NSEA Astronomy

Past Year Questions

Contents

2025

Single Correct Option (SCQ)

2. Gravity on the surface of Ganymede, a satellite of Jupiter, is $\left(\frac{1}{7^{\text{th}}}\right)$ of that on the Earth, while the gravity on the surface of the Moon is $\left(\frac{1}{6^{\text{th}}}\right)$ of that on the Earth. Two identical pendulums are taken one on Ganymede and the other on the Moon. The two pendulums start oscillating together, after how many oscillations on Moon will they come again in the same phase with approximately 1% uncertainty?

   (a) 24
   (b) 25
   (c) 26
   (d) 27

3. Consider two telescopes having equal apertures of 400 mm. One has a focal ratio of $\frac{f}{5}$, the other has the focal ratio of $\frac{f}{10}$. What is the relation between their focal lengths?

   (a) Focal length of the telescope with $\frac{f}{5}$ ratio is twice as compared to the focal length of telescope with $\frac{f}{10}$ ratio.
   (b) Focal length of the telescope with $\frac{f}{10}$ ratio is twice as compared to the focal length of telescope with $\frac{f}{5}$ ratio.
   (c) Focal length of the telescope with $\frac{f}{10}$ ratio is four times smaller as compared to the focal length of telescope with $\frac{f}{5}$ ratio.
   (d) Focal lengths of both telescopes are the same.

4. Statement I: The radius vector of a planet sweeps equal area in equal time while revolving around the Sun.
   Statement II: Gravitational force between the Sun and the planet is along the line joining the two.

   (a) Both the Statements are true, and Statement II is correct reason of Statement I.
   (b) Both the Statements are true, but Statement II is not the correct reason of Statement I.
   (c) The Statement I is true and the Statement II is false.
   (d) The Statement I is false and the Statement II is true.

33. It has been four hours since Regulus (10h 08m, $+11^\circ 58'$) has crossed the local meridian at Mumbai ($19^\circ 2' 11.11''\text{N}, 72^\circ 51' 34.09''\text{E}$). Which of the following stars will be closest to the meridian now?

   (a) Arcturus (14h 16m 50.74s, $19^\circ 02' 8''$)
   (b) Sirius (6h 46m 15.1s, $-16^\circ 44'.6''$)
   (c) Betelgeuse (5h 56m 31.86s, $19^\circ 02' 8''$)
   (d) Spica (13h 26m 32.96s, $-11^\circ 17' 44.7''$)

34. A star has an apparent magnitude of 10, and an Absolute magnitude of 10. How many parsecs away from the Earth is it?

   (a) 100

(b) 10

(c) 1

(d) 0.1

35. Which of the following statement or statements about stars are true?

(a) Among all one solar mass stars, the one with the largest radius is also the hottest.

(b) Type I supernovae are characterized by the absence of Hydrogen in the spectrum.

(c) Cooler stars show less absorption lines in their spectra.

(d) The stars are spectrally classified as O, B, A, F, G, K, M; with O type stars showing dense hydrogen line while M type stars having very less hydrogen lines.

36. As seen from Earth, angular separation between Proxima Centauri and Alpha Centauri is 2.2°. What is the physical separation between the two stars?

(a) 4.25 light years

(b) 0.16 light years

(c) 2.2 light years

(d) 0.33 light years

37. Two stars in a binary system are separated by 3.0 AU and have mass ratio of $2:1$. Their orbital period is 6.0 years. What are the masses of the stars in terms of solar mass?

(a) $2.0, 1.0$

(b) $0.50, 0.25$

(c) $2.25, 1.125$

(d) $1.78, 0.88$

38. A comet's closest approach to Sun is at 1 AU. What is the radial component of its velocity at this position?

(a) 0 km/s

(b) 21.2 km/s

(c) 30 km/s

(d) 42.4 km/s

39. A new space station orbits the sun every four and a half years. In a particular year, it is seen on the local meridian at $1:00$ am of the 21^{st} of June, 2020. It will be again seen on the local meridian from the Earth, approximately, on:

(a) 21 June, 2024, at $1:00$ am

(b) 20 December, 2024, at $4:00$ pm

(c) 3 October, 2021, $4:00$ pm

(d) 21 March, 2021, $9:00$ pm

40. What is the advantage of an equatorial telescope mount over an alt-azimuth mount?

(a) Reduced vibrations and provides a more stable viewing platform.

(b) It allows tracking celestial objects using only one axis of motion.

(c) It eliminates the need for polar alignment before observing.

(d) It is easier to carry and transport due to its lightweight design.

41. Which of the following statements is correct about constellations?

    (a) Any star cannot belong to two constellations simultaneously.
    (b) Only the bright stars which are imagined as some figure in the sky make constellations.
    (c) Brightest star in any constellation has magnitude 1.
    (d) There are only 12 constellations along the Ecliptic belt.

42. What would be the speed of a comet, on a parabolic orbit around the sun, whose point of closest approach is 1 AU, when at a distance of 4.0 AU?

    (a) 42.1 km/s
    (b) 29.8 km/s
    (c) 21.1 km/s
    (d) 84.4 km/s

43. Globular clusters are typically found in the halo of Milky Way. In which of the following constellation, there are higher chances of seeing globular cluster?

    (a) Orion
    (b) Sagittarius
    (c) Ursa Minor
    (d) Virgo

44. Ecliptic plane makes approximately 60° with the Milky Way plane. One point of intersection lies in the constellation of Sagittarius, in which constellation does the other intersection point lie?

    (a) Aquarius
    (b) Libra
    (c) Pisces
    (d) Gemini

45. Which of the following places will have minimum duration between the two zero shadow days in a given calendar year?

    (a) Manila ($14°36' \text{ N}, 120°59' \text{ E}$)
    (b) Monteiro ($7°53'\text{S}, 37°7'\text{W}$)
    (c) Kansanshi ($12°6' \text{ S}, 26°26' \text{ W}$)
    (d) Barah ($13°42' \text{ N}, 30°22' \text{ E}$)

46. An observer from Delhi, will see the Sun on the local meridian 365 times in the year 2025. A star, located on the celestial equator, will be seen how many times on the local meridian by the same observer in 2025?

    (a) 364
    (b) 365
    (c) 366
    (d) 367

47. Considering the nuclear reactions that power the energy output of the stars, the correct statements is:

    (a) the p-p chain is the dominant process that creates He in very massive stars.

    (b) the fusion of H into He is an exothermic process.

    (c) the CNO (Carbon-Nitrogen-Oxygen) cycle results in the creation of the elements like Si, S and P following the fusion of the lighter elements.

    (d) the fusion process is replaced by the fission process in heavier stars.

48. Which of the following constellations is broken in two disjoint parts in the sky?

    (a) Draco

    (b) Ursa

    (c) Serpens

    (d) Eridanus

Multiple Correct Option (MCQ)

52. Two black bodies A and B are emitting in the approximate ratio $2 : 5$. Which of the following statements may be correct from the given information?

    (a) Body B is 20% hotter and 10% larger in diameter than body A.

    (b) Body B is 50% hotter but half in diameter than body A.

    (c) Body B is 10% hotter and 30% larger in diameter than body A.

    (d) Body B has double the temperature of A and only 40% diameter of body A.

57. The Pole star:

    (a) can be seen at night from all locations on the Earth.

    (b) will be visible during a solar eclipse from nearly the whole of the northern hemisphere.

    (c) will be visible during a solar eclipse from the equator.

    (d) can, in principle, be observed from India anytime during the day and night.

58. An observer measures the location of the Sun, moon, planets, and bright stars like Sirius, very diligently. The correct conclusions that she may reach is/are:

    (a) Planets rise and set at the same time as per the sidereal clock but not as per the solar clock for all days of the year.

    (b) The Sun rises and sets at the same time as per the solar clock and not as per the sidereal clock for all days of the year.

    (c) The stars rise and set at the same time as per the sidereal clock but not as per the solar clock for all days of the year.

    (d) The moon rises and sets at different times as per the sidereal clock and also as per the solar clock for all days of the month.

59. Which of the following stars is/are circumpolar in Warsaw $(52^\circ 14' \mathrm{N}, 21^\circ 01' \mathrm{E})$?

    (a) α Cygni $(16\mathrm{h}\ 41\mathrm{m}, +31^\circ 36')$

    (b) β Böotis $(15\mathrm{h}\ 01\mathrm{m}, +40^\circ 23')$

    (c) θ Aurigae $(5\mathrm{h}\ 59\mathrm{m}, +37^\circ 12')$

(d) γ Draconis (17h 56m, $+51°26'$)

60. Star A rises half an hour before star B and it sets half an hour after star B from a particular location. Which of the following statement(s) is/are correct?

(a) The location is on equator.

(b) The location is in southern hemisphere and star A is more south than star B.

(c) The location is in northern hemisphere and star A is more north than star B.

(d) Both stars have the same right ascension.

2024

Single Correct Option (SCQ)

1. The energy radiated per second by star A is twice that radiated per second by star B. Also the distance of star A from Earth is twice to that of star B from Earth. Which of the two stars appears brighter when seen from the Earth, and by how much?

   (a) Star A appears 2 times brighter than star B

   (b) Star B appears 2 times brighter than star A

   (c) Star B appears 4 times brighter than star A

   (d) The observed brightness of the stars A and B are equal

2. How large should the aperture of a telescope be in order to achieve a diffraction limit of 0.001 arc second for visible light of wavelength 500 nm?

   (a) 2.4 m

   (b) 12.6 m

   (c) 126 m

   (d) 24 m

3. A nearby star, Alpha Centauri, subtends a parallax angle of $0.7420''$. The distance to Alpha Centauri from us is

   (a) 1.35 pc

   (b) 13.5 pc

   (c) 0.742 pc

   (d) 7.42 pc

4. The spectral lines of two stars in an eclipsing binary system with both stars moving in circular orbits, shift back and forth with a period of 2 years, $T = 6.3 \times 10^7$ second. The lines of one star (star 1) shift twice as far as the lines of the other (star 2). Which one of the following statements is true?

