GATE Aerospace Engineering

Sample Paper – 4

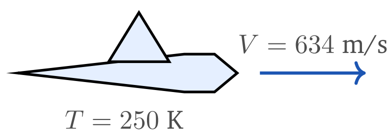
Duration: 128 Minutes **Maximum Marks: 72**

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. An aircraft cruises at a true airspeed of 634 m/s at an altitude where the static air temperature is 250 K, as shown. Taking $\gamma = 1.4$ and $R = 287$ J/kg · K, the flight Mach number is nearest to: **[1 mark]**



(A) 1.86

(B) 1.50

(C) 2.50

(D) 2.00

Q2. In the low-speed (incompressible) flow over an airfoil, the local velocity at a point on the surface is 1.5 times the freestream velocity. The pressure coefficient C_p at that point $\left(C_p = 1 - (V/V_\infty)^2\right)$ is: **[1 mark]**

(A) 0.25

(B) -0.56

(C) 1.25

(D) -1.25

Q3. A stream of air ($\gamma = 1.4$) has a static pressure of 50 kPa and a Mach number of 1.0. Using the compressible form of the dynamic pressure $q = \frac{\gamma}{2}\, p\, M^2$, the dynamic pressure of the stream is: **[1 mark]**

(A) 35.0 kPa

(B) 25.0 kPa

(C) 50.0 kPa

(D) 70.0 kPa

Q4. A wing of planform area 20 m^2 operates at a lift coefficient of 0.5 while flying at 60 m/s at sea level ($\rho = 1.225$ kg/m^3). The lift generated by the wing is nearest to: **[1 mark]**

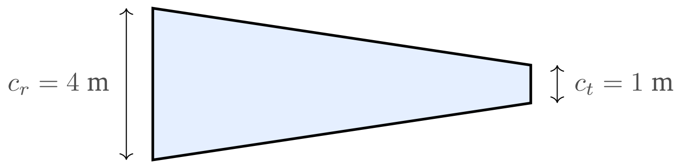
(A) 22050 N

(B) 44100 N

(C) 11025 N

(D) 2205 N

Q5. The trapezoidal wing planform shown has a root chord of 4 m and a tip chord of 1 m. The taper ratio $\lambda = c_t/c_r$ of the wing is: **[1 mark]**



(A) 4

(B) 1

(C) 0.5

(D) 0.25

Q6. A wing has a zero-lift drag coefficient of 0.020 and operates at a lift coefficient of 0.5, with an aspect ratio of 5 and an Oswald efficiency factor of 0.8. Using the drag polar $C_D = C_{D,0} + \dfrac{C_L^2}{\pi e\, AR}$, the total drag coefficient is nearest to: **[1 mark]**

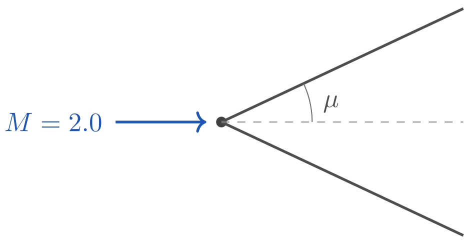
(A) 0.0200

(B) 0.0199

(C) 0.0399

(D) 0.0600

Q7. A body moves through still air at a Mach number of 2.0, generating the Mach wave shown. The Mach angle μ, where $\sin\mu = 1/M$, is: **[1 mark]**



(A) $45°$

(B) $30°$

(C) $60°$

(D) $90°$

Q8. A normal shock forms ahead of a blunt body in an air stream $(\gamma = 1.4)$ at an upstream Mach number of 2.0. Using $\dfrac{p_2}{p_1} = 1 + \dfrac{2\gamma}{\gamma+1}\left(M_1^2 - 1\right)$, the static pressure ratio across the shock is: **[1 mark]**

