer in the Northern Hemisphere, how does the right ascension of the Sun change from the start to the end of Summer?
NB: we define the start of a season by its corresponding equinox/solstice. So the summer solstice marks the start of Summer
- A. From 0h to 6h
 - B. From 6h to 12h
 - C. From 12h to 18h
 - D. From 18h to 00h
 - E. This is a trick question. RA of the Sun does not change with season.
20. Planet X with radius $1.0 \times 10^7 m$ orbits around Star Y with the period of revolution about Star Y and the period of rotation about its own axis being equal. The average surface temperature of the hemisphere of the planet facing Star Y on a normal day is at 300K. Which of the following represents the rate at which energy is being emitted from the surface of planet X? You may assume that planet X is a blackbody, with no ocean and/or atmosphere.
- A. $1.44 \times 10^{17} W$
 - B. $2.89 \times 10^{17} W$
 - C. $5.77 \times 10^{17} W$
 - D. $1.15 \times 10^{18} W$
 - E. $2.31 \times 10^{18} W$

For Questions 21 to 23, refer to the following diagram



21. What is the name of the star labelled as A
- A. Aldebaran (α Tauri)
 - B. Arcturus (α Boötis)
 - C. Acrux (α Crucis)
 - D. Almaak (γ Andromedae)
 - E. None of the Above
22. There is a circled region in the sky above. What DSO do I expect to see there?
- A. Double Cluster
 - B. Andromeda Galaxy
 - C. Triangulum Galaxy
 - D. I know there is something there but it's none of the above
 - E. Trick Question, this patch of sky contains nothing of particular interest
23. Stars B, C, D and E together form an commonly known asterism. What is the name of the asterism?
- A. The Great Square of Pegasus
 - B. The Northern Cross
 - C. Keystone of Hercules
 - D. Circllet of Pisces
 - E. This asterism does not exist

24. For any black hole, we can always define its event horizon in which as observers outside of the black hole, we would not be able to observe that is happening beyond the event horizon.

It turns out that we can associate an entropy value to the surface of the event horizon. In this case, the entropy S of the event horizon of a black hole relates to the area of an event horizon A by the following formula:

$$S = \frac{k_B A c^3}{4G\hbar}$$

Here, k_B refers to the Boltzmann's Constant and \hbar refers to the Reduced Planck's Constant (which both can be found in the AC formula booklet).

Which of the following represents the entropy associated to a Schwarzschild black hole in 3 dimensions, given that it has mass equivalent to 100 solar masses.

- A. $5.0 \times 10^{57} J K^{-1}$
 - B. $1.0 \times 10^{58} J K^{-1}$
 - C. $1.5 \times 10^{58} J K^{-1}$
 - D. $2.0 \times 10^{58} J K^{-1}$
 - E. $2.5 \times 10^{58} J K^{-1}$
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.

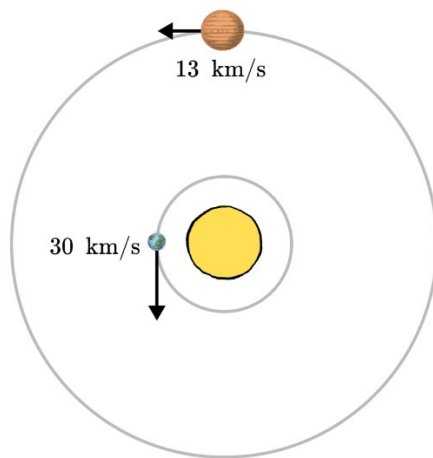
Suppose I only can vary the aperture of my telescope. What is the minimum diameter my telescope needs to have, such that all exposures satisfy my technical requirements?

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.

26. Twilight is the illumination of the Earth's atmosphere by the sun when it is below the horizon. The duration of twilight is typically defined by angle of the geometric center of the sun's disk below the horizon, with astronomical twilight ending when the sun is 18 degrees below the horizon. The length of twilight is on average longer at higher latitudes. What causes the length of twilight to vary across latitudes?
- A. An observer at the equator moves faster than an observer at higher latitudes, thus twilight is shorter at the equator.
 - B. At higher latitudes the local horizon is angled to the sun, causing the sun's rays to scatter in the atmosphere even when the sun is more than the threshold angle below the horizon.
 - C. The path of the sun cuts the horizon at a less steep angle at higher latitudes, and thus has to take a longer time travelling a longer path to reach the threshold angle below the horizon.
 - D. At the equator, light pollution causes astronomical twilight to be virtually indistinguishable from nighttime, causing the duration of twilight to appear shorter.
 - E. The runtime of the original theatrical release of *Twilight* (2008) was cut short in equatorial countries such as Singapore and Brunei due to censorship regulations.
27. Which of these statements about stellar remnants are true?
- A. Black holes can result from a pair-instability supernova
 - B. Neutron stars are denser and less massive than white dwarves
 - C. As a neutron star grows more massive, it increases in radius
 - D. A solar mass white dwarf has a smaller radius than Jupiter
 - E. None of the preceding statements are true
28. Which of the following statements best explains why 'hot Jupiters' so dominated the number of exoplanets discovered, before the launch of the Kepler space probe?
- A. Hot Jupiters are highly diffuse and have large radii, and can be easily detected by orbital transit photometry
 - B. The orbital planes of all systems with hot Jupiters are parallel to our line of sight, and may be discovered by orbital transit photometry.
 - C. Hot Jupiters have high surface temperatures, and can be discovered by occluding the glare of the parent star and looking for points of thermal emission, discrete from the parent star.
 - D. The orbits of hot Jupiters have very small semi-major axes; hence, they exert a large, periodic gravitational tug on their parent stars, allowing easy detection by the radial velocity method.
 - E. Hot Jupiters have several moons just like Jupiter within the solar system, all of which repeatedly occlude the parent star. This makes detection by orbital transit photometry straightforward.

