11th SAO Round 1 Question List

Question 1

The orbital speed *v* of planets in the solar system varies with the mean orbital radius *R* according to the relationship

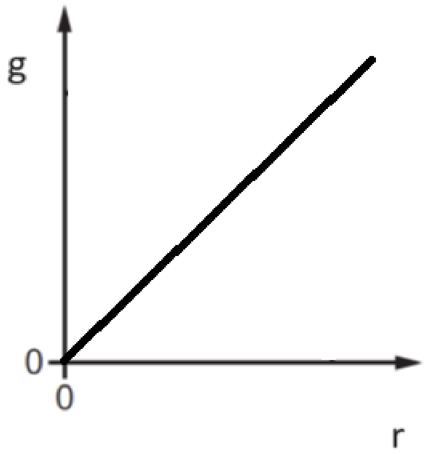
a) $v \propto R^{-1}$
b) $v \propto R^{-0.5}$
c) $v \propto R^{0.5}$
d) $v \propto R$

Answer/explanation:
b. Kepler's 3rd Law and divide R by R^1.5

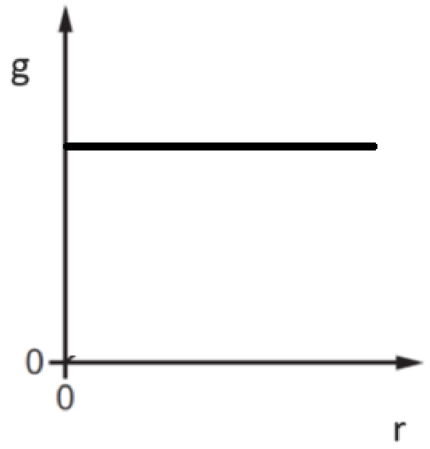
Question 2

The Earth's radius is *R*. Which of the following graphs is most likely to show the variation of gravitational field strength with distance *r* from the centre the earth, for $0 < r < R$?

A



B



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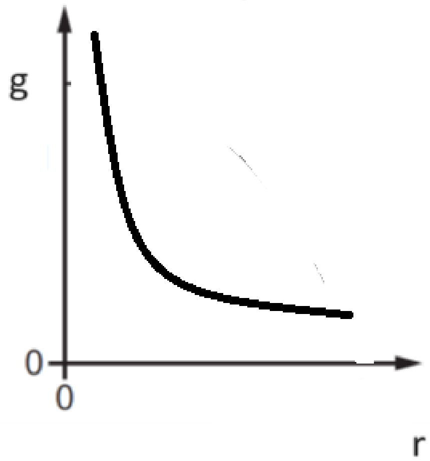
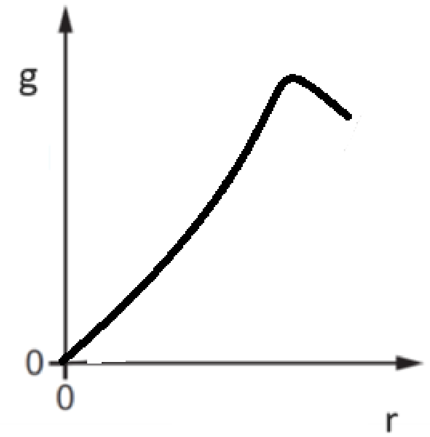


D



Answer/explanation:
d. The Earth is not uniform, it is denser in the centre.

***Questions 3 to 4** refer to a 1000 kg communication satellite transferred from a low earth orbit (LEO) at an orbital radius of 6700 km to a geostationary orbit (GEO) at 42240 km using a Hohmann transfer. The orbital speed at the LEO is 7713 m/s.*

Question 3

Calculate the total energy of the satellite in the LEO.

a) -58.5 GJ
b) -29.7 GJ
c) 29.7 GJ
d) 58.5 GJ

Answer/explanation:
b. By Virial Theorem, K = -U/2, E = U/2 = -K.

Question 4

Calculate the absolute value of the total energy of the satellite in the Hohmann transfer orbit.

a) 4.71 GJ
b) 8.13 GJ
c) 108 GJ
d) 187 GJ

Answer/explanation:
b. The Hohmann transfer orbit has semi-major axis equal to the average of the two circular orbit radii. Since U ~ 1/r, E ~ 1/r. Can also use E = -GMm/2a

Question 5

For binary stars, Kepler's 3rd Law can be written as $M \propto \omega^k a^n$, where k and n are integers and ω is the angular velocity of orbit. What do *M* and *a* represent?