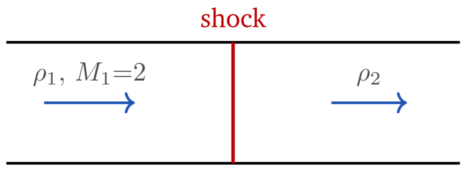
(A) 2.0

(B) 4.5

(C) 5.0

(D) 1.5

Q9. Air ($\gamma = 1.4$) passes through the normal shock shown at an upstream Mach number of 2.0. Using $\dfrac{\rho_2}{\rho_1} = \dfrac{(\gamma+1)M_1^2}{(\gamma-1)M_1^2+2}$, the density ratio across the shock is nearest to: **[1 mark]**



(A) 1.50

(B) 2.00

(C) 2.67

(D) 3.00

Q10. A laminar boundary layer grows on a flat plate held parallel to the flow. At a station where $x = 1$ m and the local Reynolds number is $Re_x = 10^6$, the displacement thickness $\left(\delta^* = 1.721\, x/\sqrt{Re_x}\right)$ is nearest to: **[1 mark]**

(A) 5.00 mm

(B) 1.72 mm

(C) 0.66 mm

(D) 0.34 mm

Q11. A body of frontal area 2 m^2 and drag coefficient 0.03 moves at 40 m/s through sea-level air ($\rho = 1.225$ kg/m^3). The drag force on the body is: **[1 mark]**

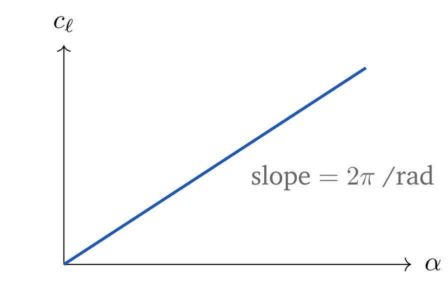
(A) 117.6 N

(B) 29.4 N

(C) 19.6 N

(D) 58.8 N

Q12. For a thin symmetric airfoil the lift-curve slope is 2π per radian, as shown on the c_ℓ–α line. Expressed per degree, the section lift-curve slope a_0 is nearest to: **[1 mark]**



(A) 0.110 per degree

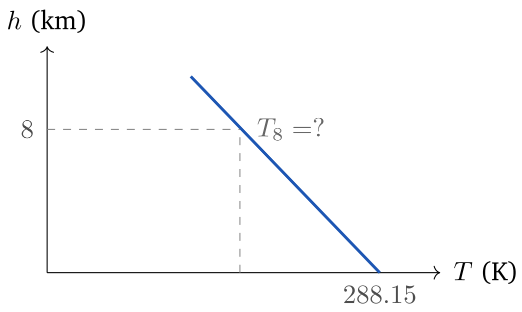
(B) 6.28 per degree

(C) 0.017 per degree

(D) 57.3 per degree

Flight Mechanics & Space Dynamics

Q13. In the International Standard Atmosphere (ISA) troposphere the sea-level temperature is 288.15 K and the lapse rate is 6.5 K per km. The ISA temperature at an altitude of 8 km, marked on the profile below, is: **[1 mark]**



(A) 223.15 K

(B) 236.15 K

(C) 255.65 K

(D) 241.50 K

Q14. An aircraft of weight 20 kN climbs steadily with an engine thrust of 6 kN against a drag of 4 kN. Using $\sin\gamma = (T - D)/W$, the climb (flight-path) angle is nearest to: **[1 mark]**

(A) 11.5°

(B) 2.87°

(C) 5.74°

(D) 8.60°

Q15. An aircraft of weight 22 kN with a wing area of 16 m^2 flies in steady, level flight at a lift coefficient of 0.5 at sea level ($\rho = 1.225$ kg/m^3). The flight speed is nearest to: **[1 mark]**

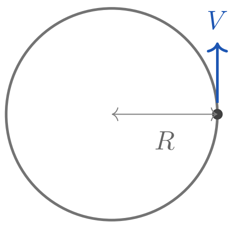
(A) 67.0 m/s

(B) 33.5 m/s

(C) 47.4 m/s

(D) 94.8 m/s

Q16. An aircraft makes a steady, level (co-ordinated) turn at a speed of 100 m/s and a bank angle of 45°, as shown in the plan view. Using $R = V^2/(g\tan\phi)$, the radius of the turn is nearest to: **[1 mark]**



