GATE Aerospace Engineering

Sample Paper – 10

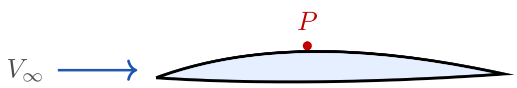
Duration: 128 Minutes **Maximum Marks: 72**

Instructions

- This paper contains **46 questions** covering the core **Aerospace Engineering** subject of the GATE paper conducted by the IITs and IISc (General Aptitude and Engineering Mathematics are provided as separate papers).
- **Q1–Q20 carry 1 mark each** and **Q21–Q46 carry 2 marks each**, for a total of **72 marks**.
- Each question carries **negative marking of one-third of its allotted marks**: a wrong 1-mark question costs **0.33** and a wrong 2-mark question costs **0.67**. Unattempted questions carry no penalty.
- Every question here is a single-correct **MCQ**. The real GATE paper also has Multiple Select (MSQ) and Numerical Answer Type (NAT) questions, and **those carry no negative marking**.
- Attempt this paper in one timed sitting of about **128 minutes**, the share this core subject earns at GATE's overall pace of 180 minutes for 65 questions. Unless stated otherwise, take air as a perfect gas with $\gamma = 1.4$ and $R = 287$ J/kg · K, $g = g_0 = 9.81$ m/s^2, and standard Earth gravitational parameter $\mu = 3.986 \times 10^{14}$ m^3/s^2.

Aerodynamics

Q1. In the low-speed (incompressible) flow of air over the airfoil shown, the local velocity at point P on the surface is 1.2 times the freestream velocity V_∞. Using $C_p = 1 - (V/V_\infty)^2$, the pressure coefficient at P is: **[1 mark]**



(A) 0.44

(B) -0.20

(C) -0.44

(D) -1.44

Q2. Air flows at a Mach number of 0.8 where the local static pressure is 50 kPa. Using the compressible form of dynamic pressure $q = \frac{1}{2}\gamma p M^2$ with $\gamma = 1.4$, the dynamic pressure of the flow is: **[1 mark]**

(A) 16000 Pa

(B) 28000 Pa

(C) 22400 Pa

(D) 11200 Pa

Q3. An aircraft flies at a true airspeed of 170 m/s through air at a static temperature of 288 K ($\gamma = 1.4$, $R = 287$ J/kg $\cdot$ K). The flight Mach number is nearest to: **[1 mark]**

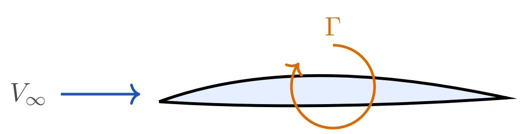
(A) 0.50

(B) 1.00

(C) 0.25

(D) 0.75

Q4. Air ($\rho = 1.225$ kg/m^3) flows at a freestream speed of 50 m/s past a two-dimensional airfoil whose bound circulation is $\Gamma = 20$ m^2/s, in the sense shown. By the Kutta–Joukowski theorem, the lift per unit span is: **[1 mark]**



(A) 2450 N/m

(B) 1225 N/m

(C) 612.5 N/m

(D) 245 N/m

Q5. A wing with a planform area of $25\ \text{m}^2$ operates at a freestream dynamic pressure of 1500 Pa and has a drag coefficient of 0.03. The drag force on the wing is: **[1 mark]**

(A) 2250 N

(B) 750 N

(C) 562.5 N

(D) 1125 N

Q6. Air ($\gamma = 1.4$) flows isentropically at a Mach number of 1.0. Using $\dfrac{p_0}{p} = \left(1 + \frac{\gamma-1}{2}M^2\right)^{\gamma/(\gamma-1)}$, the ratio of stagnation pressure to static pressure is nearest to: **[1 mark]**

(A) 1.000

(B) 2.000

(C) 1.893

(D) 0.528

Q7. At a point on an airfoil the incompressible pressure coefficient is $C_{p,0} = -0.40$. When the same airfoil flies at a freestream Mach number of 0.6, the Prandtl–Glauert rule $\left(C_p = C_{p,0}/\sqrt{1 - M_\infty^2}\right)$ gives the compressible pressure coefficient as: **[1 mark]**

(A) -0.40

(B) -0.32

(C) -0.44

(D) -0.50

Q8. A flat plate is held parallel to a low-speed stream. At a chord Reynolds number of 10^6 the laminar (Blasius) total skin-friction drag coefficient is $C_f = \dfrac{1.328}{\sqrt{Re_L}}$. Its value is nearest to: **[1 mark]**

(A) 0.001328

(B) 0.006640

(C) 0.000664

(D) 0.002656

Q9. A turbulent boundary layer grows over a flat plate. At a station where $x = 2$ m and the local Reynolds number is $Re_x = 10^7$, the boundary-layer thickness from $\delta = \dfrac{0.37x}{Re_x^{1/5}}$ is nearest to: **[1 mark]**

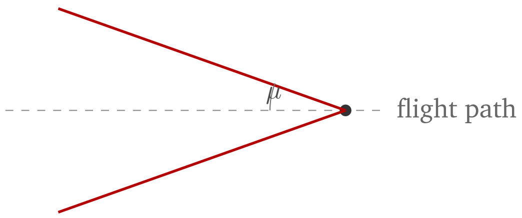
(A) 14.7 mm

(B) 29.5 mm

(C) 37.0 mm

(D) 7.4 mm

Q10. An aircraft flies at a Mach number of 2.0, generating the Mach cone shown. The Mach angle $\big(\mu = \sin^{-1}(1/M)\big)$ is: **[1 mark]**



(A) $45°$

(B) $30°$

(C) $60°$

(D) $19.47°$

Q11. A finite wing has an aspect ratio of 7 and a span efficiency factor of 0.95. The two-dimensional (airfoil) lift-curve slope is $a_0 = 2\pi$ per radian. Using $a = \dfrac{a_0}{1 + a_0/(\pi e\, AR)}$, the finite-wing lift-curve slope is nearest to: **[1 mark]**

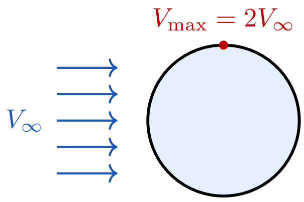
(A) 4.83 per rad

(B) 6.28 per rad

(C) 5.65 per rad

(D) 3.14 per rad

Q12. In the ideal incompressible potential flow over a circular cylinder shown, the maximum surface velocity is twice the freestream velocity. Using $C_p = 1 - (V/V_\infty)^2$, the minimum pressure coefficient on the cylinder is: **[1 mark]**



(A) -1

(B) $+1$

(C) -4

(D) -3

Flight Mechanics & Space Dynamics

Q13. An aircraft of weight $40{,}000$ N is climbing. At its climb speed the engine supplies 1000 kW of power while the power required to overcome drag is 600 kW. The steady rate of climb $\big(R/C = (P_a - P_r)/W\big)$ is: **[1 mark]**

