AstroChallenge 2019
Senior MCQ Round

Monday, 3rd June 2019

Please read these instructions carefully.

1. This paper consists of **??** 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. Which of the following is the best approximate ratio of the brightness of a magnitude 1 star, to that of a magnitude 3 star?

   (A) 2 (B) 4 (C) $\frac{631}{100}$ (D) $\frac{100}{631}$ (E) $\frac{89}{5}$

2. A rule of thumb is that it is best to stargaze during a new moon, rather than during a full moon. Why?

   (A) The Moon will pass in front of several objects in the sky.

   (B) Celestial objects only align with their charted positions, under a new moon.

   (C) Telescopes **only** function under a new moon, and **never** under a full moon.

   (D) The glare of the Moon washes out the fainter objects in the sky.

   (E) **All** celestial objects are only visible in the sky under a new moon.

3. During an astronomy outreach event, a member of the public asked, 'How would you visually tell a star apart from a planet?' Which of the following would be the best response?

   (A) Planets always appear **brighter** than stars.

   (B) Stars 'twinkle', but planets don't.

   (C) Planets appear significantly **bigger** than stars to the naked eye.

   (D) Stars are of a different colour compared to the planets.

   (E) Planets are only visible through a telescope.

4. Which of the following is an approximate ratio of a man's weight on Saturn to his weight on Earth?

   (A) 1 (B) $\frac{1}{2}$ (C) $\frac{1}{3}$ (D) $\frac{1}{5}$ (E) $\frac{1}{6}$

5. Which of the following stellar spectral classes has the highest surface temperature?

   (A) A (B) B (C) F (D) G (E) K

6. While Clarence was reading a book on telescopes, he came across a rather interesting-looking equation, which suggested that for a night sky object with a declination of δ, if an object was to be kept within the field of view (FOV) for a certain amount of time t seconds, the required FOV (in degrees) would be given by the equation:

$$\text{FOV} = kt\cos\delta$$

where k is some constant to be determined. This is provided that we position the object to one side of the eyepiece (along the edge of the field of view) and turn off the telescope drive.

Which of the following could be a possible value of the constant k?

(A) 1.04×10^{-3} (B) 2.09×10^{-3} (C) 4.18×10^{-3} (D) 6.25×10^{-3} (E) 8.33×10^{-3}

7. Table **??** lists some information about three stars: Vega, Aldebaran, and 10 Lacertae.

Star	**Vega**	**Aldebaran**	**10 Lacertae**
Spectral type	A0V	K5III	O9V
Declination	$-38°\,47'\,1''$	$+16°\,30'\,33''$	$-39°\,3'$
Apparent magnitude	+0.026	+0.86	+4.88
Distance from Earth	25.04 ly	65.3 ly	2330.9 ly
Colour index (B–V)	+0.00	+1.44	-0.21

Table 1: Spectral data of three stars

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

(A) 10 Lacertae is the hottest star.

(B) All three stars are in the Milky Way.

(C) There are exactly **two** main-sequence stars.

(D) Aldebaran cannot be seen in the southern hemisphere.

(E) Vega is the dimmest in terms of absolute magnitude.

8. Contrary to what one might expect, the latest sunrise of the year does not occur during the respective hemispheres' winter solstices. Why is this so?

   You may assume this location does not lie within equatorial latitudes.

   (A) The **Earth** is significantly oblate. This leads to variations in the time of sunrise due to horizon effects.

   (B) The **Sun** is significantly oblate. This leads to variations in the time of sunrise as our perspective of the Sun's shape changes across time.

   (C) As the Earth's orbit is elliptical, the Sun appears to drift across the night sky at different rates, over the year.

   (D) Milankovitch cycles affect the Earth's axial tilt, causing a large constant drift in sunrise timing.

   (E) The question statement is false. The latest sunrise of the year *does* in fact occur during the respective hemispheres' winter solstices.

9. What is meant by the statement, 'an object has a redshift of $z = 1.2$'?

   (A) The object has a luminosity distance of 1.2 Mpc.

   (B) The object has a co-moving distance of 1.2 Mpc.

   (C) If x % of the total emission of our Sun is red light at 600 nm, then $(1.2x)$ % of the total emission of the object is red light at 600 nm.

   (D) The wavelengths of the object's emitted light are all increased by 1.2× compared to the original wavelength.

   (E) The object's observed velocity is 1.2× greater than the velocity generated by the Hubble flow at that distance.