(A) 1019 m

(B) 509 m

(C) 2039 m

(D) 720 m

Q17. An aircraft glides at a forward speed of 50 m/s with a lift-to-drag ratio of 10 in still air. The rate of descent (sink rate $\approx V/(L/D)$) is: **[1 mark]**

(A) 50 m/s

(B) 10 m/s

(C) 0.5 m/s

(D) 5 m/s

Q18. For an airplane to possess directional (weathercock) static stability about its centre of gravity, the yawing-moment characteristic must satisfy: **[1 mark]**

(A) $\dfrac{dC_n}{d\beta} > 0$

(B) $\dfrac{dC_n}{d\beta} < 0$

(C) $\dfrac{dC_n}{d\beta} = 0$

(D) $\dfrac{dC_l}{d\beta} > 0$

Q19. An aircraft turns at a load factor of 2.0 while flying at 100 m/s. Using the minimum-radius relation $R = \dfrac{V^2}{g\sqrt{n^2-1}}$, the turn radius is nearest to: **[1 mark]**

(A) 1019 m

(B) 588.5 m

(C) 294 m

(D) 1732 m

Q20. An aircraft has a horizontal-tail area of 4 m^2, a tail moment arm of 6 m, a wing area of 20 m^2 and a mean aerodynamic chord of 1.5 m. The horizontal-tail volume coefficient $V_H = \dfrac{l_t\, S_t}{S_w\, \bar{c}}$ is: **[1 mark]**

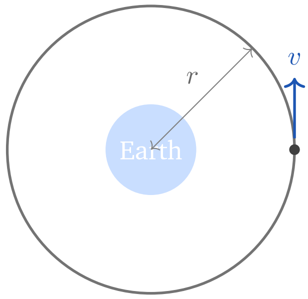
(A) 1.2

(B) 0.8

(C) 0.6

(D) 0.4

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



(A) 5829 s

(B) 2914 s

(C) 8600 s

(D) 3600 s

Q22. A satellite is in an elliptic orbit about the Earth (radius 6378 km) with a perigee altitude of 200 km and an apogee altitude of 2000 km. Taking $\mu = 3.986 \times 10^{14}$ m^3/s^2 and using the vis-viva relation $v = \sqrt{\mu\left(\frac{2}{r} - \frac{1}{a}\right)}$, the speed at perigee is nearest to: **[2 marks]**

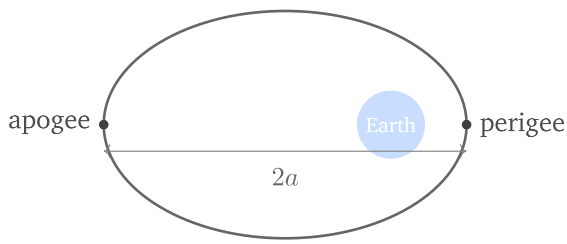
(A) 8.24 km/s

(B) 7.55 km/s

(C) 7.13 km/s

(D) 11.2 km/s

Q23. For the same elliptic orbit shown (perigee radius 6578 km, apogee radius 8378 km), the orbital eccentricity $e = \dfrac{r_a - r_p}{r_a + r_p}$ is nearest to: **[2 marks]**



(A) 0.215

(B) 0.120

(C) 0.060

(D) 0.273

Aerospace Structures

Q24. A steel bar of length 2 m and cross-sectional area 500 mm^2 ($E = 200$ GPa) carries an axial tensile load of 100 kN. The elongation of the bar $(\delta = PL/AE)$ is: **[2 marks]**

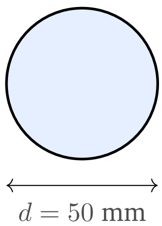
(A) 1 mm

(B) 2 mm

(C) 4 mm

(D) 0.5 mm

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



(A) 81.5 MPa

(B) 326 MPa

(C) 163 MPa

(D) 122 MPa

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

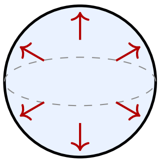
(A) 0.0124 rad

(B) 0.0498 rad

(C) 0.0249 rad

(D) 0.00622 rad

Q27. A thin-walled spherical pressure vessel of internal diameter 2 m and wall thickness 10 mm carries an internal gauge pressure of 1.5 MPa, as shown. Using $\sigma = \dfrac{p\,d}{4t}$, the membrane (wall) stress is: **[2 marks]**



