	Question	Answer
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	A Only A would prevent solar eclipses from occurring every new moon – the others would have no effect
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	A Orbital speed is inversely proportional to the distance to the Sun. Thus, from the list, pick the planet that is the closest to the Sun. Further, as all planets have roughly circular orbits, their orbital speed remains roughly the same across time.
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.	D Trick/troll question. The lunar maria is made of basalt, a type of extrusive igneous rock that formed by volcanic eruptions on the Moon billions of years ago. These basaltic plains i.e. mare have low albedo due to a low reflectivity.
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)	B Polaris is the Pole Star, thus aligning the polar axis to it approximately means the mount is aligned with celestial north.
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 Brown dwarves are failed stars, red dwarves are still fusing

	C. White dwarf D. Neutron star E. Black hole	hydrogen in their cores and the Sun is not massive enough to create a neutron star or 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	C The process starts with the collapse of a gas cloud (iv), and ends with the Late Heavy Bombardment (i). This leaves only one sensible option – option C.
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	C A is false, this is half a sidereal day, which is not dependent on the length of a year. B is false, the length of the solar day would not double. However it would change slightly for the same reason why a solar day is of different length than a sidereal day. D is false – seasons depend on axial tilt not length of year. C is true, for the time between equinoxes/solstices would be doubled due to the increase in orbital period. For this reason, E is false
8	A Dyson sphere is a hypothetical megastructure that completely encompasses a star and captures a large	C

	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	Just use Wien's displacement Law here. $\lambda = \frac{2.897\times10^{-3}}{3400} = 852\ nm \approx 850\ nm$
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	A Simple application of equation: angular resolution (in radians) = 1.22 wavelength / diameter of telescope. 1.2120342 * 10^-10 = 1.22 x / 12000km x 10^3, where x is 0.001m.
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	A See KW's submission for images along with explanatory text Chromatic aberration: Effect of colour fringing (individual colours at edges of object) due to lens element since refractive index of glass varies with the wavelength of light. Hence the colours are not all focused to the same pointComatic aberration: Due to light rays striking the parabolic mirror of the telescope at an angle to the axis of the parabola. Hence the stars which should be point dots appear as comets, which the effect being greater further from the centre of the image/viewAstigmatism: Spherical Aberration: Light passing/reflecting of a spherical surface do not focus at the

		same point. Aka caused by spherical lenses or mirrors.
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	Ans: c. Distance from Venus to Earth is (1.496-1.082)x10^11=4.14x10^10m. Radius of Earth is 6.370x10^6m Using small angle approximation, θ=radius of earth/distance from Earth to Venus = 1.5386x10^-4 rad = 31.74 arc seconds Taking the anglex2: 31.74x2=63.5 arc seconds = 1.06 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	D When a star crosses the local meridian is only determined by the right ascension of the star & the time of year (thus A/C/E is wrong). The last part of the puzzle requires one to know that stars rise approximately 4 minutes later every night, yielding D
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	A There’s no way to remove certain wavelengths of light after the image is taken.
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.	B Option A is wrong because the sun only rises and sets due East

	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.	and West at equinox. For option C, 30 degrees and 120 degrees azimuth are random values with no physical basis whatsoever. Options D and E are non-answers to begin with.B: Consider the scenario of the sun at summer solstice, i.e. at its most northerly declination of 23.4 deg. The above diagram shows the path of the sun (in red) at the north pole (90 deg N latitude), with the red arrow pointing towards the north celestial pole.N Moving towards more southern latitudes, at about 66.6 deg N, the path of the sun tilts such that it touches the horizon at a single point, which is in the direction ofdue North.Moving further south, the path of the sun crosses the horizon at two points on the northeast and northwest.At the equator, the sun rises 23.4 deg north of east and sets 23.4 deg north of west. Moving south of the equator, the scenario repeats, and the point of sunrise and sunset slowly converges towards the north, and you can see that the length of the day gets shorter and shorter until it reaches eternal night beyond 66.6 deg South. Thus at summer solstice the azimuth of sunrise ranges between due North and 23.4 deg north of east across latitudes.The inverse is true at winter solstice, where the azimuth of sunrise ranges between due south and 23.4 deg south of east.The sun rises between 23.4 deg north and 23.4 deg south of east in the period between solstices at latitudes nearer to the equator