(A) 25 m/s

(B) 40 m/s

(C) 10 m/s

(D) 5 m/s

Q14. An aircraft flies a steady, level, co-ordinated turn at a speed of 100 m/s with a bank angle of $45°$. The radius of the turn $\big(R = V^2/(g \tan\phi)\big)$ is nearest to: **[1 mark]**

(A) 1019 m

(B) 510 m

(C) 2039 m

(D) 720 m

Q15. An aircraft performs a steady, level turn at a speed of 200 m/s with a bank angle of $60°$. The rate of turn $\left(\dot{\psi} = g\tan\phi/V\right)$ is nearest to: **[1 mark]**

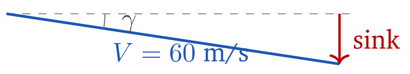
(A) 0.170 rad/s

(B) 0.0425 rad/s

(C) 0.0850 rad/s

(D) 0.0491 rad/s

Q16. An aircraft descends in a steady, unpowered glide at a forward (flight-path) speed of 60 m/s with a glide ratio (lift-to-drag ratio) of 20, as shown. The rate of descent (sink rate) is nearest to: **[1 mark]**



(A) 6 m/s

(B) 1.5 m/s

(C) 3 m/s

(D) 12 m/s

Q17. At a given instant an aircraft is at an altitude of 1000 m and flies at a true airspeed of 140 m/s. Its specific energy height $\left(h_e = h + V^2/(2g)\right)$ is nearest to: **[1 mark]**

(A) 2000 m

(B) 1000 m

(C) 3000 m

(D) 1500 m

Q18. For an aircraft to possess positive static *directional* (weathercock) stability about its centre of gravity, the yawing-moment derivative with respect to sideslip angle β must satisfy: **[1 mark]**

(A) $C_{n_\beta} < 0$

(B) $C_{l_\beta} > 0$

(C) $C_{m_\alpha} > 0$

(D) $C_{n_\beta} > 0$

Q19. In a steady, level, co-ordinated turn an aircraft pulls a load factor of $n = 2.0$. Using $n = 1/\cos\phi$, the corresponding bank angle ϕ is: **[1 mark]**

(A) $45°$

(B) $60°$

(C) $30°$

(D) $75.5°$

Q20. An aircraft has a straight-and-level stalling speed of 50 m/s. In a steady turn it flies at a load factor of $n = 4$. The stalling speed in the turn $\left(V_{s,\text{turn}} = V_s\sqrt{n}\right)$ is: **[1 mark]**

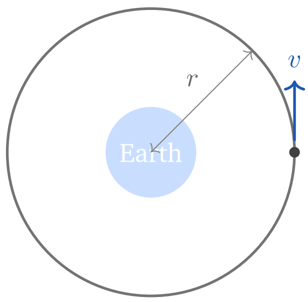
(A) 50 m/s

(B) 200 m/s

(C) 25 m/s

(D) 100 m/s

Q21. A satellite is in a circular orbit of radius 7000 km about the Earth ($\mu = 3.986 \times 10^{14}$ m^3/s^2), as shown. Using $T = 2\pi\sqrt{a^3/\mu}$, the orbital period is nearest to: **[2 marks]**



(A) 84.5 min

(B) 97.2 min

(C) 106 min

(D) 60 min

Q22. A satellite is in a circular orbit of radius 7000 km about the Earth ($\mu = 3.986 \times 10^{14}$ m^3/s^2). The specific mechanical (orbital) energy $(\varepsilon = -\mu/(2a))$ of the orbit is nearest to: **[2 marks]**

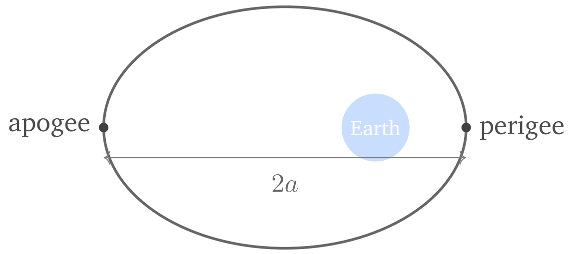
(A) -56.9 MJ/kg

(B) -28.5 MJ/kg

(C) -14.2 MJ/kg

(D) -5.69 MJ/kg

Q23. A satellite orbits the Earth (radius 6378 km) in an ellipse of perigee altitude 400 km and apogee altitude 2000 km, as shown. The eccentricity $(e = (r_a - r_p)/(r_a + r_p))$ of the orbit is nearest to: **[2 marks]**



(A) 0.50

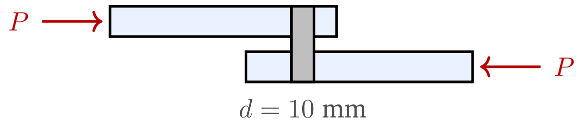
(B) 0.20

(C) 0.15

(D) 0.106

Aerospace Structures

Q24. A single rivet of diameter 10 mm connects two plates in a lap joint and carries a shear load of 12 kN in single shear, as shown. The average shear stress in the rivet is nearest to: **[2 marks]**



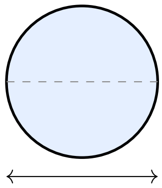
(A) 305.6 MPa

(B) 76.4 MPa

(C) 152.8 MPa

(D) 100 MPa

Q25. A beam of solid circular cross-section of diameter 50 mm, shown below, carries a bending moment of 2 kN·m at a section. Using $\sigma = 32M/(\pi d^3)$, the maximum bending stress at that section is nearest to: **[2 marks]**



(A) 81.5 MPa

(B) 163.0 MPa

(C) 326.0 MPa

(D) 100 MPa

Q26. A solid circular shaft of diameter 40 mm and length 1 m is made of a material with shear modulus $G = 80$ GPa and carries a torque of 500 N·m. Using $\theta = TL/(GJ)$ with $J = \pi d^4/32$, the angle of twist over the length is nearest to: **[2 marks]**

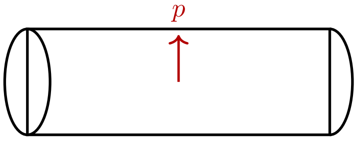
(A) $0.71°$

(B) $2.85°$

(C) $1.42°$

(D) $1.00°$

Q27. A thin-walled cylindrical pressure vessel of internal diameter 800 mm and wall thickness 8 mm carries an internal gauge pressure of 1.5 MPa. The longitudinal (axial) stress in the wall $\left(\sigma_l = pd/(4t)\right)$ is: **[2 marks]**



(A) 150 MPa

(B) 75 MPa

(C) 18.75 MPa

(D) 37.5 MPa

Q28. A slender column of length 2 m is fixed at its base and free at its top (a cantilever column). It has a second moment of area of 2×10^6 mm^4 and Young's modulus 200 GPa. Using an effective length $L_e = 2L$, the Euler critical buckling load $\left(P_{cr} = \pi^2 EI/L_e^2\right)$ is nearest to: **[2 marks]**