10. Figure **??** depicts the light curve of a hypothetical star system.

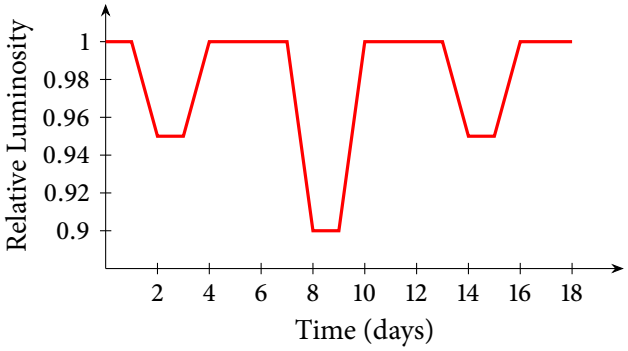

Figure 2: The observed light curve of a hypothetical star system

Which of the following are plausible explanations for this observation?

I. The star is part of a binary-star system, and this curve is a result of eclipses.

II. The star is likely a small red dwarf with at least two massive exoplanets.

III. The star is a classical Cepheid variable.

IV. The star is a RR Lyrae variable.

(A) **I** and **II**

(B) **II** only

(C) **III** and **IV**

(D) **III** only

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

11. Brian noticed two satellites passing directly overhead in opposite directions. He decided to label the satellite moving from West to East **A**, and the satellite moving from East to West **C**. He then noticed the same two satellites passing directly over his head again, exactly 8 hours later.

Suppose that the satellites are in circular orbits, and that Brian is on the equator. What is the ratio of the orbital radius of satellite **A** to that of satellite **C**?

(A) 0.481 (B) 0.630 (C) 1 (D) 1.587 (E) 2.080

12. Mercury's orbit has a semi-major axis of 0.387 AU. At aphelion, Mercury is 0.467 AU from the Sun; at perihelion, it is 0.307 AU from the Sun. It has an orbital period of 0.241 y. What is the **ratio** of its **angular momentum** at its aphelion to its perihelion?

(A) 0.5

(B) 1.52

(C) 1.21

(D) 0.657

(E) None of the above.

13. Which of the following statements about the celestial sphere is **false**?

(A) The angle between the ecliptic and the celestial equator is the axial tilt of the Earth.

(B) An observer stationed at a *fixed* location would observe *exactly* the same night sky every year at the same date and time.

(C) The rotational axis of the Earth always points at the celestial North and South poles.

(D) Most of the planets of the solar system lie close to the ecliptic.

(E) The equatorial coordinate system uses declination and right ascension, the latter being the 'longitude' of the object from the March equinox.

14. If the escape velocity of an object of one solar mass exceeded the speed of light, what would be its radius?

(A) 4.43×10^{11} m

(B) 8.85×10^{11} m

(C) 2950 m

(D) 4.43×10^{13} m

(E) 1476 m

15. Ceres has an eccentricity of 0.0758. What is the ratio of its **angular velocity** at its perihelion to that at its aphelion?

(A) 0.28 (B) 1 (C) 1.16 (D) 1.35 (E) 3.63

16. Figure **??** shows an empirically derived relationship between mass and radius for a particular subset of stars, given a certain surface temperature.

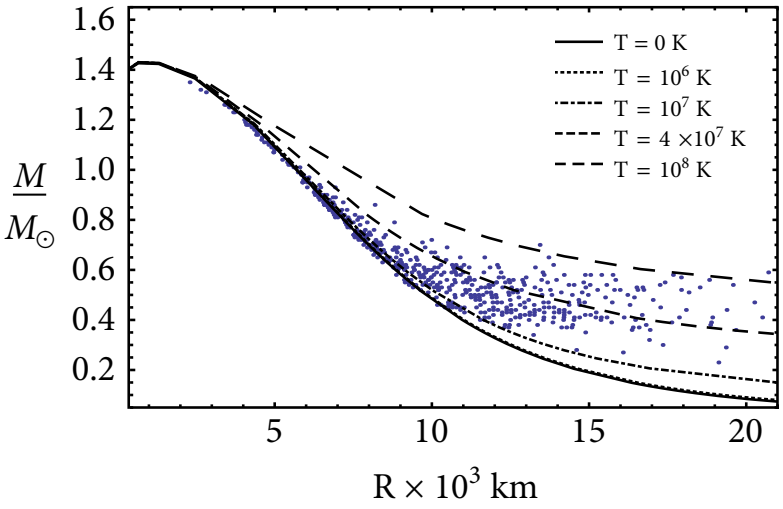

Figure 3: Mass-radius relationship of a certain subset of stars

Which of the following stars might belong in the subset that Figure **??** depicts?

	Star	Stellar classification	Type
(A)	Sirius B	A1	white dwarf
(B)	β Tauri	B7	blue giant
(C)	Rigel	B8	blue supergiant
(D)	α Herculis	M5	red giant
(E)	σ Orionis	O9	main-sequence

17. Below are five solar system objects and their respective deities according to ancient Vedic astrology, dated to 700 BCE. Which of the five object-deity pairs is **incorrect**?

