Class Test — 52 Objective Questions

Devendra Ghate

November 18, 2026

Table of contents

How to use these questions 1

Answer key 9

How to use these questions

There are 52 questions drawn from the four topics of the study plan — the n-body problem, the two-body problem, orbital elements, and orbital maneuvers — across three difficulty levels. Every question has exactly one correct option. Choose it before opening the **Answer**, which gives the reason and, for a number, the calculation. All the answers are listed together in the answer key at the end.

Every number in the questions and answers is recomputed by objective-questions-verify.py. The figures are drawn by fig-oq-objective.py.

Data, unless a question says otherwise. $\mu_\oplus = 398\,600\ \mathrm{km^3/s^2}$, $R_\oplus = 6378\ \mathrm{km}$, $g_0 = 9.80665\ \mathrm{m/s^2}$, $G = 6.674\times10^{-11}\ \mathrm{m^3\,kg^{-1}\,s^{-2}}$, $\mu_\odot = 1.327\times10^{11}\ \mathrm{km^3/s^2}$, $1\ \mathrm{AU} = 1.496\times10^{8}\ \mathrm{km}$, $M_\odot/m_{\mathrm{Jupiter}} = 1047.6$, $J_2 = 1.08263\times10^{-3}$. Burns are impulsive and orbits are two-body, unless a question says otherwise. Angles in Kepler's equation are in radians.

Symbols and constants shared by all the notes are collected on the notation page; the study plan gives the order in which to read the notes.

1. The n-body problem in three dimensions, written as first-order equations for the positions and velocities, is a system of how many scalar ODEs?

(A) 10
(B) $6n - 10$
(C) $6n$
(D) $3n$

Answer. (**C**) Each body has three position and three velocity components, so the state has $6n$ numbers, and each needs its own first-order equation.

2. For an isolated system of n point masses, the centre of mass

(A) is always at rest
(B) moves on a conic section
(C) moves in a straight line at constant speed
(D) moves towards the heaviest body

Answer. (**C**) The internal forces cancel in pairs, so $\sum m_i \ddot{\mathrm{R}}_i = 0$. Integrating twice gives $\mathrm{R}_{\mathrm{cm}} = \mathrm{C}_1 t/M + \mathrm{C}_2/M$: uniform straight-line motion. We may choose a frame in which it is at rest, but that is a choice.

3. The distance between two point masses is halved. The gravitational force between them becomes

(A) half as large
(B) twice as large
(C) four times as large
(D) eight times as large

Answer. **(C)** $F = Gm_1m_2/r^2$, so $r \to r/2$ multiplies F by $2^2 = 4$.

4. Which of these force fields is **not** conservative?

(A) the field of an oblate Earth
(B) the field of a point mass
(C) the field of two fixed point masses
(D) $\mathbf{F} = k\,(-y,\ x,\ 0)$

Answer. **(D)** Its curl is $(0, 0, 2k) \neq 0$. Every gravitational field, however irregular the body, is a superposition of point-mass fields and so has zero curl.

5. A planet has four times the semi-major axis of another. By Kepler's third law its period is larger by a factor of

(A) 2
(B) 4
(C) 8
(D) 16

Answer. **(C)** $T \propto a^{3/2}$, so $T_2/T_1 = 4^{3/2} = 8$.

6. Jupiter ($m_J = M_\odot/1047.6$) is at 5.203 AU. Treating the Sun and Jupiter as a two-body pair, the Sun–Jupiter barycentre is at a distance from the Sun's centre of about ($R_\odot = 6.96 \times 10^5$ km)

(A) $0.1\,R_\odot$, deep inside the Sun
(B) $0.5\,R_\odot$
(C) $1.07\,R_\odot$, just outside the Sun's surface
(D) $10\,R_\odot$

Answer. **(C)** $d = a_J\, m_J/(M_\odot + m_J) = 5.203 \times 1.496 \times 10^8/1048.6 = 7.42 \times 10^5$ km $= 1.07\,R_\odot$. The Sun really does orbit a point outside itself.