	M	*a*
(a)	Average mass of both stars	Average of orbital radii of both stars
(b)	Sum of masses of both stars	Average of orbital radii of both stars
(c)	Average mass of both stars	Average of orbital diameters of both stars
(d)	Sum of masses of both stars	Average of orbital diameters of both stars

Answer/explanation:
d. a= r1+r2 = 0.5(d1+d2)

Question 6

Black holes are objects that are so massive that light cannot escape. The limit where the escape velocity is the speed of light, is called the event horizon. This horizon forms a sphere with the Schwarzschild radius as the radius. What is the Schwarzschild radius of Earth?

a) 0.1 mm
b) 9 mm
c) 3 km
d) 30 km

Answer/explanation:
b) An object is moving at the escape velocity when its total energy is zero. Thise leads to the equation $\frac{1}{2}mv^2 = GMm/R^2$, so $v_{escape} = (2GM/R)^{1/2}$. For an escape velocity equal to c, the Schwarzschild radius becomes $r_{Schwarzschild} = 2GM/c^2$. The mass of the Earth is 6 x 10^{24} kg, so the Earth's Schwarzschild radius is about 0.009 m or 9 mm.

Question 7

We see more low-mass than high-mass stars in the universe. Which of the two statements below is/are correct?

1. More high-mass stars than low-mass stars are formed.
2. Low-mass stars live longer than high-mass stars.

a) Only statement 1 is correct.
b) Only statement 2 is correct.
c) Both statements are correct.
d) Both statements are wrong.

Answer/explanation:
b) Light stars are formed much more often than heavy stars *and* they live much longer.

Question 8

The present solar mass is $M_\odot$. Which of these is the best estimate for the mass that has been converted to energy since the sun started its main sequence?

a) 0.0003 $M_\odot$
b) 0.0007 $M_\odot$
c) 0.003 $M_\odot$
d) 0.007 $M_\odot$

Answer/explanation:
a. Only 10% of the sun is available for fusion, and fusion converts 0.71% of mass to energy. Further, the sun is roughly halfway through its life.

Question 9

Which of the following process(es) is/are responsible for energy transfer in the **interior** of the sun?

a) Conduction only
b) Convection only
c) Conduction and convection

d) Convection and radiation

Answer/explanation:
d. In a sun-sized star the Schwarzchild criterion extends from the core to 0.7 solar radii.

Question 10

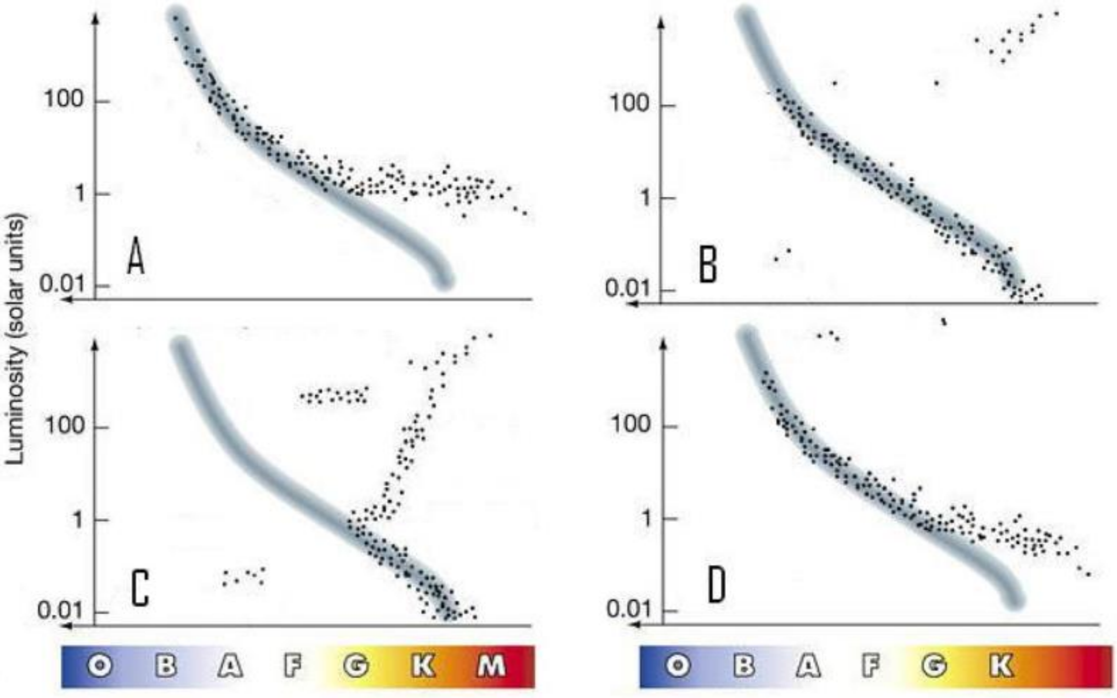
Which of the following options correctly shows the two forces that are in equilibrium in the compact object?