	Object	**Hindu deity**
(A)	Sun	Surya
(B)	Mercury	Budha
(C)	Mars	Maṅgala
(D)	Saturn	Sani
(E)	Neptune	Rahu

18. A region of the Eagle Nebula has a thickness of 50 pc. The near edge of the nebula is 6900 ly from Earth.

    An A1 subgiant was observed along the line of sight of the nebula, and spectroscopic analysis showed that the star had an absolute magnitude of −0.01. What is the difference in apparent magnitude if the star was behind the nebula instead of in front of it?

    You may assume a fixed interstellar extinction of 0.8 magnitude due to the nebula.

    (A) 0.77 (B) 0.80 (C) 0.83 (D) 0.85 (E) 0.87

19. A planet with a strong magnetic field tends to collect and trap highly energetic and charged particles emitted by the Sun in belts around its equator. Jupiter's radiation belts are particularly intense, and pose a major radiation hazard to any orbiting spacecraft or human.

    Which of the following methods is **least effective** in mitigating radiation damage caused by charged particles?

    (A) Orbiting the planet in an highly elliptical polar orbit.

    (B) Storing food and water in the walls of the spacecraft.

    (C) Constructing a Faraday cage of metal wire mesh around the essential parts of the spacecraft.

    (D) Constructing a lead box around essential parts of the spacecraft.

    (E) All of the above methods are feasible.

20. Which of the following statements about large telescopes is correct?

    I. For large observatory-class telescopes, perfectly spherical optical elements are recommended to minimize aberrations.

    II. **All** space telescopes follow a Cassegrain-Nasmyth design.

    III. In recent decades, refractors are generally not seen among large telescopes. Instead, reflectors are more popular.

    (A) **I** only (B) **I** and **II** only (C) **II** only (D) **III** only (E) **I**, **II**, and **III** only

21. Bob was trying to measure the distance from the Earth to the Large Magellanic Cloud, using Type Ia supernovae and Cepheid variables. He discovered that the result he obtained using Cepheid variables was much farther than the result from using Type Ia supernovae.

    Which of the following is **not** a possible reason for the discrepancy in his results?

    (A) He misidentified Type Ib/Ic supernovae as Type Ia supernovae.

    (B) He underestimated the interstellar extinction when measuring the brightness of Cepheids.

    (C) He mistook RR Lyrae variables for classical Cepheids.

    (D) He failed to account for atmospheric disturbances on the days of his observation.

    (E) All of the above are possible reasons for the observed discrepancy in his results.

22. ʻOumuamua was discovered using the Pan-STARRS telescope at Haleakala Observatory, Hawaii, on 19 October 2017, 40 days after it passed its closest point to the Sun. At this point, ʻOumuamua was 0.22 AU away from Earth.

    The focal length of the Pan-STARRS telescope is 6.11 m with an image sensor of diameter 32 cm. It also has an aperture diameter of 1.8 m.

    Determine the **mimimum** size of an object that the telescope could resolve at the distance between the Earth and ʻOumuamua on 19 October 2017 , and the actual field of view (TFOV) of the telescope.

	Resolution (m)	**TFOV (°)**
(A)	1.4×10^4	3.0
(B)	2.8×10^4	1.5
(C)	1.4×10^4	1.5
(D)	2.8×10^4	6.0
(E)	5.6×10^4	3.0

23. Which of the following are major factors contributing to the equation of time?

    I. The diameter of the Earth

    II. The orbital eccentricity of the Earth's orbit

    III. The axial tilt of the Earth's rotation

    IV. The sidereal rotation period of the Earth

    (A) **I** and **II** only

    (B) **I** and **III** only

    (C) **II** and **III** only

    (D) **III** and **IV** only

    (E) **II**, **III**, and **IV** only

24. Which of the following statements are **true**?

I. The complete analemma may be photographed **anywhere** on Earth.

II. The analemma may be composed from photographs of the Sun taken everyday at exactly local apparent noon.

III. The Sun spends equal fractions of the year tracing out each lobe of the analemma.

IV. The analemma photographed from the Equator has its long axis exactly perpendicular to the horizon.

(A) **I** only

(B) **I** and **II**

(C) **II** and **III**

(D) **II** and **IV**

(E) None of the above options are correct.

25. The hyperbolic excess velocity, v_∞, is defined as the velocity attained by a spacecraft as the spacecraft approaches infinity. The velocity at any given distance r from a gravitating body is given by v and the escape velocity from the gravitating body is v_e.

Which of the following expressions used to calculate the hyperbolic excess velocity of a gravitating body v_∞ is **correct**?

