

1. On the night of 3-4 November 1971, the Moon, about one and a half days after full phase, passed through the Pleiades cluster. The right ascension of the Sun was 14h 30m at that time. Hence, the right ascension of the Pleiades cluster is approximately
- A. 1h 15m
  - B. 3h 45m
  - C. 5h 45m
  - D. 8h 15m
  - E. 15h 45m
2. One night at an unknown location, the Moon was observed to be rising over the horizon. An observer reads off her broken watch and found that the time on her watch right then was 22:50. The phase of the Moon is a...
- A. Waxing crescent
  - B. Waxing gibbous
  - C. Waning crescent
  - D. Waning gibbous
  - E. Insufficient information to answer the question

**Solution:**

First of all, the question reads, "broken watch". If that wasn't a clear indication of the answer, the next hint is that the local time doesn't necessarily correspond to the local solar time, just as in Singapore in which for economic purposes, we are GMT+8 whereas geographically we should be GMT+7.

3. Travelling from the core of the Sun to the Earth, some percentage of electron neutrinos are converted into other types of neutrinos, which we shall refer to as X neutrinos. The efficiency of a detector for detecting X neutrinos is one fourth of its efficiency for detecting electron neutrinos. If there is no neutrino conversion, we expect to detect an average of 100 neutrinos in a period of time. However, due to the conversion, an average of 70 neutrinos are actually detected in the same period of time. How many percent of electron neutrinos are converted to X neutrinos?
- A. 10%
  - B. 20%
  - C. 30%
  - D. 40%
  - E. 50%

**Solution:**

This is solved by simple mathematical logic. From the problem statement, we can set up an equation:

$$(f/4)*100 + (1-f)*100 = 70$$
$$F = 0.4 = 40\%$$

Addendum:

This is an oversimplification to the solar neutrino problem, in which there is a discrepancy

between the neutrino flux expected from theory compared to experimental data. This is already solved by the evidence of neutrino oscillation. Takaaki Kajita from the Super-Kamiokande Observatory and Arthur McDonald from the Sudbury Neutrino Observatory were awarded the 2015 Nobel Prize in Physics for providing the firm evidence of neutrino oscillation.

4. An astronomer observes a very small moon orbiting a planet and measures the moon's minimum and maximum distances from the planet's centre, as well as the moon's maximum orbital speed. Which of the following cannot be calculated from these measurements?

- A. The mass of the moon
- B. The mass of the planet
- C. The minimum orbital speed of the moon
- D. The period of the orbit
- E. The length of the semi major axis of the orbit

**Solution:**

We are told we are able to find the min and max distance of the Moon from the planet, as well as orbital speed, which are presumably much larger in magnitude compared to whatever effects the small moon might have on the planet. As such, a quality such as the mass of the moon cannot be calculated from such measurements.

Addendum:

- B. Since the system is in equilibrium, the centripetal force acting on the moon must equal the gravitational force acting on it. Thus,

$$\frac{mv^2}{r} = \frac{GMm}{r^2} \rightarrow v^2 = \frac{GM}{r} \rightarrow M = \frac{v^2 r}{G}$$

And so the mass of the planet can be found.

- C. The velocity of an object at any point in an elliptical orbit is given by

$$v = \sqrt{GM \left( \frac{2}{r} - \frac{1}{a} \right)}$$

Where  $r$  is the distance between the bodies and  $a$  the length of the semi-major axis. Since the minimum and maximum distance of the moon to the planet is known, the semi-major axis can be found (Refer to E). For the minimum orbital speed, the moon should logically be furthest away from the planet, which we also know the value of. As such, the minimum orbital speed of the moon may be found.

- D. We can find the period easily through Kepler's 3<sup>rd</sup> Law.
- E. The moon is very light, and so we can assume the planet to be stationary. Then, the semi-major axis is simple the sum of the minimum and maximum distance the moon is from the planet.

5. A 10-inch refracting telescope with f-ratio (defined as the ratio of the focal length and aperture) of f/10 is used with a 25 mm focal length eyepiece. What is the magnifying power of the telescope? (1 inch = 2.54 cm)
- A. 10x
  - B. 20x
  - C. 50x
  - D. 100x
  - E. 200x

**Solution:**

The magnifying power is given by

$$M = \frac{f_o}{f_e}$$

Where  $f_o$  is the focal length of the telescope and  $f_e$  the focal length of the eyepiece.

