GLOBAL ASTRONOMY & ASTROPHYSICS CHALLENGE

ROUND 1

Test Bank

40 Multiple-Choice Questions with Full Solutions

TOPICS COVERED

Observational Astronomy · Astrophysics · Planetology

Cosmology · Orbital Mechanics · Space Missions

2026

Questions

Physical and Astronomical Constants (Reference)

- Speed of light $c = 3.0 \times 10^8$ m/s
- Gravitational constant $G = 6.674 \times 10^{-11}$ m^3 kg^{-1} s^{-2}
- Photon energy constant $hc = 1240$ eV·nm
- Solar mass $M_\odot = 1.989 \times 10^{30}$ kg
- Solar luminosity $L_\odot = 3.8 \times 10^{26}$ W
- Solar radius $R_\odot = 6.96 \times 10^8$ m
- Astronomical unit 1 AU $= 1.496 \times 10^{11}$ m
- Parsec 1 pc $= 2.06 \times 10^5$ AU
- Arcseconds per radian 206 265
- Earth's gravitational parameter $\mu_\oplus = 398\,600$ km^3/s^2
- Earth's mean radius $R_\oplus = 6371$ km
- Hubble constant $H_0 = 70$ km/s/Mpc
- Wien displacement constant $b = 2.9 \times 10^{-3}$ m·K
- CMB temperature today $T_0 = 2.73$ K
- Sun's main-sequence lifetime 10 Gyr

Q1

Every clear night for one full year, Adel plots the position of two stars against the fixed background of distant galaxies. Both sweep out exactly the same tiny parallax ellipse, and yet one of them drifts visibly across the sky from season to season while the other barely moves. What must be true?

(A) The drifting star must be hotter than the other

(B) The two stars sit at the same distance, but the drifting one moves faster across our line of sight

(C) The drifting star is closer, so its parallax is smaller

(D) The stationary star is rushing straight toward Earth

Answer: (B) **Difficulty:** Medium

Solution: Identical parallax ellipses mean identical distances. The drift across the sky is proper motion, which traces the part of the space velocity that points sideways across our line of sight, and it says nothing about temperature or radial motion.

Q2

Adel classifies a bright dwarf as spectral type A0V, a type whose standard absolute magnitude is about +0.6. Photometry records $V = 10.6$, and interstellar extinction along this sightline is negligible. How far away does Adel place the star?

(A) 100 pc

(B) 316 pc

(C) 1000 pc

(D) 3160 pc

Answer: (C) **Difficulty:** Medium

Solution: Distance modulus first, then solve for the distance:

$$m - M = 10.6 - 0.6 = 10.0, \qquad 5\log_{10}\frac{d}{10} = 10 \;\Rightarrow\; \log_{10}\frac{d}{10} = 2 \;\Rightarrow\; d = 1000 \text{ pc}. \tag{1}$$

Q3

A star in the arm of a distant spiral galaxy swells and shrinks every thirty days. Adel reduces the night's photometry to $V = 26.0$, and the period calibration for such stars gives an absolute magnitude of -6.0. With extinction ignored, what distance does Adel report for the galaxy?

(A) 2.5 Mpc

(B) 25 Mpc

(C) 250 Mpc

(D) 2.5 Gpc

Answer: (B) **Difficulty:** Medium

Solution: The magnitude gap is $m - M = 26 - (-6) = 32$, so

$$5\log_{10}\frac{d}{10} = 32 \;\Rightarrow\; d = 10^{7.4} \text{ pc} \approx 2.5 \times 10^{7} \text{ pc} = 25 \text{ Mpc}. \tag{2}$$

Q4

At the focus of a telescope of one-metre focal length, a CCD camera samples the image with square pixels 15 μm wide. Roughly what angle of sky does a single pixel cover?

(A) $1.5''$

(B) $3.1''$

(C) $6.2''$

(D) $15''$

Answer: (B) **Difficulty:** Easy

Solution: The plate scale divides pixel size by focal length:

$$\theta = \frac{15 \times 10^{-6}}{1.00} = 1.5 \times 10^{-5} \text{ rad} = 1.5 \times 10^{-5} \times 206\,265 \approx 3.1''. \tag{3}$$

Q5

The dome of the new ten-metre telescope finally opens, and on the very first image every star is a wobbling, smeared blob instead of a sharp point. The director is told that an adaptive optics system can rescue the night. What does that instrument actually correct?