(A) $v_\infty = v + v_e$

(B) $v_\infty{}^2 = v^2 + v_e{}^2$

(C) $v_\infty = \sqrt{(v - v_e)(v + v_e)}$

(D) $v_\infty{}^2 = v^2 + \dfrac{v_e{}^2}{4}$

(E) $v_\infty = \sqrt{\left(v - \dfrac{v_e}{2}\right)\left(v + \dfrac{v_e}{2}\right)}$

26. Figure **??** shows the stellar evolution of a low-mass main sequence star such as our Sun.

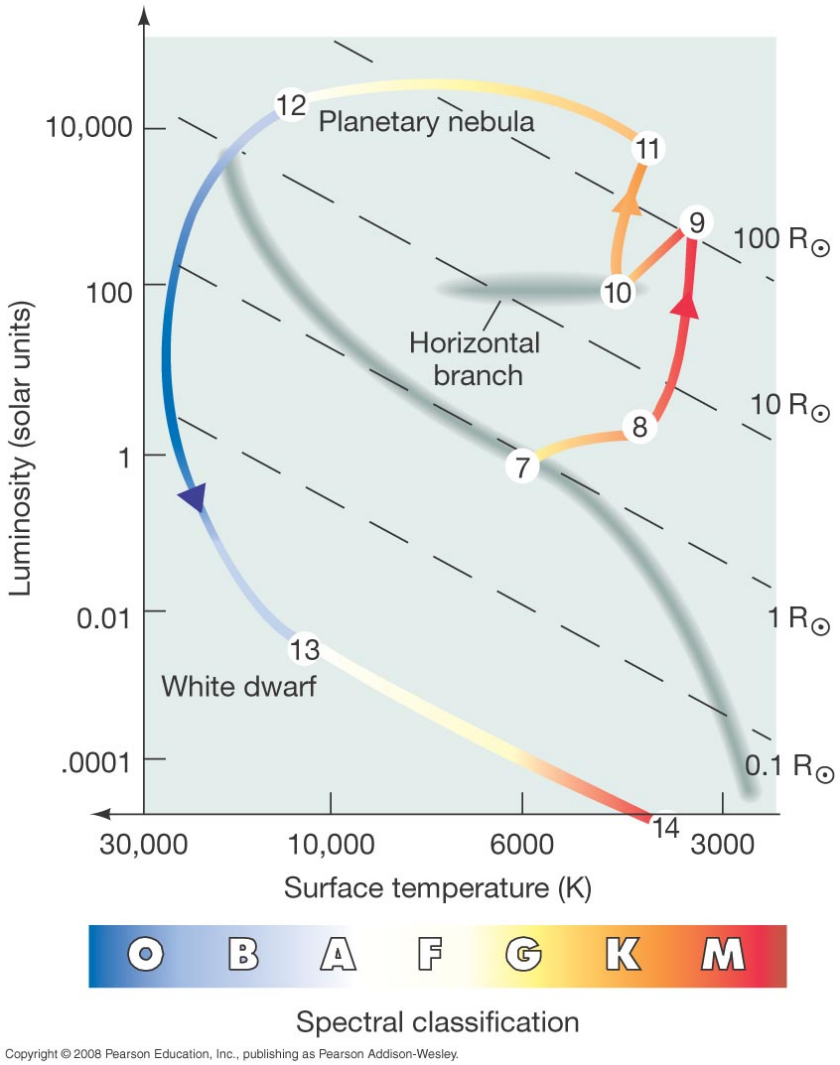

Figure 4: The evolutionary path of a star like the Sun

Which of the following nuclear equations best describes the dominant source of energy production during event 9?

(A) $3\,{}^{4}_{2}\mathrm{He} \longrightarrow {}^{12}_{6}\mathrm{C}$

(B) $2\,{}^{1}_{1}\mathrm{H} \longrightarrow {}^{2}_{1}\mathrm{H}$

(C) $4\,{}^{1}_{1}\mathrm{H} \longrightarrow {}^{4}_{2}\mathrm{He}$

(D) ${}^{12}_{6}\mathrm{C} + {}^{1}_{1}\mathrm{H} \longrightarrow {}^{13}_{7}\mathrm{N}$

(E) ${}^{15}_{7}\mathrm{N} + {}^{1}_{1}\mathrm{H} \longrightarrow {}^{16}_{8}\mathrm{O}$

27. Manhattanhenge is an event during which the setting sun or the rising sun is aligned with the main street grid of Manhattan, New York City. It is known that Manhattanhenge sunsets occur in pairs annually.

Given that a Manhattanhenge sunset occurred on 30 May 2019, on what date does the other Manhattanhenge sunset occur in 2019?