(A) 246.7 kN

(B) 493.5 kN

(C) 123.4 kN

(D) 61.7 kN

Q29. At a point in a structural member the principal stresses are $\sigma_1 = 100$ MPa and $\sigma_2 = 40$ MPa (both in-plane, with the third principal stress zero). Using the plane-stress von Mises criterion $\left(\sigma_{vm} = \sqrt{\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2}\right)$, the equivalent (von Mises) stress is nearest to: **[2 marks]**

(A) 140.0 MPa

(B) 87.2 MPa

(C) 60.0 MPa

(D) 100.0 MPa

Q30. A bar is rigidly held between two immovable supports so that it cannot expand. It is made of a material with Young's modulus 200 GPa and coefficient of thermal expansion 12×10^{-6} per °C, and its temperature rises by 50 °C. The thermal (compressive) stress induced $\left(\sigma = E\alpha\,\Delta T\right)$ is: **[2 marks]**

(A) 240 MPa

(B) 120 MPa

(C) 60 MPa

(D) 100 MPa

Q31. A single-degree-of-freedom spring–mass system has a stiffness of 2000 N/m and a mass of 5 kg. The undamped natural period $\left(T = 2\pi\sqrt{m/k}\right)$ of free vibration is nearest to: **[2 marks]**

(A) 0.314 s

(B) 0.628 s

(C) 0.157 s

(D) 0.100 s

Q32. A thin-walled closed section encloses a mean area of 0.02 m^2 and carries a torque of 400 N·m. Using the Bredt–Batho theory, the shear flow $\left(q = T/(2A_m)\right)$ around the wall is: **[2 marks]**

(A) 20 kN/m

(B) 10 kN/m

(C) 5 kN/m

(D) 40 kN/m

Q33. A simply supported beam of span 2 m carries a concentrated load of 2 kN at mid-span. The beam has $E = 200$ GPa and $I = 2 \times 10^6$ mm^4. The mid-span deflection $\left(\delta = PL^3/(48EI)\right)$ is nearest to: **[2 marks]**

(A) 3.33 mm

(B) 1.67 mm

(C) 0.833 mm

(D) 0.417 mm

Q34. A thin-walled column member has a cross-sectional area of 500 mm^2 and a second moment of area of 2×10^6 mm^4 about the buckling axis. The radius of gyration $\left(r = \sqrt{I/A}\right)$ of the section is nearest to: **[2 marks]**

(A) 63.2 mm

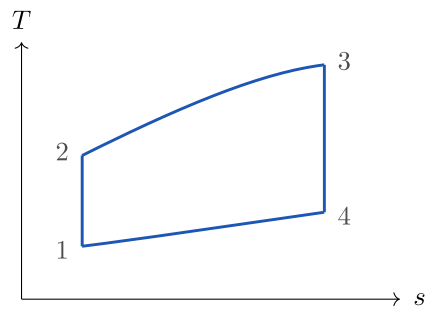
(B) 40.0 mm

(C) 89.4 mm

(D) 20.0 mm

Propulsion

Q35. An ideal (air-standard) Brayton cycle operates with a compressor pressure ratio of 10 and $\gamma = 1.4$, as shown on the T–s diagram. Using $\eta = 1 - r_p^{-(\gamma-1)/\gamma}$, the thermal efficiency of the cycle is nearest to: **[2 marks]**



(A) 51.8%

(B) 40.0%

(C) 37.5%

(D) 48.2%

Q36. A turbojet ingests air at an inlet velocity of 250 m/s and discharges the exhaust jet at 800 m/s. Neglecting fuel mass flow and pressure-thrust terms, the specific thrust (thrust per unit mass flow of air, $F/\dot{m} = V_e - V_0$) is: **[2 marks]**

(A) 550 N·s/kg

(B) 1050 N·s/kg

(C) 275 N·s/kg

(D) 800 N·s/kg

Q37. A jet engine produces a net thrust of 20 kN while the aircraft flies at 250 m/s. The thrust (propulsive) power delivered $\left(P = F\,V_0\right)$ is: **[2 marks]**

(A) 10 MW

(B) 2.5 MW

(C) 20 MW

(D) 5 MW

Q38. Air ($\gamma = 1.4$) expands from a large chamber through a convergent–divergent nozzle and is choked at the throat ($M = 1$). If the chamber (stagnation) temperature is 600 K, the static temperature at the throat $\left(T^*/T_0 = 2/(\gamma+1)\right)$ is: **[2 marks]**

(A) 300 K

(B) 480 K

(C) 500 K

(D) 360 K

Q39. Air expands through a nozzle from stagnation conditions with a static-temperature drop of 300 K from chamber to exit. Taking $c_p = 1005$ J/kg·K and negligible inlet velocity, the exit velocity $\left(V_e = \sqrt{2c_p\,\Delta T}\right)$ is nearest to: **[2 marks]**

(A) 549 m/s

(B) 634 m/s

(C) 449 m/s

(D) 776.5 m/s

Q40. In an axial-flow turbine stage the mean blade speed is 350 m/s and the whirl (tangential) component of the absolute velocity changes by 250 m/s across the rotor. By the Euler turbomachinery equation, the specific work output $\left(w = U\,\Delta C_w\right)$ is: **[2 marks]**

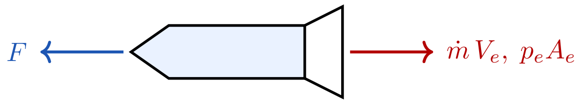
(A) 87.5 kJ/kg

(B) 175 kJ/kg

(C) 43.75 kJ/kg

(D) 60 kJ/kg

Q41. A rocket engine expels propellant at 50 kg/s with an exhaust velocity of 2500 m/s. The nozzle is under-expanded, so the exit static pressure exceeds the ambient by 20 kPa over an exit area of 0.2 m^2. The total thrust $\left(F = \dot{m}V_e + (p_e - p_a)A_e\right)$ is: **[2 marks]**



(A) 125 kN

(B) 250 kN

(C) 62.5 kN

(D) 129 kN

Q42. A rocket engine produces a thrust of 100 kN while consuming propellant at a mass flow rate of 40 kg/s. Taking $g_0 = 9.81$ m/s^2, the specific impulse $\left(I_{sp} = F/(\dot{m}g_0)\right)$ is nearest to: **[2 marks]**

(A) 254.8 s

(B) 300 s

(C) 350 s

(D) 200 s

Q43. A single-stage rocket must achieve an ideal velocity increment of $\Delta v = 4000$ m/s using an engine with an effective exhaust velocity of 2000 m/s. From the Tsiolkovsky rocket equation, the required initial-to-final mass ratio $\left(m_0/m_f = e^{\Delta v/V_e}\right)$ is nearest to: **[2 marks]**

(A) 2.72

(B) 4.00

(C) 7.39

(D) 20.1

Q44. A gas-turbine combustor burns a fuel whose stoichiometric air–fuel ratio is 15. The mixture is run lean at an equivalence ratio of $\phi = 0.8$. The actual air–fuel ratio supplied $\left((A/F)_{\text{actual}} = (A/F)_{\text{stoich}}/\phi\right)$ is: **[2 marks]**

(A) 12.0

(B) 18.75

(C) 15.0

(D) 20.0

Q45. A turbojet engine has a thermal efficiency of 0.40 and a propulsive efficiency of 0.60. The overall efficiency $\left(\eta_o = \eta_{th}\,\eta_p\right)$ of the engine is: **[2 marks]**

(A) 0.24

(B) 0.50

(C) 1.00

(D) 0.10

Q46. Combustion gas ($\gamma = 1.4$) enters a turbine at a stagnation temperature of 1200 K and expands isentropically through a pressure ratio of 8. Using $T_{02}/T_{01} = r_p^{-(\gamma-1)/\gamma}$, the turbine-exit stagnation temperature is nearest to: **[2 marks]**

(A) 543 K

(B) 662.6 K

(C) 480 K

(D) 900 K

Detailed Solutions

Q1.