7. A 1 kg mass moves at $(3, 0)$ m/s and a 2 kg mass at $(0, 3)$ m/s. The speed of their centre of mass is

(A) 1.0 m/s
(B) 2.0 m/s
(C) 2.24 m/s
(D) 3.0 m/s

Answer. **(C)** $\mathrm{V}_{\mathrm{cm}} = (1 \cdot (3,0) + 2 \cdot (0,3))/3 = (1, 2)$ m/s, whose magnitude is $\sqrt{5} = 2.24$ m/s.

8. Two equal masses m are a distance d apart. At the midpoint, the gravitational field and potential are

(A) field 0, potential 0
(B) field $8Gm/d^2$, potential $-2Gm/d$
(C) field $2Gm/d^2$, potential 0
(D) field 0, potential $-4Gm/d$

Answer. **(D)** The two fields are equal and opposite, so they cancel. Potentials are scalars and add: $2 \times (-Gm/(d/2)) = -4Gm/d$.

9. At closest approach Jupiter is 4.203 AU from the Earth. Its direct pull on the Earth, as a fraction of the Sun's pull, is about ($m_J = M_\odot/1047.6$)

(A) 5×10^{-3}
(B) 5×10^{-4}
(C) 5×10^{-5}
(D) 5×10^{-7}

Answer. **(C)** $(1/1047.6) \times (1\ \mathrm{AU}/4.203\ \mathrm{AU})^2 = 5.4 \times 10^{-5}$. Small, but it accumulates: this is why the planets are only *nearly* on Kepler orbits.

10. Treat Jupiter (1.898×10^{27} kg, 5.203 AU) and Saturn (5.683×10^{26} kg, 9.537 AU) as on circular orbits about the Sun. The ratio of their orbital angular momenta, L_J/L_S, is about

(A) 1.8

(B) 2.5
(C) 3.3
(D) 6.1

Answer. **(B)** For a circular orbit $L = m\sqrt{\mu a}$, so $L_J/L_S = (m_J/m_S)\sqrt{a_J/a_S} = 3.340 \times 0.7386 = 2.47$. Saturn's larger distance makes up part of its smaller mass.

11. Three bodies of *arbitrary* masses sit at the corners of an equilateral triangle. The net gravitational force on each body

(A) points towards the common centre of mass, with magnitude proportional to the body's distance from it
(B) points towards the heaviest body
(C) points towards the centre of mass only if the masses are equal
(D) is zero

Answer. **(A)** $\mathrm{F}_i = \sum_j Gm_i m_j(\mathrm{R}_j - \mathrm{R}_i)/d^3 = Gm_i M(\mathrm{R}_{\mathrm{cm}} - \mathrm{R}_i)/d^3$. This is what allows the whole triangle to rotate rigidly: Lagrange's equilateral solution.

12. Three equal masses m on an equilateral triangle of side d rotate rigidly about their centre of mass. The angular velocity satisfies

(A) $\omega^2 = 3Gm/d^3$
(B) $\omega^2 = Gm/d^3$
(C) $\omega^2 = Gm/(3d^3)$
(D) $\omega^2 = \sqrt{3}\,Gm/d^3$

Answer. **(A)** The net force on one mass is $2(Gm^2/d^2)\cos 30^\circ = \sqrt{3}\,Gm^2/d^2$, towards the centre at distance $d/\sqrt{3}$. So $m\omega^2 d/\sqrt{3} = \sqrt{3}\,Gm^2/d^2$, i.e. $\omega^2 = 3Gm/d^3 = G(3m)/d^3$, Kepler's third law with the total mass.

13. In the relative two-body equation $\ddot{\mathrm{r}} = -\mu\,\mathrm{r}/r^3$, the gravitational parameter is

(A) $G(m_1 + m_2)$
(B) $Gm_1m_2/(m_1 + m_2)$
(C) Gm_1
(D) Gm_2

Answer. **(A)** Subtracting the two equations of motion, $\ddot{\mathrm{R}}_2 - \ddot{\mathrm{R}}_1 = -G(m_1 + m_2)\mathrm{r}/r^3$. Both bodies accelerate towards each other, so their masses add.