A focal ratio of  $\frac{f}{10}$  indicates that  $\frac{f_o}{10 \text{ inch}} = 10$ . We can thus find the value of  $f_o$  in mm, and subbing in the value of  $f_e$  which is provided, we obtain D as the answer.

6. In which of the following events is Mars best observed from the Earth?
- A. Western or eastern quadrature
  - B. Conjunction
  - C. Opposition
  - D. Aphelion
  - E. Perihelion

**Solution:**

Logically, we would see something clearest is something is closest to us. Opposition refers to the event where Mars is located closest to Earth. As such, opposition, C, is the answer.

Addendum:

A. This simply refers to whether the planet is located to the East or West of the Sun from the Earth. It has nothing to do with distance.

B. Conjunction refers to the event where Mars and Earth are located opposite each other with reference to the Sun. In which case, Mars is obviously not visible in the sky.

C/D. Aphelion and perihelion refers to the point of an object furthest/closest to the Sun. This however has nothing to do with the distance from the Earth to Mars. As such, this is not the correct option.

7. Two stars are visibly located very close to each other on celestial sphere. It then reveals that both stars have the same apparent brightness magnitude of +6.5. If both stars are considered as a single point object in the night sky, what is its combined apparent magnitude?
- A. +1.50
  - B. +3.75
  - C. +5.75
  - D. +7.25
  - E. +13.0

**Solution:**

Again, the only logical answer is C.

D and E are not possible choices as this would mean that the combined magnitude is somehow dimmer than the individual magnitude.

B indicates a  $2^{6.5-3.75} = 6.7$  times increase in luminosity, which is simply not possible since the two stars are of the same magnitude, and by adding them together the luminosity only increases 2-fold. On a similar argument, option A is illogical.

8. Sirius, the brightest star in the night sky, is a visual binary. Sirius A is 10 magnitudes brighter than Sirius B, but Sirius A's surface temperature is about half that of Sirius B. What is the ratio of Sirius A's radius to that of Sirius B?
- A. 2.5
  - B. 12.6
  - C. 25
  - D. 200
  - E. 400

**Solution:**

A difference of one magnitude refers to a change in luminosity of factor  $\sqrt[5]{100} \approx 2.512$ . Since Sirius A is 10 magnitudes brighter, the luminosity of Sirius A is actually  $2.512^{10}$  times larger than that of Sirius B.

By the Stefan-Boltzmann Law, cancelling out all the equal terms and substituting in the temperatures as given:

$$r_A^2 \times \left(\frac{1}{2}T\right)^4 = 2.512^{10} \times r_B^2 \times T^4$$

Rearranging the terms, we obtain:

$$\frac{r_A}{r_B} \approx 400$$

9. Sirius is located some 8.60 light years away. The average distance between both stars in the binary system is 19.80 AU. If we are to observe the Sirius binary at visible wavelengths (~550 nm), determine the minimum aperture needed to resolve the binary (Given: 1 rad = 206265")

- A. 25 cm
- B. 23 cm
- C. 30 cm
- D. 1.8 cm
- E. 2.0 cm

**Solution:**

We use Rayleigh's Criterion for this question, which states that two objects are resolvable if and only if

$$\sin(\theta) \geq \frac{1.22\lambda}{d}$$

Where  $\theta$  is the angular distance between the objects,  $\lambda$  is the wavelength of light we are observing at, and  $d$  is the aperture.

The angular distance can be found easily, since we have the length of the base and the height of an isosceles triangle. Using simple trigonometry, we find

$$\theta = 2 \times \tan^{-1}\left(\frac{19.80 \text{ AU}}{2 \times 8.60 \text{ ly}}\right)$$

Convert units and simply sub the output into the first equation, to obtain D.