   (a) Masses of star 1 and star 2 are equal

   (b) Mass of star 2 is twice the mass of star 1

   (c) Mass of star 1 is twice the mass of star 2

   (d) Nothing can be predicted about the masses of the two stars from the given data

5. The reciprocal of Hubble's constant, or $1/H_0$, tells us the age of the universe if the expansion rate has remained constant over time. How would the estimated age of the universe differ if the measured value of H_0 were 44 km/s/Mly rather than 22 km/s/Mly?

   (a) The estimated age will remain the same

   (b) Indeterminate

   (c) The estimated age will be twice the current estimated age

   (d) The estimated age will be half the current estimated age

6. If you live at latitude of 28 degrees North, what is the angle you observe between the northern horizon and North Celestial pole?

(a) 62 degrees

(b) 90 degrees

(c) 23.5 degrees

(d) 28 degrees

7. A new planet is discovered to be orbiting a star which has the same mass as our Sun in an approximately circular orbit. The planet orbits the star every 3 months. Approximately, what is the average distance of the planet from the star?

   (a) 3 AU

   (b) 0.4 AU

   (c) 0.125 AU

   (d) 1.25 AU

8. Suppose a future space station orbits the Earth in a circular geosynchronous orbit, $42,000$ kilometre from the centre of the Earth. With what speed with respect to Earth, must a spacecraft be launched from this space station so as to escape the Earth?

   (a) 11.2 km/s

   (b) 112 km/s

   (c) 4.35 km/s

   (d) 2.45 km/s

9. Planets orbiting very close to black holes show general relativistic effects; the orbits of such planets are precessing ellipses i.e. the major axis of the ellipse rotates about the occupied focus. A planet is on an elliptical orbit with semi-major axis 1.0 AU around an isolated black hole of one solar mass. A second planet is orbiting the black hole at a distance of 0.3 AU. If observations of this second planet are started when it is closest to the black hole, the minimum length of time over which observations should be carried out so that the precession rate may be ascertained with better accuracy, is a little more than

   (a) 30 days

   (b) 60 days

   (c) 75 days

   (d) 90 days

10. Spectral resolution of a grating is given by $RP = \frac{\lambda}{\delta\lambda}$ where $\delta\lambda$ is the smallest difference in wavelength between two lines that may be resolved as separate at some order after dispersion by the grating. In the binary system consisting of a star and a planet, both the masses orbit around the common centre of mass. The orbital speed of the star will be extremely small due to its comparatively very large mass. The Doppler shift due to this orbital motion will also be extremely small. Doppler spectroscopy is a technique used to detect and estimate the orbital speeds of stars, induced by the presence of exoplanets around them. With what accuracy can the recession speed of a star be determined by simple use of a high resolution spectrograph with $RP = 1,00,000$ observing a spectral line at 0.3 micron?

    (a) 3.0 m/s

    (b) 30.0 m/s

    (c) 3.0 km/s

(d) 30.0 km/s

11. Fermions (half-integer spin particles) obey the Pauli Exclusion Principle which says that no two fermions can have all physical characteristics (like position, momentum, spin, charge, electron number, muon number etc....) the same. As per the uncertainty principle position and momentum can be simultaneously measured only to a precision that satisfies the relation $\Delta r\ \Delta p_x \geq \frac{\hbar}{2}$. So a 'cell' in phase space (position-momentum space) of size $(\frac{\hbar}{2})^3$ can contain only a pair of any one type of neutrino (for example electron neutrino) of opposing spin and all other quantum numbers the same. Consider a spherical dwarf galaxy of a total mass M and radius R consisting of a large amount of dark matter and very little ordinary matter. Suppose dark matter consists of n_f different types of neutrinos all having the same mass m equivalent to 1 eV. Given that the escape speed from the galaxy $v_{esc} = \sqrt{\frac{2GM}{R}}$, a limit may be put on n_f by the relation.

(a) $\frac{(\frac{4\pi}{3})^2(mv_mR)^3}{(\frac{\hbar}{2})^3} \times 2n_f \times m < M$

(b) $\frac{(\frac{4\pi}{3})(mv_mR)^3}{(\frac{\hbar}{2})^3} \times n_f \times m < M$

(c) $\frac{(\frac{4\pi}{3})^2(mv_mR)^3}{(\frac{\hbar}{2})^3} \times n_f \times m > M$

(d) No such limit may be extracted

12. Inverse Compton scattering is the scattering of low energy photon by high energy ultra-relativistic charged particle. The photon gains energy and the charged particle loses energy. The frequency of the photon gets multiplied by a factor equal to the square of the Lorentz factor of the ultra-relativistic particle. The low energy photons of the Cosmic Microwave Background (CMB) can be scattered by ultra-relativistic electrons in radio relics in galaxy clusters. If the microwave photons of the CMB (wavelength around 10 cm) get scattered, on the average, into soft X-ray region (wavelength $\sim$ 1 nanometre), the Lorentz factor for the electrons involved is

(a) $\sim 10^4$

(b) $\sim 10^8$

(c) $\sim 2.73 \times 10^9$

(d) ~ 2.73

13. The Saha ionization formula gives the ratio of the number of $(n+1)$ times ionized ions of an element per unit volume to the number of n times ionized ions of the same element in the same volume in a plasma. Normal stars show absorption spectra due to atoms/ions/molecules of the atmosphere of the star in a lower energy state absorbing photons of appropriate energy, from the continuum radiation emitted by the photosphere, to go into a higher energy state. Given the Saha ionization formula as $log\frac{n_{i+1}}{n_i} = -0.1761 - log\ P_e + log\frac{U_{i+1}(T)}{U_i(T)} + 2.5\ log\ T - \frac{5040E_i}{T}$ where, n_{i+1} is the number density of $(i+1)$ times ionized ions, n_i is the number density of i times ionized ions, P_e is the electron pressure, $U_i(T)$ is the partition function and E_i is the ionization energy of the i times ionized ion. The ionization energy of hydrogen 13.54 eV, of first ionization of helium = 24.48 eV and of second ionization of helium 54.17 eV. As the temperature of photosphere decreases from $\sim 50,000$ K, in the spectrum

(a) Strength of lines of ionized helium and hydrogen will decrease together

(b) Lines of hydrogen will decrease in strength, helium will increase

(c) Lines of ionized helium will decrease in strength, of helium increase

(d) Strength of hydrogen lines will decrease, ionized helium will increase

14. The observed Doppler shift of spectral lines of galaxies is used to determine their velocity of recession from us using the formula $v = cz$ where $z = \frac{\delta\lambda}{\lambda}$ (this may then be used in the Hubble relation $v = HD$ to determine the distance to the galaxy). Spectrometry is expensive since the received light is highly dispersed and only a small number of photons are available in small frequency ranges and so observations have to be integrated over long hours to capture the spectrum. In photometry, light transmitted through various filters (which transmit light in a small band of wavelengths centred on given wavelengths) is measured. Photometry is much cheaper and faster. The hydrogen surrounding galaxies absorb light with wavelength below $\sim$ 100 nm. Hence the observed brightness of the galaxy will drop drastically below this wavelength of emission. A galaxy was imaged through the u, g, r, i, z filters in the Sloan Digital Sky Survey. The pivot wavelengths of these filters are $354, 477, 623, 763$, and 913 nm respectively. A galaxy is visible when imaged through the last three filters. The galaxy 'drops out' and is not visible through the other filters. The redshift of the galaxy as determined by this 'dropout method' lies between

(a) 4.77 and 6.23
(b) 5.77 and 7.23
(c) 3.77 and 5.23
(d) 5.23 and 6.63

15. A liquid column of height 1.0 cm and having density 0.8 g/cc, is in a closed container on a horizontal surface inside Chandrayaan-3 Lander on the surface of Moon. The temperature where the landing took place was around 50°C. What is the hydrostatic pressure on the bottom of the container? Mass of the Moon=7×10^{22} kg and radius of the Moon=1750 km.

(a) 12.2 N/m^2
(b) 98.0 N/m^2
(c) 78.4 N/m^2
(d) 1.22 N/m^2

16. Cerenkov radiation may be defined as "electromagnetic radiation emitted when a charged particle (such as an electron) passes through a dielectric medium (such as distilled water) at a speed greater than the phase velocity (speed of propagation of a wave front in a medium) of light in that medium". Which of the following cosmic ray particles is likely to be detectable by the recording of the Cerenkov radiation emitted by it in its passage through the Earth's atmosphere. The lower atmosphere near the Earth has a refractive index of 1.002.

(a) A 13 GeV proton
(b) A 13 MeV electron
(c) A 25 MeV proton
(d) A 0.51 MeV electron

18. The Mercator projection maps the surface of the globe (excluding latitudes close to the two poles) onto a cylinder whose axis coincides with the rotation axis of the globe. The cylinder when cut open with a straight cut parallel to its axis gives a rectangular map which preserves directions. Maps made utilizing this projection are hence used for marine navigation and also by major online street mapping services. On a map of this kind the length of the equator is 40 cm. How many kilometres on the Earth does 1 cm at 60° N latitude on this map correspond to? Assume that the earth is a perfect sphere.