	Object	Forces
(a)	White dwarf	Gravity and electron degeneracy
(b)	White dwarf	Radiation pressure and electron degeneracy
(c)	Neutron star	Gravity and electron degeneracy
(d)	Neutron star	Radiation pressure and electron degeneracy

Answer/explanation:
a.

Question 11

The figure below shows 4 star clusters, A, B, C and D. Each point represents one star.



Which of the following statements best describes the data?
a) A is the youngest among the four clusters
b) B is formed from a nebula with less mass than A and D
c) C is likely to contain unobserved blue supergiants obscured by dust
d) D is likely to contain unobserved red supergiants obscured by dust

Answer/explanation:
a. Main sequence candle wick

Question 12

In 1844 the German astronomer Friedrich Bessel concluded from his observations of the star Sirius, the brightest star in the sky, that it must have an invisible accompanying star, which he dubbed Sirius B. How did he come to this conclusion?

a) Sirius appeared to wobble in the sky.
b) Sirius is a pulsar, and Bessel observed slight anomalies in the timing of the observed pulses.
c) Sirius' light periodically appeared blueshifted and redshifted.
d) Sirius periodically dimmed and brightened.

Answer/explanation:
a) The proper motion, the speed that a star has on the sky, of Sirius showed periodic variations that correspond to an object that orbits Sirius (A) with the mass of Sirius B.

Question 13

Unfortunately, Bessel died in 1846, and he never knew the answer to this mystery. In 1862, American Alvin Clark discovered that Sirius B is a star, with a similar spectral type as that of Sirius A. However, Sirius B shone about 10 magnitudes less brightly as Sirius A. Given that the radius of Sirius A is 1.7 that of the Sun, what is the radius of Sirius B?

a) 12 km
b) 120 km
c) 1200 km
d) 12,000 km

Answer/explanation:
d) A similar spectral type means that both stars have approximately the same temperature. Both stars are at the same distance to the Earth, so their brightnesses are proportional to their luminosities. Comparing their magnitudes, we find

$$m_{\mathrm{B}} - m_{\mathrm{A}} = 10 = 2.5 \log\left(\frac{L_{\mathrm{A}}}{L_{\mathrm{B}}}\right) \Leftrightarrow \frac{L_{\mathrm{A}}}{L_{\mathrm{B}}} = 10^4 \Leftrightarrow \frac{4\pi R_{\mathrm{A}}^2 \sigma T_{\mathrm{A}}^4}{4\pi R_{\mathrm{B}}^2 \sigma T_{\mathrm{B}}^4} = 10^4$$

$$\frac{R_{\mathrm{A}}^2}{R_{\mathrm{B}}^2} = 10^4 \Leftrightarrow R_{\mathrm{B}} = 0.01 R_{\mathrm{A}} = 0.017 R_{\mathrm{Earth}} = 12{,}000\ \mathrm{km}$$

Question 14

Sirius B is a white dwarf. Why is Sirius B still so hot?

a) Nuclear reactions take place in Sirius B.
b) Sirius B is in thermal equilibrium with Sirius A given their proximity.
c) Sirius B is contracting under gravity, leading to the radiation of the lost gravitational potential energy as thermal energy.
d) Sirius B is the remnant nucleus of a dead star, and the nuclei of stars have very high temperatures.