(A) The stray light of the rising Moon

(B) The blur produced by atmospheric turbulence

(C) The thermal sagging of the primary mirror

(D) The chromatic error of the eyepiece

Answer: (B) **Difficulty:** Medium

Solution: Turbulent cells of air at different temperatures act like a set of shifting lenses that break an incoming wavefront into patches. Adaptive optics uses a wavefront sensor and a flexible mirror to flatten that wavefront many times per second, restoring sharp images.

Q6

Across the high desert, radio astronomers spread their dishes over an ever-widening baseline. As the baseline grows, what happens to the finest angular detail the array can distinguish?

(A) The smallest resolvable angle grows larger

(B) The smallest resolvable angle grows smaller, giving finer images

(C) The resolution does not change at all

(D) Only the total collecting area changes

Answer: (B) **Difficulty:** Easy

Solution: For an interferometer the resolving angle is roughly the observing wavelength divided by the baseline length. Stretching the baseline, or shrinking the wavelength, makes the smallest separable angle finer.

Q7

Inside a dark molecular cloud a newborn star lies wrapped in a thick cocoon of dust. In visible light the region is a black blot against the sky, yet with an infrared camera the young star blazes into view. Which chain of events makes this possible?

(A) The star shines only at infrared wavelengths and never in the visible

(B) The dust absorbs the visible light and reradiates that energy at longer, infrared wavelengths

(C) The infrared light comes from the dust alone, with no star involved

(D) The cloud blocks the camera only at visible wavelengths

Answer: (B) **Difficulty:** Medium

Solution: Dust grains are smaller than visible wavelengths, so they scatter and absorb optical light strongly while staying fairly transparent in the infrared. The absorbed energy is reheated and re-emitted as a cool infrared glow, which is how the embedded star is finally revealed.

Q8

Sami records a hot star whose light peaks sharply at 400 nm. The Wien displacement constant can be read from the reference sheet at the front of the paper. What surface temperature does Sami conclude for the star?

(A) 5800 K

(B) 7250 K

(C) 9700 K

(D) 14 500 K

Answer: (B) **Difficulty:** Medium

Solution: Convert nanometres to metres, then divide the Wien constant by the peak wavelength:

$$T = \frac{b}{\lambda_{\max}} = \frac{2.9 \times 10^{-3}}{400 \times 10^{-9}} \approx 7250\ \text{K}. \tag{4}$$

A hotter body always peaks at a shorter wavelength.

Q9

Dr. Hussein describes the solar furnace: every time four protons are fused into one helium-4 nucleus, neutrinos stream away in the process. Which statement about those neutrinos is correct?

(A) They carry away most of the Sun's luminosity

(B) Two neutrinos escape for every helium nucleus that forms

(C) They are swallowed inside the Sun long before reaching the surface

(D) They carry no energy at all

Answer: (B) **Difficulty:** Easy

Solution: In the dominant pp chain two proton-proton steps occur per helium nucleus, so two electron neutrinos escape for every ^{4}He formed. Neutrinos interact so weakly that they leave the Sun almost instantly, carrying only about 2% of the released energy.

Q10

Before dawn, instruments record the Sun's surface rising and falling like a struck drum, steadily, day after day. Dr. Hussein tells the class that astronomers read these oscillations for a living. What do the oscillations reveal?

(A) The Sun's internal temperature, composition, and rotation

(B) The number of solar storms on the visible surface

(C) The exact position of the Moon at any moment

(D) Only how bright the solar disk happens to be

Answer: (A) **Difficulty:** Medium

Solution: Pressure waves trapped inside the Sun make its surface ring with many different periods. The frequencies depend on the sound speed, which stores information about temperature, pressure, and composition inside, while the internal rotation splits the frequencies apart.

Q11

A rocky companion world nicknamed Super-Earth carries 64 times Earth's mass squeezed into only 4 times Earth's radius. Ignoring its rapid rotation and clouds, how does its escape speed compare with Earth's?