(a) 866 km

(b) 1732 km

(c) 1000 km

(d) 500 km

21. Consider a planet moving on an elliptical orbit that may be represented by the equation $\frac{x^2}{9} + \frac{y^2}{5} = 1$ (in some units) with the parent star at the focus at $(-2, 0)$. The area swept by the radius vector from the focus to the planet in equal intervals of time is a constant. The ratio of the time taken to traverse the portion of the path with $x < -2$ to the time taken to traverse the portion of the path with $x > -2$ is

(a) $\frac{(\frac{\pi}{2}-A-B)}{(\frac{\pi}{2}+A+B)}$. where $A = sin^{-1}\frac{2}{3}$ and $B = \frac{2\sqrt{5}}{9}$

(b) $\frac{(\frac{\pi}{4}-\alpha-\beta)}{(\frac{\pi}{4}+\alpha+\beta)}$, where $\alpha = \frac{1}{2}sin^{-1}\frac{2}{3}$ and $\beta = \frac{5}{27}$

(c) $1 : 4$

(d) $4 : 1$

33. Auroral Kilometric Radiation occurs due to emission from charged particles moving in helical paths around planetary magnetic field lines at or around the electron gyro frequency and/or its lower harmonics. Considering the emission from relativistic particles, the emission peaks around a frequency $\sim \gamma^2 \nu_c$ where $\gamma = \frac{1}{\sqrt{(1-(\frac{v}{c})^2)}}$ is the Lorentz factor and the cyclotron frequency is $\upsilon_c = \frac{eB}{2\pi m}$. Determine the frequency of peak emission by electrons moving at one-third the speed of light near the Earth's poles. The average strength of the Earth's magnetic field (which is approximately a dipole) at its surface is 50 µTesla. It varies from about 25 µTesla to 65 µTesla over the surface.

(a) 1.78×10^{12} Hz

(b) 1.89 MHz

(c) 2×10^{12} Hz

(d) 2 MHz

44. Stars emit radiation approximately like perfectly black bodies. The amount of light energy emitted per unit time is called the luminosity of the star. Luminosity L and radius R of main sequece stars whose masses are neither too high nor too low are related to mass m of star as $L \propto m^{3.5}$ and $R \propto m^{0.8}$. The surface temperature T depends on the mass as

(a) $T \propto m^{-2.1}$

(b) $T \propto m^{0.475}$

(c) $T \propto m^{1.1}$

(d) $T \propto m^{1.275}$

Multiple Correct Option (MCQ)

49. A spectrometer can be used for

(a) determining the wavelength of different lines seen in the spectrum

(b) determining the extent to which specific spectral lines are Doppler shifted

(c) determining the elements present in the atmosphere of a star

(d) ascertaining the physical properties of the outer cooler layers of a star

50. Choose all the correct statements pertaining to Earth

    (a) Winter in Southern hemisphere is longer than winter in Northern hemisphere
    (b) The Earth moves fastest in its orbit during summer in Northern hemisphere
    (c) The Earth is closest to the Sun in January
    (d) The orbit of the Earth is farthest from the Sun close to the summer solstice in the Northern hemisphere

51. A gas cloud will collapse under self-gravity if the expansive force due to gas pressure is insufficient to counter the self-gravitational force. Such collapse and condensation can lead to the formation of stars. One way of expressing the situation is to note that collapse can take place if the travel time of sound (speed of sound is $\sim$ rms speed of the gas molecules) across the cloud is more than the free fall time of the cloud under its own gravity. The condition for collapse may be specified as

    (i) The radius of the cloud $>$ Jeans length or
    (ii) The mass of the cloud $>$ Jeans mass, which works out as $\sim \frac{1000}{\sqrt{\rho}}(\frac{T}{\mu})^{3/2}$ in units of solar mass.

    Here, μ is the mean molecular mass of the particles of the cloud, ρ is the density, n is the number density i.e. the number of particles per cc and T is the temperature of the cloud. Which of the following interstellar molecular hydrogen clouds are unstable to collapse?

    (a) Giant molecular cloud of mass 10^4 solar masses, with $n = 100$ per cc and $T = 20$ K
    (b) Molecular cloud core of mass 10 solar masses, with $n = 10^5$ per cc and $T = 10$ K
    (c) Molecular cloud core of mass equal to 1 solar mass, radius 0.001 pc and $T = 10$ K
    (d) A molecular cloud core of radius 10 pc, temperature 10 K with $n = 10^4$ per cc

52. Consider a spherical satellite of mass m and radius r, held intact by its own gravity, moving in a circular orbit around a planet of mass M and radius R. Consider the following possible critical distance d_R (say), between the planet and the satellite. When the distance d is less than d_R the tidal force on the satellite, which is stretching the satellite along the line from the planet to the satellite, is greater than the self-gravitational force holding the satellite together. Hence if the planet-satellite separation d becomes less than d_R, the satellite disintegrates. Now consider the rotating reference frame in which both the planet and the satellite are stationary with respect to each other. In this frame, at the side of the satellite that is closest to the planet, the tidal acceleration towards the planet is given by $a_{tidal} = \frac{2GMr}{d^3}$. The magnitude of the acceleration due to self-gravity of the satellite is $a_{self} = \frac{Gm}{r^2}$. The most appropriate value of d_R may be obtained as

    (a) $d_R = R\left(\frac{2\rho_M}{\rho_m}\right)^{1/3}$
    (b) $d_R = R\left(\frac{\rho_M}{\rho_m}\right)^{1/3}$
    (c) $d_R = r\left(\frac{2M}{m}\right)^{1/3}$
    (d) $d_R = R\left(\frac{2\rho_M}{\rho_m}\right)^{1/2}$

53. Calculus was invented by Newton to solve the equations that came up when he examined motion under a central force such as gravity. The force of gravity is the controlling force underlying the laws of Kepler. The possible solutions to the equation were obtained as conic sections. Which of the following is/are possible solutions (x, y, t, r, θ are standard coordinates; A, B, k and K are constants) to the Kepler problem?

(a) $x(t) = A\cos kt;\ y(t) = B\sin kt$

(b) $r(t) = k;\ \theta(t) = Kt \pmod{2\pi}$

(c) $x(t) = A\sec\theta;\ y(t) = B\tan\theta$

(d) $\frac{x-2}{2} = \frac{y-3}{3} = \frac{z-4}{4}$

59. Two bodies are moving under their mutual gravitational force in circular orbits. Their mass ratio is $2:5$. The ratio of their

    (a) Speeds of the two masses will be in ratio of $5:2$

    (b) Angular speeds around CoM will be in ration of $4:25$

    (c) Angular momenta about the CoM will be $1:1$

    (d) Kinetic energies will be $5:2$

60. Assume that the Moon's orbit around the Earth is an almost circular ellipse and that neither its orbit nor its rotation axis precesses. From the Earth we can see more than 50% of the surface of the Moon because

    (a) rotation period and revolution period of the Moon are not equal

    (b) the Moon's speed of revolution increases and decreases along the elliptical orbit

    (c) inclination of the Moon's orbit with the ecliptic plane makes the Moon alternately show more northern or more southern part

    (d) other side of the Moon is also visible sometimes

2024 Delhi NCR

Single Correct Option (SCQ)

2. For a binary star system with two identical stars,

   (a) the stars are always at the same distance from each other.

   (b) Doppler effects of both cancel out each other resulting in a normal spectrum.

   (c) the inclination of the circular orbit with respect to observer does not affect the observed orbital parameters.

   (d) Kepler's law for orbital periods is always applicable.

3. A double star is a system of two stars of masses m and $2m$, rotating about their centre of mass only under their mutual gravitational attraction. If r is the separation between these two stars then their time period of rotation about their centre of mass is proportional is r^x and m^y, where x and y are constants. Determine the value of x and y.

   (a) $x = 3$, $y = -1$

   (b) $x = \frac{3}{2}$, $y = -\frac{1}{2}$

   (c) $x = 2$, $y = 2$

   (d) $x = 1$, $y = 1$

10. A reflector telescope has a spherical mirror of focal length 750 mm. What should be the maximum focal length of an eyepiece so that a normal human eye can just resolve a binary with separation 3 arc second?

    (a) 9 mm

    (b) 25 mm

    (c) 32 mm

    (d) 40 mm

13. A satellite is in a circular LEO (low earth orbit) at a distance of 1000 km from the surface of the earth with velocity v. Its rockets are now fired, and it is imparted an additional velocity v directed towards the earth in negligible time. What can be said about the new orbit of the satellite?

    (a) The satellite will continue to remain a circular orbit.

    (b) The satellite will follow a spiral path and fall back to earth.

    (c) The satellite will move along a parabolic path.

    (d) The satellite will orbit the earth in an elliptical path.

14. Voyager 1 is currently 166 AU away from Earth. A signal was received from Voyager 1 and it was replied instantaneously. After how many hours will the reply reach to Voyager 1 after the transmission by Voyager 1?

    (a) 11.5 hours

    (b) 23 hours

    (c) 46 hours

    (d) Never, as it has crossed the Heliopause boundary

15. Statement I: A satellite having an orbital period of 24 h, appears stationary as seen from the Earth's surface.
Statement II: Time period of a geostationary satellite is 24 h.

    (a) Statement I is true, statement II is true; statement II is a correct explanation for statement I.

    (b) Statement I is true, statement II is true; statement II is NOT a correct explanation for statement I.

    (c) Statement I is true; statement II is false.

    (d) Statement I is false; statement II is true.

16. If there is a total solar eclipse on 21^{st} June, what should be the approximate declination of Moon?

    (a) $0°$

    (b) $5°$

    (c) $23.5°$

    (d) $28.5°$

17. The absolute magnitude of the Sun and Sirius are $M_{\odot} = 4.8$ and $M_{sir} = 1.4$, respectively. If the Sun were replaced by Sirius in the solar system, from which planet will it appear as bright as current appearance of the Sun from the Earth?

    (a) Jupiter

    (b) Saturn

    (c) Mars

    (d) Uranus

18. Messier catalogue contains which of the following celestial objects?

    (a) asteroids

    (b) comets

    (c) galaxies

    (d) pulsars

20. A star's spectral line is observed to be shifted from 500 nm to 505 nm. What is the star's radial velocity relative to the observer?

    (a) 3×10^3 m $\cdot$ s^{-1} away from the observer.

    (b) 3×10^3 m $\cdot$ s^{-1} towards from the observer.

    (c) 3×10^6 m $\cdot$ s^{-1} away from the observer.

    (d) 3×10^6 m $\cdot$ s^{-1} towards from the observer.

31. If the Sun sets 6 pm on a particular day, what approximate time should Venus set if it is at greatest western elongation?

