AstroChallenge 2021
Junior MCQ Round

SOLUTIONS

Monday 7th June 2021

PLEASE READ THESE INSTRUCTIONS CAREFULLY.

1. This paper consists of **29** printed pages, including this cover page.

2. You are required to keep your microphone and camera on at all times throughout the round.

3. You are not allowed to use your keyboard at all times, but you may use your mouse to scroll through the question paper as well as switch to the formula booklet.

4. Any materials other than the Question Paper and Formula Booklet are strictly prohibited.

5. 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.

6. Write your answers on a piece of A4 paper. Write your **Name**, **School**, and **Team Number** at the **bottom right corner** before taking a photo to submit. Failure to conform to this may result in us being unable to find the owner of the script.

7. It is *your* responsibility to ensure that your answer script has been submitted.

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1. Which of the following statements about stars is generally true?

    (A)   Star hopping refers to the act of an exoplanet in a binary system periodically jumping from being under the gravitational influence of one star to the other.

    (B)   White dwarfs continue to undergo nuclear fusion in their cores.

    (C)   **All stars can be plotted on the Hertzsprung–Russell diagram.**

    (D)   Stars of the same surface temperature generally have the same luminosities.

    (E)   None of the above statements are generally true.

    > **Solution:**
    >
    > A   False. Star hopping is the technique used to locate DSOs using visual markers.
    >
    > B   False. White dwarfs are stellar remnants and hence do not undergo nuclear fusion.
    >
    > C   True.
    >
    > D   False. The HR diagram will show us that there are stars of similar temperatures but different luminosities.

2. Which of the statements below is generally true?

    (A)   Epicycles cannot explain the retrograde motion of superior planets.

    (B)   The cube of a body's orbital period is directly proportional to the square of the semi-major axis of its orbit.

    (C)   The gravitational force between two objects is proportional to both the product of the masses of the two objects as well as the square of the distance between them.

    (D)   The geocentric model cannot explain seasons on Earth.

    (E)   **None of the above statements are generally true.**

    > **Solution:**
    >
    > A   False. Epicycles were invented to explain the observation of retrograde motion, thus they certainly can explain it.
    >
    > B   False. Kepler's Third Law tells us that the square of the orbital period is proportional to the cube of the semi-major axis of the orbit.
    >
    > C   False. The gravitational force is inversely proportional to the square of the distance between them, not proportional.
    >
    > D   False. Seasons are caused by axial tilt which can still be explained in a geocenteric model.

3. During the quarter moon, what kind of tides are generally expected on Earth? Where is the Moon approximately located?

(A)   Spring tides. The Moon is between the Earth and the Sun.

(B)   Spring tides. The Moon is on the opposite side of the Sun.

(C)   Neap tides. The Moon is on the opposite side of the Sun.

(D)   Trick question. Tides occur every day and are of the same magnitude regardless of the Moon's position, hence there is no differentiation.

(E)   **None of the above.**

> **Solution:**
>
> The moon is neither between the Earth and the Sun nor is the moon on the opposite side as the Sun. The moon must be "beside" the Earth relative to the Sun so as to observe a Quarter-Moon. The tides are known as Neap Tides.

4. Which of the following stars make up the Summer Triangle?

(A)   Vega, Shaula, and Mizar

(B)   Albeiro, Altair, and Vega

(C)   Vega, Albeiro, and Deneb

(D)   Altair, Denebola, and Vega

(E)   **None of the above**

> **Solution:**
>
> None of the above is correct. The Summer Triangle consists of the stars of Vega in Lyra, Altair in Aquila and Deneb in Cygnus.

5. Billy was visiting his alien friend Timmy who had set up base at Mercury to observe our Sun. While there, Billy saw the Sun rising from the east, only to backtrack in the opposite direction and then set below the horizon again two Earth days later! Billy was bewildered. How can Timmy best explain what was observed?

A) Mercury is at perihelion and its angular rotational velocity has exceeded its angular orbital speed.

B) Mercury is at aphelion and its angular orbital speed has exceeded its angular rotational velocity.

C) Mercury is tidally locked to the Sun but wobbles just enough for the solar terminator to shift.

D) Atmospheric distortion creates this optical illusion.

E) **None of the above explains the phenomenon.**

> **Solution:**
>
> This question requires knowledge of apparent retrograde motion and Kepler's second law. Mercury's orbit is quite elliptical; when it is at its nearest approach to the Sun (at perihelion), it experiences a stronger gravitational pull from the Sun and moves faster. You can think of the Sun's gravity acting like a slingshot, and Mercury is accelerating before getting catapulted away. Given how slowly Mercury already rotates around its own axis (one Mercury day = 58 Earth days), and that it rotates very quickly around the Sun (one Mercury year = 88 Earth days), the extra speed boost it gets at perihelion increases its orbital speed beyond its angular rotational velocity. With a little visualisation, we can imagine how the Sun can go through apparent retrograde motion in the Mercurian sky.
>
> A This comes close but inaccurately describes the mechanism behind the phenomenon.
>
> B This comes close but inaccurately describes the mechanism behind the phenomenon.
>
> C This is wrong because Mercury is not tidally locked to the Sun.
>
> D This is dubious and unlikely.