(A) It equals Earth's escape speed

(B) It is twice Earth's escape speed

(C) It is half of Earth's escape speed

(D) It is four times Earth's escape speed

Answer: (D) **Difficulty:** Hard

Solution: Escape speed scales as $\sqrt{M/R}$, so

$$v_{\mathrm{esc}} = v_{\oplus}\sqrt{\frac{64}{4}} = 11.2 \times \sqrt{16} = 44.8\ \mathrm{km/s}, \tag{5}$$

exactly four times Earth's 11.2 km/s. A higher escape speed actually makes holding an atmosphere easier, not harder.

Q12

Adel lays down cards describing the life of a star that begins with three times the Sun's mass. Which line-up tells the correct story of its evolution?

(A) Main sequence → red giant → helium core burning → AGB → planetary nebula → white dwarf

(B) Main sequence → subgiant → AGB → red giant → white dwarf

(C) Main sequence → subgiant → red giant → helium core burning → AGB → planetary nebula → white dwarf

(D) Main sequence → supergiant → supernova → neutron star

Answer: (C) **Difficulty:** Medium

Solution: After core hydrogen is exhausted the star leaves the main sequence through the subgiant branch, then swells into a red giant. Helium ignites quietly in its core, and after helium burning ends the star climbs the asymptotic giant branch before shedding a planetary nebula and leaving a white dwarf. A $3\,M_{\odot}$ star is too light to explode as a core-collapse supernova.

Q13

Spread across the desk is a catalogue of variable stars in a globular cluster. Sami sorts them by period, from a few hours to several weeks. Which step most directly pins down the cluster's distance?

(A) RR Lyrae stars carry nearly the same absolute magnitude, so one magnitude measurement fixes the distance

(B) RR Lyrae stars are always brighter than Cepheids

(C) All the variables in the cluster share a single period

(D) RR Lyrae stars must lie closer than 100 pc

Answer: (A) **Difficulty:** Medium

Solution: RR Lyrae stars are horizontal-branch variables with a nearly constant absolute magnitude, almost independent of period. Since they belong to the cluster, their distance modulus is the cluster's, so one good magnitude measurement fixes the distance directly.

Q14

Inside the Sun, a single gamma ray begins a slow climb toward the surface, taking thousands of years to finally get out. Why does light take so long to escape?

(A) Light moves slowly inside hot, dense matter

(B) The photon is constantly absorbed and re-emitted in random directions, so its path zigzags

(C) The Sun's gravity drags every ray back toward the core

(D) Light freezes inside the Sun's magnetic field

Answer: (B) **Difficulty:** Easy

Solution: Photons are absorbed and re-emitted by the surrounding gas at random angles. The journey is an enormous random walk covering roughly a millimetre per step, and only enough random steps can drag the photon outward. It still travels at the speed of light between absorptions, but the shredded, zigzag path takes millennia.

Q15

Deep in the night a northern outpost loses radio contact for several hours, and pale auroras spread over latitudes where they are never seen in daylight. A billion-tonne cloud of magnetised plasma had been flung from the Sun about a day earlier. What was the responsible solar phenomenon?

(A) A large sunspot drifting slowly across the disk

(B) A coronal mass ejection (CME) aimed toward Earth

(C) A total lunar eclipse in progress

(D) The steady solar wind briefly reversing direction

Answer: (B) **Difficulty:** Medium

Solution: A CME hurls a large blob of corona into the heliosphere. When its embedded field presses against Earth's field, magnetic reconnection pours energy into the magnetosphere, driving geomagnetic storms, low-latitude auroras, and radio blackouts.

Q16

A blue supergiant sheds its outer layers in a wind that streams off into space at 2000 km/s, carrying away one millionth of a solar mass every year. How much mechanical power is the wind whisking off the star?