Answer/explanation:

d) The heat of a white dwarf does not come from internal nuclear fusion, but from the fact that a white dwarf is the remnant nucleus of a dead star. The nuclei of stars have a very high temperature. Because it can only lose thermal energy through radiation, it takes a long time before the white dwarf has cooled down.

Question 15

The spectrum of an imaginary galaxy is observed. A line with observed wavelength 400 nm is identified to have a wavelength of 500 nm in the lab. The galaxy is moving

a) away from us with a speed of 0.2*c*
b) away from us with a speed of 0.25*c*
c) towards us with a speed of 0.2*c*
d) towards us with a speed of 0.25*c*

Answer/explanation:
c. the galaxy is blueshifted and the denominator should be the rest wavelength.

Question 16

How many measurements from the following list can be used in conjunction with apparent magnitude to measure distance to a spiral galaxy?

Light curves from Type I Supernovae
Position of spectral lines
Width of spectral lines

a) 0
b) 1
c) 2
d) 3

Answer/explanation:
d. light curve is standard candle method. Position is using hubbles law. Width is used in the Tully-Fisher's relationship.

Question 17

Below are four different astronomical measurements. Only one of them cannot be determined from stellar spectra. Which is it?

a) The temperature of a star
b) The age of a star
c) The distance to a star
d) Whether a star has planets

Answer/explanation:
c) The distance to a star

Question 18

A star has a mass of 3 solar masses. Estimate its main sequence lifetime.

a) 210 million years
b) 640 million years
c) 3.3 billion years
d) 30 billion years

Answer/explanation:
b. L ~ M^3.5. So T ~ M^-2.5

Question 19

An imaginary object exhibits an angle of parallax of 0.01'. What is the distance to the object?

a) 0.01 pc
b) 0.6 pc
c) 1.7 pc
d) 100 pc

Answer/explanation:
c. 0.01' = 0.6". d=1/p

Question 20

Due to the turbulence in the atmosphere (the 'twinkling' of stars) the image of a telescope that is within the atmosphere is constantly being deformed. This means that for observers, even if they were at the best locations on Earth, until recently it was not possible to get a resolution of better than about a half an arcsecond with their telescope. This limit is called the 'seeing.'
Over the past 50 years, several techniques have been developed within astronomy to adapt to this 'seeing.' Which of the following techniques is not one of them?

a) Adaptive Optics
b) Speckle Imaging
c) Observing with X-rays since the Rayleigh criterion is wavelength dependent
d) Observing using radio waves by placing a few dishes far apart

Answer/explanation:
c) X-rays are absorbed by the atmosphere.

Question 21

A planet is in the habitable zone. The peak wavelength of the electromagnetic spectrum emitted is likely to be

a) 0.01 mm
b) 0.1 mm
c) 1 mm
d) 10 mm

Answer/explanation:

a. This should be in the infrared region. Alternatively, apply Wien's Law for T = 300 K.

Question 22

Assume that a star has a luminosity twice that of the Sun, $L = 2L_{Sun}$. At what distance from that star should an exoplanet be to be in the habitable zone? Assume the planet's albedo to be $A_v = 0.5$.

a) Between 0.57 AU and 1.07 AU
b) Between 0.57 AU and 1.51 AU
c) Between 0.81 AU and 1.07 AU
d) Between 0.81 AU and 1.51 AU

Answer/explanation:

a) Between 0.57 AU and 1.07 AU

Question 23

What effect does the interstellar medium have on a distant star?

a) To an observer, the star appears to be shining brighter and bluer.
b) To an observer, the star appears to be shining brighter and redder.
c) To an observer, the star appears to be shining dimmer and bluer.
d) To an observer, the star appears to be shining dimmer and redder.

Answer/explanation:
d) The star appears to be shining dimmer and redder.

Question 24

Assume the entire sky to have 6000 stars visible to the naked eye, equally distributed. How many of these are circumpolar to an observer at 60°N?

a) 1000
b) 1500
c) 2000
d) 4000

Answer/explanation:
b. The northern hemisphere has roughly 3000 stars. At 60°N, any stars between Dec +30° to +90° are circumpolar. The surface area of a sphere segment is $2\pi r^2(1-\cos\theta)$.