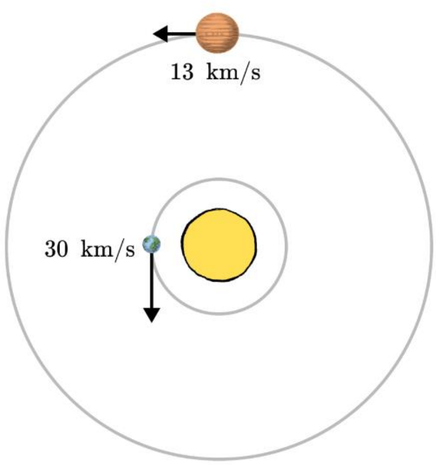
		(diagrams can be found in the original document, but I have omitted them here for the sake of brevity)
15	On June 21st, an observer in the Northern hemisphere notices that the maximum and minimum length of shadow of a 1.0 m pole is 16.3 m and 1.05 m respectively. What is the latitude of the observer? A. 10 degrees N B. 25 degrees N C. 40 degrees N D. 55 degrees N E. 70 degrees N	E While the declination of the sun (already given as + 23.5) and latitude of observer can be solved for, it is faster to note that the maximum length of shadow is given (i.e. the sun does not set). A circumpolar sun is only possible for Northern observers above the arctic circle. (66.5 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.	C Most globular clusters were some of the first objects to have formed in the galaxies, and most are over 12 billion years old. Their gas has long since depleted over this time and thus no star formation occurs within them today.
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.	A With a higher rotational velocity, the gas atmosphere thus experiences a higher centrifugal force (proportional to speed) at the equator than at the poles, causing it to bulge in the middle. A similar phenomenon happens to Jupiter and Saturn. B is incorrect as stellar atmospheres are mostly confined by the star's gravity and not its magnetic field. C is incorrect as tidal forces will result in an ellipsoid (stretched sphere) shape rather than a spheroid shape. D is incorrect as mass transfer will not change the shape of the

		accretor star, and instead form an accretion disk. E is a troll option as 'Post-partum' is a medical term meaning post-childbirth.
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	Answer: D Use $a = \frac{97.5+38}{2} = 67.75\ AU$ and Kepler's 3rd Law, $T = \sqrt{\frac{4\pi^2}{GM}a^3} = 1.75 \times 10^{10} s \approx$ $558\ years$
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 seasons	B Recall that during the northern vernal equinox, the Sun is at 0h by definition. The right ascension of the sun increases as the season progresses. Further, after 1 season, the Earth would have moved along ¼ of its orbit, leading to B.
20	Planet X with radius 1.0×107m 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. 1.44×10^{17} W B. 2.89×10^{17} W C. 5.77×10^{17} W D. 1.15×10^{18} W E. 2.31×10^{18} W	Answer: B This question looks deceptively simple but it is actually not! We know from the Stefan-Boltzmann Law that the rate at which energy is being emitted from the surface of a blackbody is given by $Rate = 4\pi\sigma R^2 T^4$ However, this is only true if we consider that energy is emitted over the entire surface of the blackbody. In this case, we note that planet X is tidally locked with Star Y. This means that only one side of the planet will face Star Y for extremely long period of time. Henceforth, only the hemisphere facing Star Y receives the solar irradiation, and only this side of the planet is in thermal equilibrium with respect to the incoming solar irradiation. Hence, the rate at which energy is emitted from the surface is halved. Thus, we should instead