(A) 1.3×10^{28} W

(B) 1.3×10^{29} W

(C) 1.3×10^{30} W

(D) 1.3×10^{31} W

Answer: (B) **Difficulty:** Medium

Solution: Mass-loss rate first, in kilograms per year then per second:

$$\dot{M} = 10^{-6}\, M_\odot = 10^{-6}(1.989 \times 10^{30}) = 1.989 \times 10^{24}\ \mathrm{kg/yr} \approx 6.3 \times 10^{16}\ \mathrm{kg/s}. \tag{6}$$

The wind kinetic power is $\frac{1}{2}\dot{M}v^2$ with $v = 2000$ km/s $= 2 \times 10^6$ m/s:

$$P = \tfrac{1}{2}(6.3 \times 10^{16})(2 \times 10^6)^2 \approx 1.3 \times 10^{29}\ \mathrm{W}. \tag{7}$$

Q17

A main-sequence star carries twice the Sun's mass and shines at 40 times the Sun's luminosity. The Sun, one solar mass at one solar luminosity, lives on the main sequence for about 10 billion years. Heavy stars burn their larger fuel tanks far faster, exactly in proportion to how much light they pour out. How long does the 2-solar-mass star live?

(A) 0.25 Gyr

(B) 0.5 Gyr

(C) 2 Gyr

(D) 5 Gyr

Answer: (B) **Difficulty:** Easy

Solution: The available fuel grows with mass, while the burn rate grows with luminosity, so the lifetime is

$$t_\star = t_\odot \frac{M_\star/L_\star}{M_\odot/L_\odot} = 10\ \mathrm{Gyr} \times \frac{2\,M_\odot/40\,L_\odot}{M_\odot/L_\odot} = 10 \times \frac{2}{40} = 0.5\ \mathrm{Gyr}. \tag{8}$$

The heavier star holds twice the fuel but spends it forty times as fast.

Q18

Just after its birth in a supernova, a neutron star spins once every 33 milliseconds, and its lighthouse beam still blinks at that rate today. The star packs about 1.4 solar masses into a radius of roughly 12 km, and its spinning magnetic wind drains rotational energy away at a rate of about 10^{30} W. Treating the star as a uniform sphere, estimate how long the spin-down power needs to eat up most of the star's rotational energy.

(A) about 100 years

(B) about 10 000 years

(C) about 100 000 years

(D) about 10 million years

Answer: (C) **Difficulty:** Hard

Solution: Chain the steps: (i) angular frequency from the period;

$$f = \frac{1}{P} = \frac{1}{0.033} \approx 30\ \text{Hz}, \qquad \omega = 2\pi f \approx 190\ \text{rad/s}. \tag{9}$$

(ii) moment of inertia of the uniform sphere, $I = \frac{2}{5}MR^2$, with $M = 1.4\,M_\odot = 2.78 \times 10^{30}$ kg and $R = 1.2 \times 10^4$ m:

$$I = \frac{2}{5}(2.78 \times 10^{30})(1.2 \times 10^4)^2 = 1.6 \times 10^{38}\ \text{kg} \cdot \text{m}^2. \tag{10}$$

(iii) rotational kinetic energy $E = \frac{1}{2}I\omega^2$:

$$E = \tfrac{1}{2}(1.6 \times 10^{38})(190)^2 = 2.9 \times 10^{42}\ \text{J}. \tag{11}$$

(iv) divide by the drain power $P = 10^{30}$ W and convert to years:

$$t = \frac{E}{P} = \frac{2.9 \times 10^{42}}{10^{30}} = 2.9 \times 10^{12}\ \text{s} = \frac{2.9 \times 10^{12}}{3.15 \times 10^7} \approx 9 \times 10^4\ \text{years}. \tag{12}$$

The stored spin is immense, so even a fierce magnetic wind bleeds it away only over a timescale of order 10^5 years.

Q19

A GPS satellite circles Earth once every 12 hours at an altitude of about 20 200 km, while a clock stays on the ground. Two relativistic corrections compete on board: the satellite's orbital motion slows its clock down, while the weaker gravity up there speeds it up. Earth's surface sits about 6371 km from the planet's centre. Estimate the satellite clock's net drift, and its sign, relative to the ground clock after one full day.

