ASTROCHALLENGE 2016 MULTIPLE CHOICE QUESTIONS
SENIOR ROUND

INSTRUCTIONS

− This paper consists of 15 printed pages, excluding this cover page.
− Do **NOT** turn over this page until instructed to do so.
− You have 2 hours to finish all questions in this paper. Choose the most appropriate answer
− At the end of the paper, staple this booklet together with your answer script.
− Your answer script should clearly indicate your name and school.
− It is your team's responsibility to ensure that all pages of your answer script have been submitted.

1. The total mass of the solar system is roughly on the order of

   A. 2×10^{29} kg
   B. 2×10^{30} kg
   C. 2×10^{31} kg
   D. 2×10^{32} kg
   E. 2×10^{33} kg

2. Extinction (absorption and scattering of electromagnetic radiation by dust and gas between an emitting astronomical object and the observer) occurs all the time in astronomical observations, due to the interstellar medium (ISM), causing distant objects to appear differently. Which of these statements about this phenomenon is true?

   A. Interstellar absorption resulting in extinction occurs equally for all wavelengths.
   B. Shorter ('bluer') wavelengths are affected more than longer ('redder') wavelength.
   C. Longer ('redder') wavelengths are affected more than shorter ('bluer') wavelength.
   D. X-rays from a pulsar do not experience interstellar absorption since they are not in the visible spectrum.
   E. The observed spectrum profile of a star is greatly affected by interstellar medium.

3. Which of the following theories requires the presence of dark energy?

   A. Steady State Universe
   B. Big Bang
   C. Big Crunch
   D. Big Rip
   E. Big Freeze

4. In order to take a picture of M7 (Ptolemy Cluster), Harshjyot attached a camera on to his telescope, with an effective diameter of 20cm and focal length of 200cm, and took a photo with an exposure time of 18 seconds. How long would it take instead to obtain a picture of the same object with the same brightness, if he used a telescope with an effective diameter of 30cm instead? Assume that the new telescope has an f-ratio of f/10.

   A. 40.5s
   B. 27s
   C. 18s
   D. 12s
   E. 8s

5. If the ratio of energy flux from the star received by a planet at its aphelion and perihelion is 3:5, what is its orbital eccentricity?

   A. 0.13
   B. 0.25
   C. 0.33
   D. 0.47
   E. 0.87

6. Suppose we were near the Equator. On March 21st, what constellation should be located around the zenith at local midnight?

   A. Virgo
   B. Aries
   C. Orion
   D. Scorpius
   E. Crux

7. Which of the following conservation laws can explain Kepler's Second Law?

   A. Conservation of Energy
   B. Conservation of Angular Momentum
   C. Conservation of Time
   D. Conservation of Torque
   E. Conservation of Charge

8. Which of the following is a postulate of either Special Relativity or General Relativity?

   A. All mass moving through spacetime generates gravitational waves.
   B. The Metric tensor of spacetime in general relativity can be diagonalized and defines the geometry of spacetime.
   C. The speed of light is constant in all inertial frames of reference.
   D. A black hole is characterized by its charge, mass and spin only.
   E. Mass tells space how to curve and space tells mass how to move.

9. Which of the following statements about the moon is true?

   A. The phrase 'Once in a blue moon' refers to the phenomenon when the far side of the moon becomes mostly visible due to lunar libration.
   B. The moon is the only astronomical object responsible for Earth's tides.
   C. Earth's moon will cross the Roche limit and fragment into pieces before the Sun swells into a Red Giant.
   D. The far side of the moon is also called the 'dark side' of the moon because it receives significantly less illumination from the sun compared to the near side facing us.
   E. Because the moon is tidally locked, the near side, generally speaking, always faces the Earth.

10. Which of the following lists contain <u>ONLY</u> main sequence stars?

   A. Aldebaran, Antares, Arcturus
   B. Bellatrix, Betelgeuse, Beta Aurigae
   C. Canopus, Capella, Castor
   D. Deneb, Denebola, Dubhe
   E. None of the above

11. Which of the following statements does <u>NOT</u> show abiogenesis (formation of organic compounds necessary for life), which in turn explain possible origins of molecules required for life to exist on Earth in the first place?