6. A distant planet has been discovered to have an orbital period of 800 days with a rotational period of 40 Earth hours per day. Assuming that the planet's rotational axis is aligned with its orbital plane, how many minutes do the stars rise earlier between successive days?

A) 5 hours

B) **3 minutes**

C) 0.5 days

D) 3.2 hours

E) 6.4 hours

> **Solution:**
>
> Distributing 40 hours across 800 days gives us a progression of 0.05 hours per day, which is equivalent to 3 minutes.

7. Every second, the sun converts roughly 600 million tons of hydrogen into 596 million tons of helium. Which statement correctly describes what happens to the remaining 4 million tons?

   (A) Ejected into space

   (B) Reabsorbed by molecular hydrogen

   (C) Converted into other elements

   (D) **Converted into light**

   (E) Trick question. This is not possible.

   > **Solution:**
   >
   > The proton-proton chain does produce energy in the form of light.

8. You observe the full moon rising at sunset. What will you see after 6 hours?

   (A) New moon

   (B) **Full moon**

   (C) Waning Gibbous

   (D) Waxing Gibbous

   (E) None of the above

   > **Solution:**
   >
   > This question is a troll question. A full moon will still be full 6 hours later.

9. What is one possible reason why Galileo Galilei come to realise that the Earth was not, as was commonly believed at that time in the West, the centre of the Solar System?

(A)   He observed the solar analemma.

(B)   He observed the Milky Way.

(C)   He read astronomy books written by the Chinese brought back by Marco Polo.

(D)   **He observed the phases of Venus.**

(E)   Trick question. Galileo had in fact thought that the Earth was in fact at the centre of the Solar System all along.

Solution:

A It is not possible to tell the centre of the solar system by merely observing the solar analemma.

B Observing the Milky Way would not help in this matter.

C Chinese books are unlikely to have made their way into Europe in large quantities at that time. Even if they had, it is unlikely that he was able to read or understand them.

D Galileo concluded that Venus must travel around the Sun, passing at times behind and beyond it, rather than revolving directly around the Earth. His observations of the phases of Venus virtually proved that the Earth was not the centre of the universe.

10. Which of the following statements is generally true?

(A)   Omega Centauri was not listed in the Messier catalogue because it had not formed yet at the time of the catalogue's publication.

(B)   Uranus was first discovered and recognised by Galileo Galilei using a telescope in 1640.

(C)   The ancient Chinese came up with 25 solar terms in a year to track the progress of the Sun every 15 degrees as it moves across the celestial sphere.

(D)   The Newtonian telescope using mirrors was invented before refractors due to the complexity of glass-making at that time.

(E)   **None of the above statements are generally true.**

Solution:

A Omega Centauri was not listed because it was located too far south.

B Uranus was first discovered and recognized by William Herschel.

C There were 24 solar terms, a full circle is 360 degrees and hence only has space for 24 divisions at 15 degrees each.

D The refractor was invented before the reflector.

11. Tom has bought a new Dobsonian Telescope with the specifications below. He is using a 1.25-inch 25mm Plössl eyepiece with an apparent field of view of 52 degrees. What is his true field of view?

Aperture	305 mm
Focal Length	1500 mm
Focal Ratio	$f/4.9$

(A)   0.41°

(B)   1.08°

(C)   **0.87°**

(D)   250°

(E)   2.08°

Solution:

The magnification of the set-up is derived by dividing the telescope focal length by the eyepiece's focal length

$$\frac{1500\text{mm}}{25\text{mm}} = 60\times$$

The apparent field of view decreases by a factor equal to the magnification to give the true field of view

$$\frac{52°}{60} = 0.867°$$

12. If you stand on the Moon and Earth gaze, what would you observe?

(A)   The Earth rises and sets every 12 hours.

(B)   The Earth looks as big from the Moon as the Moon looks from the Earth.

(C)   Total solar eclipses on the moon make the Earth appear red, just like the Moon does during total lunar eclipses on Earth.

(D)   **The Earth's geographical features will change over the course of a lunar day.**

(E)   None of the above are correct.

> **Solution:**
>
> A The Earth rotates on its axis faster than the moon does. Hence, it would not rise or set but will move around the sky slightly.
>
> B The Earth would look bigger.
>
> C The frequency of solar eclipses as seen on the Moon is roughly equivalent to the frequency of lunar eclipses as seen on Earth.
>
> D The Earth rotates its axis faster than the moon does. Hence, there is no "dark-side" of the earth as the moon has.

13. Which of the following statements about the Hubble tuning fork is true?

(A)   It shows the evolutionary sequence of galaxies from elliptical galaxies to lenticular galaxies to spiral galaxies.

(B)   All galaxies can be classified into their types using the Hubble tuning fork.

(C)   It tells us the different types of nebulae and galaxies.

(D)   **S0, also known as a lenticular galaxy, appears round but is actually flat like a disk.**

(E)   The Milky Way is classified as a spiral galaxy on the Hubble tuning fork.

> **Solution:**
>
> A False. The Hubble tuning fork is a classification and not the evolution of galaxies, even though in the past it is thought for galaxies to evolve from elliptical galaxies to lenticular ones to spiral ones.
>
> B False. Irregular and dwarf galaxies are not classified on the Hubble tuning fork.
>
> C False. The Hubble tuning fork is only about the classification of galaxies.
>
> D True.
>
> E False. The Milky Way is classified as a barred spiral galaxy.