29. A cosmic ray detector detected a high energy particle with a speed of $0.999\,999\,999\,995c$. Assuming the particle originated from 150 million light years away, how much time had elapsed from the particle's reference frame?
- A. 47.4 billion years
 - B. 4.74 million years
 - C. 474 thousand years
 - D. 474 years
 - E. 4.74 years
30. Suppose that Jupiter and Earth are at the positions in their orbits shown below.



If you measured Io's period (one of Jupiter's moons) from Earth, which of the following statement about your measurement is true?

- A. The period measured will be exactly the same as those measured from spacecraft like Juno but the position of Io will be slightly delayed from those measured from the spacecraft due to the finite speed of light
- B. Such a measurement would be impossible in most amateur telescope as the resolution of most amateur telescope will not be able to resolve Io from Jupiter
- C. You would observe that the period measured would depend on its position in the orbits relative to earth, when it is further away from Earth, it will have a slightly longer orbit and vice versa.
- D. You could not accurately measure Io's period because there is no reliable point of reference to indicate the start of a new orbit.
- E. None of the above

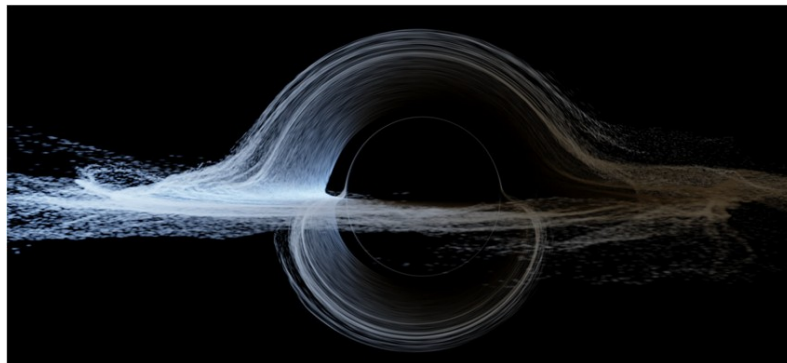
31. A topic of recent interest is the formation of molecules in the interstellar medium. Consider the following statements about the chemistry in cold, dark interstellar clouds, in which large molecules are able to form.

- I. There is a protected reaction environment inside the clouds due to shielding from UV radiation.
- II. Large molecules form in part due to the high density of the cloud.
- III. Grains act as nucleation sites for further reactions.

Which of the above statements is/are true?

- A. I only.
- B. II only.
- C. II and III only.
- D. I, II, and III.
- E. None of the statements are true.

32. The figure below is a realistic rendering of a *quiescent* and *rotating* supermassive black hole, based on a paper by Kip Thorne et al. This rendering was initially meant to be used in the film *Interstellar*, before it was decided that it would be 'too confusing' for viewers, and some artistic licence was taken in the final cut



The following statements are some claims about features in the image.

- I. The accretion disc is darker on the right because of the presence of interstellar dust that blocks light emitted by the disc, on the right.
- II. The black hole appears laterally compressed (squashed on the left and right) because it is rotating, and space-time is dragged by the rotating black hole, thus bending light accordingly.
- III. The accretion disc doesn't merely *appear* curved; it *actually* loops above and below the black hole.
- IV. The rendering is incorrect because the black hole is missing its polar relativistic jets.

The following options denote which of the above claims might be true. Choose the correct option.