    A. Formation of amino acids from atmospheric gases in the early terrestrial atmosphere due to lightning and heat.
    B. Aggregation of molecules and eventual formation of simple organic compounds (e.g. methanol) on cosmic dust grains.
    C. Conversion of simple organic compounds into complex polycyclic aromatic hydrocarbons due to cosmic ray catalysed mechanisms in nebulae.
    D. Conversion of fatty acids, glycerol and phosphates into (phospho)lipids on clay surfaces in deep sea hydrothermal vents.
    E. All of the above statements are examples of abiogenesis.

12. Which of the following concepts has been demonstrated in this interesting excerpt?
    "Believe it or not, some scientists argue that the young Solar system was a lot more compact, and Neptune used to be within Uranus' orbit. These used to be near-circular, post accretion from a protoplanetary disk. But as early planetesimals confer more and more angular momentum to each gas giant, Jupiter and Saturn eventually displaced Uranus and Neptune outwards. As Uranus and Neptune plough into the remnants of the planetesimals disk, they scattered many of them in all directions, some of them towards the inner solar system, resulting in a flurry of impacts on terrestrial planets."
       i. The Nice Model
       ii. Great Switcheroo
       iii. No-Hair Theorem
       iv. Late Heavy Bombardment
       v. Shapley-Curtis Debate, or the Great Debate

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

13. Which of the following statements regarding the night sky is False? (Hint: This is not a trick question. All named stars are correctly spelled, designated and located in their respective constellations)

    A. If you extend a line through the three stars along Orion's Belt (Alnitak, Alnilam, Mintaka), you'll arrive at Pollux in Gemini and obtain a line almost perfectly perpendicular to the ecliptic.
    B. Extend a line from Beta Ursae Majoris (Merak) towards Alpha Ursae Majoris (Dubhe), the 'leading edge' of the Big Dipper, and you will eventually arrive at Polaris (Alpha Ursae Minoris), in turn finding the north celestial pole.
    C. Alpha Centauri (Rigil Kent) and Beta Centauri serves as not only guide stars to locate the Southern Cross (Crux) more easily, but a line perpendicular about the midway of both stars can be used in conjunction with the Southern Cross to find the south celestial pole.
    D. Omega Centauri, despite its prominence in the night sky, is not listed as a Messier object due to its Declination of about −47° 28' 46.1", and thus Charles Messier (in France) would not have observed it.
    E. Stars twinkle because of atmospheric turbulence when observed from Earth. The reason the 'Morning/Evening star' doesn't twinkle is because it isn't a star- it's actually Venus.

Use the following information for questions 14 and 15.

Star X is a red dwarf with a peak wavelength of 904nm, and a radius of 0.4 $R_\odot$.

14. Estimate the luminosity of the Red dwarf, in terms of solar luminosity ($L_\odot$).

    A. 1.51 $L_\odot$
    B. 0.584 $L_\odot$
    C. 0.0948 $L_\odot$
    D. 0.0584 $L_\odot$
    E. 0.0151 $L_\odot$

15. Suppose that you used $L = 1.5\,M^{3.5}$ as the Mass-Luminosity Relation of Main Sequence stars to estimate the mass of the Red dwarf. It turns out, however, that the actual mass of the Red Dwarf is higher than calculated. Which of the following is the MOST likely explanation?

    A. Red dwarfs should not be treated as main-sequence stars; we should use the same Mass-Luminosity relation as Red giants as they emit similar light at longer wavelengths.
    B. Red dwarfs form plenty of heavy elements by nuclear fusion (e.g. Iron), and thus the overall mass of the red dwarf will increase significantly.
    C. Convection is the main form of energy transfer instead of Radiation in stars lower than 0.43 solar masses, and thus Red dwarfs (by mass) actually gives rise to less luminosity per unit mass. Thus, the Mass-Luminosity relation differs for main-sequence red dwarfs
    D. The 'tired light' of the Red Dwarf took too long to reach Earth, resulting in a much longer, redshifted peak wavelength than expected, affecting your calculation of its luminosity in the first place.
    E. A red dwarf is in fact a 'greybody' instead of an almost ideal blackbody, and fails to provide enough outgoing light due to a poor magnetic field.