14. Why does a two-body orbit lie in a fixed plane?

(A) Because $\mathrm{h} = \mathrm{r} \times \dot{\mathrm{r}}$ is constant, and r is always perpendicular to it
(B) Because the energy is conserved
(C) Because the force is inverse-square
(D) Because the centre of mass is at rest

Answer. **(A)** $\dot{\mathrm{h}} = \mathrm{r} \times \ddot{\mathrm{r}} = 0$ for any central force. Since $\mathrm{r} \cdot \mathrm{h} = 0$ at every instant, r stays in the plane perpendicular to the fixed vector h.

15. On any elliptical orbit, at the points where $r = a$ the speed is

(A) the largest on the orbit
(B) zero
(C) $\sqrt{2\mu/a}$
(D) $\sqrt{\mu/a}$, the circular speed at that radius

Answer. **(D)** *Vis-viva*: $v^2 = \mu(2/r - 1/a) = \mu/a$ at $r = a$. These are the ends of the minor axis.

16. The period of a circular orbit of radius 6678 km (about 300 km altitude) is about

(A) 24 h
(B) 98 min
(C) 90.5 min
(D) 84 min

Answer. (**C**) $T = 2\pi\sqrt{r^3/\mu} = 2\pi\sqrt{6678^3/398\,600} = 5431$ s $= 90.5$ min.

17. The eccentricity vector e of an orbit points

(A) from the focus towards apoapsis
(B) along h
(C) from the focus towards periapsis
(D) along the velocity at periapsis

Answer. (**C**) At periapsis, v × h/μ and $\hat{\mathrm{r}}$ both point outwards, and e is their difference, of length e, along the line to periapsis.

18. An orbit has $r_p = 7000$ km and $r_a = 14\,000$ km. Its semi-major axis and eccentricity are

(A) $a = 14\,000$ km, $e = 1/3$
(B) $a = 10\,500$ km, $e = 1/3$
(C) $a = 10\,500$ km, $e = 0.5$
(D) $a = 7000$ km, $e = 0.5$

Answer. (**B**) $a = (r_p + r_a)/2 = 10\,500$ km and $e = (r_a - r_p)/(r_a + r_p) = 7000/21\,000 = 1/3$.

19. At $r = 7000$ km a spacecraft moves at 12 km/s. Its hyperbolic excess speed is about

(A) 8.70 km/s
(B) 7.55 km/s
(C) 5.49 km/s
(D) 1.33 km/s

Answer. (**C**) $v_\infty^2 = v^2 - 2\mu/r = 144 - 113.9 = 30.1$, so $v_\infty = 5.49$ km/s. Subtracting the escape speed itself $(12 - 10.67)$ is the common mistake.

20. An orbit has specific energy $\varepsilon = -20$ km^2/s^2 and $h = 60\,000$ km^2/s. Its eccentricity is about

(A) 0.91
(B) 0.55
(C) 0.31
(D) 0.09

Answer. (**C**) $e^2 = 1 + 2\varepsilon h^2/\mu^2 = 1 - 2 \times 20 \times 3.6 \times 10^9/398\,600^2 = 1 - 0.906 = 0.094$, so $e = 0.306$.

21. At $r = 8000$ km a spacecraft moves at 8 km/s, in any direction. Its semi-major axis is about

(A) 8000 km
(B) 11 180 km
(C) 13 600 km
(D) 22 360 km

Answer. (**B**) $1/a = 2/r - v^2/\mu = 2/8000 - 64/398\,600 = 8.944 \times 10^{-5}$ km^{-1}, so $a = 11\,181$ km. The direction does not enter: a depends only on the energy.