14. The Moon is often cited as a potential factor for the development of life on Earth. In what manner might the Moon contribute to Earth's habitability?

    I The moon stabilises and reduces the Earth's axial precession, thereby making climate changes less extreme.

    II Life on Earth may have arrived on asteroids originating from the Moon.

    III The magnetic field of the early molten Moon shielded life on Earth from solar activity.

    IV Tidal flow generated by the Moon's gravity distributes heat and helps to mitigate extreme climates.

    (A) **IV only**

    (B) II and III only

    (C) I, III, and IV only

    (D) I and IV only

    (E) I, II, III, and IV

    > **Solution:**
    >
    > This question has been **VOIDED**.

15. Earth's atmosphere is mostly transparent to the Sun's radiation. Why then does it trap radiation re-radiated from Earth?

    (A) The greenhouse effect causes Earth's radiation to be trapped by the atmosphere.

    (B) Rayleigh scattering of light in the atmosphere scatters the solar radiation instead of absorbing it. Infrared radiation emitted by the Earth has too long a wavelength to be scattered and is absorbed.

    (C) **The wavelengths of both radiation types are different: infrared radiation emitted by the Earth is largely absorbed by the atmosphere while solar radiation, comprising of mostly visible wavelengths, is not.**

    (D) The intensity of solar radiation is too high to be absorbed directly by the atmosphere. As such, it passes right through.

    (E) None of the above are correct.

    > **Solution:**
    >
    > The atmosphere is transparent to most of the solar radiation, blocking out only the UV spectrum, allowing the mostly near-infrared and visual wavelengths of solar radiation to pass through. As the Earth absorbs the solar radiation, it heats up and radiate its own radiation too. Due to the lower temperature of the Earth, it emits radiation mostly in the infrared spectrum, which the atmosphere absorbs.

For Questions 16 and 17, please refer to the following scenario.

A moon that orbits at a distance of 1×10^9m from the surface of a planet takes 60 hours to complete one revolution. The planet has a radius of 3×10^9m.

16. What is the acceleration of the moon? (Assume the moon has a circular orbit, the gravitational force of the planet acts from its centre, and the radius of the moon is negligible)

   (A) **3.38ms^{-2}**

   (B) 7.32ms^{-2}

   (C) 8.46ms^{-2}

   (D) 9.81ms^{-2}

   (E) 10.0ms^{-2}

Solution:

Since we have the radius of the orbit as well as the orbital period, we can just use the expression for centripetal acceleration

$$a = r\omega^2$$

$$= r\left(\frac{2\pi}{T}\right)^2$$

$$= (1 \times 10^9 + 3 \times 10^9)\left(\frac{2\pi}{60 \times 3600}\right)^2$$

$$= 3.384\text{ms}^{-1}$$

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17. The moon has a mass of 6×10^{12}kg. What is the gravitational force acting on the moon?

   (A) $1.05 \times 10^{13}\text{N}$

   (B) **$2.03 \times 10^{13}\text{N}$**

   (C) $3.04 \times 10^{14}\text{N}$

   (D) $3.14 \times 10^{14}\text{N}$

   (E) $2.30 \times 10^{15}\text{N}$

Solution:

Since we have calculated the centripetal acceleration from the previous question, we can just use Newton's second law:

$$F = ma$$

$$= (6 \times 10^{12})(3.384)$$

$$= 2.03 \times 10^{13}\text{N}$$

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18. Claudia is at a latitude of 15°S. She wants to observe the Geminids meteor shower. She checked that the declination of the Geminids meteor shower is about +32°. Assuming she has an unobstructed view of the horizon, she is...

  (A)   **able to see the meteor shower as it will be above the horizon.**

  (B)   not able to see the meteor shower as it will be below the horizon.

  (C)   not able to see the meteor shower if she is standing on ground level, but would be able to see it if she is elevated by 10 meters.

  (D)   able to see the meteor shower as the meteor shower can be seen from anywhere on Earth.

  (E)   None of the above

  > **Solution:**
  >
  > Only objects with a declination of above +75° will not be visible. Meteors can be seen even if the radiant is below ground, but this is not very significant once we get beyond 1° to 2°. It would require the meteor to arc significantly.

19. Using the information in the formula booklet or otherwise, calculate the length of an average lunar day (from local lunar sunrise to sunset).

  (A)   27.32 days

  (B)   29.53 days

  (C)   **14.77 days**

  (D)   13.66 days

  (E)   None of the above

  > **Solution:**
  >
  > 1 lunar day is simply half of the synodic period (half a lunar month).

20. The Drake equation, developed by Dr. Frank Drake in 1961, attempts to quantify the number of civilisations in our galaxy capable of communicating with us. Why is the Drake equation not a useful quantity for us to determine if intelligent aliens exist?

    (A)   Dr. Frank Drake's background is in biology and he is not qualified to talk about astronomy.

    (B)   **The term for the fraction of habitable planets that develops life has a high uncertainty since there exists observational bias in using our planet as a model.**

    (C)   The Drake equation was created as a tool to popularise the Search for Extra-Terrestrial Intelligence (SETI) and was never meant to be used scientifically.