16. Which of the following astronomical phenomena can contribute to changes in Earth's long term climate, including periods of ice ages and warming throughout geological history (Milankovitch cycles)?
    i. Variation in the eccentricity or shape of Earth's orbit.
    ii. Variation in the angle of the axial tilt of the Earth.
    iii. Axial precession of Earth's axis and thus changes in Earth's axis of rotation.
    iv. Apsidal precession of Earth's orbit due to gradual shifts in Earth's orbit path.
    v. Orbital inclination or planetary precession of Earth, causing it to move up or down with respect to the plane of the ecliptic.

    A. i and iv. only
    B. i, ii, and iii only
    C. ii, iii and v only
    D. All of the above.
    E. None of the above: Astronomical phenomena have no correlation with ice ages.

17. Geostationary satellites are man-made satellites made to orbit above the Earth's equator at a particular altitude with an orbital period same as the Earth's rotational period. As a result, when a person observe the night sky at a particular time during two nights, a few days apart, these satellites appear at the same position relative to the neighbouring stars. How do you tell the geostationary satellites apart from the neighbouring stars?

    i. The context given above is inaccurate, these man-made satellite are usually too small to be seen by the naked eye on Earth.

    ii. These satellites usually have pulsating light sources. As a result, we can observe these satellites "twinkle" in the night sky.

    iii. Throughout one night, the geostationary satellite will remain at the same position in the night sky while the neighbouring stars will rise and set.

    iv. Cross refer to a star chart to check if there is an extra object in the area where the suspected object is.

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

18. You are using a reflector type telescope on a clear, moonless night. Despite your best efforts, you are unable to properly focus the telescope with a camera. Only up to half of the image can be focused at any time. Furthermore, you are certain that the image circle is much larger than the camera sensor. What might be the problem here?

A. The telescope is suffering from chromatic aberrations.
B. Turbulence in high altitude air causes seeing that affects the focus of the image.
C. A portion of the front objective is obstructed.
D. The telescope is not properly collimated.
E. All of the above.

19. The surface temperature of a star can be determined from the observed light spectrum. However, it is observed that the hottest stars often lack any distinguishing hydrogen lines. Why is this so?

A. The above context is incorrect. The hotter the surface of the stars, the brighter they should appear and should have the shortest wavelength in the hydrogen spectrum.
B. This is because the hottest stars have surface temperatures hot enough to fully ionise the hydrogen atoms at the surface.
C. The hottest stars have all the hydrogen on the surface used up in nuclear fusion processes. Hence there is no hydrogen spectral lines.
D. The hottest stars usually have little hydrogen atoms, but instead have larger proportions of heavier elements formed from nuclear fusion.
E. The hydrogen atoms at the surface are in atomic form and do not have an emission line.

20. The graph shows the variation with time t of the apparent magnitude m of a particular Cepheid star.
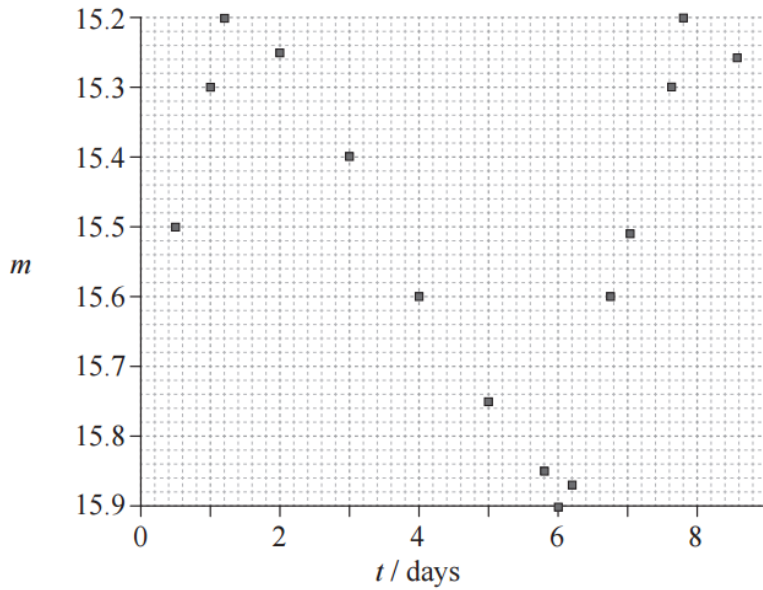
What is the distance to the star?