(A) It runs fast by about 40 μs per day

(B) It runs slow by about 40 μs per day

(C) It runs fast by about 7 μs per day

(D) It runs slow by about 7 μs per day

Answer: (A) **Difficulty:** Brutal

Solution: Work in metres. (i) Orbital radius:

$$r = R_\oplus + h = 6.371 \times 10^6 + 2.02 \times 10^7 = 2.66 \times 10^7 \text{ m}. \tag{13}$$

(ii) Circular speed from the gravitational parameter $\mu = GM_\oplus = 3.986 \times 10^{14}\ \text{m}^3/\text{s}^2$:

$$v = \sqrt{\frac{\mu}{r}} = \sqrt{\frac{3.986 \times 10^{14}}{2.66 \times 10^7}} = 3.9 \times 10^3 \text{ m/s}. \tag{14}$$

(iii) Special-relativity slow-down of the satellite clock, a fraction $\frac{1}{2}(v/c)^2$:

$$\left.\frac{\Delta t}{t}\right|_{\text{SR}} = \frac{1}{2}\left(\frac{3.9 \times 10^3}{3 \times 10^8}\right)^2 = 8.4 \times 10^{-11}. \tag{15}$$

(iv) General-relativity speed-up of the higher clock, a fraction $(GM_\oplus/c^2)(1/R_\oplus - 1/r)$:

$$\frac{GM_\oplus}{c^2} = \frac{3.986 \times 10^{14}}{9 \times 10^{16}} = 4.43\times10^{-3} \text{ m}, \qquad \frac{1}{R_\oplus} - \frac{1}{r} = 1.57\times10^{-7} - 3.76\times10^{-8} = 1.19\times10^{-7} \text{ m}^{-1}, \tag{16}$$

$$\left.\frac{\Delta t}{t}\right|_{\text{GR}} = 4.43 \times 10^{-3} \times 1.19 \times 10^{-7} = 5.3 \times 10^{-10}. \tag{17}$$

(v) Net fractional gain, then scale to one day:

$$\frac{\Delta t}{t} = 5.3\times10^{-10} - 8.4\times10^{-11} = 4.46\times10^{-10}, \qquad \Delta t = 4.46\times10^{-10}\times86\,400 \approx 3.9\times10^{-5} \text{ s} \approx +40\,\mu\text{s/day}. \tag{18}$$

Gravity wins by a wide margin, so the uncompensated satellite clock gains about 40 microseconds a day. That is exactly why real GPS clocks are pre-set to tick slightly slow before launch. The 7 μs answer is the special-relativity piece alone, and it has the wrong sign.

Q20

Philosophers at the court aim a pulsed light-beacon toward the event horizon of a black hole. An observer very far away watches the blinks grow steadily fainter and redder, yet never sees one actually cross the horizon. What is the reason?

(A) The pulses are destroyed the instant they touch the horizon

(B) Time is infinitely dilated at the horizon, so each crossing reaches the far observer only after an infinite delay

(C) The beacon stops emitting light before reaching the horizon

(D) Gravity is somehow stronger than light at the horizon

Answer: (B) **Difficulty:** Medium

Solution: For the distant observer, gravitational time dilation stretches the beacon's clock intervals without bound as it nears the horizon: each pulse arrives after an ever longer delay, reddened and fainter. The beacon itself crosses the horizon in ordinary, finite proper time and feels nothing special there.

Q21

An unlucky astronaut falls feet-first toward a stellar-mass black hole. As she approaches the event horizon, what does she actually feel?

(A) A gentle push carrying her outward
(B) Nothing at all, since passing a horizon is completely safe
(C) A stretching force pulling her apart along her length
(D) An intense electric shock

Answer: (C) **Difficulty:** Easy

Solution: Gravity pulls harder on her feet, closer to the hole, than on her head, so a tidal stretch grows along her body. For a small stellar-mass hole this force is enormous before the horizon, tearing her apart in a process called spaghettification. For a supermassive hole, the same force is gentle at the horizon.

Q22

Two neutron stars spiral around each other, radiating gravitational waves. Just before they touch, their orbital period has fallen to 0.02 s. The gravitational wave a binary emits oscillates at twice the orbital frequency. What frequency do the detectors capture at that instant?

(A) 10 Hz
(B) 25 Hz
(C) 50 Hz
(D) 100 Hz

Answer: (D) **Difficulty:** Medium

Solution: Invert the period to get the orbital frequency, then double it:

$$f_{\text{orb}} = \frac{1}{P} = \frac{1}{0.02} = 50 \text{ Hz}, \qquad f_{\text{GW}} = 2f_{\text{orb}} = 100 \text{ Hz}. \tag{19}$$

As the orbit shrinks, the period drops and this tone climbs right into the detectors' audible band before the merger.