(A) 11 June (B) 12 July (C) 30 August (D) 30 September (E) 11 October

28. Being an inquisitive astronomer, Keven wants to determine the **speed** of a star that is moving away from Earth, with respect to an observer from the Earth (i.e himself).

Keven is provided with the following information:

- The spectral line of iron from the star at λ_{rest} (wavelength recorded with respect to the frame of the star) is redshifted by a magnitude $\Delta\lambda$.

  We can assume that $\Delta\lambda \ll \lambda_{\text{rest}}$. The wavelengths are all recorded in metres.

- The proper motion is μ, recorded in arc seconds per year.

- The parallax of the star is given by p, recorded in arc-seconds. We can assume that p is small enough such that $\sin p \approx p$.

Which of the following expressions best represents the expression that Keven should use to determine the speed of the star relative to him, in $\text{km} \cdot \text{s}^{-1}$?

Hint: To ease your calculation, note that $\dfrac{1\,\text{AU}}{1\,\text{y}}$ is approximately $4.74\,\text{km} \cdot \text{s}^{-1}$.

(A) $\sqrt{\left(\dfrac{c\Delta\lambda}{\lambda_{\text{rest}}+\Delta\lambda}\right)^2+\left(\dfrac{4740p}{\mu}\right)^2}$

(B) $\sqrt{\left(\dfrac{c\Delta\lambda}{1000\lambda_{\text{rest}}}\right)^2+\left(\dfrac{4.74\mu}{p}\right)^2}$

(C) $\sqrt{\left(\dfrac{c\Delta\lambda}{\lambda_{\text{rest}}}\right)^2+\left(\dfrac{4.74p}{\mu}\right)^2}$

(D) $\sqrt{\left(\dfrac{c\Delta\lambda}{1000\lambda_{\text{rest}}}\right)^2+\left(\dfrac{4.74p}{\mu}\right)^2}$

(E) $\sqrt{\left[\dfrac{c\Delta\lambda}{1000\left(\lambda_{\text{rest}}+\Delta\lambda\right)}\right]^2+\left(\dfrac{4740\mu}{p}\right)^2}$

29. Some astronomers suggest that the search for extra-terrestrial life should include planets and moons outside of the circumstellar habitable zone. A possible reason is:

(A) Liquid water is the only possible solvent for biochemical reactions to occur in.

(B) Many other celestial bodies are well-known sources of radio emissions.

(C) Besides radiation from a star, other mechanisms could generate heat on a celestial body, to provide energy for respiration.

(D) All of the above.

(E) None of the above; they simply have too much free time.

30. Suppose that scientists are about to place a spherical rock of uniform mass 5×10^{11} kg and radius 1 km in orbit around Jupiter. However, they would prefer it if the rock were as close as possible to Jupiter's surface.

Which of the following distances, from Jupiter's **surface** to that of the rock, is the most ideal?

Assume that the rock is held together only by gravity, and that Jupiter is perfectly spherical.

(A) 126 000 000 km

(B) 12 600 000 km

(C) 1 260 000 km

(D) 126 000 km

(E) It does not matter where the satellite is placed if it is not going to crash.

31. A possible reason why intelligent life might be rare, is that there exist factors that prevent its development or prematurely ends it. This is known as the Great Filter hypothesis. Which of the following are examples of such a 'Great Filter'?

    I. Most, if not all other planets, do not have the necessary requirement(s) to support life in the first place (Rare Earth Hypothesis).

    II. It is highly improbable that inorganic molecules develop into living cells.

    III. Rational intelligent life is unwilling to communicate or transmit signals to space that indicate its existence, over fears of elimination by a more advanced alien civilisation.

    IV. Many catastrophes result in large or even full-scale extinction events before intelligent life can develop, engineer, and build technology to prevent its demise.

    V. Intelligent life tends to be self-destructive in nature, whether intentional (e.g. wiping itself out by nuclear warfare) or unintentional (e.g. causing irreversible ecological collapse).

    (A) **I**, **II**, and **III** only

    (B) **IV** and **V** only

    (C) **III**, **IV** and **V** only

    (D) **I**, **II**, **IV**, and **V** only

    (E) All of the above

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

    (A) A dark nebula that consists of mostly un-ionised hydrogen is likely designated as a HI region.

    (B) A nebula with a large HII region is highly likely to be a star-forming region.

    (C) There is no such thing as a HIII region, because hydrogen only has one valence electron.

    (D) High levels of OIII is responsible for green-cyan spectral colours in planetary nebulae.

    (E) None of the above are false.