    (D)   The equation fails to account for the fact that intelligent aliens would not want to communicate with humans whom they consider a primitive species.

    (E)   Many terms in the Drake equation have been found to be invalid since we have discovered exoplanets such as hot Jupiters that do not conform to the assumption that life can exist outside our solar system.

    > **Solution:**
    >
    > The fraction of habitable planets that develops life is highly controversial as it ranges from 1 in a trillion to 1. This gives the Rare Earth hypothesis (that we are alone in the universe) and a highly optimistic view that there are millions of communicable civilizations respectively.

21. Which of the following combinations will give the widest true field of view?

    (A)   100mm $f/5$ refractor telescope with a 5mm eyepiece at 70° AFOV.

    (B)   8″ $f/5$ Newtonian telescope with a 12mm eyepiece at 54° AFOV.

    (C)   **6″ $f/8$ Ritchey-Chrétien telescope with a 20mm eyepiece at 48° AFOV.**

    (D)   80mm $f/7$ refractor telescope with a 5mm eyepiece at 70° AFOV.

    (E)   10″ $f/4$ Dall-Kirkham telescope with a 12mm eyepiece at 54° AFOV.

    > **Solution:**
    >
    > To find the magnification, we can use
    > $$\text{Magnification} = \frac{\text{Aperture} \times \text{FocalRatio}}{\text{EyePieceFocalLength}}$$
    > We can then take
    > $$\text{TrueFOV} = \frac{\text{ApparentFOV}}{\text{Magnification}}$$
    > These give the following True FOVs in degrees:
    >
    > A 0.70
    >
    > B 0.64
    >
    > C 0.79
    >
    > D 0.625
    >
    > E 0.64

22. Under what circumstances will the tip of the shadow of a stick in Singapore, over the period of a day, draw a straight line on the ground?

(A)   At the winter solstice.

(B)   At the vernal equinox.

(C)   In places at high latitudes.

(D)   Trick question. It is impossible.

(E)   **It is possible, but none of the above circumstances are correct.**

> **Solution:**
>
> This question has been **VOIDED**. The shadow of a gnomon/sundial traces out a straight line at equinox regardless of latitude or sundial positioning. There is effectively no tilt of the Earth during the equinoxes.[1]

23. On a winter evening, Aquila the Eagle is found to be setting. You are given that Altair has a right ascension of 19h 52min and a declination of $+8°55'25''$. Assuming that you are on the equator, what is the local sidereal time?

(A)   **1h 52min**

(B)   5h 8min

(C)   7h 52min

(D)   13h 52min

(E)   19h 52min

> **Solution:**
>
> Sidereal time is calculated from the hour angle + RA of a particular object, where the hour angle is the number of hours after the object has passed the meridian. In other words if 0h is the local meridian, 18h would be at the western horizon. In this case, it is given that 19h52min is at that horizon. This means that the correct local sidereal time is 1h52min.

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[1]More information is linked here.

24. Eta Carinae is one of the most luminous star systems ever discovered. Given that its absolute magnitude is -12.0 and that the Sun's absolute magnitude is $+4.83$, how many times brighter is Eta Carinae compared to the Sun?

(A)   700

(B) 4×10^5

(C) $\mathbf{5 \times 10^6}$

(D) 6×10^9

(E) 2×10^{15}

> **Solution:**
>
> We can use the formula for the relationship between Luminosity and Absolute Magnitude, that is
>
> $$\frac{L_1}{L_2} = 10^{\frac{M_2 - M_1}{2.5}}$$
>
> $$= 10^{\frac{4.83 + 12.0}{2.5}}$$
>
> $$L_1 = 5 \times 10^6 L_\odot$$

25. The following steps describe the life cycle of a Sun-like star. Arrange these steps in chronological order, from earliest to latest.

   I   Main sequence

   II   Red giant

   III   Protoplanetary nebula

   IV   Henyey track

   V   Planetary nebula

   VI   White dwarf

   VII   Brown dwarf

(A)   III, IV, I, II, V, VI, VII

(B)   III, I, II, V, VI, VII

(C)   IV, III, I, II, V, VI

(D)   IV, III, I, II, VI, VII

(E)   **None of the above orders are correct**

> **Solution:**
>
> The correct order should be III,IV,I,II,V,VI. A white dwarf does not simply become a brown dwarf. They are conceptually different.

26. Which statement correctly explains why Pluto is not classified as a planet?

Ⓐ It is too far away from the Sun.

Ⓑ It is not in orbit around the Sun.

Ⓒ It does not have sufficient mass to assume hydrostatic equilibrium.

Ⓓ It has not cleared the neighbourhood around its orbit.

Ⓔ It has no life on it.

Solution:

The International Astronomical Union (IAU) downgraded the status of Pluto to that of a dwarf planet because it did not meet the three criteria the IAU uses to define a full-sized planet, which are the following:

1. It is in orbit around the Sun.

2. It has sufficient mass to assume hydrostatic equilibrium.

3. It has "cleared the neighbourhood" around its orbit.

Pluto only meets two of these criteria, losing out on the third.

27. Which of the following reasons best explains why we can have both total and annular solar eclipses?

Ⓐ The Sun is periodically increasing and decreasing in size.

Ⓑ Atmospheric refraction on bad pollution days produces annular eclipses.

Ⓒ The Moon is gradually receding away from the Earth.