    A. 31kpc
    B. 54kpc
    C. 55kpc
    D. 65kpc
    E. 76kpc

21. W, X, Y and Z are the explanation of different types of optical aberrations found in astronomical instruments. Which of the following matches the explanations to their correct optical aberrations?

W: Due to optical dispersion, different wavelengths of light do not focus onto the same plane.

X: On-axis light does not reflect in a manner that is parallel to the optical train.

Y: In a parabolic reflector, off-axis light rays do not focus onto the same plane as on-axis light rays.

Z: Reflected or refracted light rays propagating in perpendicular planes do not focus onto the same point.

	Chromatic Aberration	Astigmatism	Coma	Tilt
A.	W	X	Y	Z
B.	W	Z	Y	X
C.	X	W	Z	Y
D.	Z	Y	X	W
E.	Z	W	X	Y

22. Dark frame subtraction is an image calibration technique in which the camera shutter is closed, but an exposure is taken using the same parameters as the original light frame. This image with a closed shutter, known as a dark frame, is then subtracted off the original light frame.

Which of the following forms of noise below can be removed by dark frame subtraction?

   i.   Photon shot noise: Due to the Heisenberg uncertainty principle, photons arriving onto an image sensor have a probabilistic energy variance that follows a Poisson distribution.
   ii. Thermal Noise: Aside from normal activation by photons, charge carriers in imaging sensors are also activated by thermal energy, which causes pixels to brighten in a linear and predictable manner as exposure time increases at a particular temperature
   iii. Read Noise: During the analog-to-digital conversion of charges accumulated on an electronic sensor into digital units, a small amount of noise is added into the image data as a result of the camera electronics. This addition of noise occurs in a predictable manner

   A. i only
   B. ii only
   C. iii only
   D. ii and iii
   E. All of the above.

23. Suppose that if the local solar time in Greenwich is 10 hours 17 minutes 14 seconds, the local solar time in Moscow is then 12 hours 47 minutes 31 seconds. The geographical longitude of Moscow is then:

   A. 20.57°W
   B. 21.20°E
   C. 37.57°E
   D. 35.70°W
   E. 40.55°E

24. On a certain day in August, a reputable astronomy guide for location X says that Antares will cross the meridian after the end of astronomical twilight (1.5 hours after local sunset). However, an observer in Singapore notes that Antares has already crossed the meridian after local sunset on that same August day. Which statement is most likely correct?

   A. The observer made the classic mistake of mistaking Aldebaran for Antares.
   B. The longitude of the observers are different.
   C. The guide is in error.
   D. Location X lies significantly south of the equator.
   E. Location X lies significantly north of the equator.

25. In mid-northern latitudes, Arcturus (α Boötis) is known as the Ghost of Summer Suns. Around late October, Arcturus occupies the same position in the sky as what the Sun did in in July. In other words, for the same local solar time X at any location:

The altitude/azimuth of Arcturus in late October ≈ The altitude/azimuth of the Sun in late July

Thus, if the Sun is known to have a RA around 08h in late July, which pair of coordinates could correspond to the RA/DE of Arcturus?

A. RA: $02^h\ 15^m$/ DE: +19° 10'
B. RA: $05^h\ 15^m$ / DE: +19° 10'
C. RA: $08^h\ 15^m$ / DE: +19° 10'
D. RA: $11^h\ 15^m$ / DE: +19° 10'
E. RA: $14^h\ 15^m$ / DE: +19° 10'

26. While trying to estimate the density of dark matter in the Universe compared to the critical density, several researchers propose the following methods:

1. Accurately measure the shape and distribution of the CMB spectrum across the Universe. By analysing the properties of the CMB, we can estimate the dark matter density.
2. Build a big dark matter detector underground, so as to accurately obtain counts of dark matter particles. To reduce background noise, this detector must be well-shielded from cosmic rays and high energy radiation.
3. Accurately measure the orbital velocity of bodies in the Solar System, and construct a rotation curve for the Solar System. By the cosmological principle, the density of dark matter within the Solar System is equal to the density of dark matter in the overall Universe.
4. Using field stars in the crowded Sagittarius region, look out for gravitational microlensing events. The frequency and intensity of these events allows us to directly observe the density of dark matter along our line-of-sight.