Solution

Concept – incompressible pressure coefficient: For low-speed flow, $C_p = 1 - (V/V_\infty)^2$, where V is the local surface velocity.

Step 1 – list the data: $V/V_\infty = 1.2$.

Step 2 – square the velocity ratio: $(V/V_\infty)^2 = 1.2^2 = 1.44$

Step 3 – substitute into the formula: $C_p = 1 - 1.44$

Step 4 – evaluate: $C_p = -0.44$

Step 5 – interpret the sign: The local flow is faster than the freestream, so the pressure is below freestream and C_p is negative.

Final Answer: $C_p = -0.44 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q1

Q2.

Solution

Concept – compressible dynamic pressure: $q = \frac{1}{2}\gamma p M^2$, which follows from $q = \frac{1}{2}\rho V^2$ using $a^2 = \gamma p/\rho$.

Step 1 – list the data: $\gamma = 1.4$, $p = 50\,000$ Pa, $M = 0.8$.

Step 2 – square the Mach number: $M^2 = 0.8^2 = 0.64$

Step 3 – form the product $\frac{1}{2}\gamma$: $\frac{1}{2} \times 1.4 = 0.7$

Step 4 – multiply by the pressure: $0.7 \times 50\,000 = 35\,000$

Step 5 – multiply by M^2: $q = 35\,000 \times 0.64 = 22\,400$ Pa

Final Answer: $q = 22\,400$ Pa $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q2

Q3.

Solution

Concept – Mach number: $M = V/a$, with $a = \sqrt{\gamma RT}$.

Step 1 – list the data: $V = 170$ m/s, $\gamma = 1.4$, $R = 287$ J/kg $\cdot$ K, $T = 288$ K.

Step 2 – form the product γR: $\gamma R = 1.4 \times 287 = 401.8$

Step 3 – multiply by the temperature: $\gamma RT = 401.8 \times 288 = 115\,718.4$

Step 4 – take the square root for the speed of sound: $a = \sqrt{115\,718.4} = 340.2$ m/s

Step 5 – divide the flight speed by the speed of sound: $M = \dfrac{170}{340.2} = 0.4997$

Step 6 – round: $M \approx 0.50$

Final Answer: $M \approx 0.50 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q3

Q4.

Solution

Concept – Kutta–Joukowski theorem: The lift per unit span is $L' = \rho V_\infty \Gamma$.

Step 1 – list the data: $\rho = 1.225$ kg/m^3, $V_\infty = 50$ m/s, $\Gamma = 20$ m^2/s.

Step 2 – multiply density by velocity: $\rho V_\infty = 1.225 \times 50 = 61.25$

Step 3 – multiply by the circulation: $L' = 61.25 \times 20$

Step 4 – evaluate: $L' = 1225$ N/m

Final Answer: $L' = 1225$ N/m $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q4

Q5.

Solution

Concept – drag from the drag coefficient: $D = q\,S\,C_D$, where q is the dynamic pressure and S the reference area.

Step 1 – list the data: $q = 1500$ Pa, $S = 25$ m^2, $C_D = 0.03$.

Step 2 – multiply the dynamic pressure by the area: $q\,S = 1500 \times 25 = 37\,500$ N

Step 3 – multiply by the drag coefficient: $D = 37\,500 \times 0.03$

Step 4 – evaluate: $D = 1125$ N

Final Answer: $D = 1125$ N $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q5

Q6.

Solution

Concept – isentropic stagnation-to-static pressure ratio: $\frac{p_0}{p} = \left(1 + \frac{\gamma-1}{2}M^2\right)^{\gamma/(\gamma-1)}$.

Step 1 – list the data: $\gamma = 1.4$, $M = 1.0$.

Step 2 – evaluate $\frac{\gamma-1}{2}$: $\dfrac{1.4-1}{2} = \dfrac{0.4}{2} = 0.2$

Step 3 – square the Mach number: $M^2 = 1.0^2 = 1$

Step 4 – form the bracket: $1 + 0.2 \times 1 = 1.2$

Step 5 – evaluate the exponent: $\dfrac{\gamma}{\gamma-1} = \dfrac{1.4}{0.4} = 3.5$

Step 6 – raise the bracket to that power: $1.2^{3.5} = 1.893$

Final Answer: $p_0/p \approx 1.893 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q6

Q7.

Solution

Concept – Prandtl–Glauert compressibility correction: $C_p = \dfrac{C_{p,0}}{\sqrt{1-M_\infty^2}}$.

Step 1 – list the data: $C_{p,0} = -0.40$, $M_\infty = 0.6$.

Step 2 – square the Mach number: $M_\infty^2 = 0.6^2 = 0.36$

Step 3 – form $1 - M_\infty^2$: $1 - 0.36 = 0.64$

Step 4 – take the square root: $\sqrt{0.64} = 0.8$

Step 5 – divide: $C_p = \dfrac{-0.40}{0.8} = -0.50$

Final Answer: $C_p = -0.50 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q7

Q8.

Solution

Concept – Blasius laminar skin-friction drag coefficient: $C_f = \dfrac{1.328}{\sqrt{Re_L}}$.

Step 1 – list the data: $Re_L = 10^6$.

Step 2 – take the square root of the Reynolds number: $\sqrt{10^6} = 1000$

Step 3 – substitute into the formula: $C_f = \dfrac{1.328}{1000}$

Step 4 – evaluate: $C_f = 0.001328$

Final Answer: $C_f = 0.001328 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q8

Q9.

Solution

Concept – turbulent boundary-layer thickness (1/7-power law): $\delta = \dfrac{0.37\,x}{Re_x^{1/5}}$.

Step 1 – list the data: $x = 2$ m, $Re_x = 10^7$.

Step 2 – evaluate $Re_x^{1/5}$: $Re_x^{1/5} = \left(10^7\right)^{0.2} = 10^{1.4}$

Step 3 – compute the power of ten: $10^{1.4} = 25.12$

Step 4 – form the numerator: $0.37 \times 2 = 0.74$

Step 5 – divide: $\delta = \dfrac{0.74}{25.12} = 0.02946$ m

Step 6 – convert to millimetres: $\delta = 0.02946 \times 1000 = 29.5$ mm

Final Answer: $\delta \approx 29.5$ mm $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q9

Q10.