- A. I and II only
- B. I and III only
- C. II and IV only

- D. None of the above options are correct, nor are any of the statements true.
 E. None of the above options are correct, but one or more statements are true.
33. Suppose the September 2020 equinox is occurring right now. Which of the following events will be occurring then?
- On this day, the length of the day exactly equals the length of the night (including twilight) for all locations around the world (excluding the poles)
 - Observers who are able to observe a sunset at this moment would agree that the Sun has an azimuth of 270° (excluding the poles)
 - The Sun reaches the First Point of Libra during this equinox by definition, and thus the Sun lies in the constellation of Libra
 - Under the standard J2000 equinox and epoch, the Sun will be observed to have an declination of exactly 0° .
 - If there is a full Moon today, it will rise exactly due east and set exactly due west for all observers (excluding the poles)
34. The Arecibo message was a transmission to the globular cluster M13. It was a demonstration of technological achievement rather than an attempt to communicate to extraterrestrials. Why then, are globular clusters (GCs) not thought to be likely candidates to search for intelligent life?
- GCs are very old and most life would have been dead since that time.
 - The interstellar distance between stars in GCs are relatively small, and gravitational interactions can destabilize planetary orbits.
 - Planets in GCs experience significantly higher background radiation which potentially destabilizes molecules.
 - A, B and C
 - B and C only
35. In Celestial Mechanics, the vis-viva equation is an important equation that can give the relationship between the speed of an asteroid/comet, v , with its distance from the centre of the sun r and the semimajor axis a . It can be easily derived from conservation of energy as show
- $$\frac{1}{2}mv^2 - \frac{GMm}{r} = -\frac{GMm}{2a}$$
- $$v^2 = GM\left(\frac{2}{r} - \frac{1}{a}\right)$$
- Given this, which of the following is a correct match between the type of orbit and the parameters observed in the solar system?
- $r=3$ AU, $v=25.4$ km/s, elliptical orbit
 - $r=5$ AU, $v=10.8$ km/s, hyperbolic orbit
 - $r=1$ AU, $v=42.2$ km/s, parabolic orbit
 - $r=7$ AU, $v=12.8$ km/s, circular orbit
 - None of the above

36. A tundra orbit is a highly elliptical orbit inclined 63.4 degrees from the Equator, and has an orbital period of one sidereal day. For which purpose would a tundra orbit offer the most advantage over using a geostationary orbit?
- A. Polar communications.
 - B. Clearing space debris.
 - C. Rapid scans of the entire Earth.
 - D. Satellite refuel docking.
 - E. Gamma wave detection.
37. The star R136a1 has the highest luminosity of any known star at 3.33×10^{33} W. It has an estimated surface temperature of 53,000 K. Supposing R136a1 only emits photons at its wavelength, calculate the number of photons emitted each second
- A. 9.18×10^{40} photons
 - B. 9.18×10^{45} photons
 - C. 9.18×10^{50} photons
 - D. 9.18×10^{55} photons
 - E. 9.18×10^{60} photons
38. At 6pm of some day, Alice observes that Schedar (α Cassiopeiae, RA: 00h 40m, DE: $+56^\circ 32'$) is exactly on her zenith. Which star is closest to the zenith after exactly 127.5 sidereal days?
- A. Castor (Alpha Geminorum, RA: 07h 34m, DE: $+31^\circ 53'$)
 - B. Eltanin (Gamma Draconis, RA: 17h 56m, DE: $+51^\circ 29'$)
 - C. Pherkad (Gamma Ursae Minoris, RA: 15h 20m, DE: $+71^\circ 50'$)
 - D. Alioth (Epsilon Ursae Majoris, RA: 12h 54m, DE: $+56^\circ 57'$)
 - E. Capella (Alpha Aurigae, RA: 05h 16m, DE: $+45^\circ 59'$)
39. During the Alpha Ladder Process (nuclear fusion), which one of the following elements is the heaviest element that can be formed during the process?
Note: Alpha Ladder Process refers to the successive collision of even atomic number nuclei with atomic number greater than that of carbon with helium nuclei to form heavier nuclei.
- A. Carbon
 - B. Gold
 - C. Nickel
 - D. Iron
 - E. Hydrogen