10. Before the 19<sup>th</sup>-century, astronomers once assumed that the Sun is the centre of the Milky Way galaxy as stars appeared evenly distributed along the galactic plane. One possible reason for this misconception about the Sun's location could be explained by
- A. The fact that the Milky Way galaxy is a spiral galaxy
  - B. The presence of dust obscures distant regions of the galactic disk
  - C. There is a supermassive black hole at the centre of Milky Way galaxy which creates an apparent void where the concentration of stars is the largest
  - D. It is surrounded by massive dark halo
  - E. The extent of the Milky Way is so great that we can't comprehend its full extent just by observing the stars

**Solution:**

This quest to find the position of the Sun in the Milky Way was carried out by William Herschel (the founder of Uranus) in the late 18<sup>th</sup> century. He simple counted the number stars visible along different lines of sights from the Earth. If there were a lot of stars in one direction, the Sun would more likely towards the centre of the galaxy. If there were few stars, the Sun would be close to the edge of the galaxy. He observed that the spread of stars were about even, which led him to conclude that the Sun is the centre of the Milky Way.

What he did not know however was the presence of dust, which covered our view from further away stars from the Earth in the visual spectrum. As such, B is the answer.

Interesting Point: Herschel is the discoverer of infrared as well, which, ironically, can be used to penetrate dust layers and see beyond them.

Addendum:

A. This option doesn't really make sense as it does not indicate how this misconception may have taken place.

C. While this is true, the Schwarzschild radius of the supermassive black hole is still small compared to the distances we were able to observe in the 19<sup>th</sup> century. As such, the presence of the supermassive black hole had little to no effect on the star count as seen from Earth.

D/E. Doesn't make sense.

11. An extrasolar planet has a diameter 7 times smaller than its parent star, which is located 7 parsecs away and has a luminosity equal to that of the Sun. If this planet has an edge-on orbit, what is the largest variation in the apparent magnitude of the parent star as observed from earth?

- A. 0.022 mag
- B. 0.167 mag
- C. 1.145 mag
- D. 2.113 mag
- E. 4.225 mag

**Solution:**

When the planet lies between us and its parent star, we expect the luminosity to decrease since the planet blocks out a small surface area of the star. We let the diameter of the parent star be  $7d$ , and thus using the Stefan-Boltzmann Law:

$$P_{\text{planet not covering}} = \pi\left(\frac{7}{2}d\right)^2\sigma T^4$$
$$P_{\text{planet covering}} = \pi\left[\left(\frac{7}{2}d\right)^2 - \left(\frac{d}{2}\right)^2\right]\sigma T^4$$

Where the second equation takes the net surface area of the parent star exposed to us.

Then, by the definition of magnitude:

$$\frac{P_{\text{planet covering}}}{P_{\text{planet not covering}}} = \frac{48}{49} = 100^{\frac{\Delta m}{5}}$$
$$\Delta m = \frac{5 \lg\left(\frac{48}{49}\right)}{\lg(100)} \approx 0.022 \text{ mag}$$

Thus, A is the answer.

12. A new star is born when
- A. Electron degeneracy pressure is reached
  - B. Its surface temperature reaches 3000K
  - C. Continued gravitational contraction stops due to the start of hydrogen fusion
  - D. Interstellar clouds rapidly contract and collapse
  - E. The core starts to fuse He nuclei
13. In 1967, Halton Arp proposed the idea of galaxies having intrinsic redshifts. He suggested that the redshift we observe in galaxies are not solely based upon their relative motion alone. If his suggestion is correct, which physical law **may not** hold true anymore?
- A. Relativistic Doppler Effect
  - B. Hubble's Law
  - C. Time Dilation and/or Length Contraction
  - D. Schwarzschild Radius
  - E. Newtonian Gravity
14. You see Venus in rising in the East at sunset. It is at
- A. Superior conjunction
  - B. Inferior conjunction
  - C. Opposition
  - D. Conjunction
  - E. Not possible

**Solution:**

Venus is an inferior planet (orbit is of smaller radius than the Earth's). As such, Venus always seems to be located close to the Sun. Since the Sun sets in the West, Venus cannot appear in the East during sunset.