Solution

Concept – Mach angle: For supersonic flight the Mach wave makes an angle $\mu = \sin^{-1}(1/M)$ with the flight direction.

Step 1 – list the data: $M = 2.0$.

Step 2 – form the ratio $1/M$: $\dfrac{1}{M} = \dfrac{1}{2.0} = 0.5$

Step 3 – take the inverse sine: $\mu = \sin^{-1}(0.5)$

Step 4 – evaluate: $\mu = 30°$

Final Answer: $\mu = 30° \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q10

Q11.

Solution

Concept – finite-wing lift-curve slope: $a = \dfrac{a_0}{1 + a_0/(\pi e\, AR)}$, where a_0 is the 2-D airfoil slope.

Step 1 – list the data: $a_0 = 2\pi = 6.2832$ per rad, $e = 0.95$, $AR = 7$.

Step 2 – form the denominator term $\pi e\, AR$**:** $\pi \times 0.95 \times 7 = 3.1416 \times 6.65 = 20.892$

Step 3 – form the ratio $a_0/(\pi e\, AR)$**:** $\dfrac{6.2832}{20.892} = 0.3008$

Step 4 – add 1**:** $1 + 0.3008 = 1.3008$

Step 5 – divide a_0 **by this:** $a = \dfrac{6.2832}{1.3008} = 4.830$ per rad

Final Answer: $a \approx 4.83$ per rad $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q11

Q12.

Solution

Concept – pressure coefficient in potential flow over a cylinder: $C_p = 1 - (V/V_\infty)^2$; the minimum C_p occurs where V is largest.

Step 1 – list the data: Maximum surface velocity $V_{\max} = 2V_\infty$, so $V/V_\infty = 2$.

Step 2 – square the velocity ratio: $(V/V_\infty)^2 = 2^2 = 4$

Step 3 – substitute into the formula: $C_{p,\min} = 1 - 4$

Step 4 – evaluate: $C_{p,\min} = -3$

Step 5 – note: This -3 is the classic minimum pressure coefficient for ideal flow over a circular cylinder, at the top and bottom shoulders.

Final Answer: $C_{p,\min} = -3 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q12

Q13.

Solution

Concept – rate of climb from excess power: $R/C = \dfrac{P_a - P_r}{W}$, the excess of available over required power divided by weight.

Step 1 – list the data: $P_a = 1000$ kW $= 1\,000\,000$ W, $P_r = 600$ kW $= 600\,000$ W, $W = 40\,000$ N.

Step 2 – form the excess power: $P_a - P_r = 1\,000\,000 - 600\,000 = 400\,000$ W

Step 3 – divide by the weight: $R/C = \dfrac{400\,000}{40\,000}$

Step 4 – evaluate: $R/C = 10$ m/s

Final Answer: $R/C = 10$ m/s $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q13

Q14.

Solution

Concept – radius of a level co-ordinated turn: $R = \dfrac{V^2}{g\tan\phi}$.

Step 1 – list the data: $V = 100$ m/s, $\phi = 45°$, $g = 9.81$ m/s^2.

Step 2 – square the speed: $V^2 = 100^2 = 10\,000$

Step 3 – evaluate $\tan\phi$**:** $\tan 45° = 1$

Step 4 – form the denominator: $g\tan\phi = 9.81 \times 1 = 9.81$

Step 5 – divide: $R = \dfrac{10\,000}{9.81} = 1019.4$ m

Final Answer: $R \approx 1019$ m $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q14

Q15.

Solution

Concept – rate of turn in a level co-ordinated turn: $\dot{\psi} = \dfrac{g\tan\phi}{V}$.

Step 1 – list the data: $g = 9.81$ m/s^2, $\phi = 60°$, $V = 200$ m/s.

Step 2 – evaluate $\tan\phi$**:** $\tan 60° = 1.7321$

Step 3 – form the numerator: $g\tan\phi = 9.81 \times 1.7321 = 16.992$

Step 4 – divide by the speed: $\dot{\psi} = \dfrac{16.992}{200}$

Step 5 – evaluate: $\dot{\psi} = 0.0850$ rad/s

Final Answer: $\dot{\psi} \approx 0.0850$ rad/s $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q15

Q16.

Solution

Concept – sink rate in a steady glide: For a shallow glide the rate of descent is $V_{\text{sink}} = V \sin\gamma \approx \dfrac{V}{L/D}$, since $\tan\gamma = 1/(L/D)$.

Step 1 – list the data: $V = 60$ m/s, $L/D = 20$.

Step 2 – write the sink-rate relation: $V_{\text{sink}} = \dfrac{V}{L/D}$

Step 3 – substitute: $V_{\text{sink}} = \dfrac{60}{20}$

Step 4 – evaluate: $V_{\text{sink}} = 3$ m/s

Final Answer: $V_{\text{sink}} = 3$ m/s $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q16

Q17.

Solution

Concept – specific energy height: $h_e = h + \dfrac{V^2}{2g}$, the total mechanical energy per unit weight expressed as a height.

Step 1 – list the data: $h = 1000$ m, $V = 140$ m/s, $g = 9.81$ m/s^2.

Step 2 – square the speed: $V^2 = 140^2 = 19\,600$

Step 3 – form the denominator $2g$: $2g = 2 \times 9.81 = 19.62$

Step 4 – compute the kinetic term: $\dfrac{V^2}{2g} = \dfrac{19\,600}{19.62} = 999.0$ m

Step 5 – add the altitude: $h_e = 1000 + 999.0 = 1999.0$ m

Step 6 – round: $h_e \approx 2000$ m

Final Answer: $h_e \approx 2000$ m $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q17

Q18.

Solution

Concept – static directional (weathercock) stability: Directional stability requires that a positive sideslip β produce a restoring (positive) yawing moment, i.e. the yawing-moment derivative $C_{n_\beta} > 0$.

Step 1 – recall the restoring condition: If the nose is pushed to one side (positive β), the aircraft must generate a yawing moment that turns it back into the wind.

Step 2 – write this as a derivative sign: A restoring moment for positive β means $\frac{dC_n}{d\beta} = C_{n_\beta} > 0$.

Step 3 – reject the distractors: $C_{n_\beta} < 0$ is destabilising in yaw; $C_{l_\beta} > 0$ concerns roll (lateral) behaviour; $C_{m_\alpha} > 0$ concerns longitudinal (pitch) stability and is in fact destabilising there.

Final Answer: $C_{n_\beta} > 0 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q18

Q19.

Solution

Concept – load factor and bank angle in a level turn: $n = \frac{1}{\cos\phi}$, so $\cos\phi = \frac{1}{n}$.

Step 1 – list the data: $n = 2.0$.

Step 2 – rearrange for $\cos\phi$: $\cos\phi = \frac{1}{2.0} = 0.5$

Step 3 – take the inverse cosine: $\phi = \cos^{-1}(0.5)$

Step 4 – evaluate: $\phi = 60°$

Final Answer: $\phi = 60° \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q19

Q20.