Question 25

Which of the following is the main contributing factor to explain the difference between the tropical year and sidereal year?

a) Motion of Earth around Sun
b) Motion of Sun around the centre of the galaxy
c) Precession of Earth's axis of rotation
d) Precession of Earth's plane of revolution

Answer/explanation:
c.

Question 26

A sailor, who is aware of rudimentary astronomy, experiences a shipwreck, which leaves them on an unknown island. Fortunately, they managed to salvage their instruments from the wreck: a sextant, a clock, and a book with coordinates of stars. How would this sailor be able to determine their latitude by observing the night sky? Would this method also have worked for a sailor in the Roman era?

a) The latitude can be determined by measuring the altitude of the pole star with the sextant. This method would also have worked for a sailor in the Roman era.
b) The latitude can be determined by measuring the altitude of the pole star with the sextant. This method would not have worked for a sailor in the Roman era.
c) The latitude can be determined by using the clock and the sextant to measure the altitude of the Sun at noon. This method would also have worked for a sailor in the Roman era.
d) The latitude can be determined by using the clock and the sextant to measure the altitude of the Sun at noon. This method would not have worked for a sailor in the Roman era.

Answer/explanation:
b) The latitude can be determined by measuring the altitude of the pole star with the sextant. This strategy would not work in the Roman era, because the pole star was not aligned with the Earth's rotational axis. This is due to the precession of the Earth. Determining the longitude has only been possible since the 18th century using clocks that are not significantly unreliable at sea. (Interesting story, the longitude prize.) A sailor in the Roman era does not have access to this.

Question 27

The sailor measures their latitude to be +28° 46'. They observe a star that exactly passes the zenith. What is this star's declination?

a) +5° 20'
b) +28° 46'
c) +52° 12'
d) +71° 16'

Answer/explanation:
b) δ = +28° 46'

Question 28

The sailor measures that, at noon, the Sun is at an altitude of 61° 14' above the horizon. What could be (a) possible date(s)?

a) The date could be the day of the summer solstice or that of the winter solstice.
b) The date could be the day of the vernal equinox or that of the autumnal equinox.
c) The date is the day of the summer solstice.
d) The date is the day of the winter solstice.

Answer/explanation:

b) The Sun is above the equator, so the date is either the day of the vernal equinox or that of the autumnal equinox. $\alpha = 90 + \varphi - \delta$

Question 29

The sailor has an excellent clock which gives the local time at the Greenwich observatory. They use this clock to measure that the star Arcturus, the brightest star in the constellation of the name Boötes, rises as their clock shows exactly 20:44. In their book it says that on this date Arcturus should rise in Greenwich at 19:33. At which longitude does our sailor find themselves?

a) -82° 15’
b) -17° 45’
c) +17° 45’
d) +62° 15’

Answer/explanation:

b) The difference in longitude (in hours) is approximately equal to minus the difference in rising time, $\delta\lambda = \delta T$. Greenwich as at longitude 0, so $\lambda = -1^h 11^m = -17° 45'$.

Question 30

The nearest exoplanets are 4.2 light years (1.3 parsecs) from Earth and orbit Proxima Centauri, the star which is closest to the Sun. Assume one of these exoplanets has the same size as Jupiter. What would be the angular diameter of this exoplanet, as seen from the Earth?

a) 0.36 milli arcseconds
b) 0.73 milli arcseconds
c) 1.2 milli arcseconds
d) 2.3 milli arcseconds

Answer/explanation:

b) The equation for the angular diameter is similar to that of the parallax, $\theta = \tan^{-1}(2r/d)$, where now θ is the angular diameter, r the radius of the exoplanet, and d the distance to the exoplanet. The radius of Jupiter is 7×10^7 m. Hence, at 4.2 light years, the angular diameter of Jupiter is 2.0×10^{-7} degrees = 0.73 milli arcseconds.