15. What is the difference between visual doubles & visual binary stars?
- A. Binary stars orbit each other while doubles only appear to be side-by-side from our point of view
  - B. Doubles have a larger orbital radius while binary stars have a much smaller radius
  - C. Doubles are 4 stars in orbit around each other while binary stars only consists of 2 stars
  - D. Binary stars can be resolved much more easily, whereas doubles are harder to resolve and hence we term them as being grouped together
  - E. Doubles are birthed only in pairs while binaries can be created one after the other
16. What is the escape velocity of a spacecraft of mass 500 kg from the edge of Jupiter's atmosphere?
- A. 40 km/s
  - B. 50 km/s
  - C. 60 km/s
  - D. 70 km/s
  - E. 80 km/s

**Solution:**

Escape speed is given by:

$$v_{escape} = \sqrt{\frac{GM}{r}}$$

Where  $M$  is the mass of the object you are trying to escape from and  $r$  is the distance from the center of mass of the object.

Subbing in the mass of Jupiter and the radius of Jupiter, you get C as the answer.

17. The following statements are proposed advantages of using achromatic refractors.
- I. They have low maintenance requirements
  - II. They are generally cheaper than Newtonian reflectors of the same aperture
  - III. They can be feasibly and reliably made into very large apertures

Which of the above statements are true?

- A. Statement I only
- B. Statements I and II
- C. Statements I and III
- D. Statements II and III
- E. Statements I, II and III



**Solution:**

Statement I is true as refractors are generally more rugged and thus less susceptible to environmental effects.

Statement II is false as lenses (in refractors) are more expensive than mirrors (in reflectors) as they are harder to manufacture with precise measurements.

Statement III also false as lenses are heavy and thus have difficulties being held stably in larger apertures.

18. Since a solar eclipse occurs whenever the moon passes between the Earth and Sun, why do eclipses not occur every new moon?

- A. Earth's gravitational forces distort the orbital path into a wavelike pattern
- B. Earth's rotation drags the moon's orbit
- C. The moon does not orbit the Earth in the same plane as the Earth's orbit around the sun.
- D. The moon does not intersect the path of the sun.
- E. None of the above statements are reasonable explanations.

19. Panspermia is a hypothesis which suggests a possible mechanism for which life could have been spread throughout the Universe. Among the proposed mechanisms, radio-panspermia proposes that single spores could have been spread due to radiation pressure from stars. Which of the following statements best explains why radio-panspermia is not likely?

- A. This mechanism is only viable for macroscopic forms of life with considerable surface area for radiation pressure to act on
- B. Radiation pressure does not provide enough energy for any form of life, both macroscopic and microscopic, to move across the Universe
- C. Shielding against harmful ultraviolet and X-ray radiation is necessary in order to prevent destruction of genetic information
- D. There is no evidence that life tends to originate within the vicinity of stars
- E. Radio-panspermia is a viable mechanism

**Solution**

Radio-panspermia is thought to be highly unlikely due to this very reason. Research suggests that a rock with a minimum diameter of 1m is required for sufficient shielding, which refutes the idea that single spores can be transported through effects of radiation pressure.

20. Which of the following statements incorrectly describe sunspots?

- A. Sunspots are regions where magnetic fields are particularly concentrated
- B. Sunspots are regions where temperatures are slightly warmer than their surroundings
- C. The number of sunspots increases and decreases in a cycle with a period of approximately 11 years.
- D. Higher number of sunspots observed during solar maximum will coincide with greater frequency of aurora display on Earth

E. Most solar flares and coronal mass ejections originate in magnetically active regions around visible sunspot groupings.

21. You are using a refractor type telescope on a clear moonless night. You decide to look at Jupiter. Despite your best effort, you notice that there is a reddish hue on one side of Jupiter's disc and a violet hue on the other. What could be the possible reason?

- A. Turbulence in high altitude air.
- B. A portion of the front objective lens is obstructed.
- C. The telescope is not properly collimated.
- D. The telescope is suffering from chromatic aberration.
- E. All of the statements are possible causes.

22. Which of the following statements regarding comet tails are false?

- A. Plasma tail are usually straight
- B. Dust tails are usually more curved and smudgy.
- C. Comet tails always point away from the Sun.
- D. A comet cannot have both a plasma tail and dust tail simultaneously.
- E. The plasma tails of comets are evidence of the solar wind.

23. What is the main reason why there no planets located within the asteroid belt?

- A. There was not enough material in this part of solar nebula to form a planet.
- B. A planet once formed here, but it was broken apart by a catastrophic collision.
- C. Gravitational tugs from Jupiter prevented material from coalescing into a planet
- D. There was too much rocky material to form a terrestrial planet, but not enough gaseous material to form a Jovian planet.
- E. The temperature in this portion of the solar nebula was just right to prevent the formation of a planet.