Solution

Concept – stalling speed in a turn: At a load factor n the lift must equal nW, so the stalling speed increases as $V_{s,\text{turn}} = V_s\sqrt{n}$.

Step 1 – list the data: $V_s = 50$ m/s, $n = 4$.

Step 2 – take the square root of the load factor: $\sqrt{4} = 2$

Step 3 – multiply the level stall speed: $V_{s,\text{turn}} = 50 \times 2$

Step 4 – evaluate: $V_{s,\text{turn}} = 100$ m/s

Final Answer: $V_{s,\text{turn}} = 100 \text{ m/s} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q20

Q21.

Solution

Concept – period of a circular orbit: $T = 2\pi\sqrt{\dfrac{a^3}{\mu}}$, with a the orbital radius.

Step 1 – list the data: $a = 7000$ km $= 7 \times 10^6$ m, $\mu = 3.986 \times 10^{14}$ m^3/s^2.

Step 2 – cube the radius: $a^3 = \left(7 \times 10^6\right)^3 = 343 \times 10^{18} = 3.43 \times 10^{20}$ m^3

Step 3 – divide by μ: $\dfrac{a^3}{\mu} = \dfrac{3.43 \times 10^{20}}{3.986 \times 10^{14}} = 8.606 \times 10^5$

Step 4 – take the square root: $\sqrt{8.606 \times 10^5} = 927.7$

Step 5 – multiply by 2π: $T = 2\pi \times 927.7 = 5829$ s

Step 6 – convert to minutes: $T = \dfrac{5829}{60} = 97.2$ min

Final Answer: $T \approx 97.2$ min $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q21

Q22.

Solution

Concept – specific mechanical energy of an orbit: $\varepsilon = -\dfrac{\mu}{2a}$, constant along the orbit.

Step 1 – list the data: $a = 7000$ km $= 7 \times 10^6$ m, $\mu = 3.986 \times 10^{14}$ m^3/s^2.

Step 2 – form the denominator $2a$: $2a = 2 \times 7 \times 10^6 = 1.4 \times 10^7$ m

Step 3 – divide μ by $2a$: $\dfrac{\mu}{2a} = \dfrac{3.986 \times 10^{14}}{1.4 \times 10^7} = 2.847 \times 10^7$ J/kg

Step 4 – apply the negative sign: $\varepsilon = -2.847 \times 10^7$ J/kg

Step 5 – express in MJ/kg: $\varepsilon = -28.5$ MJ/kg

Final Answer: $\varepsilon \approx -28.5$ MJ/kg $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q22

Q23.

Solution

Concept – eccentricity from apogee and perigee radii: $e = \dfrac{r_a - r_p}{r_a + r_p}$, measured from the Earth's centre.

Step 1 – form the radii: $r_p = 6378 + 400 = 6778$ km

$r_a = 6378 + 2000 = 8378$ km

Step 2 – form the numerator: $r_a - r_p = 8378 - 6778 = 1600$ km

Step 3 – form the denominator: $r_a + r_p = 8378 + 6778 = 15\,156$ km

Step 4 – divide: $e = \dfrac{1600}{15\,156}$

Step 5 – evaluate: $e = 0.1056 \approx 0.106$

Final Answer: $e \approx 0.106 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q23

Q24.

Solution

Concept – average shear stress in a rivet (single shear): $\tau = \dfrac{P}{A}$, with $A = \dfrac{\pi}{4}d^2$ the rivet cross-sectional area.

Step 1 – list the data: $P = 12$ kN $= 12\,000$ N, $d = 10$ mm.

Step 2 – compute the cross-sectional area: $A = \dfrac{\pi}{4} \times 10^2 = \dfrac{\pi}{4} \times 100 = 78.54\ \text{mm}^2$

Step 3 – divide the load by the area: $\tau = \dfrac{12\,000}{78.54}$

Step 4 – evaluate: $\tau = 152.8\ \text{N/mm}^2 = 152.8$ MPa

Final Answer: $\tau \approx 152.8$ MPa $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q24

Q25.

Solution

Concept – maximum bending stress of a solid circular section: $\sigma = \dfrac{M}{Z}$ with the section modulus $Z = \dfrac{\pi d^3}{32}$, so $\sigma = \dfrac{32M}{\pi d^3}$.

Step 1 – list the data: $M = 2$ kN·m $= 2 \times 10^6$ N · mm, $d = 50$ mm.

Step 2 – cube the diameter: $d^3 = 50^3 = 125\,000\ \text{mm}^3$

Step 3 – form the denominator πd^3: $\pi \times 125\,000 = 392\,699\ \text{mm}^3$

Step 4 – form the numerator $32M$: $32 \times 2 \times 10^6 = 6.4 \times 10^7$ N · mm

Step 5 – divide: $\sigma = \dfrac{6.4 \times 10^7}{392\,699} = 162.98\ \text{N/mm}^2$

Step 6 – round: $\sigma \approx 163.0$ MPa

Final Answer: $\sigma \approx 163.0$ MPa $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q25

Q26.

Solution

Concept – angle of twist of a circular shaft: $\theta = \frac{TL}{GJ}$ with the polar moment $J = \frac{\pi d^4}{32}$.

Step 1 – list the data: $T = 500$ N $\cdot$ m, $L = 1$ m, $G = 80$ GPa $= 80 \times 10^9$ Pa, $d = 40$ mm $= 0.04$ m.

Step 2 – compute the polar moment of area: $J = \frac{\pi \times 0.04^4}{32}$

$0.04^4 = 2.56 \times 10^{-6}$ m^4

$J = \frac{\pi \times 2.56 \times 10^{-6}}{32} = 2.513 \times 10^{-7}$ m^4

Step 3 – form the product GJ: $GJ = 80 \times 10^9 \times 2.513 \times 10^{-7} = 20\,106$ N $\cdot$ m^2

Step 4 – form the numerator TL: $TL = 500 \times 1 = 500$ N $\cdot$ m^2

Step 5 – divide to get the twist in radians: $\theta = \frac{500}{20\,106} = 0.02487$ rad

Step 6 – convert to degrees: $\theta = 0.02487 \times \frac{180}{\pi} = 1.425°$

Final Answer: $\theta \approx 1.42° \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q26

Q27.

Solution

Concept – longitudinal stress in a thin cylindrical vessel: $\sigma_l = \frac{pd}{4t}$ (half the hoop stress).

Step 1 – list the data: $p = 1.5$ MPa, $d = 800$ mm, $t = 8$ mm.

Step 2 – form the numerator pd: $pd = 1.5 \times 800 = 1200$

Step 3 – form the denominator $4t$: $4t = 4 \times 8 = 32$

Step 4 – divide: $\sigma_l = \frac{1200}{32}$

Step 5 – evaluate: $\sigma_l = 37.5$ MPa

Final Answer: $\sigma_l = 37.5$ MPa $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q27

Q28.

Solution

Concept – Euler buckling of a fixed–free column: $P_{cr} = \dfrac{\pi^2 EI}{L_e^2}$ with effective length $L_e = 2L$ for a column fixed at one end and free at the other.