33. A physics student derived the following formula from the Stefan-Boltzmann law to estimate the radius, surface temperature, or luminosity of a given star, if any two of the three values were known, in comparison to the Sun:

$$\frac{R}{R_\odot} \approx \left(\frac{T_\odot}{T}\right)^2 \times \sqrt{\frac{L}{L_\odot}}$$

where R is the radius of the star, $R_\odot$ is the radius of the Sun, T is the surface temperature of the star, $T_\odot$ is the surface temperature of the Sun, L is the luminosity of the star, and $L_\odot$ is the luminosity of the Sun.

He then investigated two different stars, X and Y. Both stars have a surface temperature of about 8000 K, but X is 1000 times **less** luminous than the Sun, whereas Y is 100 000 times **more** luminous.

Suggest identities for X and Y, given that their estimated radius is of the correct order of magnitude from this estimation formulae.

	Star *X*	**Star *Y***
(A)	white dwarf	white supergiant
(B)	white dwarf	main-sequence
(C)	main-sequence	white supergiant
(D)	small main-sequence	large main-sequence

(E) None of the above combinations are valid.

34. Which of the following claims about the Solar System is **false**?

(A) Io, a moon of Jupiter, is subjected to extreme tidal heating. As such, it is the most volcanically active object in our Solar system, with several of its volcanoes being taller than Mount Everest on Earth.

(B) Mercury has a very thin atmosphere (approximately 1 nPa), but due to its extreme proximity to the sun, most of it is constantly lost from the solar wind, and it is shaped like a comet's tail behind the planet.

(C) Uranus, due to its axial tilt of about 98°, ends up having its poles facing the Sun during a solstice. Yet, strangely, the temperature of its equator is higher than that of its poles.

(D) 50 km above the deadly sulfuric acid clouds of Venus, there exists a zone at 1 atm, with an average temperature of 25 °C, theoretically making it possible for humans to stay in floating cities on this otherwise inhospitable planet.

(E) Titan, a moon of Saturn, is the largest moon by radius in the Solar System. It is also the only other place in the solar system, besides Earth and Venus, to experience precipitation.

35. Consider the effects of axial tilt and axial precession on the position of the celestial poles.

Earth's axial tilt varies from 22.1° to 24.5° over a period of 41 000 years. The current tilt is 23.44° and decreasing. Axial precession has a period of around 25 800 years. By the year 20350, the North celestial pole will be very near Thuban (RA: 14 h 04 m; Dec: +64° 22′, J2000.0).

Using the RA and Dec system of that date, what would be the declination of the Sun during the northern vernal equinox in the year 20350?

(A) 1° (B) 25° (C) 0° (D) 22° (E) 24°

Use the following information to answer questions ?? and ??.

Consider a bi-elliptical transfer, a more general case of the Hohmann transfer. Figure **??** illustrates this process.

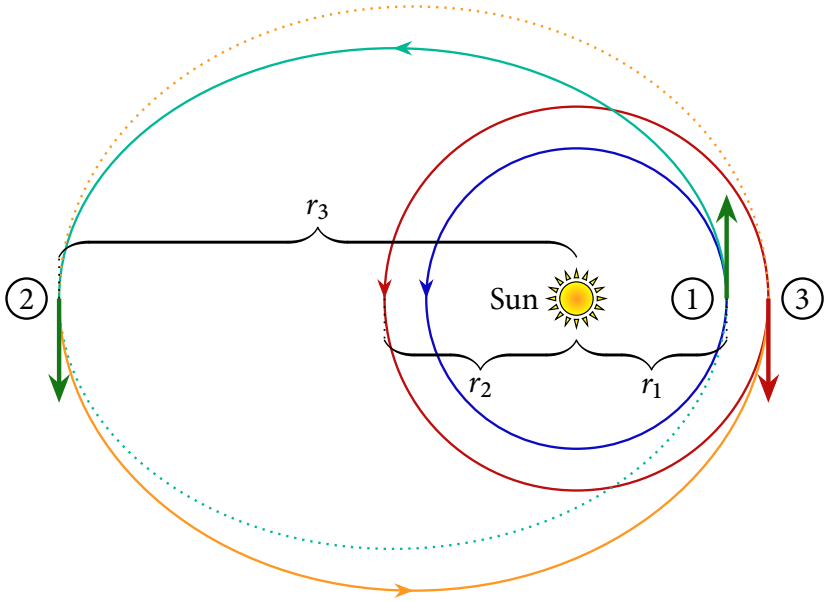

Figure 5: A bi-elliptical transfer from Earth to Mars

- Starting from an initial circular orbit of radius r_1, at the position indicated (1), a prograde burn puts the spacecraft on the first elliptical transfer.
- Next, at the position indicated (2), at a distance r_3 from the Sun, a second prograde burn puts the spacecraft on its second elliptical transfer
- Lastly, at the position indicated (3), when the final desired circular orbital radius of r_2 is reached, a **retrograde** burn circularizes the trajectory.