Which of the above methods is likely to give accurate estimates for the density of dark matter in the overall universe?

A. Method 1
B. Method 2
C. Method 3
D. Method 4
E. None of the above.

Refer to the following table for questions 27 and 28.

Suppose I have 5 objects that I wish to observe during an observation session on the Equator:

Object	Right Ascension	Declination
A	02^h 30^m	+58° 15'
B	01^h 25^m	-03° 20'
C	12^h 50^m	-27° 00'
D	18^h 45^m	-12° 10'
E	11^h 05^m	+20° 15'

27. In the course of my observations, I noticed that the entire Eastern horizon is obstructed by trees. Due to this, objects only become visible once they attain an <u>altitude of 10°</u> above the Eastern horizon. Thus, to account for the obstructions, the computed rise times have to be increased by a certain amount for each object.

    Rank the objects by the magnitude of this adjustment (largest adjustment first)

    A. D, B, E, C, A
    B. B, D, E, C, A
    C. A, C, E, D, B
    D. A, B, C, D, E
    E. The rise times of all objects are adjusted upwards by the same amount

28. On another day, I observe Object A rising immediately after sunset. Which objects will rise before sunrise, and in what order will they rise?

    A. A, B, D, C
    B. A, B, D
    C. A, E, C, D
    D. A, E, C
    E. A, B, D, C, E

29. Suppose that the Sun will became a pulsar at the end of its lifespan, with a final radius of 20 km (In reality the sun won't have the required mass and will form a white dwarf instead). Assuming an exact rotation period, T = 27 days, determine the angular momentum of the hypothetical solar pulsar.

    A. 2.6 x 10^{42} kgm^2/s
    B. 3.78 x 10^{42} kgm^2/s
    C. 2.6 x 10^{45} kgm^2/s
    D. 3.78 x 10^{45} kgm^2/s
    E. 5.2 x 10^{45} kgm^2/s

30. A double star is observed from Earth to have a period of 1.2 days. It turns out that the star system is moving away from Earth at a speed of 500km/s. The actual orbital period of the binary star is thus:

    A. 0.599 day
    B. 1.198 day
    C. 1.2 day
    D. 1.204 day
    E. 2.408 days

31. Given the following equation:

cos ω = - tan Φ × tan δ

where:
ω is the hour angle at either sunrise (when negative value is taken) or sunset (when positive value is taken);
Φ is the latitude of the observer on the Earth;
δ is the sun's declination.

NB: Hour angles essentially measure how long since an object last crossed the meridian. To convert this period into an angle, first divide it by the length of a day. Since the Sun makes a 360 degree revolution across the sky in a day, multiply this fraction by 360 degrees to obtain the hour angle.

What is the length of the longest day in a certain town with a geographic latitude of 43^0 31' N?

A. 7 hours 38 minutes
B. 8 hours 45 minutes
C. 13 hours 20 minutes
D. 15 hours 15 minutes
E. 17 hours 45 minutes

32. If the temperature at the time when the universe became transparent happened to be 8320K and the expansion rate per unit length *a(t)* has increased 1650 times till today, what will be the temperature of the Cosmic Microwave Background today? (You may want to consider a region of volume of photon gas that expands at the same rate of the universe, ie. $V \propto \lambda(t)^3$. Energy density and pressure of the gas can be assumed to be $\varepsilon_\gamma = \beta T^4$ and $P_\gamma = \varepsilon_\gamma/3$ respectively, where β is a constant.

A. 0.124K
B. 3.677K
C. 5.042K
D. 59.58K
E. 204.8K

33. I wish to find the mass of the Milky way's central black hole, believed to be situated at Sagittarius A*. Which of these methods will yield the best estimate of its mass?