Step 1 – list the data: $L = 2$ m, $I = 2 \times 10^6$ mm^4 $= 2 \times 10^{-6}$ m^4, $E = 200$ GPa $= 200 \times 10^9$ Pa.

Step 2 – find the effective length and its square: $L_e = 2 \times 2 = 4$ m

$L_e^2 = 16$ m^2

Step 3 – form the product EI: $EI = 200 \times 10^9 \times 2 \times 10^{-6} = 4 \times 10^5$ N $\cdot$ m^2

Step 4 – multiply by π^2: $\pi^2 \times 4 \times 10^5 = 9.8696 \times 4 \times 10^5 = 3.9478 \times 10^6$

Step 5 – divide by L_e^2: $P_{cr} = \dfrac{3.9478 \times 10^6}{16} = 246\,740$ N

Step 6 – express in kN: $P_{cr} \approx 246.7$ kN

Final Answer: $P_{cr} \approx 246.7$ kN $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q28

Q29.

Solution

Concept – plane-stress von Mises equivalent stress: With the principal stresses σ_1, σ_2 (third principal stress zero), $\sigma_{vm} = \sqrt{\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2}$.

Step 1 – list the data: $\sigma_1 = 100$ MPa, $\sigma_2 = 40$ MPa.

Step 2 – square the first principal stress: $\sigma_1^2 = 100^2 = 10\,000$

Step 3 – form the cross term: $\sigma_1\sigma_2 = 100 \times 40 = 4000$

Step 4 – square the second principal stress: $\sigma_2^2 = 40^2 = 1600$

Step 5 – combine under the root: $10\,000 - 4000 + 1600 = 7600$

Step 6 – take the square root: $\sigma_{vm} = \sqrt{7600} = 87.18$ MPa

Final Answer: $\sigma_{vm} \approx 87.2$ MPa $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q29

Q30.

Solution

Concept – thermal stress in a fully restrained bar: If free expansion is prevented, $\sigma = E\,\varepsilon_{th} = E\,\alpha\,\Delta T$.

Step 1 – list the data: $E = 200$ GPa $= 200 \times 10^9$ Pa, $\alpha = 12 \times 10^{-6}$ per °C, $\Delta T = 50$ °C.

Step 2 – form the thermal strain $\alpha\,\Delta T$: $\alpha\,\Delta T = 12 \times 10^{-6} \times 50 = 6 \times 10^{-4}$

Step 3 – multiply by the modulus: $\sigma = 200 \times 10^9 \times 6 \times 10^{-4}$

Step 4 – evaluate: $\sigma = 1.2 \times 10^8$ Pa $= 120$ MPa

Final Answer: $\sigma = 120$ MPa $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q30

Q31.

Solution

Concept – natural period of a spring–mass system: $T = 2\pi\sqrt{\dfrac{m}{k}}$.

Step 1 – list the data: $m = 5$ kg, $k = 2000$ N/m.

Step 2 – form the ratio m/k: $\dfrac{m}{k} = \dfrac{5}{2000} = 0.0025\ \text{s}^2$

Step 3 – take the square root: $\sqrt{0.0025} = 0.05$ s

Step 4 – multiply by 2π: $T = 2\pi \times 0.05$

Step 5 – evaluate: $T = 0.3142$ s

Final Answer: $T \approx 0.314$ s $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q31

Q32.

Solution

Concept – Bredt–Batho shear flow in a closed thin-walled section: $q = \dfrac{T}{2A_m}$, where A_m is the area enclosed by the wall mid-line.

Step 1 – list the data: $T = 400$ N · m, $A_m = 0.02\ \text{m}^2$.

Step 2 – form the denominator $2A_m$: $2A_m = 2 \times 0.02 = 0.04\ \text{m}^2$

Step 3 – divide the torque: $q = \dfrac{400}{0.04}$

Step 4 – evaluate: $q = 10\,000$ N/m $= 10$ kN/m

Final Answer: $q = 10$ kN/m $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q32

Q33.

Solution

Concept – mid-span deflection of a simply supported beam with a central point load: $\delta = \dfrac{PL^3}{48EI}$.

Step 1 – list the data: $P = 2$ kN $= 2000$ N, $L = 2$ m, $E = 200$ GPa $= 200 \times 10^9$ Pa, $I = 2 \times 10^6$ mm^4 $= 2 \times 10^{-6}$ m^4.

Step 2 – cube the span: $L^3 = 2^3 = 8$ m^3

Step 3 – form the numerator PL^3: $PL^3 = 2000 \times 8 = 16\,000$

Step 4 – form the product EI: $EI = 200 \times 10^9 \times 2 \times 10^{-6} = 4 \times 10^5$ N $\cdot$ m^2

Step 5 – form the denominator $48EI$: $48 \times 4 \times 10^5 = 1.92 \times 10^7$

Step 6 – divide: $\delta = \dfrac{16\,000}{1.92 \times 10^7} = 8.333 \times 10^{-4}$ m

Step 7 – convert to millimetres: $\delta = 0.833$ mm

Final Answer: $\delta \approx 0.833$ mm $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q33

Q34.

Solution

Concept – radius of gyration of a section: $r = \sqrt{\dfrac{I}{A}}$.

Step 1 – list the data: $I = 2 \times 10^6$ mm^4, $A = 500$ mm^2.

Step 2 – form the ratio I/A: $\dfrac{I}{A} = \dfrac{2 \times 10^6}{500} = 4000$ mm^2

Step 3 – take the square root: $r = \sqrt{4000}$

Step 4 – evaluate: $r = 63.25$ mm

Final Answer: $r \approx 63.2$ mm $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q34

Q35.

Solution

Concept – ideal Brayton-cycle thermal efficiency: $\eta = 1 - r_p^{-(\gamma-1)/\gamma}$, a function of pressure ratio only.

Step 1 – list the data: $r_p = 10$, $\gamma = 1.4$.

Step 2 – evaluate the exponent: $\dfrac{\gamma - 1}{\gamma} = \dfrac{0.4}{1.4} = 0.2857$

Step 3 – raise the pressure ratio to that power: $10^{0.2857} = 1.931$

Step 4 – take the reciprocal: $r_p^{-0.2857} = \dfrac{1}{1.931} = 0.5179$

Step 5 – subtract from one: $\eta = 1 - 0.5179 = 0.4821$

Step 6 – express as a percentage: $\eta = 48.2\%$

Final Answer: $\eta \approx 48.2\% \Rightarrow \boxed{\text{D}}$

Answer: (D) **Go Back to Q35**

Q36.

Solution

Concept – specific thrust of a turbojet: Neglecting fuel flow and pressure terms, $\dfrac{F}{\dot{m}} = V_e - V_0$.

Step 1 – list the data: $V_e = 800$ m/s, $V_0 = 250$ m/s.

Step 2 – subtract the inlet velocity from the exhaust velocity: $V_e - V_0 = 800 - 250$

Step 3 – evaluate: $\dfrac{F}{\dot{m}} = 550$ N·s/kg

Final Answer: specific thrust $= 550$ N·s/kg $\Rightarrow \boxed{\text{A}}$

Answer: (A) **Go Back to Q36**

Q37.