		calculate $\frac{1}{2} \times Rate = 2\pi\sigma R^2 T^4$. Inserting the relevant numerical values, we get option (B).
21	For Questions 21 to 23, refer to the following diagram <diagram at end of document> 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	B See annotated diagram. Recall that the Big Dipper arcs to Arcturus
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	B See annotated diagram. Andromeda can be found using the Great Square of Pegasus as a guide.
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. Circlet of Pisces e. This asterism does not exist	E See annotated image The identities of the stars are: B – Capella (Alpha Aurigae) C – Mirphak (Alpha Persei) D – El Nath (Beta Tauri) E – Aldebaran (Alpha Tauri) Two of these stars are members of the Winter Hexagon, and that's about it.
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:	C Despite the daunting equation, everything on the RHS is either a constant, or easily computable. Recall that a Schwarzschild black hole is uncharged and non-rotating, thus it is spherical.

	$$S = \frac{k_B A c^3}{4G\hbar}$$ 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. $2.5 \times 10^{58}\ J\ K^{-1}$	Thus, note that $A = 4\pi R_S^2$, where R_S is the Schwarzschild Radius, $R_S = \frac{2GM}{c^2}$. Hence, $S = \frac{k_B \pi R_S^2 c^3}{G\hbar} = \frac{k_B \pi c^3}{G\hbar} \times \frac{4G^2M^2}{c^4} = \frac{k_B 4\pi G M^2}{\hbar c} = 1.5 \times 10^{58}\ J\ K^{-1}$
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.	Answer: E. Using trigonometry, the Great Dark Spot (if it exists) would span $\arcsin\left(\frac{6600}{4.4\ billion}\right) = 3.18\ \times 10^{-7}\ rad = 0.065\ arcsec$. Since the Rayleigh Criterion is given by: $$\sin\theta_{min} = 1.22\frac{\lambda}{D}$$ This reduces to $$D = 1.22\lambda \div \frac{6600}{4.4\ billion}$$ Yielding approximately 53 cm, 45 cm and 37 cm for each wavelength of light respectively. But wait a minute: we have had telescopes way larger than this since Neptune was discovered. Even Herschel's telescope had an aperture of 48 inches (122 cm)! Why didn't we know of the Great Dark Spot then? The answer is that due to atmospheric turbulence, large telescopes are limited by seeing. In other words, without adaptive optics, beyond 4-8", increasing the aperture does not increase the resolution of a ground-based telescope.

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.	C <see original document for attached diagrams> A: An observer at the equator has a higher tangential velocity, but the same rotational velocity as an observer at a higher latitude. B: This option does not even make sense because the angle of the local horizon w.r.t. the sun is the same as the angle of the sun below the horizon. C: The path of the sun crosses the horizon at a shallower angle at higher latitudes compared to the equator. As a result, the sun has to travel a longer path (and thus take a longer time) to reach the same vertical angle below the horizon at higher latitudes than at the equator. D: Twilight is defined by the angle of the sun, as per the question, and not by the brightness of the sky. E: This is a troll answer.
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	D A is false – in a pair-instability supernova, the entire core of the star undergoes fusion in fractions of a second, leaving nothing behind. B is false, neutron stars are MORE massive than white dwarves. C is false – the increasing mass of the stellar remnant compresses the star, reducing its density. For similar reasons, D is true (and thus E is false)
28	<Sharadh's Q1>	D

	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.	<insert explanation from Sharadh's doc>
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	D Simple application of the Lorentz equation 1 / sqrt[1-(0.9999999999995^2 /1)] = 316227. 150 million / 316227 = 474 years
30	Suppose that Jupiter and Earth are at the positions in their orbits shown below.  	Ans: B <define how it is measured?>

	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.	D All statements are true. The temperature of such clouds is low and the density is high. High density offers two effects: increasing the collision rate and reducing the penetration of UV light. This settles I and II. The low temperature naturally implies a high sticking coefficient, since molecules do not have energy to escape the grains.
32	<Sharadh's Q10>	<Sharadh's Q10>
33	Suppose the September 2020 equinox is occurring right now. Which of the following events will be occurring then? A. 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) B. Observers who are able to observe a sunset at this moment would agree that the Sun has an azimuth of 270° (excluding the poles)	B A is false as atmospheric refraction actually means the day would be longer than the night for all observers on this day.