Ⓓ The Sun is slowly increasing in size.

Ⓔ The orbital path of the Moon around the Earth is elliptical.

Solution:

A The Sun does not periodically increase or decrease in brightness significantly.

B Atmospheric refraction affect the distinction between total and annular eclipses.

C This is negligible and does not explain the current observation.

D This is negligible and does not explain the current observation.

E This is the best explanation for the phenomenon.

28. Given a telescope with an aperture of 100mm and a focal length of 1600mm, when a 1.25-inch eyepiece of focal length 40mm is used, what is the effective magnification?

   (A)   20×

   (B)   **40×**

   (C)   80×

   (D)   1560×

   (E)   None of the above

   > **Solution:**
   >
   > Telescope magnification is calculated by dividing the focal length of the telescope by the focal length of the eyepiece. This yields option B.

For Questions 29 and 30, please refer to the following image.
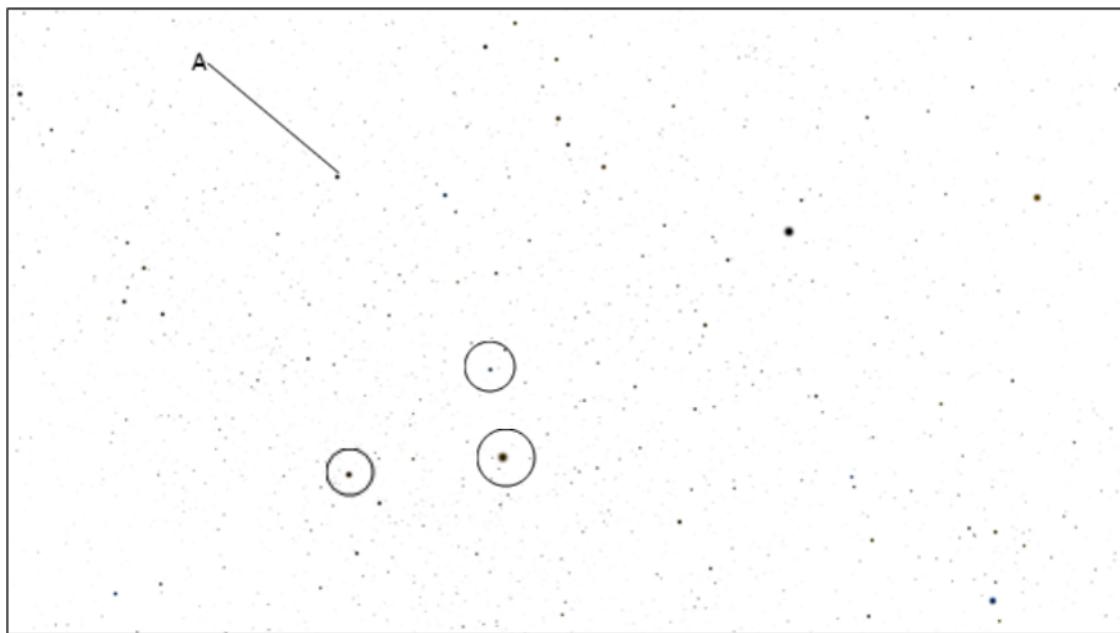
29. The three circled stars form a famous asterism in the night sky. What is this asterism?

    (A)   The tail of Leo

    (B)   Summer Triangle

    (C)   Winter Triangle

    (D)   Arrowhead of Orion

    (E)   Trick question. There is no asterism located there.

    Solution:

    There is nothing over here. This is part of the summer triangle but it is not complete.
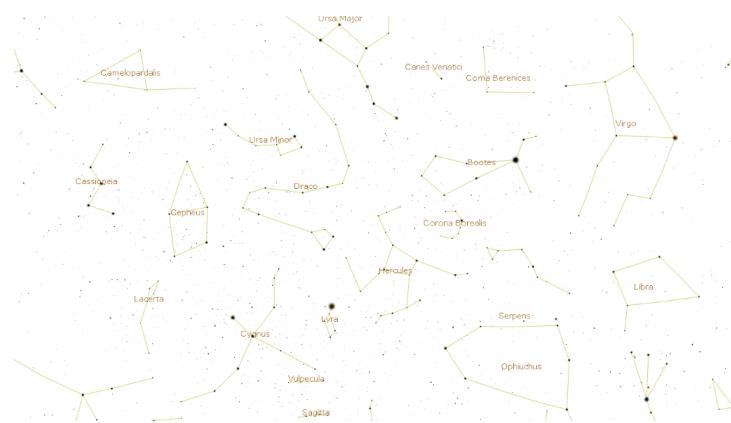
30. Name the star labelled 'A' above.

    (A) Vega

    (B) Altair

    (C) Arcturus

    (D) Spica

    (E) Polaris

    > **Solution:**
    >
    > This is Polaris. You can tell by using the Big Dipper and extrapolating. Alternatively, we know that Polaris is located in between the W of Cassiopeia and the Big Dipper. Another way would be to simply eliminate the options.

31. A deep-sky object located directly at the celestial equator with an angular diameter of $10'$ is viewed from the eyepiece of a telescope with a true field of view of $0.8°$. Object tracking on the telescope is disabled and the object is aligned at the edge of the field of view. Assuming the object moves along the diameter of the eyepiece before disappearing, calculate the time it takes for the object to drift out of view of the eyepiece.