36. Which of the following expressions represents the total transfer time of the entire bi-elliptical transfer process?

Note: **total time** refers to the time taken to travel from position (1) to (3).

(A) $\frac{\pi}{2\sqrt{2GM}}\left[(r_3 - r_1)^{3/2} + (r_3 - r_2)^{3/2}\right]$

(B) $\frac{\pi}{2\sqrt{GM}}\left[(r_3 - r_1)^{3/2} + (r_3 - r_2)^{3/2}\right]$

(C) $\frac{\pi}{\sqrt{2GM}}(r_3)^{3/2}$

(D) $\frac{\pi}{2\sqrt{GM}}\left[(r_1 + r_2)^{3/2} + (r_2 + r_3)^{3/2}\right]$

(E) $\frac{\pi}{2\sqrt{2GM}}\left[(r_1 + r_2)^{3/2} + (r_2 + r_3)^{3/2}\right]$

37. To measure the efficiency of fuel being used, we consider the quantity known as the *delta-v*, or Δv. Simply put, Δv is the **magnitude** of the difference between the velocity before and after a burn occurs.

Which of the following expressions correctly represents the Δv quantity associated with the second burn?

(A) $\sqrt{\frac{2GM(r_2 - r_1)}{r_3(r_1 + r_3)}}$

(B) $\sqrt{\frac{2GM(r_3 - r_1)}{r_3(r_2 + r_3)}}$

(C) $\sqrt{\frac{2GM}{r_3}}\left(\sqrt{\frac{r_1}{r_1 + r_3}} - \sqrt{\frac{r_2}{r_2 + r_3}}\right)$

(D) $\sqrt{\frac{2GM}{r_3}}\left(\sqrt{\frac{r_2}{r_1 + r_3}} - \sqrt{\frac{r_1}{r_2 + r_3}}\right)$

(E) 0

38. With respect to a hypothetical observer on the Sun, approximately how often do the phases of the Moon as seen by the observer repeat?

Disregard eclipses and occultations.

(A) 24 hours (B) 27.3 days (C) 29.5 days (D) 365.25 days (E) None of the preceding

39. According to the formula booklet, the formula for the Jeans length is

$$R_J = \sqrt{\frac{15k_BT}{4\pi G\langle m\rangle\langle\rho\rangle}}.$$

Here, the formula assumes that one is dealing with the collapse of a spherical nebula of uniform density.

Which of the following statements about the Jeans length, R'_J, is true if, instead of a uniform distribution, the mass of the nebula were to be concentrated on the surface of the spherical nebula, i.e. a spherical shell nebula?

(A) $R'_J > R_J$

(B) $R'_J = R_J$

(C) $R'_J < R_J$

(D) There is no valid expression for R'_J, since the quantity representing average density, $\langle\rho\rangle$, is ill-defined.

(E) The expressions in (A) to (C) are all possible, depending on the dominant element in the nebula.

40. Which one of the following celestial objects is **not** fictional?

	Object	**Description**
(A)	Tachyon Ring	A stream of relativistic particles travelling faster than the speed of light due to its high-speed orbit ($> 0.95c$) around a high-velocity ($> 0.95c$) neutron star.
(B)	Tired Star	A special type of redshifted star discovered by Fritz Zwicky, its high surface gravity cause photons to lose energy over time, resulting in redshift of its emission spectra.
(C)	The Blazar	An active galactic nucleus from another galaxy that is emitting a relativistic jet of ionised particles at nearly the speed of light ($> 0.95c$), with the jet facing the Earth.
(D)	Type X Supernova	A supernova resulting from a neutron star crossing the Chandrasekhar limit and exploding into a burst of high energy X-rays and gamma rays.
(E)	Poison Nebula	A HII region in space consisting of ionised formaldehyde and cyanide and its derivatives, detectable by shifts in its hydrogen emission spectra as a result.

41. The upcoming James Webb Space Telescope (JWST) will observe primarily in infrared (1.3 μm), while the Hubble Space Telescope (HST) observes primarily in visible light (500 nm). Given that the JWST has the same angular resolution as the HST, approximately how much larger must the surface area of the aperture of JWST be compared to the HST, assuming both mirrors are perfect circles?

(A) 2.6× (B) 6.8× (C) 3.2× (D) 8.4× (E) None of the preceding

42. Which optical phenomenon is **not** caused by interplanetary dust?

(A) Zodiacal light

(B) Gegenschein

(C) Airglow

(D) False dawn

(E) None of the above.

Use Table ?? to answer questions ??, ??, and ??.