A. Given $M_\odot$, the sun's orbital velocity and the distance of the Sun from the black hole, I can find the mass of the black hole.
B. Get an optical telescope to directly observe the angular diameter (and thus actual diameter) of the event horizon. We can then plug this into the formula for the Schwarzschild Radius
C. Observe nearby stars in the Milky Way centre. Through astrometry, we can constrain their orbital parameters and hence estimate the mass.
D. Train radio telescopes on Sagittarius A* and measure the flux. We can then apply the Hawking Radiation equations to yield its mass.
E. More than one of these methods will yield accurate estimates.

34. Which of the following statements regarding telescopes is true?

A. To improve the angular resolution of radio telescopes, we can use several widely separated telescopes and Earth's rotation. As the Earth rotates, the baseline between the telescopes changes relative to the observing target. This changing baseline effectively increases the number of detectors in an interferometric array.

B. Combining the signals from multiple radio telescopes in an interferometric array can increase the ratio λ/D, which governs the diffraction limit from the Rayleigh criterion.

C. In order to withstand the harsh conditions of space, specialised mirrors/lenses made of leaded glass must be made for X-ray telescopes. Though these optical elements are heavier, they work exactly the same way as their visible light counterparts.

D. One of the disadvantages of a reflector is that the prime focus is in front of the mirror and some incoming light may be blocked. To resolve this specific problem, we can use Cassegrain telescopes whose focus is underneath the telescope.

E. The reason why paraboloidal mirrors are used in reflecting telescope is because of its special geometry that will not distort the wavelength of the incoming light so much before the light reaches the focus.

35. Which of the following statements regarding spectral classification of stars are correct?
   i. The spectra of class A stars consists of strong hydrogen and ionized metals.
   ii. Massive Class O stars are among the most luminous stars in the galaxy. These stars are characterised by prominent ionized helium absorption lines.
   iii. One of the key differences between F and G stars is that G stars contain absorption lines of neutral metals while F stars don't.
   iv. The spectra of K stars is dominated by hydrogen and neutral metals like iron and manganese.

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

36. Which of the following statements is correct?

A. Cosmological redshift refers to frequency decrease of a light source due to expansion of space whereas relativistic Doppler redshift refers to the increase in frequency radiated from within a high gravitational field.

B. The only way we can measure the mass of any distant object is to measure the orbital period of the object.

C. Gravitational microlensing events involve a noticeable distortion in the shape and position of background stars, and are thus detected by monitoring crowded fields of stars.