24. The Roche limit states that a body will disintegrate due to tidal forces, yet many satellites still come within the Roche limit. Which of the following adequately explains this discrepancy?

- A. The Roche limit only applies for large bodies
- B. The Roche limit only applies to objects whose integrity primarily relies on gravitational equilibrium
- C. The Roche limit only applies to objects with a fluid core
- D. The Roche limit applies to bodies with primarily rocky mass
- E. The Roche limit applies to completely fluid objects

**Solution:**

This is indeed the key reason why satellites in low-earth orbit can hold together. If we only considered self-gravity, calculations can easily show that these satellites must have densities much greater than that of lead. To keep them together, tension within the satellite resists the force of gravity, preventing the satellite from breaking up.

25. Why will Pluto never collide with Neptune?

- A. Pluto's orbit is completely outside Neptune's orbit.
- B. Pluto's orbit is completely inside Neptune's orbit.
- C. Pluto's orbit never comes anywhere close to Neptune's orbit.
- D. The two planets have an orbital resonance that prevents them from colliding.
- E. A collision is predicted to happen some 2 billion years later, far beyond the timespan of human lives.

26. If we are about to observe a very distant star with a telescope ( $D = 10$  cm), what is the apparent magnitude of the dimmest star observable by the telescope? It is known that the diameter of our pupil is 6 mm and the apparent magnitude of the dimmest star that a naked eye can observe is +6.

- A. +10.75
- B. +10.63
- C. +11.67
- D. +12.11
- E. +12.67

**Solution:**

The limiting magnitude of a telescope is given by

$$m_{limit} = m_{naked\ eye} + 5 \lg \left( \frac{D_{telescope}}{D_{eye}} \right)$$

Simply subbing in the values in SI units gives the answer D.

27. Which of the following statements about the equinoxes is incorrect?

- A. The Sun crosses the celestial equator twice in a year; once during the vernal equinox and the following during the autumnal equinox.
- B. The equinoxes mark the days when the length of day differs by the smallest amount across all locations on Earth.
- C. The position of the autumnal equinox (in Virgo) is independent of the gyroscopic precession of the earth.
- D. The vernal equinox is defined from a point on the celestial sphere where the Sun passes through.
- E. The equinoxes and solstices are spaced approximately 3 months between each other.

Remarks: The autumnal and vernal equinoxes are in fact drifting away due to the gyroscopic precession of the earth. This is the same effect accountable for the change in the pole stars.

28. Which of the following statements about the seasons is incorrect?

- A. The Winter Triangle and Hexagon is recognised as the indication that winter is coming in various cultures around the globe.
- B. Seasonal changes are marked by equinoxes.
- C. Seasonal variations in weather are ultimately due to the position of the Sun relative to the celestial equator.
- D. Summer occurs at different times for the two hemispheres.
- E. During summer months in the northern hemisphere, the Sun's northern declination causes it to appear higher in the sky.

29. One fateful winter evening, Orion the Hunter was found to have just crossed the local meridian. Given that Alnilam, the middle star of the "Belt of Orion" has RA/DEC: 5h 36min/-1°12'1", what is the local sidereal time at that instance?

- A. 23h 56min
- B. 13h 36min
- C. 12h 36min
- D. 5h 36min
- E. 0h 00min

Remarks: Local Sidereal Time = RA of object passing through local meridian.

30. On a different day at local midnight, Orion the Hunter was found to have just crossed the local meridian too. Which constellation is the Sun approximately found in? Hint: at local midnight, the hour angle of the sun is defined to be 12h if we were to set 0h to be at noon.

- A. Taurus the Bull
- B. Sirius the Dog
- C. Aquila the Eagle
- D. Virgo the Maiden

E. **Scorpius the Scorpion**

Remarks: Scorpius and Orion the Hunter are practically opposites. So for one to be at "midnight", Scorpius would be at "noon" position. Knowing the story of Scorpius and Orion would help too.

31. It is the vernal equinox on September 21<sup>st</sup> in **Quito, Ecuador (0°S 78 °W, GMT -5h)**, at what **local solar time** would Ptolemy Cluster, M7, with RA/DEC: 17h 53min rise from the east?