22. On an orbit with $e = 0.5$, what fraction of the period does the body take to go from periapsis to $f = 90°$?

(A) 0.050
(B) 0.098
(C) 0.167
(D) 0.250

Answer. (**B**) $\tan\frac{E}{2} = \sqrt{\frac{1-e}{1+e}}\tan 45° = 1/\sqrt{3}$, so $E = 60°$. Then $M = \pi/3 - 0.5\sin 60° = 0.614$, and $M/2\pi = 0.098$. A quarter of the angle takes under a tenth of the time.

23. At $r = 7000$ km a body moves at 8.266 km/s with flight-path angle $10°$ (so $rv^2/\mu = 1.2$). Its eccentricity is about

(A) 0.35
(B) 0.26
(C) 0.20
(D) 0.14

Answer. (**B**) With $\nu = rv^2/\mu$, $e^2 = 1 - \nu(2-\nu)\cos^2\gamma = 1 - 1.2 \times 0.8 \times \cos^2 10^\circ = 0.0689$, so $e = 0.263$. With $\gamma = 0$ it would be $|\nu - 1| = 0.2$.

24. For an orbit with $e = 0.6$, the time average of the distance r over one period is

(A) $0.80\,a$
(B) a
(C) $1.18\,a$
(D) $1.36\,a$

Answer. (**C**) Using $dt \propto (1 - e\cos E)\,dE$: $\langle r \rangle_t = \frac{a}{2\pi}\oint(1 - e\cos E)^2 dE = a(1 + e^2/2) = 1.18\,a$. The body lingers far out. ($0.80\,a = b$ is the average over true anomaly). Needs the formula $r = a(1 - e\cos E)$ and $M = nt = E - e\sin E$.

25. In the two-body problem, body 1 moves about the barycentre on

(A) an ellipse with the barycentre at its centre
(B) a circle
(C) the same ellipse as body 2
(D) an ellipse with the same e and period as the relative orbit, scaled by $m_2/(m_1 + m_2)$

Answer. (**D**) $\mathrm{R}_1 - \mathrm{R}_{\mathrm{cm}} = -\frac{m_2}{m_1+m_2}\mathrm{r}$: a scaled, point-reflected copy of the relative orbit, with the barycentre at its focus.

26. Why are exactly six classical orbital elements needed?

(A) Because the two-body equations of motion need six initial conditions
(B) Because the orbit lies in a plane
(C) Because the ellipse has six symmetries
(D) Because Kepler stated three laws, each fixing two numbers

Answer. (**A**) The relative motion is three second-order ODEs, i.e. six first-order ones, so a state needs six numbers; the elements are just a more meaningful choice of those six.

27. An orbit with $i = 120^\circ$ is

(A) equatorial
(B) prograde
(C) polar
(D) retrograde

Answer. (**D**) For $90^\circ < i \leq 180^\circ$, $h_K < 0$: the body moves westward, against the Earth's rotation.

28. For a circular orbit, which element is undefined?

(A) Ω
(B) a
(C) i
(D) ω

Answer. (**D**) $e = 0$, so e = 0 has no direction and there is no periapsis to measure ω (or f) from.

29. Which two elements fix the size and shape of an orbit?

(A) i and Ω
(B) ω and f
(C) e and ω
(D) a and e

Answer. (**D**) a fixes the size (and the energy and period), and e the shape. i, Ω, ω orient the orbit, and f places the body on it.

30. A polar orbit has inclination

(A) 180°
(B) 90°
(C) 45°
(D) 0°

Answer. (**B**) $i = 90^\circ$ makes h lie in the equatorial plane, so the orbit passes over both poles.

31. An orbit has h along $(0,\ -\sqrt{3},\ 1)$. Its inclination is

(A) 150°
(B) 120°
(C) 60°
(D) 30°

Answer. (**C**) $|\mathrm{h}| \propto 2$, so $\cos i = 1/2$ and $i = 60^\circ$. Also $\mathrm{n} \propto (\sqrt{3},\ 0,\ 0)$, so $\Omega = 0^\circ$.