D. As we progress from E0 to E7 (for the Hubble Tuning Fork), the corresponding galaxies become rounder and rounder.

E. Contrary to what one might believe, the Hubble Tuning Fork does not represent the evolution of galaxies (aka Ellipticals do not gradually evolve into spirals).
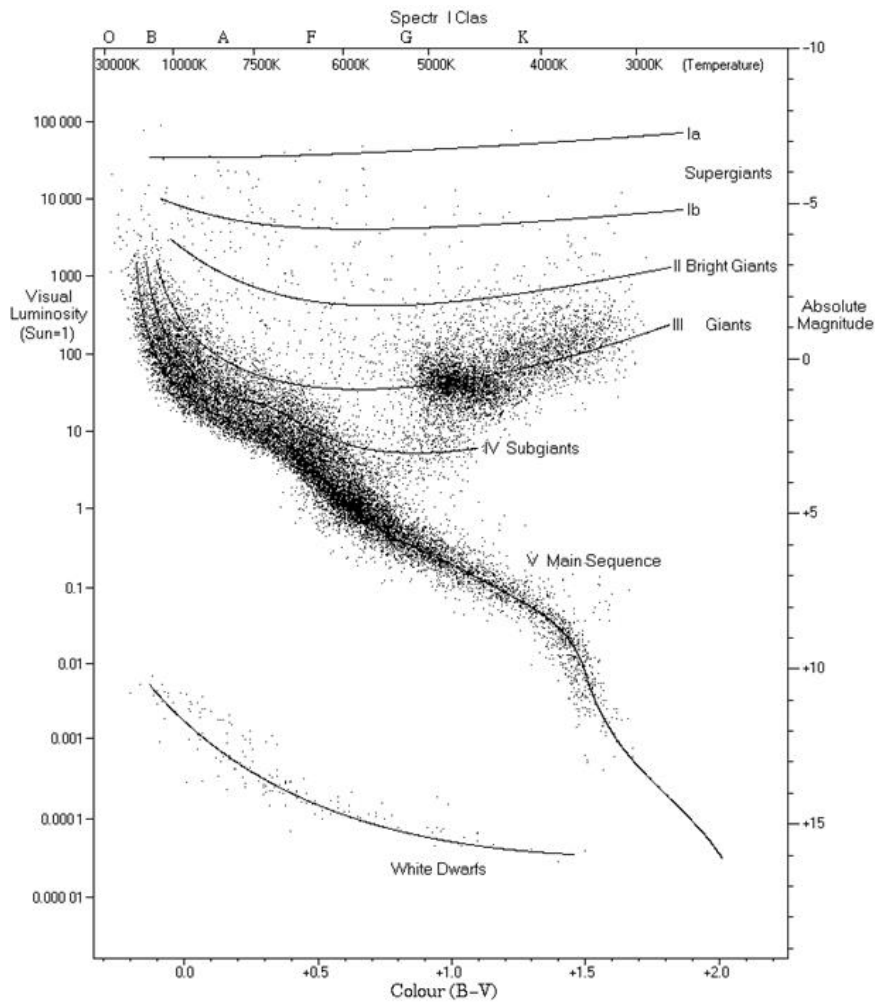
37. A star is observed to have a visual luminosity of 100 times that of our Sun and found to have a peak wavelength of 350nm. Hence, determine its radius.
    A. 15.9 AU
    B. 20.6 AU
    C. 15.9 $R_{\odot}$
    D. 20.6 $R_{\odot}$
    E. None of the above

38. Despite the fact that its peak wavelength is 350nm (UV region), the star is optically observable. Suggest a reason why this is so.

    A. There are telescopes in space that are capable of detecting stars giving out UV radiation.
    B. The peak wavelength of the star does not suggest that it does not radiate in the visible spectrum for observation. It hence can be observed to be reddish.
    C. The luminosity of the star is sufficiently large enough such that it does not matter what is the nature of its peak wavelength.
    D. After applying a proper filter to our telescope, the star will then become visible to us.
    E. The star will be perceived to be bluish in the visible spectrum as the peak wavelength only suggests that the majority of the flux emitted is in the shorter wavelengths.

39. Which of the following is a key difference between lenticular and spiral galaxies?

    A. Unlike spiral galaxies, lenticulars show no signs of having a disk.
    B. Lenticulars are only rich in dust, whereas spirals are only rich in gas.
    C. Lenticulars were among the first galaxies that formed, gradually evolving into spirals.
    D. Lenticulars have very little ongoing star formation compared to spirals.
    E. There are no practical differences between lenticular and spiral galaxies.

40. It is known that the helium flash phenomenon occurs in the core of low mass stars. Initially, these cores are supported by electron degeneracy until the temperature of the core reaches approximately 100 million Kelvin, allowing helium fusion to finally occur. Which of the following thermodynamic equations of state best describes the core of a low mass star prior to the helium flash?

    Note that a, b, c and K are arbitrary constants, n refers to the number density of particles and T is the temperature of the system.

    A. $P = \frac{1}{3}aT^4$
    B. $P = Kn^{5/3}$
    C. $PV = NkT$
    D. $PV = bT^3$
    E. $PV = cT^7$

41. The constant k in the Friedmann equation tells us about the geometry of the universe i.e. curvature of spacetime as described by General Relativity. Where k > 0 suggests the universe to be spherical and hence closed; k = 0 to be flat and k < 0 for the universe to be hyperbolic and opened. Which of the following statements may be made for k = 0 and k < 0 where the universe may be seen to be infinite?

    A. The universe is infinite in size and the expansion of the universe is accelerating.
    B. The universe is infinite in size and may possibly have existed for a finite time.
    C. The universe is infinite and dark matter is responsible for the geometry of the universe.
    D. The universe is infinite and run the risk of experiencing heat death.
    E. None of the statements above are true.