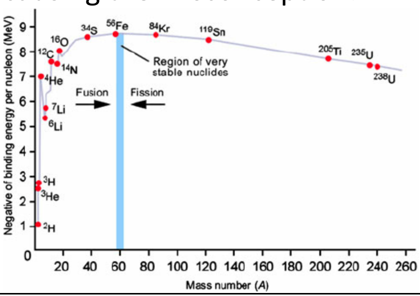
	C. The Sun reaches the First Point of Libra during this equinox by definition, and thus the Sun lies in the constellation of Libra D. Under the standard J2000 equinox and epoch, the Sun will be observed to have an declination of exactly 0°. E. If there is a full Moon today, it will rise exactly due east and set exactly due west for all observers (excluding the poles)	C is false – due to precession, the First Point of Libra does not lie in Libra today. D is false – due to precession, the celestial equator at this point of time does not coincide with the J2000 equinox and epoch. E is false for two reasons– 1) as the Moon's orbit is inclined to the ecliptic, this is not true in general. 2) as the Moon is located close to Earth, perspective effects are significant. Different observers will observe the Moon to be at different locations with respect to background stars, and thus moonrise/moonset does not lie exactly east/west for all observers.
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? A. GCs are very old and most life would have been dead since that time. B. The interstellar distance between stars in GCs are relatively small, and gravitational interactions can destabilize planetary orbits. C. Planets in GCs experience significantly higher background radiation which potentially destabilizes molecules. D. A, B and C E. B and C only	E GCs are very chaotic stellar neighbourhoods. The interstellar distances are typically smaller than 0.5 light years. This potentially destabilizes orbits and floods stellar systems with very high amounts of radiation.
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 shown $\frac{1}{2}mv^2 - \frac{GMm}{r} = -\frac{GMm}{2a}$ $v^2 = GM\left(\frac{2}{r} - \frac{1}{a}\right)$	Answer: C There are two ways to attempt this question. The first is by substituting the value of v and r into the equation given and find a value of a which is an indication of the total energy of the system. By referring to the equation of

	Given this, which of the following is a correct match between the type of orbit and the parameters observed in the solar system? A. r=3 AU, v=25.4km/s, elliptical orbit B. r=5 AU, v=10.8km/s, hyperbolic orbit C. r=1 AU, v=42.2km/s, parabolic orbit D. r=7 AU, v=12.8km/s, circular orbit E. None of the above	the total energy of the system, you can notice that an positive a indicates a bound orbit (elliptical/circular) , a negative a indicates a unbounded orbit (hyperbolic) otherwise if 1/a=0 then it is a barely (un)bounded orbit(parabolic). Also it is easier to do the calculation by making 1/a the subject of the equation given by : $\frac{1}{a} = \frac{2}{r} - \frac{v^2}{GM}$ Using the value given you will obtain: A. $a = \left(\frac{2}{3*1.496*10^{11}} - \frac{(25.4*10^3)^2}{6.67*10^{-11}*2*10^{30}}\right)^{-1} \approx -2.63*10^{12}m$(hyperbolic orbit) B. $a = \left(\frac{2}{5*1.496*10^{11}} - \frac{(10.8*10^3)^2}{6.67*10^{-11}*2*10^{30}}\right)^{-1} \approx 5.56*10^{11}m$(elliptical orbit) C. $a = \left(\frac{2}{1*1.496*10^{11}} - \frac{(42.2*10^3)^2}{6.67*10^{-11}*2*10^{30}}\right)^{-1} \approx 5.17*10^{13}m$(parabolic orbit) Note: you will have to vary the speed slightly to see that with a small change in initial speed result in a huge increase in value of a which is a indication that 1/a is very close to 0 D. $a = \left(\frac{2}{7*1.496*10^{11}} - \frac{(12.8*10^3)^2}{6.67*10^{-11}*2*10^{30}}\right)^{-1} \approx 1.47*10^{12}m$(elliptical orbit) It is important to note that D and B cannot be circular orbits since the semimajor axis a calculated must be approximately equal to the given radius for it to be a circular orbits thus C is the correct option.