Q23

Dr. Hussein writes the spectral sequence on the board from hottest to coolest: O, B, A, F, G, K, M. Which of the stars shown below is the hottest of the four?

(A) G2II
(B) K5III
(C) B8V
(D) M1V

Answer: (C) **Difficulty:** Easy

Solution: In the sequence O, B, A, F, G, K, M from hottest to coolest, an early B star (B8V) is hotter than any G or K giant and far hotter than an M dwarf. The luminosity class (V, III, II) does not set the surface-temperature order.

Q24

Astronomers trust Type Ia supernovae as standard candles for the distances of the universe. What is the physical reason the same kind of explosion repeats at nearly the same peak brightness?

(A) White dwarfs ignite accreted matter around the same critical mass, and brighter ones are corrected by their decline rate

(B) They all occur inside the very same kind of host galaxy

(C) Their light curves always last exactly one week

(D) They never suffer any interstellar extinction

Answer: (A) **Difficulty:** Hard

Solution: A carbon-oxygen white dwarf accretes until it approaches the critical mass at which electron degeneracy can no longer support it, then detonates with a nearly fixed mass. The peak brightness also correlates with how fast the light curve declines, so the measured curve lets the luminosity be calibrated to a common value.

Q25

Gas drained from a companion star spirals inward through a blazing disk around a compact object. The mage asks what feeds such intense radiation.

(A) Viscous friction heats the falling gas, turning gravitational energy into radiation

(B) The disk is powered by nuclear fusion along its rim

(C) The disk merely reflects the light of the companion star

(D) The disk glows because it spins through a vacuum

Answer: (A) **Difficulty:** Medium

Solution: Matter can only spiral inward by dissipating orbital energy through viscosity, which heats the gas. The released gravitational energy becomes heat and then radiation, with the innermost, fastest rings the hottest and bluest.

Q26

A small moon drifts past the probe with a measured mass of 1.5×10^{21} kg and a measured volume of 5.0×10^{17} m^3. Its craters and thin exosphere are irrelevant to the calculation. What is the moon's average density?

(A) $1000\ \mathrm{kg/m^3}$
(B) $2000\ \mathrm{kg/m^3}$
(C) $3000\ \mathrm{kg/m^3}$
(D) $4000\ \mathrm{kg/m^3}$

Answer: (C) **Difficulty:** Easy

Solution:

$$\rho = \frac{M}{V} = \frac{1.5 \times 10^{21}}{5.0 \times 10^{17}} = 3000\ \mathrm{kg/m^3}. \tag{20}$$

A density near $3000\ \mathrm{kg/m^3}$ points to a rocky-icy mix rather than a purely icy body.

Q27

An exoplanet hunter notices that a planet's transits arrive early, then late, then early again, in a gentle repeating rhythm, even though the star itself shows no variability. What is happening?

(A) An unseen second planet is gravitationally tugging the transiting one
(B) The host star is pumping out its own brightness in phase
(C) The timing jitter comes from detector noise alone
(D) Transits can only appear when a planet crosses the disk

Answer: (A) **Difficulty:** Medium

Solution: Two planets tug each other gravitationally, so the transiting planet's orbit wobbles and its crossings arrive alternately early and late. The amplitude and rhythm of the wobble reveal the hidden companion's period and a fair estimate of its mass.

Q28

Sami watches a quiet Sun-like star wobble toward and away from Earth with a gentle rhythm that repeats every four years, while an unseen planet pulls on it. What does this wobble directly measure about the planet?

(A) Its surface temperature
(B) Its minimum mass along the line of sight
(C) Its exact radius
(D) Its colour

Answer: (B) **Difficulty:** Easy

Solution: The Doppler wobble of the star traces its orbital motion around the shared centre of mass. Its amplitude gives the planet's mass times the sine of the orbit inclination, so it fixes a minimum mass; the true mass could be larger and the radius and temperature are not measured here at all.

Q29

Landing near a dim red dwarf, the crew finds a planet frozen on one side and scorched on the other, with a ring of perpetual twilight between them. Which property of the system explains such a world?