Solution

Concept – thrust (propulsive) power: $P = F\,V_0$, the rate at which thrust does useful work on the airframe.

Step 1 – list the data: $F = 20$ kN $= 20\,000$ N, $V_0 = 250$ m/s.

Step 2 – multiply thrust by flight speed: $P = 20\,000 \times 250$

Step 3 – evaluate: $P = 5\,000\,000$ W

Step 4 – express in megawatts: $P = 5$ MW

Final Answer: $P = 5$ MW $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q37

Q38.

Solution

Concept – critical (throat) temperature ratio at $M = 1$: $\dfrac{T^*}{T_0} = \dfrac{2}{\gamma + 1}$.

Step 1 – list the data: $\gamma = 1.4$, $T_0 = 600$ K.

Step 2 – form the ratio: $\dfrac{2}{\gamma + 1} = \dfrac{2}{2.4} = 0.8333$

Step 3 – multiply by the stagnation temperature: $T^* = 0.8333 \times 600$

Step 4 – evaluate: $T^* = 500$ K

Final Answer: $T^* = 500$ K $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q38

Q39.

Solution

Concept – nozzle exit velocity from the energy equation: With negligible inlet velocity, $V_e = \sqrt{2c_p\,\Delta T}$, where ΔT is the static-temperature drop.

Step 1 – list the data: $c_p = 1005$ J/kg · K, $\Delta T = 300$ K.

Step 2 – form the product $2c_p\,\Delta T$**:** $2 \times 1005 = 2010$

$2010 \times 300 = 603\,000$

Step 3 – take the square root: $V_e = \sqrt{603\,000}$

Step 4 – evaluate: $V_e = 776.5$ m/s

Final Answer: $V_e \approx 776.5$ m/s $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q39

Q40.

Solution

Concept – Euler turbomachinery work: For an axial stage, $w = U\,\Delta C_w$, the product of blade speed and the change in whirl velocity.

Step 1 – list the data: $U = 350$ m/s, $\Delta C_w = 250$ m/s.

Step 2 – multiply: $w = 350 \times 250$

Step 3 – evaluate: $w = 87\,500$ J/kg

Step 4 – express in kJ/kg: $w = 87.5$ kJ/kg

Final Answer: $w = 87.5$ kJ/kg $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q40

Q41.

Solution

Concept – total rocket thrust with a pressure-thrust term: $F = \dot{m}V_e + (p_e - p_a)A_e$.

Step 1 – list the data: $\dot{m} = 50$ kg/s, $V_e = 2500$ m/s, $(p_e - p_a) = 20$ kPa $= 20\,000$ Pa, $A_e = 0.2$ m^2.

Step 2 – compute the momentum thrust: $\dot{m}V_e = 50 \times 2500 = 125\,000$ N

Step 3 – compute the pressure thrust: $(p_e - p_a)A_e = 20\,000 \times 0.2 = 4000$ N

Step 4 – add the two contributions: $F = 125\,000 + 4000 = 129\,000$ N

Step 5 – express in kN: $F = 129$ kN

Final Answer: $F = 129$ kN $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q41

Q42.

Solution

Concept – specific impulse from thrust and mass flow: $I_{sp} = \dfrac{F}{\dot{m}\, g_0}$.

Step 1 – list the data: $F = 100$ kN $= 100\,000$ N, $\dot{m} = 40$ kg/s, $g_0 = 9.81$ m/s^2.

Step 2 – form the denominator $\dot{m}\, g_0$: $\dot{m}\, g_0 = 40 \times 9.81 = 392.4$

Step 3 – divide the thrust: $I_{sp} = \dfrac{100\,000}{392.4}$

Step 4 – evaluate: $I_{sp} = 254.8$ s

Final Answer: $I_{sp} \approx 254.8$ s $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q42

Q43.

Solution

Concept – Tsiolkovsky rocket equation (mass ratio form): $\Delta v = V_e \ln \frac{m_0}{m_f}$, so $\frac{m_0}{m_f} = e^{\Delta v / V_e}$.

Step 1 – list the data: $\Delta v = 4000$ m/s, $V_e = 2000$ m/s.

Step 2 – form the exponent $\Delta v / V_e$: $\frac{4000}{2000} = 2$

Step 3 – exponentiate: $\frac{m_0}{m_f} = e^2$

Step 4 – evaluate: $e^2 = 7.389$

Final Answer: $m_0/m_f \approx 7.39 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q43

Q44.

Solution

Concept – equivalence ratio and actual air–fuel ratio: $\phi = \frac{(A/F)_{\text{stoich}}}{(A/F)_{\text{actual}}}$, so $(A/F)_{\text{actual}} = \frac{(A/F)_{\text{stoich}}}{\phi}$.

Step 1 – list the data: $(A/F)_{\text{stoich}} = 15$, $\phi = 0.8$.

Step 2 – divide the stoichiometric ratio by ϕ: $(A/F)_{\text{actual}} = \frac{15}{0.8}$

Step 3 – evaluate: $(A/F)_{\text{actual}} = 18.75$

Step 4 – check: $\phi < 1$ means more air than stoichiometric, so the actual air–fuel ratio (18.75) exceeds the stoichiometric value (15), as expected for a lean mixture.

Final Answer: $(A/F)_{\text{actual}} = 18.75 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q44

Q45.

Solution

Concept – overall efficiency of an air-breathing engine: $\eta_o = \eta_{th}\,\eta_p$, the product of thermal and propulsive efficiencies.

Step 1 – list the data: $\eta_{th} = 0.40$, $\eta_p = 0.60$.

Step 2 – multiply the two efficiencies: $\eta_o = 0.40 \times 0.60$

Step 3 – evaluate: $\eta_o = 0.24$

Final Answer: $\eta_o = 0.24 \Rightarrow \boxed{A}$

Answer: (A) Go Back to Q45

Q46.

Solution

Concept – isentropic turbine expansion temperature ratio: $\dfrac{T_{02}}{T_{01}} = r_p^{-(\gamma-1)/\gamma}$, where r_p is the expansion (inlet-to-exit) pressure ratio.

Step 1 – list the data: $T_{01} = 1200$ K, $r_p = 8$, $\gamma = 1.4$.

Step 2 – evaluate the exponent: $\dfrac{\gamma - 1}{\gamma} = \dfrac{0.4}{1.4} = 0.2857$

Step 3 – raise the pressure ratio to that power: $8^{0.2857} = 1.8114$

Step 4 – take the reciprocal (expansion lowers temperature): $r_p^{-0.2857} = \dfrac{1}{1.8114} = 0.5521$

Step 5 – multiply by the inlet temperature: $T_{02} = 1200 \times 0.5521$

Step 6 – evaluate: $T_{02} = 662.6$ K

Final Answer: $T_{02} \approx 662.6 \text{ K} \Rightarrow \boxed{B}$

Answer: (B) Go Back to Q46

Answer Key

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