		The alternative way to attempt this question is to determine the escape velocity of the given orbits, if the escape velocity is greater than the velocity given then it is a bound orbit (elliptical/circular orbits) otherwise it is a barely (un)bounded/ unbounded orbit(parabolic/ hyperbolic orbit) Using the information given the escape velocity can be calculated as follows. A. $v_{esc} = \sqrt{\frac{2*6.67*10^{-11}*2*10^{30}}{3*1.496*10^{11}}} \approx 24.4\frac{km}{s} < 25.4\ km/s$ (hyperbolic orbits) B. $v_{esc} = \sqrt{\frac{2*6.67*10^{-11}*2*10^{30}}{5*1.496*10^{11}}} \approx 18.9\frac{km}{s} > 10.8\frac{km}{s}$(elliptical orbits) C. $v_{esc} = \sqrt{\frac{2*6.67*10^{-11}*2*10^{30}}{1*1.496*10^{11}}} \approx 42.23\frac{km}{s} \approx 42.2\frac{km}{s}$(parabolic orbits) D. $v_{esc} = \sqrt{\frac{2*6.67*10^{-11}*2*10^{30}}{7*1.496*10^{11}}} \approx 16.0\frac{km}{s} > 12.8\frac{km}{s}$(elliptical orbits)
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.	A With its highly eccentric orbit, such a spacecraft spends most of its time at apogee (apogee dwell). In other words, it is well

	B. Clearing space debris. C. Rapid scans of the entire Earth. D. Satellite refuel docking. E. Gamma wave detection.	placed for providing communications services for polar latitudes, which has issues with communicating with geostationary orbits. In contrast, a tundra orbit confers little to no additional advantage over a geostationary orbit for the other options. -most space debris is located in low Earth orbit (LEO) -both orbits share the same period (1 sidereal day). As both satellites are geosynchronous, the other side of Earth is not visible to them. - a refuel station would be best placed at LEO for accessibility - type of orbit does not affect gamma wave detection – what matters is that the spacecraft is out of Earth's atmosphere
37	The star R136a1 has the highest luminosity of any known star at 3.33 x 10^33 W. It has an estimated surface temperature of 53,000 K. Supposing R136a1 only emits photons at it wavelength, calculate the number of photons emitted each second a. 9.18 x 10^40 photons b. 9.18 x 10^45 photons c. 9.18 x 10^50 photons d. 9.18 x 10^55 photons e. 9.18 x 10^60 photons	C Using Wien's Displacement Law: λ_max = b/T = 5.4674 x 10^-8mE = hf = hc/λ= 3.6332 x10^-18 J N_photons = L/E = 9.18 x 10^50 photons
38	At 6pm of some day, Alice observes that Schedar (α Cassiopeiae, RA: 00h 40m, DE: +56° 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° 53′) B. Eltanin (Gamma Draconis, RA: 17h 56m, DE: +51° 29′) C. Pherkad (Gamma Ursae Minoris, RA: 15h 20m, DE: +71° 50′) D. Alioth (Epsilon Ursae Majoris, RA: 12h 54m, DE: +56° 57′) E. Capella (Alpha Aurigae, RA: 05h 16m, DE: +45° 59′)	D The key insight is that after 0.5 sidereal days, the local sidereal time has increased by 12 hours. Thus, find a star with similar declination but separated by 12 hours of right ascension.

<table>
<tr><td></td><td></td><td></td></tr>
<tr><td>39</td><td>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</td><td>C.
By referring to a binding energy per nucleon diagram, we can see that the most closely bounded nuclei indicated have a mass number of 56.Atoms with mass number beyond this point will require the incoming helium nuclei to have sufficient energy to put into the atom to fuse further, thus it does not happen with significant quantity in a dying star where such nuclei are in short supply. It is a common misconception that the fusion through alpha ladder ends at Iron since closer inspection of the Iron nuclei fused through this process reveal that it have an mass number of 52 which is not the most closely bounded atom possible since the binding energy in this case is only a function of the mass number of the atom. The nickel fused this way is however unstable and thus will quickly decay to the more stable Iron-56 nuclei thus causing the misconception.