(A) Light pressure from the star slowly brakes the planet's spin

(B) The planet is tidally locked, always showing one face to its star

(C) The planet was captured into orbit only recently

(D) The two hemispheres formed from different material

Answer: (B) **Difficulty:** Medium

Solution: A dim red dwarf keeps its habitable zone very close in, where tides are strong. Within a billion years this usually forces synchronous rotation, leaving one hemisphere permanently facing the star and the other permanently in night.

Q30

Dr. Hussein compares two rocky worlds at the same distance from the same star. World A is brilliant white and reflects most of the incoming light; World B is dark and absorbs nearly all of it. Which conclusion is correct?

(A) World A ends up the warmer

(B) World A ends up the cooler

(C) The two worlds settle at the same temperature

(D) Nothing can be said without more measurements

Answer: (B) **Difficulty:** Easy

Solution: Albedo is the fraction of light a world reflects. The bright world (A) absorbs only a little starlight, so it stays cooler than the dark world (B), which swallows nearly all the light and must radiate it back at a higher temperature.

Q31

Mapping the moons of Jupiter, a scout is astonished: the innermost of the large moons is the most volcanically active body in the Solar System, with hundreds of erupting volcanoes, while a similar-sized moon farther out is frozen and smooth. What keeps that innermost moon molten?

(A) Radioactive decay of heavy elements in its core

(B) Tidal flexing driven by Jupiter's strong gravity

(C) A long history of giant impacts

(D) Its position closer to the Sun than the other moons

Answer: (B) **Difficulty:** Medium

Solution: Io is pulled hard by Jupiter and nudged by Europa and Ganymede in a resonant dance, which keeps its orbit slightly eccentric. The varying tidal squeeze flexes and heats Io's interior, melting rock and driving the fiercest volcanism in the Solar System.

Q32

A world circles its Sun-like star at a distance of 9 AU, far beyond the snow line. Let the orbit be nearly circular, and leave all moons out of the story. What is the length of this world's year?

(A) 3 years
(B) 9 years
(C) 27 years
(D) 81 years

Answer: (C) **Difficulty:** Easy

Solution:

$$P^2 = a^3 = 9^3 = 729 \;\Rightarrow\; P = \sqrt{729} = 27 \text{ years.} \tag{21}$$

More directly, the period grows as $a^{3/2}$, so $P = 9^{3/2} = 27$ years.

Q33

On a moonless night Dr. Hussein asks why the sky is dark rather than one brilliant sheet of starlight. If the universe were infinite, eternal, and full of stars, every line of sight would eventually land on a stellar surface. What settles the puzzle?

(A) Stars become invisible simply because they are so far away
(B) The universe has a finite past and space is expanding, so the light of most distant stars never reaches us
(C) Dust absorbs all starlight perfectly, forever
(D) The Sun's own glow simply overpowers everything else

Answer: (B) **Difficulty:** Medium

Solution: In an infinite, eternal, static universe the sky would blaze like the Sun in every direction, which is the heart of Olbers' paradox. The sky stays dark because the universe has a finite age and because expansion redshifts and dims the light from distant galaxies.

Q34

Survey workers log a faint galaxy that seems to recede at 8400 km/s, and the survey adopts a Hubble constant of 70 km/s per Mpc. Setting aside the tiny peculiar motions within its group, what distance do they infer?

(A) 60 Mpc

(B) 120 Mpc

(C) 240 Mpc

(D) 840 Mpc

Answer: (B) **Difficulty:** Easy

Solution:

$$d = \frac{v}{H_0} = \frac{8400}{70} = 120 \text{ Mpc}. \tag{22}$$

A single galaxy's distance is rough because any peculiar motion contaminates its measured recession speed.

Q35

The cosmic microwave background looks almost perfectly smooth in every direction, yet a careful map shows a pattern: a blue shift across one half of the sky, a red shift across the opposite half, and very faint ripples everywhere else. What causes the large dipole?

(A) Our own motion relative to the CMB rest frame

(B) The Sun sitting at the centre of the universe

(C) The gravitational pull of the Moon

(D) The background being emitted by nearby clouds

Answer: (A) **Difficulty:** Medium

Solution: The dominant, large-scale pattern is a Doppler dipole from the Solar System's motion relative to the CMB rest frame: the background is boosted toward the direction we move and dimmed behind us. The remaining ripples, at one part in a hundred thousand, are genuine primordial density variations.