    (A) 13 seconds

    (B) 19 seconds

    (C) 3.2 minutes

    (D) 4.8 minutes

    (E) There is not enough information to determine the time.

    > **Solution:**
    >
    > Objects on the Celestial Equator in the sky rotate once every sidereal day, that is, $360°$ in 23h56m4.1s. This gives $0.251°$/min. THe time it takes to drift out of the eyepiece is thus
    >
    > $$\frac{0.8°}{0.251°/\text{min}} = 3.19\text{min}$$

32. You see the Moon rising in the east at 9pm. Assuming you are in Singapore, what phase is it in?

    (A) Full moon

    (B) New moon

    (C) Waning gibbous

    (D) Waxing gibbous

    (E) None of the above

    > **Solution:**
    >
    > The moon rose just after sunset. As such, the moon is past full but only just.

33. The Hubble Space Telescope (HST) has a Cassegrain reflector design and employs a hyperbolic primary and secondary mirror. When the HST was first deployed, it was found that the outer perimeter of the primary mirror was polished to be too flat, a serious problem that caused its images to be flawed. What was the type and cause of the main optical aberration that was introduced?

    (A) Chromatic aberration due to different wavelengths of light being reflected at different angles.

    (B) Coma aberration where light reflected from the edges of the primary mirror is focused at the image plane closer to the optical axis compared to light reflected nearer to the centre.

    (C) Coma aberration where light reflected from the edges of the primary mirror is focused at the image plane further from the optical axis compared to light reflected nearer to the centre.

    (D) Spherical aberration where light reflected from the edges of the primary mirror are focused to a plane closer to the mirror compared to light reflected nearer to the centre.

    (E) Spherical aberration where light reflected from the edges of the primary mirror are focused at a plane further from the mirror compared to light reflected nearer to the centre.

    > **Solution:**
    >
    > For A/B/C, the HST mirror is supposed to be hyperbolic / parabolic. When it is polished too flat, the mirror becomes more spherical and hence, spherical aberration is introduced. This has nothing to do with chromatic aberration and coma aberration. For D and E, there will be negative spherical aberration since the mirror is too flat. This means the light rays are insufficiently bent, and light further from the optical axis will be focused to a longer focal distance compared to light closer to the optical axis.

34. Mercury was named after the Greek god Hermes, commonly referred to as the messenger of the gods, and is the innermost planet of the Solar System. Which of the following statements about Mercury is false?

(A) It has the largest orbital eccentricity of all the planets.

(B) **The diurnal surface temperature of Mercury varies more greatly than any other planet mainly because of its highly eccentric orbit.**

(C) A line segment joining Mercury and the Sun sweeps out an equal area for a fixed interval of time, regardless of Mercury's location with respect to the Sun.

(D) The square of Mercury's orbital period around the Sun is proportional to the cube of the semi-major axis of its orbit.

(E) Mercury has the shortest orbital period of all the planets.

> **Solution:**
>
> A True. Mercury has an orbital eccentricity of approximately 0.206.
>
> B False. The surface temperature of Mercury varies most significantly because it lackcs a significant atmosphere.
>
> C True. This is Kepler's second law.
>
> D True. This is Kepler's third law.
>
> E True. Mercury completes one orbit in approximately 88 days.

35. Which of the following characteristics of common telescope mounts is incorrect?

(A) Altazimuth – Has two motions, altitude (vertical) and azimuthal (horizontal).

(B) **Dobsonian – A variant of altazimuth and is commonly used to mount large refracting telescopes.**

(C) German equatorial – Contains two axes of rotation, right ascension and declination.

(D) Fork mount – A Wedge can be added to convert it from altazimuth to equatorial mode of operation.

(E) All the above statements are correct.

> **Solution:**
>
> Dobsonians are commonly used to mount large reflecting telescopes, not refracting ones. This is because refractors usually have the viewing port locatd below and if you were to mount it on a Dobsonian mount, you may encounter difficulties in viewing objects near the zenith.

36. Gravity assists are commonly used to slingshot spacecraft by utilising the gravitational pull of astronomical bodies. Which of the following statements is/are true?

    I A gravity assist can be used to increase or decrease the speed of a spacecraft, as well as redirect its path.

    II A practical limitation of gravitational assists using planets is atmospheric drag, where the energy lost due to drag is greater than the energy gained from the planet's gravity.

    III Assuming no atmospheric drag, the total sum of kinetic energy of the spacecraft and astronomical body remains constant.

    IV Gravitational assists using the Sun are feasible but depend solely on the spacecraft's ability to resist the Sun's heat.

    (A)   I only

    (B)   I and III only

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

    (D)   I, III, and IV only

    (E)   I, II, III, and IV

    Solution:

    I True. The direction and kinetic energy of a spacecraft can be altered depending on the trajectory of its path.

    II True. Kinetic energy will be lost through friction with the atmosphere.

    III True. The sum of kinetic energies remain constant, similar to the case of an elastic collision.

    IV False. Gravitational assists using the Sun is not possible because the Sun is stationary relative to the solar system and gravitational assists involve using the relative motions of astronomical bodies. The mechanism involved here is the Oberth Maneuver.