    (a) 9 pm

    (b) 6 pm

    (c) 6 am

    (d) 3 pm

32. Statement I: Geminid meteor shower is caused on particular days of a year.
Statement II: Every year on the same days, Gemini constellation rises at the same time.

    (a) Statement I is true, statement II is true; statement II is a correct explanation for statement I.

    (b) Statement I is true, statement II is true; statement II is NOT a correct explanation for statement I.

    (c) Statement I is true; statement II is false.

    (d) Statement I is false; statement II is true.

35. Arrange the following types of stars in order of increasing surface temperature.

    (a) Yellow dwarf, Brown dwarf, Red giant, Blue giant

    (b) Brown dwarf, Yellow dwarf, Blue giant, Red giant

    (c) Red giant, Blue giant, Yellow dwarf, Brown dwarf

    (d) Brown dwarf, Red giant, Yellow dwarf, Blue giant

36. Astronaut visiting the Mars watches the sunset from its equator. Mars is at 1.52 AU distance from the Sun. Approximately for how much duration the sunset will last?

    (a) 60 s

    (b) 80 s

    (c) 120 s

    (d) 150 s

37. Which of the following star is a part of Summer Triangle?

    (a) Betelgeuse

    (b) Sirius

    (c) Fomalhaut

    (d) Deneb

38. Approximately how much later would the moon rise as compared to the previous moonrise, if it were half the present distance?

    (a) 165 min

    (b) 90 min

    (c) 35 min

    (d) 30 min

39. The solar constant is the amount of energy received per unit area from the sun at Earth and it is about 1400 Wm^{-2}. A star has a luminosity of $1.6L_{\odot}$. This star is observed to have a flux of 24.92×10^{-14} Wm^{-2}. The distance to this star from the earth is

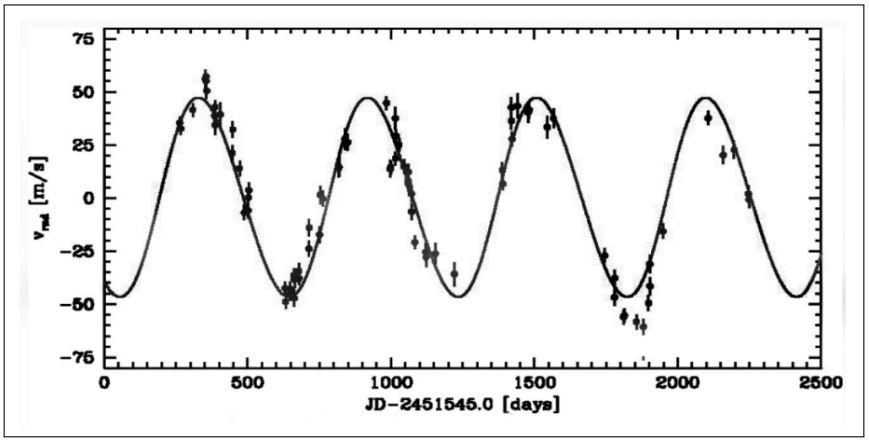
    (a) 225 pchli

    (b) 380 pc

    (c) 450 pc

    (d) 600 pc

43. When a planet orbits a star, the star appears to wobble as seen from the Earth. The wobble is measured in terms of Radial Velocity (RV). The RV plot for the star Pollux in the constellation of Gemini shows that there is at least one planet orbiting the star. If the mass of Pollux is $M_{\text{pollux}} = 1.86 M_{\odot}$ what is the average distance of the planet from the star?



(a) 0.75 AU

(b) 1.2 AU

(c) 1.5 AU

(d) 1.7 AU

44. In a visual binary system, the difference in the apparent magnitudes of the two stars is 2, the hotter component being the brighter. If the surface temperatures of the two stars are 12000 K and 6000 K, calculate the ratio of the hotter star's radius to that of the cooler star.

(a) 0.40

(b) 0.63

(c) 1.60

(d) 2.52

45. Which of the following statements about the Pole Star (Polaris) is correct?

(a) It is the brightest star in the night sky

(b) It is located exactly above the Earth's North pole

(c) It is never visible from $20°S$ latitude

(d) Polaris is the closest star to the Sun

47. From a particular location on the Earth it is observed that a star A rises a few minutes before star B. Which of the following statements is correct?

(a) Star A will rise the same duration before star B, as seen from the same location on any other day.

(b) Star A will set before star B, as seen from the same location.

(c) Star A will rise before star B, as seen from any other location on the Earth.

(d) Star A will set the same duration after star B, as seen from the same location.

Multiple Correct Option (MCQ)

50. While observing a star, by measuring the energy of the light emitted, it is possible to directly estimate the

    (a) elements and molecules present in the core of the star.

    (b) elements and molecules present in the atmosphere of the star.

    (c) luminosity of the star.

    (d) flux of the star measured by the observer.

51. The sunlit side of the moon's surface can reach a temperature of 400 K and the side opposite to the sun facing surface can reach a temperature of 140 K, while the coldest spots near the lunar poles can be at a temperature of 20 K. The moon will appear bright in the wavelengths around

    (a) $19 - 21$ μm when observed the dark side.

    (b) $500 - 550$ nm anytime.

    (c) $700 - 750$ nm when the sunlit side is observed.

    (d) 120 μm when the lunar poles are observed.

55. Which of the following parameters does the period of the Moon around the Earth depend upon? Both the Earth and the Moon are assumed to be spherical in shape.

    (a) mass of the Moon

    (b) mass of the Earth

    (c) radius of the Moon's orbit

    (d) inclination of the orbit to the equatorial plane

56. A lunar eclipse is observed on 15^{th} March in a particular year. On which of the following days the solar eclipse is possible?

    (a) 30^{th} March

    (b) 28^{th} April

    (c) 25^{th} August

    (d) 9^{th} September

57. The Schwarzschild radius of a black hole is:

    (a) The distance from its center at which gravitational force becomes infinite.

    (b) The radius of the event horizon.

    (c) The radius at which the escape velocity from the black hole equals the speed of light.

    (d) The distance at which time stops relative to a distant observer.

2023

Single Correct Option (SCQ)

1. Venus has an equatorial radius of 6052 km. The semi-major axis of its orbit around the Sun is 0.72 AU. The smallest diameter of the primary mirror/lens (objective) of an optical telescope to be used to just resolve the Venus disc during the transit of Venus is approximately

   (a) 200 cm
   (b) 20 cm
   (c) 10 cm
   (d) 0.25 cm

2. The Earth's atmosphere is transparent across the most of the optical region and _____ region of the electromagnetic spectrum. Choose the correct option to fill the blank.

   (a) ultraviolet
   (b) X-ray
   (c) some portions of the radio wave
   (d) gamma-ray

3. It is given that the pupil of the human eye is about 5 mm (in diameter). How many times more light-gathering power does a telescope with a primary mirror of diameter about 20 cm (8 inches) have than the human eye?

   (a) 4 times
   (b) 16 times
   (c) 40 times
   (d) 1600 times

4. An astronomer observes a spectral emission line from a galaxy at a wavelength of 600 nm. This same spectral line is measured in the laboratory using a stationary source and is seen to have wavelength 500 nm. The speed of the galaxy toward or away from Earth (in units of the speed of light c) is equal to

   (a) 0.2 c moving away from Earth
   (b) 0.2 c moving toward Earth
   (c) 0.9 c moving away from Earth
   (d) 1.0 c moving toward Earth

5. An astronomer observes that Polaris is 40 degrees above her northern horizon. What can you say about the longitude of her location from her observations?

   (a) nothing
   (b) that it is 40 degrees north
   (c) that it is 50 degrees south
   (d) that it is 40 degrees east

6. The spectrum of a cloud of cool gas seen against a bright background black body would show

(a) bright lines (emission spectrum) against a continuum spectral emission background
(b) a continuous spectrum
(c) dark lines (absorption lines) against a continuum emission background
(d) either bright or dark lines, depending on distance, against a continuum emission background

7. If a star has a parallax of one-eighth of a second of arc, its distance from the earth is

(a) $2,06,265$ astronomical units
(b) eight light years
(c) one-eighth parsec
(d) eight parsec

8. The elemental composition of the Sun, by mass, is about

(a) 50% metals, 50% hydrogen
(b) 71% hydrogen, 27% helium, 2% others
(c) 75% helium, 20% hydrogen, 5% others
(d) 75% carbon, 25% helium

9. Which of the following planets has essentially no atmosphere?

(a) Venus
(b) Mercury
(c) Jupiter
(d) Mars

10. Sunspots are

(a) relatively cool compared to the photosphere
(b) related to convection cells
(c) related to the Sun's electric field
(d) cyclonic storms similar to Jupiter's great red spot

11. A planet moves fastest in its orbit

(a) when it is in opposition
(b) when it is closest to the Sun
(c) the greater its mass
(d) when it is farthest from the Sun

13. In 1912 Henrietta Leavitt making observations of Cepheid variable stars in the Magellanic clouds discovered the period luminosity relation - fainter stars have shorter periods. The relation between the apparent magnitude m (the measured magnitude of a star situated at its actual distance D pc) and its absolute magnitude M (its magnitude if located at a distance of 10 pc) is given by the magnitude distance relation $m - M = 5 \log D - 5$. Here D is the distance in parsec. The distance from Milky Way to the Andromeda galaxy is 765 kpc. The observed period luminosity relation determined by observations in the K band for Cepheid variables in the Andromeda galaxy is $m_K = -3.26(\log P - 1) + 18.73$ with slope 3.26 and zero-point 18.73. For Cepheids in the Milky Way $M_K = -3.26(\log P - 1) + c$ where c is approximately

(a) -5.69
(b) 5.67
(c) $+18.73$
(d) -10.67

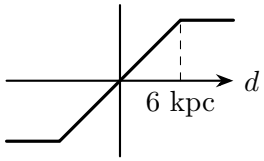
14. A Red Giant star of mass $M_{\text{Red Giant}}$ and a White Dwarf star of mass $m_{\text{White Dwarf}}$ form a binary system and are rotating in circular orbits around their common centre of mass with a period of one year. The White Dwarf is orbiting just within the photosphere of the Red Giant star. The Red Giant has a radius of 3.6 AU. An estimate for the mass of the Red Giant star in solar mass units is (note that $m_{\text{White Dwarf}} \ll M_{\text{Red Giant}}$)