32. A satellite has $i = 98^\circ$. The greatest latitude its ground track reaches is (*Assume spherical Earth*)

(A) 98°
(B) 90°
(C) 82°
(D) 8°

Answer. (**C**) $\sin\delta = \sin i \sin u$, so $|\delta|_{\max} = i$ for a prograde orbit and $180^\circ - i = 82^\circ$ for a retrograde one.

33. A body is at $\mathrm{r} = (7000, 0, 0)$ km with $\mathrm{v} = (0, 8, 0)$ km/s. Its eccentricity is about

(A) 0.50
(B) 0.25
(C) 0.12
(D) 0.06

Answer. (**C**) The velocity is horizontal, so the body is at an apsis, with $e = |\nu - 1|$ for $\nu = rv^2/\mu = 7000 \times 64/398\,600 = 1.124$. Hence $e = 0.124$; $\nu > 1$, so this is periapsis, $f = 0^\circ$.

34. The ISS orbit has $i = 51.6^\circ$. When its argument of latitude is $u = 30^\circ$, its latitude is about

(A) 15.0°
(B) 23.1°
(C) 25.8°
(D) 30.0°

Answer. (**B**) $\sin\delta = \sin i \sin u = 0.7837 \times 0.5 = 0.392$, so $\delta = 23.1^\circ$. (Halving i, 25.8°, is the common mistake.)

35. The velocity of a satellite is reversed at some instant, $\mathrm{v} \to -\mathrm{v}$. Its new (i, Ω, ω) are

(A) $(180^\circ - i,\ \Omega + 180^\circ,\ 180^\circ - \omega)$
(B) $(i,\ \Omega,\ \omega)$
(C) $(i,\ \Omega + 180^\circ,\ \omega + 180^\circ)$
(D) $(180^\circ - i,\ \Omega,\ \omega)$

Answer. (**A**) $\mathrm{h} \to -\mathrm{h}$ but e is unchanged. So $\cos i$ flips, the node becomes the old descending node, and since $e_K = e \sin i \sin\omega$ keeps its value while $\cos\omega$ flips, $\omega \to 180^\circ - \omega$. Option (C) is the reflection in the equator.

36. A Molniya orbit has $e = 0.74$ and $\omega = 270^\circ$. The fraction of each period it spends north of the equator is about

(A) 50%
(B) 74%
(C) 92%
(D) 99%

Answer. (**C**) The southern arc is the half centred on periapsis, $|f| < 90^\circ$, which takes $(\arccos e - e\sqrt{1-e^2})/\pi = 0.076$ of the period. So 92% is spent north, near apoapsis.

37. With $J_2 = 1.08263 \times 10^{-3}$, a circular sun-synchronous orbit at 700 km altitude needs an inclination of about

(A) 90.0°
(B) 96.5°
(C) 98.2°
(D) 101.4°

Answer. (**C**) $n = \sqrt{\mu/a^3} = 1.060 \times 10^{-3}$ rad/s for $a = 7078$ km. Then $\cos i = -\dfrac{2\dot{\alpha}_\odot}{3nJ_2(R_\oplus/a)^2} = -\dfrac{2 \times 1.991 \times 10^{-7}}{3 \times 9.32 \times 10^{-7}} = -0.142$, so $i = 98.2°$.

38. A burn may be treated as *impulsive* when

(A) it is made at periapsis
(B) its duration is short compared with the orbital period, so the position barely changes during it
(C) the engine has a high specific impulse
(D) its Δv is small compared with the orbital speed

Answer. (**B**) The impulsive model changes v instantly at fixed r. That is accurate when the spacecraft moves through only a small arc while the engine fires.

39. An engine with $I_{sp} = 300$ s burns until the mass has halved. The Δv delivered is about ($g_0 = 9.80665$ m/s^2)

(A) 4.08 km/s
(B) 2.94 km/s
(C) 2.04 km/s
(D) 1.47 km/s

Answer. (**C**) Rocket equation: $\Delta v = g_0 I_{sp} \ln(m_0/m_f) = 9.80665 \times 300 \times \ln 2 = 2039$ m/s.