42. Two bodies are known to be orbiting about each other. Which of the following statements is **generally** true?

    A. The two bodies have the same orbital velocities.
    B. The two bodies are equidistant from the centre of mass.
    C. The two bodies have the same eccentricity.
    D. The orbits of both bodies cannot be confined into a single 2-dimensional plane.
    E. Due to tidal forces, the two bodies would gradually move further apart from each other.

43. Due to Earth's orbital motion, even distant objects in the Solar System appear to drift against the background stars. Given that V774104 (currently the furthest observable object in our Solar System) is 103 AU away from the Sun, what is the **maximum instantaneous** apparent angular velocity, $\frac{d\theta}{dt}$, of V774104 as seen from Earth? Assume that V774104 is stationary, Earth follows a circular orbit and V774104 lies along Earth's orbital plane. Recall: $s = r\,\theta$ and treat Earth as travelling in a nearly straight line (during small time intervals).

   A. $4 \times 10^{-4"}$ hr^{-1}
   B. 0.228" hr^{-1}
   C. 1.45" hr^{-1}
   D. 5.48" hr^{-1}
   E. 324" hr^{-1}

44. Given the orbital semi-major axis of Jupiter (as found in the formula booklet), calculate the minimal and maximal angular diameter of the sun, as seen from Jupiter.

   A. 0.2155°, 0.1954°
   B. 0.0017°, 0.0019°
   C. 0.0977°, 0.1078°
   D. 0.0037°, 0.0034°
   E. 0.0053°, 0.0488°

45. Hence or otherwise, using information found from 42, which of the following Galilean moons can eclipse the entire sun?

   i.   Io (average radius of **1822km**, a = 422,000 km)
   ii.   Europa (average radius of **1561km**, a = 671,000 km)
   iii.   Ganymede (average radius of **2634km**, a = 1,070,000 km)
   iv.   Callisto (average radius of **2410km**, a = 1,883,000 km)

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

46. Generally, what is the key difference between a lunar and the lunisolar calendar?

   A. The date of the full moon is different every month in the lunisolar calendar
   B. The lunisolar calendar would occasionally have a leap month.
   C. The date of the vernal equinox on the lunisolar Calendar is always fixed.
   D. The first day of the month is the new moon in the lunar calendar, but can be any other moon phase in a lunisolar calendar
   E. There is no difference between the lunar and the lunisolar calendar.

47. After an extensive period of orbital decay, two black holes finally spiral inwards and merge. Which of the following properties of the resultant black hole is conserved?

    A. The event horizon radius of the resultant black hole is equal to the sum of the event horizon radii of both black holes.
    B. Charge of the resultant black hole
    C. Mass of the resultant black hole
    D. Total volume enclosed by the event horizon(s)
    E. Angular momentum of the resultant black hole

48. Which of the following methods is likely to yield the **most accurate** estimate for the distance of M87, an elliptical galaxy in the Virgo cluster?

    A. Identify the most luminous red giant stars in M87, then treat them as standard candles (spectroscopic parallax/tip of the red giant branch).
    B. Find its recessionary velocity and use Hubble's law.
    C. Search for fresh supernovae remnants in M87. By measuring their apparent size (and their velocity) over time, we can get a distance estimate.
    D. Detect its rotational velocity and apply the Tully-Fisher Relation.
    E. Identify individual main sequence stars in M87, then treat them as standard candles using the technique of spectroscopic parallax.

49. Enraged over the fact that his birthday falls on February 29th, a mad scientist schemes to change the Earth's orbit such that the length of a year increases from 365.25 days to 366 days. If the Earth's black body temperature is initially -18°C, what will be its black body temperature after the change? Assume circular orbits and no changes in albedo.

    A. -17.99°C
    B. -18.18°C
    C. -18.55°C
    D. -18.91°C
    E. -19.03°C

50. A binary star system has a combined apparent magnitude of 4.3. The star system contains 2 main sequence stars, known as A and B respectively. A is believed to have a mass of 3.1 solar masses, while B is believed to have a mass of 2.2 solar masses. Estimate the apparent magnitude of each member.

    A. -0.41, 0.89
    B. -3.67, -2.37
    C. 4.59, 5.89
    D. 6.34, 7.64
    E. None of the above

-The End-