    (a) 188
    (b) 94
    (c) 47
    (d) 13

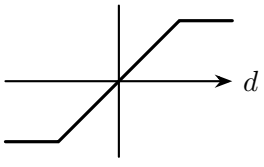
15. In spectroscopy doublet lines are closely spaced spectral lines that arise from transitions from a common fundamental state to states which differ only in their total angular momentum value. If a source of light is moving away from us the light from the source will appear shifted to the longer wavelength (red) side of the spectrum. The shift is quantified by the redshift $z = \frac{\Delta\lambda}{\lambda} = \frac{v}{c}$, where λ is the observed wavelength of the spectral line when the emitting source is at rest with respect to the observer and $\Delta\lambda$ is the observed shift in the wavelength. Hubble observed that spectral lines of galaxies not very close to us are redshifted. A galaxy is showing a redshift of $z = 0.005$. The observed wavelength separation, in nanometre, of the sodium doublet at 589 and 589.6 nm and of the potassium doublet at 766.5 and 769.9 nm in the spectrum of the galaxy are respectively

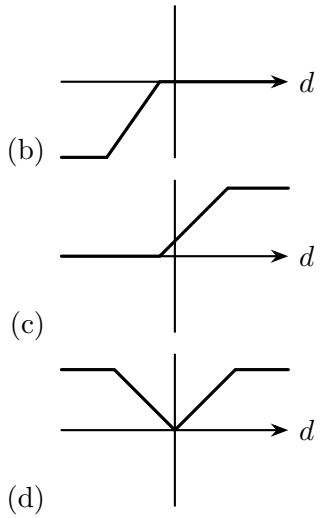
    (a) $0.603, 3.417$
    (b) $0.003, 0.017$
    (c) $38.33, 29.45$
    (d) $38.33, 38.5$

16. The rotation curve of a spiral galaxy gives the 'instantaneous' local mean tangential velocity in the plane of the galaxy of stars/gas clouds in the galaxy lying along a line through the centre of the galaxy, with respect to the distant quasars as observed from the centre of the galaxy. The following is a schematic diagram of the rotation curve of a particular spiral galaxy.



    As measured from a star orbiting at a distance $r = 8$ kilo parsec from the centre, which one of the following diagrams gives a schematic representation of the mean tangential velocity $v(d)$ with which objects at various distances d from the star, along the line joining the star to the centre of the galaxy, will appear to move with respect to the distant quasars?

(a)




28. The Lane Emden equation $\frac{1}{x^2}\frac{d}{dx}(x^2\frac{dy}{dx}) + y^n = 0$ is the governing equation for a crude model for a star. Here the star is treated as a sphere of gas with a polytropic equation of state. The differential equation admits exact solutions for polytropic index $n = 0, 1, 5$. The value of $x = x_0$ is such that $y(x_0) = 0$ defines the surface of the star. The quantity $R = \frac{x_0^3}{3|-x^2\frac{dy}{dx}|_{x_0}}$ gives $\frac{\rho_{\text{central}}}{\rho_{\text{average}}}$ the ratio of the central density to the average density for the model star. $|-x^2\frac{dy}{dx}|_{x_0}$ means the value of $-x^2\frac{dy}{dx}$ evaluated at x_0. The value of R for $n = 0, 1$ are

(a) $1, \frac{\pi}{3}$

(b) $\sqrt{6}, \frac{\pi}{3}$

(c) $\infty, \frac{\pi^2}{3}$

(d) $1, \frac{\pi^2}{3}$

33. The objective of a reflecting telescope is a concave mirror of focal length 750 mm. To double the magnification, a concave lens of focal length 20 mm is placed near the focus of the primary mirror. What should be the position of the eyepiece focus from the concave lens?

(a) 10 mm away from mirror

(b) 10 mm towards mirror

(c) 20 mm away from mirror

(d) 20 mm towards mirror

46. Formation of the iron peak elements $^{56}_{26}$Fe, $^{56}_{27}$Co and $^{56}_{28}$Ni by nuclear fusion marks the end of energy production in a star. If the mass of the iron core is greater than the Chandrasekhar mass (1.4 solar masses) the core cannot be supported by the degeneracy pressure of the electrons and will collapse to form a neutron star. Matter is crushed to nuclear densities with protons combining with electrons as $p^+ + e^- \rightarrow n + v_e$. Neutron stars whose masses are not too high are supported by neutron degeneracy pressure against gravitational collapse. The number of neutrinos released, when a neutron star of 1.4 solar masses forms, is approximately

(a) 7.77×10^{56}

(b) 1.74×10^{57}

(c) 8.68×10^{56}

(d) 8.38×10^{57}

48. The mean power received per unit area just outside Earth's atmosphere from the Sun known as the solar constant, is 1.362 kilowatt per square meter (kW/m^2). For receiving this much power per unit area at Earth, the Sun, if it is radiating like a black body, must have a surface temperature of

    (a) 5349 K

    (b) 5779 K

    (c) 5709 K

    (d) 5479 K

Multiple Correct Option (MCQ)

49. Consider the electromagnetic radiation emitted by two stars. The hotter star will

    (a) emit more radiation at all wavelengths

    (b) have a higher frequency of peak emission in its spectrum

    (c) radiate energy at more than one wavelength

    (d) exhibit a continuous spectrum

50. Because of the precession of the axis of rotation of Earth

    (a) the polaris is not always our 'pole star'

    (b) the average length of a sidereal day changes slowly with time

    (c) the declinations of the stars change slowly with time

    (d) the Vernal Equinox moves with respect to the stars

51. A planet orbits the Sun at a distance of 4.0 AU from the Sun. The orbital speed (v_o) and the time period (T) of the planet are approximately

    (a) $v_o = 7.92$ km/s

    (b) $v_o = 14.93$ km/s

    (c) $T = 4$ years

    (d) $T = 8$ years

52. The rotation period of a spherical moon about its own axis is equal to its period of revolution round its parent planet. Which of the following statements is/are true?

    (a) If the orbital and spin angular momentum vectors of the moon are parallel to each other then, the moon will always show the same portion of its surface to the planet

    (b) If the spin angular momentum vector of the moon lies in its orbital plane, then every portion of the surface of the moon may be seen from the planet

    (c) If the orbital and spin angular momentum vectors of the moon are antiparallel with respect to each other then, viewed from the planet, the moon will appear to be non-rotating

    (d) If the spin angular momentum vector of the moon lies in its orbital plane, then, viewed from the planet, the moon will appear to be rotating with a higher angular speed

57. An artificial satellite is moving in an orbit around the Earth with orbital period of 8 hours, from west to east, with its orbit making an angle of 30° with equator. An observer on the equator will see it

    (a) again after 6 hour, moving from east to west

    (b) again after about 11 hours, moving from west to east

    (c) going up to about 46.8° from the equatorial plane

    (d) going up to about 43.2° from the equatorial plane

58. A particle of mass 'm' is moving under the influence of a central force; the correct statement(s) is/are

    (a) The motion always remains constrained to be in a plane

    (b) The trajectory will always be elliptical

    (c) The total angular momentum remains constant

    (d) The torque about the force center is always zero

2023 Rajasthan

Single Correct Option (SCQ)

1. Venus has an equatorial radius of 6052 km. The semi-major axis of its orbit is 0.72 AU. The Sun has a radius of 7×10^{10} cm. A Venus transit is observed from Earth. The angular diameter of Venus, in arc seconds, when observed during the transit is

   (a) 60
   (b) 30
   (c) 0.6
   (d) 1.2

2. A telescope with a 5 meter objective mirror diameter gathers _____ times more light and can resolve objects of _____ times angular size when compared to a 1 meter telescope.

   (a) 25, $\frac{1}{5}$
   (b) 5, $\frac{1}{25}$
   (c) 25, $\frac{1}{25}$
   (d) 5, $\frac{1}{5}$

3. The location of Sun in the sky, is the farthest from the celestial equator

   (a) in winter solstice and summer solstice
   (b) in vernal equinox and autumnal equinox
   (c) they coincide at all times
   (d) at noon each day of the year

4. The Sun's core contains about 10^{26} particles per cubic centimeter at a temperature of 15 million K. On the other hand, Earth's atmosphere at sea level has a density of about 2.4×10^{19} particles per cubic centimeter and the temperature is about 300 K. If we compare the pressure at Sun's core and Earth's atmospheric pressure at sea level the ratio becomes

   (a) 2×10^3
   (b) 2×10^6
   (c) 2×10^9
   (d) 2×10^{11}

5. Sirius, the brightest star in our sky, has a measured parallax angle of $0.379''$. Its distance in parsecs is

   (a) 0.379 pc
   (b) 3.379 pc
   (c) 2.64 pc
   (d) 0.264 pc

6. The Sun's orbital velocity is 220 km/s and it is at distance of $27,000$ light-years from the centre of the galaxy. Assuming simple Keplerian motion, the mass of the Milky Way Galaxy enclosed within the Sun's orbit is about

(a) 10^{60} kg

(b) 10^{41} kg

(c) 10^{55} kg

(d) 10^{82} kg

7. A visible-light emission line of hydrogen has rest wavelength of 656.3 nm, but it appears at 662.9 nm, in the spectrum of a distant galaxy. How fast is the galaxy moving away from us?

(a) 300 km/s

(b) $\frac{1}{3000}$ km/s

(c) 3000 km/s

(d) 30000 km/s

8. The orbital period of a geosynchronous satellite is equal to Earth's rotation period. The orbital radius of such a geosynchronous satellite in a circular orbit is about

(a) $42,000$ km

(b) $35,800$ km

(c) $42,220$ km

(d) $42,180$ km

9. Assume that you are looking at this question paper using the Hubble space telescope which has an angular resolution of 0.05 arc seconds, how far away could you place the question paper and still be able to read it? You would need to resolve at least 0.2 mm to read the letters clearly.