40. A Hohmann transfer between coplanar circles consists of

(A) three burns, the middle one at infinity
(B) one burn at the crossing point of the circles
(C) two radial burns
(D) two tangential burns, at the periapsis and the apoapsis of the transfer ellipse

Answer. (**D**) The transfer ellipse touches the inner circle at its periapsis and the outer circle at its apoapsis; both burns are along the velocity.

41. The total Δv of a coplanar Hohmann transfer from a 6678 km circle to GEO (42 164 km) is about

(A) 2.43 km/s
(B) 3.89 km/s
(C) 4.33 km/s
(D) 5.40 km/s

Answer. (**B**) $\Delta v_1 = v_{t1} - v_{c1} = 10.151 - 7.726 = 2.426$ km/s and $\Delta v_2 = v_{c2} - v_{t2} = 3.075 - 1.608 = 1.467$ km/s; the total is 3.893 km/s.

42. To change the plane of an orbit most cheaply, the burn should be made where

(A) the spacecraft's orbital speed is greatest
(B) at either of the two points where the orbits cross each other
(C) at periapsis
(D) at only one of the two points where the orbits cross each other

Answer. (**D**) A pure plane change costs $2v\sin(\Delta i/2)$, proportional to the speed at the burn. It must be made on the line where the two planes meet, at the slower of the two crossings.

43. A spacecraft on a 7000 km circle raises its apoapsis to 14 000 km with one tangential burn. The burn is about

(A) 8.71 km/s
(B) 1.54 km/s
(C) 1.17 km/s
(D) 0.58 km/s

Answer. (**C**) $v_p = \sqrt{2\mu r_a/(r_p(r_p + r_a))} = 8.713$ km/s and $v_c = 7.546$ km/s, so $\Delta v = 1.167$ km/s.

44. At the apogee of a Hohmann orbit raising, the spacecraft has a velocity of $v_{t2} = 1.608$ km/s, and the circular speed it should attain is $v_{c2} = 3.075$ km/s. But the required orbit is inclined by 28.5° to the transfer plane. Find the absolute value of the difference between the Δv of a single burn at apogee and the Δv of the two consecutive burns that would separately circularize and plane-change.

(A) 1.15 km/s
(B) 1.83 km/s
(C) 2.98 km/s
(D) 4.68 km/s

Answer. (**A**) *Reasoning:*

- Single burn at apogee: $\Delta v_{\text{single}} = \sqrt{v_{t2}^2 + v_{c2}^2 - 2 v_{t2} v_{c2} \cos 28.5^\circ} \approx 1.830$ km/s.
- Two separate burns: raise orbit $\Delta v_1 = v_{c2} - v_{t2} = 3.075 - 1.608 = 1.467$ km/s; plane change $\Delta v_2 = 2 v_{c2} \sin(14.25^\circ) \approx 1.514$ km/s. Sum ≈ 2.981 km/s.
- Absolute difference $|1.830 - 2.981| \approx 1.150$ km/s, closest to **1.15 km/s**.

45. A Hohmann transfer from the Earth's orbit (1 AU) to Mars's orbit (1.524 AU), both taken circular and coplanar, takes about

(A) 146 d
(B) 259 d
(C) 343 d
(D) 517 d

Answer. (**B**) $a_t = 1.262$ AU, and half its period is $\frac{1}{2}(1.262)^{3/2}$ yr $= 0.709$ yr $= 259$ d.

46. A circular orbit with $v = 7.5$ km/s and $i = 30^\circ$ has its node moved by 60° at constant inclination. The single burn costs

(A) 1.88 km/s
(B) 3.75 km/s
(C) 6.50 km/s
(D) 7.50 km/s

Answer. (**B**) $\Delta v = 2v \sin i \sin(\Delta\Omega/2) = 2 \times 7.5 \times 0.5 \times 0.5 = 3.75$ km/s, half of what an inclination change of 60° would cost.