Object	Type	Angular size (')	RA	Declination	Apparent magnitude
IC1805	bright nebula	212	02 h 34 m	+61° 31′	6.50
IC1848	bright nebula	168	02 h 52 m	+60° 29′	6.50
NGC7789	open cluster	16.0	23 h 58 m	+56° 48′	6.70
NGC3918	planetary nebula	0.15	11 h 51 m	−57° 17′	8.50
NGC362	globular cluster	12.9	01 h 03 m	−70° 44′	6.58
B68	dark nebula	3.50	17 h 23 m	−23° 50′	NA

Table 6: Celestial objects and their optical data

43. The Island of Coll in Scotland is a designated dark sky site with coordinates 56° 37′ N, 6° 32′ W. At local midnight of the autumnal equinox, which of the objects in Table **??** can be seen?

    Assume that the current sky follows the J2000.0 Epoch.

    (A) IC1805, IC1848 and NGC7789 only

    (B) IC1805, IC1848, NGC7789 and B68 only

    (C) IC1805, IC1848, NGC362 and B68 only

    (D) NGC3918 and NGC362 only

    (E) NGC362, NGC3918, NGC7789 and B68 only

44. The Great Barrier Island in New Zealand is another such offshore island which is excellent for stargazing. Its coordinates are 36° 13′ 50.3″ S,175° 28′ 30.9″ W.

    Given that at this location, NGC 362 is currently crossing the local meridian, which objects in Table **??** will **not** be seen crossing the local meridian within the next 6 hours?

    (A) NGC 3918 and B68 only

    (B) IC 1805, IC 1848, and NGC 7789 only

    (C) IC 1805, IC 1848, and B68 only

    (D) IC 1805, IC 1848, NGC 7789, and NGC 3918 only

    (E) IC 1805, IC 1848, NGC 7789, NGC 3918, and B68 only

45. From a certain location, NGC7789 is observed to be circumpolar. On New Year's Day, NGC7789's altitude from the ground was measured. The object reached its highest altitude at around 1801 hours local time at 80.4° and its lowest at around 0600 hours local time at 14.1°. What is the latitude of the location?

    (A) 43° N

    (B) 47° N

    (C) 43° S

    (D) 47° S

    (E) 47° E

46. Consider the equation for hydrostatic equilibrium in the Formula Book. Given that we have a star in such a hydrostatic equilibrium, which of the following statements is **false**?

(A) The pressure within a star always decreases as we move outwards from the core.

(B) For a star in hydrostatic equilibrium, $P = \dfrac{\rho_r G M_r}{r}$ at all points in the star.

(C) Outside of the star where $\rho \approx 0$, $\dfrac{\mathrm{d}P}{\mathrm{d}r} \approx 0$

(D) For a star to be in hydrostatic equilibrium, the local pressure gradient must equal the local gravitational acceleration multiplied by the local density at all points in the star.

(E) An object does not need to be undergoing fusion in order to be in hydrostatic equilibrium.

47. While camping in a secluded island on 25 May 2019, Ryan noticed a meteor in the night sky. Which of the following would the meteor most certainly be associated with?

(A) Eta Aquarids

(B) Orionids

(C) Geminids

(D) Anti-helion source

(E) There is insufficient information to answer the question.

48. Compared to the Sun, Betelgeuse has nearly no hydrogen absorption lines. Instead, Betelgeuse displays numerous oxide absorption lines like TiO. Why is this the case?

(A) Due to the lower surface temperature of Betelgeuse, most hydrogen atoms do not have electrons in the right energy level to absorb/re-emit photons.

(B) As Betelgeuse is a highly evolved star, its hydrogen shell has been ejected in the surrounding planetary nebula.

(C) Oxide molecules preferentially absorb radiation, thus suppressing the hydrogen absorption line.

(D) All hydrogen in Betelguese has been used up in the s-process, creating the raw elements for heavy metal oxides like TiO.

(E) Due to the high velocity of Betelgeuse, the hydrogen absorption lines are all Doppler-shifted into oxide absorption lines.

49. Which of the following statements are possible information that can be gleaned from observing the light curve of an object?

I. The rotation period of a comet

II. Whether the object is an intrinsic variable star or an extrinsic variable star

III. The age of a star

IV. The type of supernova that has occurred

(A) I, II, and III only

(B) I, II, and IV only

(C) I, III, and IV only

(D) II, III, and IV only

(E) All of the above are possible.

50. A supernova shines with a luminosity 10^{10} times that of the Sun. If such a supernova appears in our sky *twice* as bright as Venus does when it approaches superior conjunction, how far away would the supernova be, in kiloparsecs?

Assume that both Venus and Earth have perfectly circular orbits, and assume that no atmospheric heat from Venus is radiated into space. The albedo of Venus is 0.689.

(A) 1.11×10^{21} kpc

(B) 2.07×10^{14} kpc

(C) 2610 kpc

(D) 72 kpc

(E) 36 kpc