(a) 8250 km

(b) 825 m

(c) 2850 km

(d) 82 km

10. For very hot stars, the higher the temperature, the weaker are the hydrogen lines in their emission spectra. The reason is

(a) Strong helium lines cover the hydrogen lines

(b) The hydrogen is used to form molecules

(c) Very hot stars have converted hydrogen to helium

(d) Too much of the hydrogen is ionized

11. The half circle in the sky, running precisely overhead between the celestial north pole and the celestial south pole is called the meridian. At any given location, the time between two successive meridian crossings (from east to west) of a star other than the Sun is _____ the time between two successive meridian crossings of the Sun.

(a) is always equal to

(b) is always less than

(c) is always greater than

(d) is varying compared to

12. At the end stages of the very massive stars, the final element that is formed at their core, after which no further stable fusion of elements proceeds, is

    (a) Uranium
    (b) Plutonium
    (c) Iron
    (d) Nickel

13. A polar satellite is revolving at a height of 600 km from the surface of the Earth (radius 6400 km). It passes over zenith of an observer. The angular displacement the observer will see in 10 seconds is

    (a) 0.04°
    (b) 0.62°
    (c) 3.7°
    (d) 7.2°

14. A dwarf galaxy, of mass 10^8 solar masses, is in orbit around its parent galaxy. The orbital radius is 30 kpc. From an analysis of its spectrum the dwarf galaxy's tangential speed in its orbit is found to be 300 km/s. How many times smaller is the dwarf galaxy's mass compared to the amount of mass of the parent galaxy encircled by the orbit of the dwarf galaxy?

    (a) the two masses are comparable
    (b) 10^4
    (c) 6250
    (d) 6000

15. Titius-Bode type relations give mutual relative distances of the planets around a parent star and also of the moons around a parent planet. One such function relation found for an exoplanetary system is $a_n = 0.0142\ e^{0.9975n}$. Here n is the order of the planet when the distances, of the planets of a system from their parent star are put in ascending order. For a particular exoplanetary system the distance to the fifth planet works out as 2 AU. At what distance (in AU) would the tenth planet be from the star?

    (a) 70.42
    (b) 14.19
    (c) 140.84
    (d) 281.69

16. The Sun rotates differentially, with the equatorial regions rotating faster compared to the regions closer to the poles. The equatorial regions complete one rotation in 24 days. Given the Sun's equatorial radius as 6.96×10^8 m, the observed difference in wavelength, between the two edges of the Sun along its equator, as observed in the oxygen 630 nm line is

    (a) 0.0044 nm
    (b) 0.1 nm
    (c) 0.0088 nm
    (d) 0.2 nm

31. The geographical coordinates of the peak of Mount Everest are 27°59′18″ N and 86°55′31″ E. Which of the following relations may be used to determine approximately the latitude l of an observer, who, standing on the same longitude as that of the peak of Everest and at mean sea level will see the pole star in line with the peak? [The curvature of Earth has been ignored; h stands for the height of Mount Everest from sea level, g stands for the longitude of the peak of Mount Everest and R_{Earth} stands for the radius of Earth.]

    (a) $l_{\text{Everest}} - \frac{h \tan l}{R_{\text{Earth}}} = l$

    (b) $l_{\text{Everest}} - \frac{h \cot l}{R_{\text{Earth}}} = l$

    (c) $l_{\text{Everest}} - \frac{h \sin g}{R_{\text{Earth}}} = l$

    (d) $l_{\text{Everest}} - \frac{h \cos l}{R_{\text{Earth}}} = l$

34. Effective solar power incident on the Earth is about 1350 W/m^2. A converging lens of 100 mm aperture diameter with focal length of 50 mm is used to focus sunlight on a paper, on a bright sunny day. As seen from Earth the angular diameter of the Sun is observed as $\frac{1}{2}$ degree. The estimated amount of power per unit area (in W/m^2) in the image is (assuming lens allows 85% energy to pass through it):

    (a) 1.1×10^7

    (b) 4.5×10^7

    (c) 6.0×10^7

    (d) 2.8×10^8

48. Radio signals are added to the signal generated by a local oscillator (LO) to get an Intermediate Frequency (IF) signal. The LO has a predefined frequency range from U_L MHz to U_U MHz. In the Giant Meter Wave Radio Telescope (GMRT) at Pune, radio waves ranging in frequency from $f_L = 30$ MHz to $f_U = 1660$ MHz are added to the output from a LO to produce an IF signal centred at 70 MHz. For the LO, it is good to keep the ratio $\frac{v_U}{v_L}$ as small as possible. For this, v_L and v_U should be such that

    (a) $v_L > f_L; v_U < f_U$

    (b) $v_L > f_L; v_U > f_U$

    (c) $v_L < f_L; v_U < f_U$

    (d) $v_L < f_L; v_U > f_U$

Multiple Correct Option (MCQ)

49. Consider a binary star system of star A (a hot star) and star B (a colder star) at edge-on configuration. In such a system eclipses occur when one star comes in front of the other in our line of sight. The correct statement(s) is/are

    (a) A shallower dip in the emission occurs when B is eclipsing (passing in front of) star A

    (b) A shallower dip in the emission occurs when the star A is eclipsing star B

    (c) The duration from start of eclipse to the minimum of the deeper dip in the binary emission is longer if star B has the smaller radius

    (d) The duration of the stronger/deeper dip is longer if star A has the larger radius

50. The position of a particular star in the sky with respect to an observer depends on

(a) the right ascension of the star

(b) the declination of the star

(c) latitude of the observer

(d) longitude of the observer

51. The typical spectrum of a star showing blackbody emission along with absorption lines gives information about

(a) temperature

(b) composition

(c) luminosity

(d) mass

52. A rocky exoplanet having radius r_p is on a circular orbit of radius r_o around its parent star. The parent star has luminosity L and its radius is r_s. The system is at a distance D from the observer. The planet has no atmosphere. Approximately how much area on the star's surface will the planet block from view when it comes in the line of sight to the star?

(a) $\pi r_p^2 \left(1 + \frac{2}{D}(r_o - r_s)\right)$

(b) $\pi r_s^2 \left(1 + \frac{r_o}{D}\right)$

(c) $\pi r_o r_p \left(1 + \frac{r_o - r_s}{D}\right)$

(d) $\pi r_p^2 \left(1 + \frac{r_o - r_s}{D}\right)$

55. Which of the following parameters does the period of the Moon around the Earth depend upon? Both the Earth and the Moon are assumed to be spherical in shape.

(a) mass of the Moon

(b) mass of the Earth

(c) radius of the Moon's orbit

(d) inclination of the orbit to the equatorial plane

56. A lunar eclipse is observed on 15^{th} March in a particular year. On which of the following days the solar eclipse is possible?

(a) 30^{th} March

(b) 28^{th} April

(c) 25^{th} August

(d) 9^{th} September

57. The Schwarzschild radius of a black hole is:

(a) The distance from its center at which gravitational force becomes infinite.

(b) The radius of the event horizon.

(c) The radius at which the escape velocity from the black hole equals the speed of light.

(d) The distance at which time stops relative to a distant observer.

2022

Single Correct Option (SCQ)

1. If the perigee and the apogee of the Moon's orbit are 362600 km and 405400 km respectively, then the largest diameter of the moon apparent from the earth is larger than the apparent smallest diameter by

   (a) 25%
   (b) 12%
   (c) 5%
   (d) None of these

4. If the moon takes 29.53 days to go from one New Moon to the next (i.e. go round in the sky once relative to the Sun), then it will go round once relative to the Vernal Equinox and the stars in a time

   (a) less than 29.53 days
   (b) 29.53 days
   (c) more than 29.53 days by about 1 day
   (d) more than 29.53 days by about 2 days

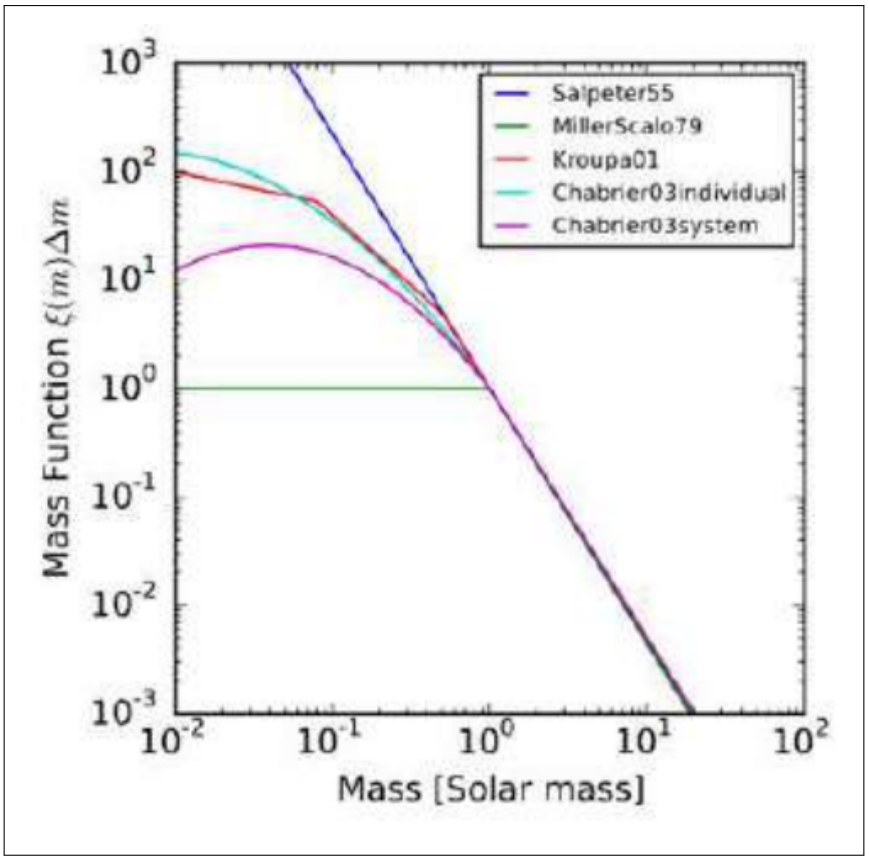
6. Consider a rocky planet with atmospheric pressure 5.0 MPa at the surface, radius 5000 km and surface gravity 7.5 m/s^2. The carbon dioxide content (by mass) of the atmosphere is 97% and the rest is mostly nitrogen. An estimate for the total mass of carbon dioxide in the planet's atmosphere is