47. A chaser on a 7000 km circle trails its target by 30° and uses circular phasing with k revolutions. Taking $R_\oplus = 6378$ km, the smallest k that keeps the phasing perigee above the Earth's surface is

(A) 1
(B) 2
(C) 3
(D) 4

Answer. (**B**) With $k = 1$, $a = 7000(11/12)^{2/3} = 6605$ km and the perigee $2a - 7000 = 6211$ km is below the surface. With $k = 2$, $a = 7000(23/24)^{2/3} = 6804$ km and the perigee is 6608 km.

48. A chaser on a 7000 km circle trails its target by 10° and closes the gap by phasing in about one day. Using $\Delta v_{\text{total}}\, t \approx \frac{2}{3}\, r\, \Delta\theta$, the total cost is about

(A) 94 m/s
(B) 28 m/s
(C) 9.4 m/s
(D) 0.9 m/s

Answer. (**C**) $\frac{2}{3} \times 7000 \times 0.1745 = 814.5$ km, divided by 86 400 s: 9.4×10^{-3} km/s. Halving the time would double the cost.

49. A satellite on a 500 km circular orbit ($R_\oplus = 6378$ km) lowers its perigee to 80 km altitude for re-entry with one retrograde burn. The burn is about

(A) 12 m/s
(B) 121 m/s

(C) 242 m/s
(D) 1.2 km/s

Answer. **(B)** $v_c = \sqrt{\mu/6878} = 7.6127$ km/s. The new apoapsis speed is $\sqrt{2\mu r_p/(r_a(r_a+r_p))} = 7.4919$ km/s with $r_p = 6458$ km, so $\Delta v = 0.1208$ km/s.

50. At the points where $r = a$ on an ellipse, the orbital speed is what fraction of the escape speed at that radius?

(A) $1/2$
(B) $1/\sqrt{2} \approx 0.707$
(C) $\sqrt{2}$
(D) 1

Answer. **(B)** $v_{\text{ell}} = \sqrt{\mu/a}$ while $v_{\text{esc}} = \sqrt{2\mu/a}$, so $v_{\text{ell}}/v_{\text{esc}} = 1/\sqrt{2}$. The answer is independent of a and e.

51. A parabolic orbit and an elliptical orbit pass through the same point at radius $r = a$, where a is the ellipse's semi-major axis. The parabolic speed there is

(A) equal to the elliptical speed
(B) $\sqrt{2}$ times the elliptical speed
(C) $1/\sqrt{2}$ times the elliptical speed
(D) 2 times the elliptical speed

Answer. **(B)** At $r = a$ the ellipse has $v = \sqrt{\mu/a}$ by *vis-viva*, while the parabola has $\varepsilon = 0$ so $v = \sqrt{2\mu/a}$. The ratio is $\sqrt{2}$.

52. At the points where $r = a$ on an ellipse of eccentricity e, the flight-path angle γ between the velocity and the radius vector satisfies

(A) $\sin\gamma = e$
(B) $\tan\gamma = e$
(C) $\gamma = 0$
(D) $\cos\gamma = e$

Answer. **(A)** At $r = a$, $\cos f = -e$, so $\tan\gamma = \dfrac{e\sin f}{1 + e\cos f} = \dfrac{e}{\sqrt{1-e^2}}$, which gives $\sin\gamma = e$. This is also where γ reaches its maximum.

Answer key

All 52 answers, in order.

Answer.

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	C	3	C	4	D	5	C	6	C	7	C	8	D	9	C	10	B
11	A	12	A	13	A	14	A	15	D	16	C	17	C	18	B	19	C	20	C
21	B	22	B	23	B	24	C	25	D	26	A	27	D	28	D	29	D	30	B
31	C	32	C	33	C	34	B	35	A	36	C	37	C	38	B	39	C	40	D
41	B	42	D	43	C	44	A	45	B	46	B	47	B	48	C	49	B	50	B
51	B	52	A																