Q36

Orbiting the rim of a spiral galaxy, an observer measures the gas and stars far beyond the bright disk and finds the rotation curve stays nearly flat instead of falling off. What does this demand?

(A) The galaxy holds large amounts of nonluminous mass stretching far beyond the seen stars

(B) Newton's laws simply stop working outside the star-forming disk

(C) The stars are all flying on unbound escape orbits

(D) The dark gaps between the spiral arms hold no mass at all

Answer: (A) **Difficulty:** Medium

Solution: For a circular orbit the enclosed mass $M(r)$ obeys $v^2 = GM(r)/r$, so a flat curve means the enclosed mass keeps growing with radius even where starlight fades. This unseen component, dark matter, outweighs the visible baryonic mass of galaxies by a large factor.

Q37

A student applies the simple approximation that recession speed is the speed of light times the redshift to a galaxy at $z = 0.1$ and obtains about 30 000 km/s. A more careful relativistic treatment of the same recession returns a velocity that is...

(A) a little less than 30 000 km/s

(B) a little more than 30 000 km/s

(C) exactly equal to 30 000 km/s

(D) half of 30 000 km/s

Answer: (A) **Difficulty:** Medium

Solution:

$$\frac{v}{c} = \frac{(1+z)^2 - 1}{(1+z)^2 + 1} = \frac{0.21}{2.21} = 0.095, \qquad v \approx 28\,500 \text{ km/s}. \tag{23}$$

The relativistic result runs about 5% below the familiar approximation 30 000 km/s.

Q38

Adel builds the cosmic distance ladder from the ground up, calibrating each new rung against the one below it to reach ever farther. Which order carries him from the nearest stars to the deep universe?

(A) Parallax → Cepheid variables → Type Ia supernovae

(B) Cepheid variables → Parallax → Type Ia supernovae

(C) Type Ia supernovae → Parallax → Cepheid variables

(D) Parallax → Type Ia supernovae → Cepheid variables

Answer: (A) **Difficulty:** Medium

Solution: Geometric parallax reaches only the nearest stars, so it calibrates the period-luminosity law of Cepheid variables, which extend across a galaxy to nearby galaxies. Those distances then calibrate bright, uniform Type Ia supernovae, which carry the ladder across gigaparsecs to the very edge of the visible universe.

Q39

A small probe, dry mass 2000 kg, lifts its ascent stage with 6000 kg of propellant. The engine throws exhaust gas backward at 3000 m/s until the tank runs dry. Estimate the total speed the probe gains from this burn.

(A) 0.75 km/s

(B) 2.1 km/s

(C) 4.2 km/s

(D) 12 km/s

Answer: (C) **Difficulty:** Medium

Solution: The mass ratio is the fully loaded over the dry mass:

$$\frac{m_0}{m_1} = \frac{2000 + 6000}{2000} = \frac{8000}{2000} = 4, \tag{24}$$

and the rocket equation gives the speed gain from the exhaust velocity and the logarithm of that ratio:

$$\Delta v = v_e \ln \frac{m_0}{m_1} = 3000 \times \ln 4 = 3000 \times 1.386 \approx 4.2 \times 10^3 \text{ m/s} = 4.2 \text{ km/s}. \tag{25}$$

Doubling the propellant mass would multiply the ratio only slightly, which is exactly why rocket builders fight for every percent of structural mass.

Q40

A capsule must climb away from Earth's surface and never fall back, coasting forever under gravity alone. Near the surface the acceleration is about 9.8 m/s^2 and Earth's radius is about 6400 km. Estimate the speed the capsule needs at launch.

(A) 7.9 km/s

(B) 11.2 km/s

(C) 15.8 km/s

(D) 42 km/s

Answer: (B) **Difficulty:** Medium

Solution: Convert the radius to metres, then set the launch kinetic energy equal to the gravitational climb against the surface gravity:

$$v_{\text{esc}} = \sqrt{2gR} = \sqrt{2(9.8)(6.4 \times 10^6)} = \sqrt{1.25 \times 10^8} \approx 1.12 \times 10^4 \text{ m/s} = 11.2 \text{ km/s}. \tag{26}$$

Notice the subtle contrast: a circular low orbit needs only about 7.9 km/s, and doubling that still barely beats the required climbing speed.