</td></tr>
<tr><td>40</td><td>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</td><td>Ans: E

Without the circular orbit assumption, we don’t know the current distance of Mercury from the Sun.</td></tr>
</table>

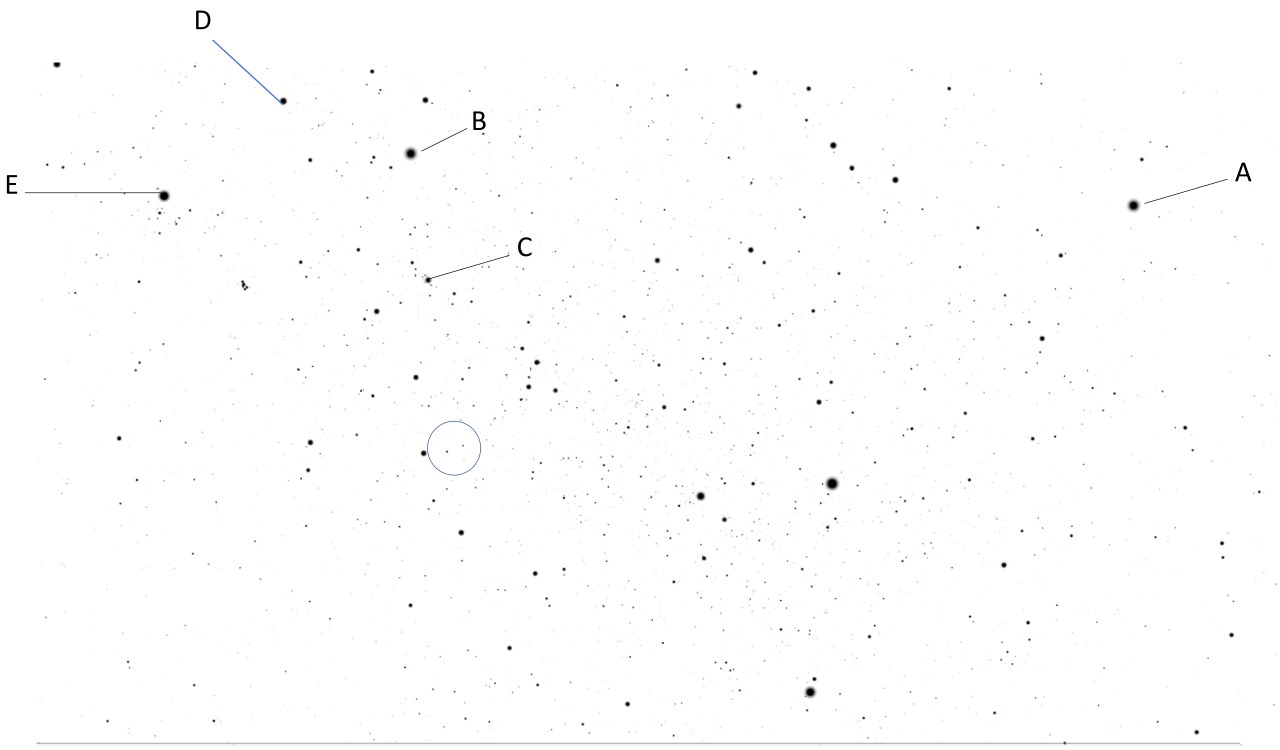
	e. It can not be determined without further information	
41	Which of the following reasons is NOT a possible reason why a planet around a red dwarf star is inhospitable for most lifeforms on Earth? A. Extended pre-main sequence phase means future planets in the habitable zone would have been exposed 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	C C implies that red dwarfs can last longer than other stars. This would be a plus point for habitability.
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=χc, where 0<χ<1. When Grace tried to observe the spectrum emitted from this astronomical object, she measures the wavelength of the Hα line to be at 892.54nm. Note that the wavelength of H$\alpha$is observed to be at 656.28$nm$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	B From the formula booklet, we note the relativistic doppler effect equation $f_{ob} = f_{source}\sqrt{\frac{c-v}{c+v}}$. Hence, the equivalent equation for wavelength, using $c = f\lambda$, would be $\lambda_{ob} = \lambda_{source}\sqrt{\frac{c+v}{c-v}}$. Rewriting, we get $\left(\frac{\lambda_{ob}}{\lambda_{source}}\right)^2 = \frac{1+\frac{v}{c}}{1-\frac{v}{c}} = \frac{1+\chi}{1-\chi}$ Solving for χ, we get $(1 - \chi)\left(\frac{\lambda_{ob}}{\lambda_{source}}\right)^2 = (1+\chi) \rightarrow \chi = \frac{\left(\frac{\lambda_{ob}}{\lambda_{source}}\right)^2 - 1}{\left(\frac{\lambda_{ob}}{\lambda_{source}}\right)^2 + 1} = 0.298$
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	C The Sun needs to have the same altitude and azimuth at the given local time. This implies that the Sun must have the same declination for this phenomenon to recur. In general (excluding the solstices), the Sun has the same declination twice a year – both