- A. 22h 53min
- B. 17h 53min
- C. 11h 53min**
- D. 7h 53min
- E. 2h 53min

Remarks: At vernal equinox, local time = local sidereal time. At 17h 53min, the object would cross the local meridian. Hence 6 hours before it would have just risen from the east.

32. Which of the following objects **cannot** be found within the Milky Way?

- A. Lagoon Nebula, M8
- B. Ptolemy Cluster, M7
- C. Omega Centauri, NGC 5139
- D. North American Nebula, NGC 7000
- E. None of the above.**

Remarks: Only going out for observations can save you.

33. In which of the following constellations (as viewed from Earth) does the Milky Way's galactic plane not pass through?

- A. Orion
- B. Canis Major
- C. Scorpius
- D. Crux
- E. Leo**

34. It's the vernal equinox at the north pole. which of the following stars can be seen?

- A. Polaris
- B. Sigma Octantis
- C. Canopus
- D. Vega
- E. None of the above.**

Remarks: During vernal equinox, the north pole experiences its first (and only) sunrise of the year (see Stellarium).

35. Which of the following statements on the endpoints of stellar evolution is incorrect?
- A. Type 1a Supernovae (SNe) are useful in determining vast distances to and between galaxies.
  - B. Supernovae will occur if the mass of the star is less than the supposed Chandrasekhar limit.
  - C. White Dwarves do not undergo further thermonuclear fusion and will cool gradually over billions of years, as such the resultant (Type 1a) supernova is useful as a standard candle.
  - D. Sufficiently massive stars do not undergo a red giant phase: rather they smoothly commence helium fusion.
  - E. There exists a theoretical maximum mass limit (the Tolman–Oppenheimer–Volkoff limit) for the neutron star, analogous to the Chandrasekhar limit, for beyond which the gravitational pull is too strong such that a black hole forms.

Remarks: Supernovae will occur if the mass of the star is MORE than the supposed Chandrasekhar limit.

36. On 14 November, 2016, we observed a perigee full moon at its closest point to Earth in over 68 years at a distance of 356, 500 km, a distance of 27,900 km closer than its usual orbital distance. Find the percentage increase in apparent brightness compared to the moon at its average orbital distance (find the closest value).
- A) 1%
  - B) 2%
  - C) 8%
  - D) 16%
  - E) 32%

**Solution:**

Using a simple use of similar triangles, the ratio of the apparent diameters would be  $(356500+27900)/356500 = 1.07826087$   
Squaring this value for the change in apparent surface area, we get a change in apparent area of 1.16, or an increase of 16%.

37. We know that giant stars are larger in diameter than the Sun because
- A. They are more luminous but have about the same surface temperature
  - B. They are less luminous but have about the same surface temperature
  - C. They are hotter but have about the same luminosity
  - D. They are cooler but have about the same luminosity
  - E. They have a larger absolute magnitude than the Sun

38. The Helix Nebula (NGC 7293) has an apparent magnitude of +7.6, while the Ring Nebula (M57) has an apparent magnitude of +8.8. The ring nebula generally appears brighter when viewed through a telescope. Which of the following statements explain this observation?

- A. The apparent magnitude of an object tells us how bright an object appears to be. Since a magnitude of +8.8 is greater than that of +7.6, the ring nebula would be brighter.
- B. The apparent magnitude of an object tells us how bright an object appears to be. An object of magnitude of +7.6 means that it is brighter than an object with a magnitude of +8.8. The statement is therefore false.
- C. Apparent magnitude values assume a point source. Since the Helix nebula has a much larger angular extent in the night sky, its brightness is spread out over a larger area, resulting in a lower surface brightness compared to the ring nebula.
- D. Apparent magnitude values ignore the effects of atmospheric extinction. Since the ring nebula emits wavelengths that tend to be absorbed by Earth's atmosphere, the resulting light we see is greatly diminished.
- E. Apparent magnitude is an averaged reading. The Helix Nebula is a class of object that pulsates in brightness. Although it is generally dim, it occasionally produces large bursts of light that skews its magnitude values when averaged.

39. Cepheid variables are the most well-known variable stars. Which of the following is not a characteristic of said stars?