40. You observe light reflected from Mercury using a large telescope. However, by the time the light from Mercury enters your telescope on Earth, Mercury has moved away from the position where you see it. How long ago was Mercury in the position where you observe it? Assume that Mercury is in inferior conjunction. (Hint: The orbits considered in this question are not circular orbits)
- A. 4.57 minutes
 - B. 5.09 minutes
 - C. 12.19 minutes
 - D. 12.32 minutes
 - E. It can not be determined without further information
41. Which of the following reasons is NOT a possible reason why a planet around a red dwarf star is inhospitable for most lifeforms on Earth?
- A. Extended pre-main sequence phase means future planets in the habitable zone would have been exposed to large amounts of radiation initially, stripping off much of the early atmosphere.
 - B. High stellar variation experienced by planets of red dwarf stars (variation in luminosity/energy output of the star)
 - C. Host star has a long main-sequence lifespan.
 - D. Spectral energy distributions shifted to the infrared part of the electromagnetic spectrum
 - E. All the above reasons are possible reasons for why a planet around a red dwarf is inhabitable
42. An astronomical object is moving away from Earth at speed which is at a significant fraction of the speed of light, i.e, $v = \chi c$, where $0 < \chi < 1$. When Grace tried to observe the spectrum emitted from this astronomical object, she measures the wavelength of the $H\alpha$ line to be at 892.54nm . Note that the wavelength of $H\alpha$ is observed to be at 656.28nm when observed in the object's rest frame. Which of the following could be the value of χ ?
- A. 0.149
 - B. 0.298
 - C. 0.447
 - D. 0.596
 - E. 0.745
43. To commemorate the inauguration of a newly formed astronomy club, the members decided to erect a tall pole in an open flat field. The monument has a special property that on the 30th of December 2012 (day of inauguration), the tip of the shadow of the pole falls on an "X" marked on the ground at noon. On 14th December 2019, the phenomenon was observed. In 2020, what will be the first time this phenomenon is observed again?
- A. 1st January
 - B. 23rd September
 - C. 14th December

- D. 30th December
- E. It will not occur in 2020.

Q44 to Q47 uses the table below. Latitude of the starting location is 30°N. Q44 to Q47 may not refer to the sky on the same day/night.

| Object/Star | Right Ascension | Declination | Apparent Magnitude |
|---------------------------|-----------------|--------------|--------------------|
| Eta Carinae system | 10h45m04s | -59° 41'04'' | 4.30 |
| Southern Pleiades | 10h43m56s | -64° 30'23'' | 1.90 |
| Omicron Velorum (C85) | 8h40m47s | -53° 08'21'' | 2.50 |
| Regulus | 10h09m27s | +11° 52'04'' | 1.35 |
| Castor | 7h35m53s | +31°50'47'' | 1.90 |
| Butterfly Cluster | 17h41m25s | -32°13'34'' | 4.20 |
| Heart Nebula | 13h23m43s | +61°44'44'' | 6.50 |
| Great Cluster in Hercules | 16h42m25s | +36°25'46'' | 5.90 |

44. Which of the following objects/stars will be the closest to the zenith when the object/star passes the meridian?
- A. Heart Nebula
 - B. Southern Pleiades
 - C. Regulus
 - D. Castor
 - E. Eta Carinae
45. At 9p.m, Castor, Regulus and the Heart Nebula can be seen in the night sky. Which astronomical season is it currently?
- A. Autumn
 - B. Summer
 - C. Winter
 - D. Spring
 - E. Insufficient information to determine the answer
46. What is the most important reason why Southern Pleiades can't be seen on a particular night at this location?
- A. It is currently autumn while Southern Pleiades is a spring constellation
 - B. It will never rise above the horizon
 - C. It is behind a tree
 - D. It is too dim to be visible through a 4-inch telescope
 - E. The moon is right next to it
47. Now suppose we are observing from Singapore. If the Butterfly Cluster rises above the horizon at 4p.m., approximately what time on the same day will the Great Cluster in Hercules rise above the horizon?
- A. 1p.m.
 - B. 2 p.m.
 - C. 3 p.m.
 - D. 4 p.m.

- E. 5p.m.
48. The Spring Equinox this year (2020) in the Northern Hemisphere will be at about 11:50 am on 20th March 2020. What is the probability that the Spring Equinox happens at about the same time on the same day for a randomly chosen year in the next three years (2021 –2023)?
- A. 0
 - B. 0.33
 - C. 0.67
 - D. 1
 - E. Not enough information to determine the probability.
49. Currently when we observe Saturn, we see the northern plane of Saturn's rings. Is it ever possible to view the southern plane of Saturn's rings from Earth within a human lifetime, and why?
- A. No. Saturn's rotational axis is tilted towards the earth so we can only ever see the northern side.
 - B. No. However, Saturn's rotational axis precesses over time and will face away from earth in 72,000 years, allowing us to view its southern plane then.
 - C. Yes. The southern side will be visible once Saturn moves further ahead in its orbit.
 - D. No. Saturn's rings will likely dissipate before its rotational axis faces away from earth.
 - E. Yes. Every 100 years the magnetic field of Saturn flips, causing its rings to flip over.
50. You brought out your club's 6" F/6 Newtonian telescope to observe M6. With a quick search you realise M6 is 25' in angular diameter. Which eyepiece would you attach to the telescope to maximise your view of M6 while still ensuring the whole of M6 can be seen in the eyepiece? (FL=Focal length, AFOV= Apparent field of view, 1 inch=2.54cm)
- A. FL: 32mm, AFOV: 50°
 - B. FL:40mm, AFOV: 40°
 - C. FL: 13mm, AFOV: 50°
 - D. FL: 7mm, AFOV: 60°
 - E. FL: 4mm, AFOV: 70°