37. Filters are often used in practical astronomy for image enhancement, especially when imaging deep-sky objects as they appear very dim even through a telescope. When imaging an emission nebula, which color/combination of filter(s) can be used to minimise light from background sources, thus allowing the nebula to stand out better?

   (A) Red filter

   (B) Clear filter

   (C) Yellow filter

   (D) Stack the red filter and yellow filter on top of each other

   (E) Stack all of the above filters on top of each other

   Solution:

   An emission nebula emits light that is dominated by the H-α spectral line (657nm) of the Balmer series (ionized hydrogen emission). Hence, an emission nebula appears red. To enhance the image, one should minimize light from other background sources (non-red light) to enter the eye. Hence, one should use a red color filter to allow the nebula to stand out more.Yellow filters are generally used when trying to look at the yellow dust tails of comets and not DSOs. Stacking all of the filters listed defeats the purpose of using a color filter, which is to expose the sensor to light of a certain wavelength (color).

38. You are lost in a tropical forest at night. The crescent moon forms a sad face at you low in the sky because you have forgotten to bring a compass. Which of the following options correctly matches the moon phase and the part of the sky it is in?

   (A) Waxing, east

   (B) Waxing, west

   (C) Waning, east

   (D) Waning, west

   (E) None of the above

   Solution:

   A crescent moon implies the moon is close to the sun, so it is not possible for the lit side to be pointed upwards while the sun is below the horizon.

39. Collimation is the process of aligning all components in a telescope to bring light to its best focus. Generally, which of the following telescopes require frequent collimation?

    I Newtonian reflector

    II Schmidt-Newtonian

    III Schmidt-Cassegrain

    IV Keplerian refractor

    V Galilean refractor

    VI Ritchey–Chrétien

(A)   I only

(B)   I and II only

(C)   I, II, III and V only

(D)   I, III, and VI only

(E)   **None of the above combinations are correct**

Solution:

I, II, III and VI all require collimation of some sort before use. Generally, all telescopes do need to be collimated. However, refractors usually have their lens locked in. As such, it is hard to go out of collimation. Alternatively, it is very hard to do so even if it is because you would have to open it to do it. All telescoes listed are real telescope types. Ritchey-Chrétien is in the telescope type used in the HST.

For Questions 40 to 43, refer to the information below.

The latitude of the location is 60°N. Questions 40 to 43 refer to the same location, but may not refer to the sky on the same day/night.

Object/Star	Right Ascension	Declination	Apparent Magnitude
Butterfly Cluster (M6)	17h 41 m 45s	−32°15′50″	4.20
Trifid Nebula (M20)	18h 04m 01s	−22°58′15″	6.23
Wild Duck Cluster (M11)	18h 52m 15s	−6°14′37″	6.30
Ring Nebula (M57)	18h 54m 23s	+33°03′24″	8.80
Albireo	19h 31m 35s	+28°00′21″	3.35
Arcturus	14h 16m 39s	+19°04′06″	0.15
Rasalhague	17h 34m 56s	+12°32′41.8″	2.05
M3	13h 42m 12s	+28°16′03″	6.20

40. Which object/star cannot be seen at this location at any time of the year?

   (A) Butterfly Cluster (M6)

   (B) Ring Nebula (M57)

   (C) Wild Duck Cluster (M11)

   (D) Albireo

   (E) Trifid Nebula (M20)

   > **Solution:**
   >
   > You cannot see any object below −30° declination.

41. Which object below cannot be seen on the night of the vernal equinox at midnight?

   (A) M3

   (B) Rasalhague

   (C) Wild Duck Cluster (M11)

   (D) All objects above can be seen

   (E) All objects above cannot be seen

   > **Solution:**
   >
   > At midnight of the Vernal Equinox, the meridian is 12h. As such, any object within 6h to 18h will not be able to be seen. That is apart from those that are circumpolar.

42. If M3 is currently at the local meridian, in how many hours will Albireo set?

$\textcircled{A}$ 6hrs

$\textcircled{B}$ 8hrs

$\textcircled{C}$ 10hrs

$\textcircled{D}$ **12hrs**

$\textcircled{E}$ 14hrs

> **Solution:**
>
> If M3 is at the local Meridian, then Albeiro would be just rising. As such, it will set in 12 hours.

43. Which object will be closest to the zenith when it culminates on the local meridian?

$\textcircled{A}$ Butterfly Cluster (M6)

$\textcircled{B}$ **Ring Nebula (M57)**

$\textcircled{C}$ Wild Duck Cluster (M11)

$\textcircled{D}$ Albireo

$\textcircled{E}$ Trifid Nebula (M20)

> **Solution:**
>
> We look for the item with the declination is the closest to $+60°$, which is local zenith at that location.

44. A person with a mass of 60kg stands on the surface of a planet that has a mass of 6.16×10^{24}kg and radius of 5.4×10^6m. Calculate the gravitational force acting on the person due to the planet, as well as the gravitational force acting on the planet due to the person.