   (a) 2.0×10^{20} kg
   (b) 6.8×10^{13} kg
   (c) 2.0×10^{19} kg
   (d) 4.7×10^{18} kg

7. Pluto is not considered as a planet of our solar system because

   (a) It does not orbit the Sun
   (b) It has not 'cleared' the neighborhood around its orbit
   (c) It does not have sufficient mass to achieve hydrostatic equilibrium under its own gravity
   (d) Its orbital plane makes an angle of 17° with the Earth's orbital plane

9. Figure shows various approximations to what is called the Initial Mass Function (IMF) of stars which gives the number of stars in various mass ranges as a function of the logarithm of the mass $\log m = x$ as say $y = f(x)$. One of the shapes is approximately an inverted parabola continuing as a straight line. Let the parabola portion be fitted by $y = y_0 + A(x - x_0)^2$ and the straight line portion be fitted by $y = -2.35x + C$. If the parabolic and linear portions join smoothly at the point (x_1, y_1) the unknown parameters A and C are given by



(a) $\frac{2.35}{2(x_1-x_0)}, y_0 + \frac{2.35(x_1+x_0)}{2}$

(b) $\frac{-2.35}{2(x_1-x_0)}, y_0 + \frac{2.35(x_1+x_0)}{2}$

(c) $\frac{-2.35}{2(x_1-x_0)}, y_0 + \frac{-2.35(x_1+x_0)}{2}$

(d) $\frac{2.35}{2(x_1-x_0)}, y_0 + \frac{-2.35(x_1+x_0)}{2}$

10. Astronomers discover an exoplanet (a planet orbiting a star other than the Sun), that has an orbital period of 4.50 Earth years in a circular orbit around its star. The star has a measured mass of 3.70×10^{30} kg. The radius r of the exoplanet's orbit is approximately.

(a) 2.7×10^{11} m

(b) 2.7×10^{12} m

(c) 5.0×10^{13} m

(d) 5.0×10^{11} m

13. The orbit of Halley's comet about the Sun is such that it arrives at perihelion every 75.3 years. If the perihelion distance is 0.586 AU, the aphelion distance is approximately

(a) 70 AU

(b) 80 AU

(c) 35 AU

(d) 40 AU

18. A wire mesh in a paraboloid shape can be used as collector of radio waves for a radio telescope. Such radio dishes are used to detect radio signals from distant galaxies. What will be the angular radius of the image of a point source emitting 21 cm radio radiation, due to diffraction effects, if the dish is 250 m in diameter?

(a) 0.0010 arc minute

(b) 0.058 arc minute

(c) 3.5 arc minute

(d) 211 arc minute

20. LIGO gravitational wave observatory detected the merger of two black holes of masses 30 and 35 solar masses to form a single black hole of mass 62 solar masses. The total energy radiated away in the form of gravitational waves in the merger is

(a) 2.3×10^{44} joule

(b) 4.0×10^{26} watt

(c) 3.6×10^{49} watt

(d) 5.4×10^{47} joule

22. Two stars A and B, have masses M_A and M_B and radii R_A and R_B respectively. It is given that $R_A = R_B = R$, but $M_A \neq M_B$. Star A has a constant density ρ, and the density profile of star B is $\rho = \rho_0(1 - \frac{r}{R})$. In the region $0 < r < R$, the gravitational accelerations g_A and g_B of these two stars are related as

(a) $g_B = g_A(1 - \frac{3r}{4R})$

(b) $g_B = g_A(1 - \frac{r}{12R})$

(c) $g_B = g_A(1 - \frac{3r}{R})$

(d) $g_B = g_A(1 - \frac{12r}{R})$

24. Imagine a large asteroid of circular disc shape with diameter $D = 50$ km and thickness 2 km. The magnitude of gravitational acceleration at distances $h = 100$ m and $h = 200$ m above the surface can be approximated to have the same value (neglecting corrections of the order of h/D)

(a) anywhere above the disc.

(b) anywhere above the disc but not near the edges.

(c) only along the axis.

(d) nowhere above the disc.

28. If the surface temperature of a star is 6000K, in which colour would it appear in a colour photograph?

(a) Red

(b) Violet

(c) Yellow

(d) Blue

31. The average flux of solar radiation on Earth is $F = 1.36 \times 10^3$ W m^{-2} and the average Earth-Sun distance is 1.5×10^{11} m. The power radiated by the Sun is

(a) 3.8×10^{26} W

(b) 3.8×10^{33} W

(c) 4.0×10^{28} W

(d) None of these

34. The photospheric radius of the Sun is 0.696 million km. Rotation period of the Sun at the solar equator is approximately 24 days. The end regions of the solar equator on the solar disc, are simultaneously and separately observed using an H alpha filter with mid wavelength 6563 Angstroms. The difference in measured wavelength between the observations at the two edges is

    (a) 0.0459 Angstrom
    (b) 0.0229 Angstrom
    (c) 0.1836 Angstrom
    (d) 0.0918 Angstrom

37. A planet of mass m is in a circular orbit of radius r around a star of mass M and radius R (radius of the star). By some physical process the star instantaneously shrinks to a black hole of the same mass M. The final orbit of the planet will be

    (a) circular with radius $2r$.
    (b) a spiral going in towards the black hole.
    (c) circular with radius r.
    (d) a hyperbola as the planet escapes with speed greater than the escape speed.

40. According to Wien's displacement law the wavelength of peak emission from a body is inversely proportional to the temperature of the body in kelvin. Two stars A and B with surface temperatures 3000 kelvin and 6000 kelvin respectively, are at the same distance from the Earth. They are of equal radius. The correct statement about the radiations emitted by the two stars is

    (a) Both A and B will look equally bright in visible.
    (b) A will look brighter than B in infrared.
    (c) B will look brighter than A in infrared.
    (d) A will emit more in the visible range than in the infrared.

41. Given the radius of the Earth as R and the height of the mast of a ship above sea level as h, when observed from a beach, the minimum distance along the sea surface d of the ship when the ship's mast goes below the horizon is (ignore the density variation of the atmosphere with height)

    (a) $R\cos\left(\frac{R}{R+h}\right)$
    (b) $R\tan\left(\frac{Rh}{R+h}\right)$
    (c) $R\sin^{-1}\left(\frac{h}{R}\right)$
    (d) $\sqrt{2Rh}$

44. A rubber band is being stretched slowly and uniformly. Hooke's law holds good. Observed from any given point on the rubber band every other point

    (a) will move away with a constant speed
    (b) will move with speed inversely proportional to the distance to the point
    (c) will appear stationary
    (d) will move with a speed proportional to the distance to the point

45. A projectile is launched horizontally with speed $v_0 \ll v_{escape}$ from a height h above Earth's surface. Considering the Earth's curvature and non-uniformity of its gravity, viewed from space, the approximate shape of the trajectory of the projectile would be the arc of

    (a) a parabola
    (b) a hyperbola
    (c) an ellipse
    (d) a circle

48. The distance to a latitude circle from the pole ($= R\theta$ where θ is the colatitude and R is the radius of the Earth assumed spherical) is equal in all directions along the surface of the sphere. For latitude circles, the ratio of circumference to the diameter along the surface of the sphere is

    (a) $\pi \frac{\cos\theta}{\theta}$
    (b) $\pi \frac{\sin\theta}{\theta}$
    (c) $\pi \frac{\theta}{\sin\theta}$
    (d) $\pi \frac{\theta}{\cos\theta}$

Multiple Correct Option (MCQ)

49. In a two body system, Lagrange points are

    (a) total six in number
    (b) total five in number
    (c) locations where net force (gravitational + centrifugal) is zero.
    (d) locations where the effective potential (gravitational + centrifugal) is zero

52. The tidal force (due to Sun/Moon) at the surface of the Earth

    (a) by Moon's gravity is stronger than that due to Sun's gravity
    (b) by Sun's gravity is stronger than that due to Moon's gravity
    (c) is proportional to $1/R^2$, if R is the distance between the centres of mass
    (d) is proportional to $1/R^3$, if R is the distance between the centres of mass

2021

Single Correct Option (SCQ)

3. A 1-inch telescope is pointed towards Sirius ($m = -1.4$) and another bigger one towards Castor ($m = 1.6$), m being the apparent magnitude, but both the telescopes deliver equal amount of energy per second to the CCD detector at the eyepiece. The objective diameter of the bigger telescope is (using $\log_{10} 2 = 0.3$)

   (a) 2-inch

   (b) 4-inch

   (c) 8-inch

   (d) 16-inch

6. A lens of diameter d and focal length f is used to project image of an object on a screen. The object is kept at a distance u from the lens and consists of two points separated by distance r_o in the plane perpendicular to the principal axis. The wavelength of light used is λ. The two points will be resolved in the image if

   (a) $u < \frac{1.22\ \lambda r_o}{d}$

   (b) $u < \frac{r_o d}{1.22\ \lambda}$

   (c) $d > \frac{1.22\ \lambda f}{r_o}$

   (d) $d > \frac{1.22 \lambda u}{r_o}$

7. Assume that the density (ρ) of the earth has following dependence on the distance r from the centre

$$\rho(r) = \rho_0 \quad \text{for } r < r_0,$$

$$\rho(r) \propto \frac{1}{r} \quad \text{for } r_0 \leq r \leq R$$

   R being earth's radius and ρ_0 is constant density of the central core. For any point r between r_0 and R, the gravitational acceleration $g(r)$ will have the following form (A and B being constants in the following)