	E. It will not occur in 2020.	times are given in the question, so pick the earliest date.
44	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. <table at end of document> 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	D At latitude 30˚N, the declination of stars at the zenith would be +30˚. Hence the object with declination closest to +30˚ is correct.
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	C Since Castor is a star in Gemini (Winter constellation), Regulus is a star in Leo (Spring Constellation) and the Heart Nebula is in Cassiopeia (Autumn constellation), the season should be approximately winter.
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	B At 30˚N, all objects with declination between -60˚ to -90˚ will never rise above the horizon
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.	C R.A of Great Cluster in Hercules – R.A. of Butterfly Cluster=~-1hour Since Great Cluster in Hercules has a smaller right ascension than Butterfly Cluster, it will rise earlier and by 1hour.
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 This is because the Spring Equinox will occur 6 hours earlier if the next year would be a non-leap year, and 18 hours

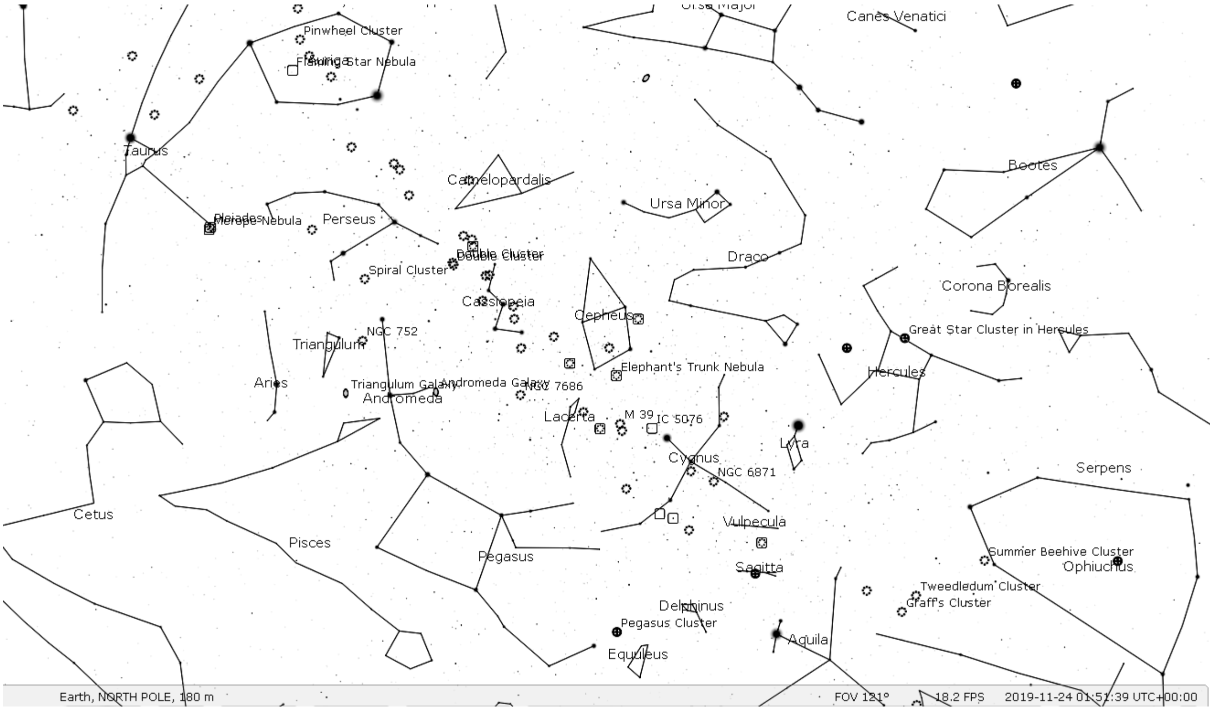
	A. 0 B. 0.33 C. 0.67 D. 1 E. Not enough information to determine the probability.	later if the next year would be a leap year. Hence, the Spring Equinox will go back to approximately the same date and time after 4 years from now. This means that within the next 3 year, you would not expect the Spring Equinox to fall on the same time and date