(A) 820N, 820N

(B) 820N, 845N

(C) **845N, 845N**

(D) 845N, 820N

(E) **None of the above are correct**

> **Solution:**
>
> To calculate the force, we can just use
>
> $$F = \frac{GM_{\text{person}}M_{\text{planet}}}{R^2_{\text{planet}}}$$
>
> $$= \frac{(6.67 \times 10^{-11})(6.16 \times 10^{24})(60)}{(5.4 \times 10^6)^2}$$
>
> $$= 845\text{N}$$
>
> By Newton's Third Law, the magnitude of the gravitational force acting on the person due to the planet and the magnitude of the gravitational force acting on the planet due to the person must be the same. This leaves us with C.
>
> If more exact numbers from the formula booklet are used for the constants, the calculated value would be 845.9N, which rounds off to give 846N. Thus, option E has also been accepted.

45. Which of the following statements about the midnight sun is false?

(A) The midnight sun lasts for 6 months for locations near the celestial poles.

(B) The midnight sun can be seen outside the Arctic Circle and the Antarctic Circle, due to atmospheric refraction of the sun below the horizon.

(C) At the north and south celestial poles, the Sun only rises and sets once a year on the equinoxes.

(D) **On the winter solstice at the north celestial pole, the Sun will stop moving north, change direction, and start to move south.**

(E) At the south celestial pole, the midnight sun can be seen longer than September 23 to March 21 due to atmospheric refraction of the Sun below the horizon.

> **Solution:**
>
> The Sun cannot be seen on the winter solstive. The Sun will also stop moving south, not north on that date.

46. Which of the below practical astronomy tips for use in Singapore is correct?

    (A) You should proceed to stargaze when the Moon is full.

    (B) You should align your mount to the north by using a polar scope and finding Polaris.

    (C) You should balance the mount before you mount the telescope.

    (D) **You should load the counterweight before loading anything else onto the mount.**

    (E) None of the above tips make sense.

> **Solution:**
>
> A False. The full moon will make it too bright to observe many dimmer objects.
>
> B False. You are likely unable to see Polaris in Singapore because we are very near the celestial equator. A compass would do.
>
> C False. You should only balance the mount after you have mounted the telescope as well as the telescope accessories.
>
> D True.

47. Which of the following factors are not considered when calculating the orbital speed of a satellite?

    (A) Gravitational constant

    (B) Mass of the parent body

    (C) **Mass of the satellite**

    (D) Orbital radius/semi-major axis of the satellite around the parent body

    (E) All of the above are considered

> **Solution:**
>
> The orbital speed is given by
> $$v = \sqrt{\frac{GM}{r}}$$
> where G is the gravitational constant, M is the mass of the parent body and r is the orbital radius / semi-major axis of the satellite around the parent body.

48. Europa is the second inner-most Galilean moon of Jupiter. It is seen as a possible candidate for extra-terrestrial life due to the conditions it experiences. Which of the following observations of Europa is/are significant in determining if it can possibly host life?

    I A subsurface ocean is hypothesised to exist below Europa's surface.

    II Europa is located outside the circumstellar habitable zone of the solar system.

    III Tidal heating exists due to the gravitational interaction between Jupiter and Europa.

    (A) I only

    (B) I and II only

    (C) **I and III only**

    (D) I, II, and III

    (E) None of the above

    Solution:

    I This is significant. Liquid water is an ideal solvent for complex organisms such as cells.

    II This is insignificant. Extremophiles can still exist in hostile conditions even if the celestial body is not within the habitable zone.

    III This is significant. The tidal heating is dissipated as heat in the core, subsurface ocean and icy crust. This source of heat is suggested to be the principal heat source to maintain Europa's liquid oceans.
    ---

49. In 1964, a weak radio signal was detected using a supersensitive horn antenna after attempting to eliminate all sources of interference. The radio waves detected were evenly spread across all parts of the sky and were subsequently attributed to the Cosmic Microwave Background Radiation (CMBR). Which of the following statements is/are true?

   I The expansion of the universe causes the temperature of the CMBR to decrease over time.

   II The discovery of the CMBR supports the steady-state model, where the density of matter in the expanding universe is constant due to the continuous creation of matter.

   III As the universe expands, the CMBR is redshifted, decreasing the wavelength of the radiation over time.

   (A) **I only**

   (B) I and II only

   (C) I and III only

   (D) I, II, and III

   (E) None of the above

   > **Solution:**
   >
   >   I True. As the universe expands, the CMBR photons are redshifted and their energy decreases, causing the temperature to decrease.
   >
   >   II False. The CMBR refutes the steady-state model since the observed spectrum of the CMBR was a thermal, black body spectrum, a result that the steady state model was unable to reproduce.
   >
   > III False. As the universe expands, the CMBR is redshifted. However, a redshift corresponds to an increase in the wavelength of radiation, not a decrease.

50. When studying the stellar spectrum of the binary Delta Orionis, Johannes Hartman realised the calcium absorption lines did not share the same periodic displacements as absorption lines of other similar stars. What did this observation lend evidence to?

   (A) Presence of a third component in the Delta Orionis star system.

   (B) The presence of atmospheric calcium in Earth's upper atmosphere.

   (C) **The presence of interstellar gas.**

   (D) The use of calcium fluoride in coating mirrors was not suitable for spectroscopy.

   (E) Hartman made a mistake somewhere somehow.

   > **Solution:**
   >
   > A This would not result in the effect.
   >
   > B This is too negligble.
   >
   > C Interstellar gas causes this to happen.
   >
   > D This is too negligble.