- A. They are reliable distance candles
- B. They are modelled by the kappa mechanism
- C. They are typically young stars which have not entered the main sequence
- D. They are some of the most important stars used to understand the structure of the universe
- E. They lack flat, constant sections in their light curves

40. Below is a list of some stars

- I. Eta Carinae (Wolf-Rayet Star)
- II. Sun
- III. Vela Pulsar
- IV. Rigel (Blue Supergiant)

Rank the above stars in order of ascending mass

- A. II, III, IV, I
- B. III, II, IV, I
- C. I, II, III, IV
- D. I, III, II, IV
- E. II, III, I, IV

**Solution:**

Wolf-Rayet Stars make up the most massive stars in the Universe with several hundred solar masses.

The Sun has a solar mass of 1

The Vela Pulsar is a neutron star, which generally has a mass of 1.4 solar masses

Rigel is a blue supergiant with a mass much larger than the Sun

41. Which of the following correctly matches the type of telescope to the minimum altitude in which they can be operated from?

	Space Based	Ground Based	Airborne
A	Gamma Ray, X-Ray	Visible, Infrared, Radio	Ultraviolet
B	Gamma Ray, X-Ray	Ultraviolet, Visible	Radio, Infrared
C	Gamma Ray, X-Ray, Ultraviolet	Visible, Radio	Infrared
D	Gamma Ray	Visible, Radio, Infrared	X-Ray, Ultraviolet
E	Visible, Radio, Infrared	X-Ray	Gamma Ray, Ultraviolet

**Solution:**

Firstly, X-Rays and Gamma rays must at least space-based, since it is harmful to humans and we're still doing mostly fine on Earth. [A, D, E eliminated]

Ultraviolet cannot be ground-based since it is harmful to living organisms, and we're still doing mostly fine on Earth. [B eliminated]

Thus, the answer is C.

42. Joel looks through a telescope of aperture 20 cm and focal length 300 cm aimed at the binary star system with an angular separation of  $22'$ . Can the two stars be resolved?

- A. Yes because the angular separation of the stars is smaller than the angle calculated from Rayleigh's criterion.
- B. Yes because the angular separation of the stars is larger than the angle calculated from Rayleigh's criterion.
- C. No because the angular separation of the stars is smaller than the angle calculated from Rayleigh's criterion.
- D. No because the angular separation of the stars is larger than the angle calculated from Rayleigh's criterion.
- E. There is insufficient information to determine the answer.

**Solution:**

Again, we can simply use Rayleigh's Criterion for this question.



43. How much mass in the Sun is being converted into energy every second?

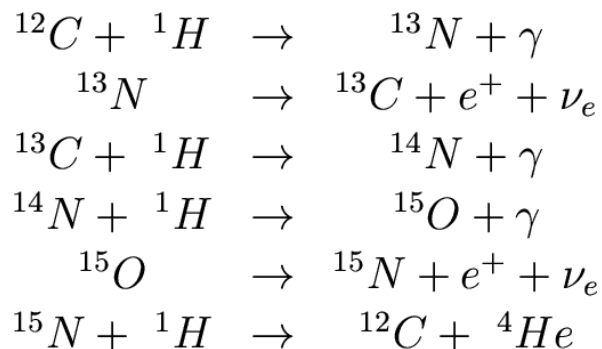
- A.  $2.54 \times 10^9$  kg
- B.  $5.08 \times 10^9$  kg
- C.  $4.27 \times 10^9$  kg
- D.  $2.13 \times 10^9$  kg
- E.  $3.65 \times 10^9$  kg

**Solution:**

Total power output of the Sun =  $3.846 \times 10^{26}$  W (from formula booklet)

Mass converted =  $E/c^2 = (3.846 \times 10^{26}) / (3 \times 10^8)^2 = 4.27 \times 10^9$  kg

44. The following set of nuclear reaction equations show the CNO cycle that occurs in stars.



Which of the following statements is true?

- A. This process is the primary means in which the Sun generates energy
- B. This process does not occur in the Sun
- C. Overall, this cycle generates more energy than the proton-proton chain, which is why it is dominant in hot, blue stars
- D. This cycle is the primary means in which heavier elements such as Nitrogen and Oxygen are produced from Carbon
- E. This can be seen as a catalytic reaction with the net effect of fusing hydrogen into helium

**Solution:**

The Sun primarily generates energy through hydrogen fusion, but that does not mean that it does not carry out the CNO cycle.