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.	C A and B are incorrect as they assume that Saturn's rotational axis remains static from the perspective of an observer on the earth, when it actually only points in the same direction in the frame of reference of the entire solar system. Right now, Saturn's rotational axis is tilted towards us and shows us the north side (when observed near opposition), and when Saturn moves half an orbit ahead, its rotational axis will appear tilted away from us and thus show us the south side. D is wrong; while it is true Saturn's rings are expected to dissipate over time, it will definitely last longer than several orbits around the sun. E is a troll answer (I hope) as Saturn's rings are held in place by gravity and not its magnetic field.
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°	D $Focal\ length = aperture \times focal\ ratio = (6 \times 2.54) \times 6 \times 10 = 914.4\ mm$ $Magnification = \frac{focal\ length\ of\ telescope}{focal\ length\ of\ eyepiece} = \frac{914.4}{x}$

		$True\ Field\ of\ View(in\ degrees) = \frac{Apparent\ field\ of\ view}{magnification}$ $True\ Field\ of\ View(in\ arcmin) = [TFOV(in\ degrees)\ \times 60] > 25'$ This question requires knowledge of the basic telescope equations to test the understanding of the relation between equipment specifications and actual observation.

Q21-23



Q21-23 Ans



Q30

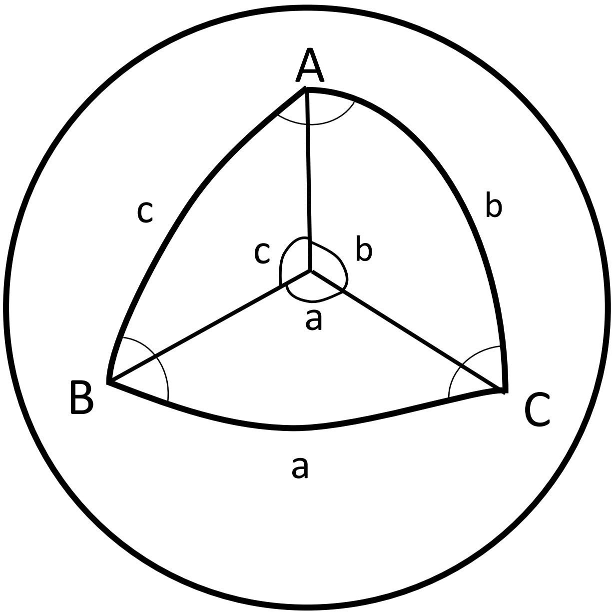
Year	Right Ascension	Declination
1888	17^h52^m	+4°23’
2020	17^h59^m	+4°45’

A: Difference in Right Ascension

a: to be found

b: 90°- declination

c: 90°- declination



Q44-47

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