Question 31

The NIRcam instrument of JWST has a resolution of 70 milli arcseconds. This means that it cannot distinguish any details that are smaller than 70 milli arcseconds, such as our hypothetical Jupiter at Proxima Centauri. Instead of directly observing the exoplanet, JWST can make use of a clever trick. When a planet moves in front of the star, a transit, a small part of the stellar light is blocked and we *can* measure that difference! Fig. 1 shows a light curve that was measured by the JWST. A light curve is a graph in which the brightness of an object over a certain time is shown.

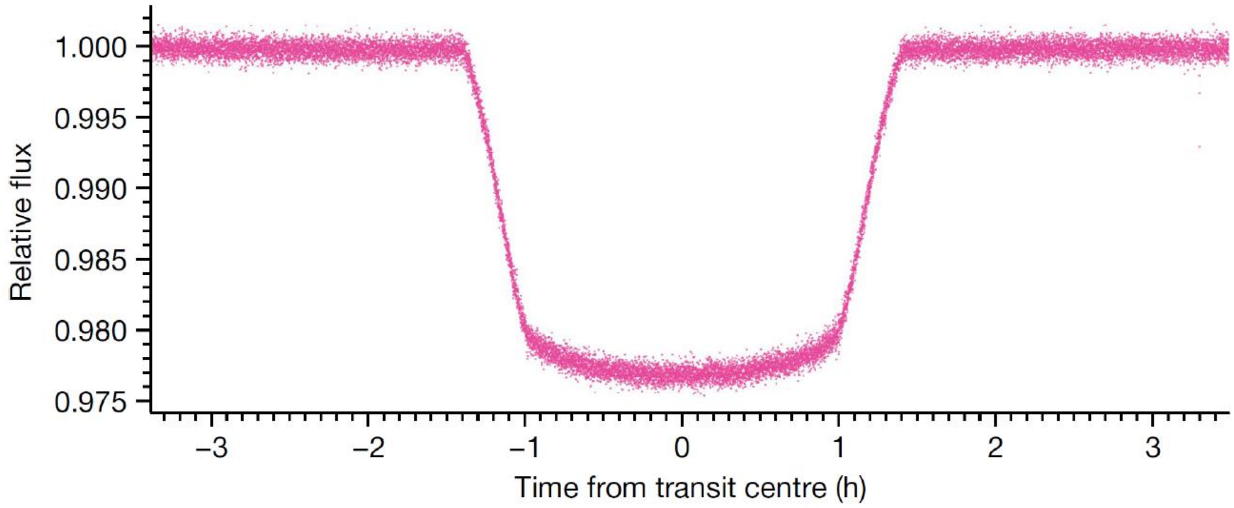


Figure 1: A light curve observed by JWST.

The relative amount of light that a planet blocks is called the transition depth. This depth only depends on the ratio of the flat circle areas of the star and the planet. Based on Fig. 1, what is this ratio?

a) 0.023
b) 0.152
c) 0.977
d) 0.988

Answer/explanation:
b) The transition depth (D) is equal to the ratio of the areas times the brightness of the star (= 1.00). The areas as seen from the Earth are circles with area $O = \pi R^2$. Hence, $D = \frac{O_{\text{planet}}}{O_{\text{star}}} = \frac{\pi R^2_{\text{planet}}}{\pi R^2_{\text{star}}} = \left(\frac{R_{\text{planet}}}{R_{\text{star}}}\right)^2$. From the figure we find a depth of about 0.023, so the ratio $\frac{R_{\text{planet}}}{R_{\text{star}}} = \sqrt{0.023} = 0.152.$

Question 32

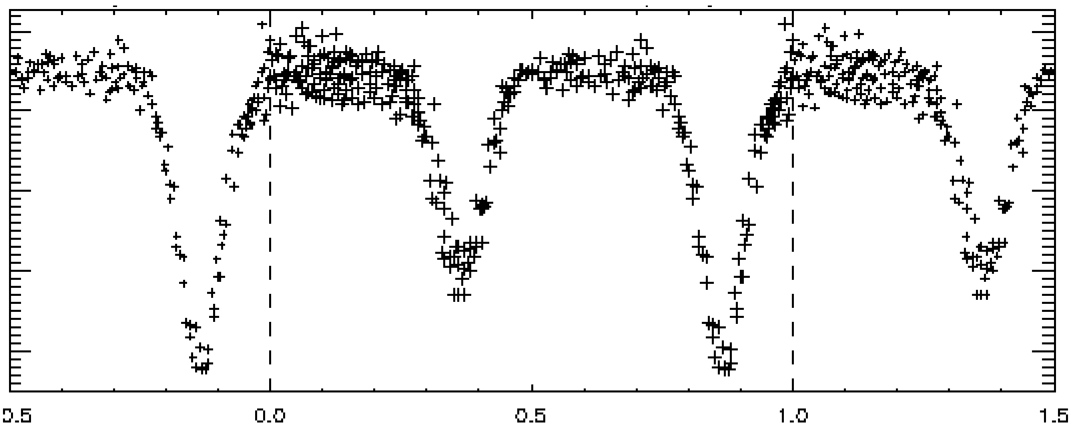
Studying exoplanets is currently one of the most interesting research areas within astronomy. Which of the following statements is correct?