The proton-proton chain still releases the most energy per reaction, due to the largest mass defect.

Finally, elements such as nitrogen and oxygen are mainly from supernovas, not due to fusion processes.

Prof Liu is a Professor of Physics in the National University of Astronomy. When he is not writing research papers, he enjoys imaging objects from his rooftop observatory in Singapore.

The following table lists the RA and DEC of some deep sky objects that he could possibly image, as well as their rise time and set time on 29/30<sup>th</sup> May in Singapore (Coordinates: 1°17'22.81" N, 103°51'0.24" E). **Use this table to answer questions 46 to 50.**

Object	RA	DEC	Rise Time	Set Time
Eta Carina Nebula (NGC 3372)	10h44m19.01s	-59°53'21.1"	1:31 pm	1:11 am
Omega Nebula (M17)	18h20m47.05s	-16°09'38.2"	8:59 pm	8:59 am
Crescent Nebula (NGC 6888)	20h12m06.96s	+38°21'18.0"	10:44 pm	10:50 am
Iris Nebula (NGC 7023)	21h01m36.89s	+68°09'47.9"	?	?
Sagittarius Star Cloud (M24)	18h16m48.01s	-18°33'00.0"	?	?

A massive power trip resulted in a blackout across Singapore, temporarily making Singapore a dark sky site over the evening. Taking advantage of this opportunity, Prof Liu decided to image the Iris Nebula (NGC 7023) and Sagittarius Star Cloud (M24). The Sun sets at 7:08 pm.

45. NGC 3372, M17 and NGC 6888 are emission nebulae, while NGC 7023 is a reflection nebula and M24 is a star cloud. Prof Liu thought that it would be a special opportunity to photograph these two objects. What is a possible reason why he thinks this is the case?
- Emission nebulae are amongst the brightest deep sky objects, making them easy to photograph even when there is no blackout.
  - Narrowband filters can be used to increase contrast on emission nebulae even from highly light polluted cities, but these filters generally are less effective on reflection nebulae and star clouds.
  - Both the Iris Nebula and Sagittarius Star Cloud do not rise very high in Singapore (less than 30 degrees of elevation), causing them to be perpetually shrouded in city light otherwise
  - Geographically, Singapore is one of the few places in the world where these two objects are visible, but they usually can't be seen due to light pollution
  - These two objects are thought to contain a special type of black hole known as a Kugelblitz, and perhaps Prof Liu is interested to gather data on them
46. Suppose that Prof Liu can only begin imaging an object 2 hours after it has rose above the horizon. At what time can he begin imaging NGC 7023?
- 9:32 pm
  - 11:17 pm
  - 1:24 am
  - 3:43 am
  - 5:15 am
47. At what time can he begin imaging M24?
- 6:30 pm
  - 7:08 pm

- C. 7:58 pm
- D. 9:28 pm
- E. 10:55 pm

48. At which of these points will M24 be best seen in the sky? (Assuming weather conditions are perfect and neglecting the effect of the moon)

- A. When it passes through the meridian
- B. When it passes through the zenith
- C. When it passes through the celestial equator
- D. When it enters inferior conjunction
- E. When it enters opposition

49. Prof Liu was awarded the Nobel prize for his discovery of the graviton, and decided to use his prize money to buy over the Siding Springs observatory in Australia (Coordinates:  $31^{\circ}16'24''\text{S}$   $149^{\circ}03'52''\text{E}$ ). Which of these objects never rise above the horizon in Siding Springs?

- A. Eta Carina Nebula
- B. Omega Nebula
- C. Crescent Nebula
- D. Iris Nebula
- E. Sagittarius Star Cloud

50. I have a 12 x 60 binoculars. This means that it has ...

- A. A magnification of 12 times and a focal length of 60mm
- B. A focal length of 12 mm and a magnification of 60 times
- C. An aperture of 12 mm and a magnification of 60 times
- D. An aperture of 12 mm and a focal length of 60mm
- E. A magnification of 12 times and an aperture of 60 mm