   (a) $A + \frac{B}{r^2}$

   (b) Ar

   (c) $\frac{A}{r} + Br$

   (d) $A + Br$

9. The geometric albedo (A) of the solar system objects is related to their absolute magnitude (M) and diameter (D) as $A = \left(\frac{1329 \times 10^{-M/5}}{D}\right)^2$. Initially it was thought that the radius of Phobos, one of the satellites of Mars, is 7 km assuming the albedo of Phobos is same as that of Mars i.e. about 0.15. But later Mariner spacecraft's photographs revised the radius to 10 km. The correct albedo of Phobos, therefore, is

   (a) 0.10

   (b) 0.05

   (c) 0.07

   (d) 0.12

11. The summer triangle refers to the three stars

    (a) Vega, Altair and Deneb

    (b) Regulus, Antares and Sirius

    (c) Sirius, Procyon and Betelgeuse

    (d) Pollux, Caster and Regulus

13. Astronomers have discovered 200 stars having parallax of $0.10''$ with fair completeness. Supposing the distribution of stars around us is pretty much homogeneous and isotropic, the number of stars having parallaxes $0.025''$ or more is

    (a) 3200

    (b) 25600

    (c) 12800

    (d) 6400

15. Kepler's laws for planetary orbits are derived using Newton's law of gravitational force. These laws state that
    First: All planets move in elliptical orbit with sun at one of the foci,
    Second: The line joining the planet to the sun sweeps equal area in equal time interval,
    Third: Square of the period of revolution of a planet is proportional to cube of semi-major axis.
    Newton's law of gravitation receives corrections from relativity theory, with the modified law of force between bodies of masses M and m at a distance r given by

    $$\vec{F} = -\frac{GMm}{r^2}\left(1 + \frac{A}{r^2}\right)\hat{r}$$

    where A is some constant. With this correct form of law of gravitation, for which of the Kepler's laws you can be sure that it (these) will remain unchanged.

    (a) First and Second

    (b) First

    (c) Second

    (d) All laws will change

16. Globular clusters in our galaxy are primarily found:

    (a) in the spiral arms.

    (b) distributed throughout the disk including regions between the spiral arms.

    (c) in the bulge at the center of our galaxy.

    (d) in the halo of our galaxy

20. Two satellites are in the same geosynchronous orbit (assumed to be circular), but in diametrically opposite positions. One satellite descends into a lower circular orbit and catches up with the other after 8 complete orbits. Neglect the time of descent into lower orbit. If the radius of the geosynchronous orbit is 40000 km, the radius of the lower, faster orbit is about (using $7.5^{2/3} \approx 3.84$)

    (a) ≈ 32400 km

    (b) ≈ 34000 km

(c) ≈ 36000 km

(d) ≈ 38400 km

21. The ratio of the masses of the Earth and Mars is 10 and the ratio of the radii of the Earth and Mars is 2. If two persons jump with the same velocity and angle off the surface of each of the planets, the ratio of maximum height reached at Earth to that reached at Mars is

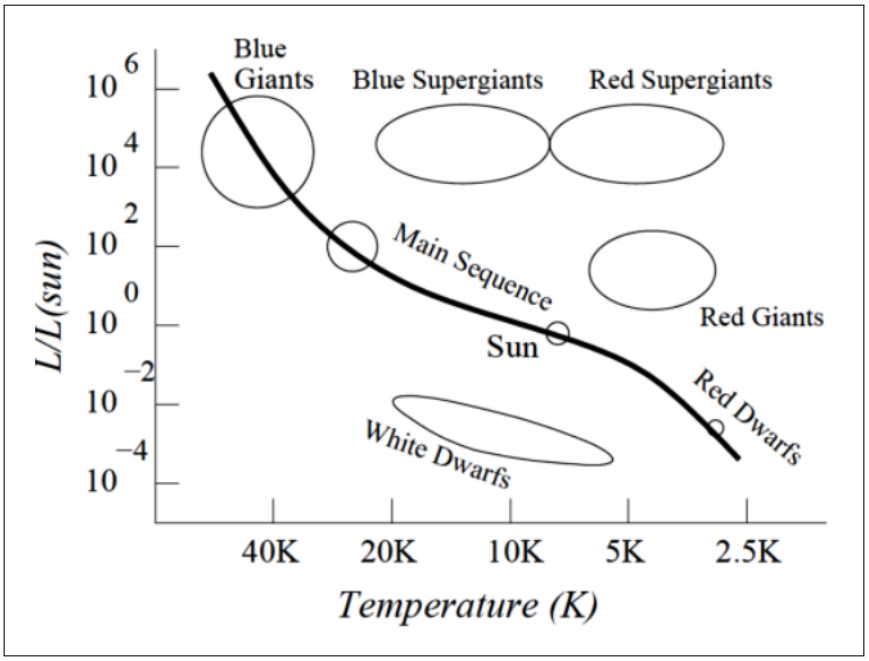
(a) $\frac{1}{5}$

(b) $\frac{2}{5}$

(c) $\frac{5}{2}$

(d) depends on the ratio of the masses of two people

22. A schematic Hertzsprung-Russel diagram for stars in the solar neighborhood is shown below. The radius R of a star, its luminosity L and surface temperature T are related as $R \propto \frac{\sqrt{L}}{T^2}$. If for a star $\frac{R}{R_{sun}} = 20$ and $T = 3000$ K (using $T_{sun} = 6000$ K) then the star is a



(a) Blue Supergiant

(b) Blue Giant

(c) Red Supergiant

(d) Red Giant

23. Statement I: We cannot see what is near the centre of Galaxy
Statement II: There is a super - massive black hole at the centre of Galaxy

(a) If statement I is true and statement II is true and also if the statement II is a correct explanation of statement I

(b) If statement I is true and statement II is true but the statement II is not a correct explanation of statement I

(c) If statement I is true but the statement II is false

(d) If statement I is false but statement II is true

24. Statement I: Hydrogen gas is not found in large amount in the atmosphere of terrestrial planets.
Statement II: Speed of Hydrogen molecules was higher than the escape velocity on the terrestrial planets.

    (a) If statement I is true and statement II is true and also if the statement II is a correct explanation of statement I

    (b) If statement I is true and statement II is true but the statement II is not a correct explanation of statement I

    (c) If statement I is true but the statement II is false

    (d) If statement I is false but statement II is true

Multiple Correct Option (MCQ)

25. Electromagnetic waves also undergo Doppler effect just as sound waves. Use the expression of Doppler effect valid for small velocities (of source, or observer, they both give the same result for small velocities), replacing sound speed by speed of light c. A hydrogen atom moving along x axis with velocity v undergoes transition of electron from 1st excited level ($n = 2$) to the ground state, emitting radiation which travels along x axis. This radiation is absorbed by another hydrogen atom at rest in its ground state causing it to get excited to $n = 3$ level. The value of v is approximately

    (a) 5.55×10^4 km/sec

    (b) 9.45×10^4 km/sec

    (c) $0.315c$

    (d) $0.185c$

31. Analysis of the spiral galaxy NGC 1357 spectra reveals a strong emission line at 6606 Å. Knowing the H_α emission line is at 6560 Å.
Use $c = 3 \times 10^5$ km/s and Hubble's constant = 70 (km/s)/Mpc. Choose correct option(s)

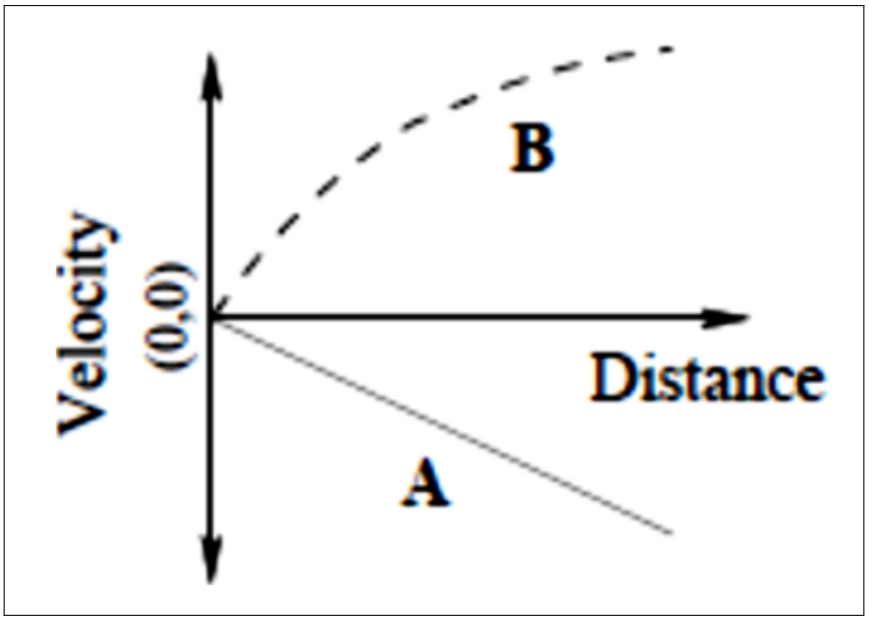
    (a) The velocity of NGC 1357 is about 2×10^3 km/s.

    (b) NGC 1357 is an example of blue-shifted galaxy.

    (c) The galaxy is at a distance of 30 Mpc from us.

    (d) It is an old galaxy having little to no star formation regions.

32. The Hubble plot below depicts two alternate universe A (solid line) and B (dashed curve). The quantity z determines the amount of redshift (negative z for blue shift) in the absorption and emission spectra of the galaxies. From the Hubble plot above, we can deduce that



(a) Both the universe A and B are contracting but at different rates.

(b) The galaxies in the universe A are blue shifted while those in B are red shifted.

(c) In the universe A, farther galaxies are approaching us at faster velocities than closer galaxies.

(d) The z-value is larger for the farther galaxies in B compared to those closer.