a) Most exoplanets were found by directly observing their light with the Kepler space telescope.
b) Exoplanet are detected using gravitational lensing.
c) Low-mass rocky planets such as the Earth are observed less often than gas giants such as Jupiter, because gas giants are produced more often during the formation of stars.
d) Objects in orbit about the Sun that are outside the heliosphere are also called exoplanets.

Answer/explanation:
b) It is possible to detect exoplanets using gravitational lensing.

Question 33

The light curve in the diagram below likely belongs to a/an



a) pulsating red giant
b) RR Lyrae variable
c) Cepheid variable
d) eclipsing binary

Answer/explanation:
d. Highly regular, with secondary dip right in the middle.

Question 34

A *f*/5 telescope with a focal length of 400 mm is used with a 8 mm eyepiece. What is the magnification?

a) 10 x
b) 40 x
c) 50 x
d) 250 x

Answer/explanation:
c. 400/8.

Question 35

A galaxy is situated 2.0 million light years away. Which of the following can be deduced?

a) It is receding from us at 41600 m/s
b) It is receding from us at 136000 m/s
c) It is receding from us at 442000 m/s
d) None of the above

Answer/explanation:
d. The local group is bound by gravity and Hubble's Law is not applicable.

Question 36

A galaxy is moving away from us with a measured distance of 2500 km s^{-1}. What is its distance from us?

a) 1.1×10^{24} m
b) 5.3×10^{24} m
c) 1.1×10^{27} m
d) 5.3×10^{27} m

Answer/explanation:
a) d = 36.9 Mpc = 1.1×10^{24} m.

Question 37

After the Big Bang, for a fraction of a second the expansion was exponentially fast, then the expansion reduced, and after that it increased again (accelerated). What caused these three phases?

	Exponential expansion	Deceleration	Acceleration
a)	Cosmological constant	Gravitation	Inflation
b)	Inflation	Gravitation	Cosmological constant
c)	Inflation	Gravitation	Inflation
d)	Gravitation	Cosmological constant	Gravitation

Answer/explanation:
b

Question 38

Which of the following statements about gravitational waves is incorrect?

a) Low-mass objects can produce gravitational waves.
b) Gravitational waves travel at a speed just slightly lower than the speed of light because space ahead of them expands.
c) It is more difficult to detect gravitational waves of merging neutron stars than those of merging black holes (at the same distance).
d) Gravitational waves can be detected by measuring the changing rotation periods of different pulsars as the waves travel through the space between the pulsar and us.

Answer/explanation:
b. They travel at speed of light

Question 39

Based on our current understanding of the universe we can say that…

a) dark energy dominated in the early universe.
b) the cosmic microwave background radiation is completely isotropic.
c) the Hubble parameter changes with time.

d) the formation of the heaviest elements (such as lead) took place just after the big bang, thanks to the extremely high temperatures at that time.

Answer/explanation:
c) The Hubble parameter changes with time.

Question 40
Which of the following statements about black holes is/are correct?

1. Amongst all the different types of black holes, Schwarzschild black holes are the most common.
2. We know that time dilation occurs in strong gravitational fields. When somebody falls into a black hole, those who stay behind will never truly see this person disappear into the black hole.

a) Only statement 1 is correct.
b) Only statement 2 is correct.
c) Both statements are correct.
d) Both statements are wrong.

Answer/explanation:
d) Both statements are wrong.