$d = 2$ m, $t = 10$ mm, $p = 1.5$ MPa

(A) 75 MPa

(B) 150 MPa

(C) 37.5 MPa

(D) 300 MPa

Q28. A straight column of length 2 m is fixed at one end and free at the other. It has a second moment of area $I = 2 \times 10^6$ mm^4 and Young's modulus $E = 200$ GPa. Using the 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) 987 kN

(B) 493 kN

(C) 247 kN

(D) 123 kN

Q29. At a point in a loaded panel the plane-stress components are $\sigma_x = 60$ MPa, $\sigma_y = 20$ MPa and $\tau_{xy} = 20$ MPa. The minor principal stress at the point is nearest to: **[2 marks]**

(A) 68.3 MPa

(B) 40.0 MPa

(C) 28.3 MPa

(D) 11.72 MPa

Q30. A rectangular beam section 50 mm wide and 100 mm deep carries a transverse shear force of 30 kN at a section. Using $\tau_{\max} = \frac{3V}{2A}$, the maximum transverse shear stress is: **[2 marks]**

(A) 6 MPa

(B) 3 MPa

(C) 12 MPa

(D) 9 MPa

Q31. A single-degree-of-freedom system has a mass of 10 kg, a stiffness of 10,000 N/m and a viscous damping coefficient of 200 N·s/m. The damping ratio $\zeta = \frac{c}{2\sqrt{km}}$ is nearest to: **[2 marks]**

(A) 0.632

(B) 0.316

(C) 0.158

(D) 0.500

Q32. A thin-walled closed tube encloses a mean area of 0.02 m^2 and carries a torque of 800 N·m. Using the shear-flow relation $q = \frac{T}{2A_m}$, the shear flow in the wall is: **[2 marks]**

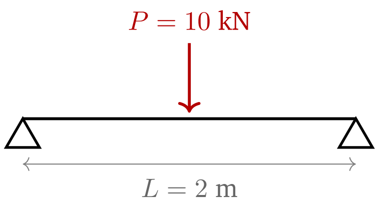
(A) 40 N/mm

(B) 10 N/mm

(C) 20 N/mm

(D) 5 N/mm

Q33. A simply-supported beam of span 2 m carries a central point load of 10 kN, as shown. The beam has $E = 200$ GPa and $I = 5 \times 10^6$ mm^4. Using $\delta = \frac{PL^3}{48EI}$, the mid-span deflection is nearest to: **[2 marks]**



(A) 1.67 mm

(B) 3.33 mm

(C) 0.83 mm

(D) 5.00 mm

Q34. At a point the plane-stress components are $\sigma_x = 50$ MPa, $\sigma_y = 10$ MPa and $\tau_{xy} = 20$ MPa. Using $\tan 2\theta_p = \dfrac{2\tau_{xy}}{\sigma_x - \sigma_y}$, the orientation θ_p of the major principal plane is: **[2 marks]**

(A) $45°$

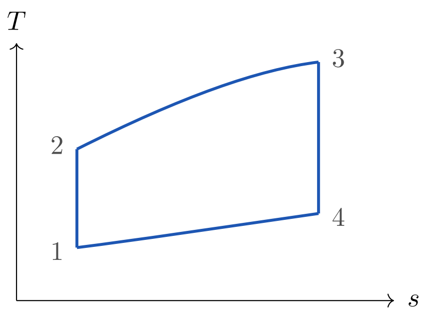
(B) $11.25°$

(C) $22.5°$

(D) $30°$

Propulsion

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



(A) 60.0%

(B) 40.0%

(C) 48.2%

(D) 54.0%

Q36. A turbojet ingests air at a mass flow rate of 40 kg/s. The flight speed is 200 m/s, the jet exit speed is 600 m/s, and the nozzle is under-expanded with a pressure-thrust term $(p_e - p_a)A_e = 2500$ N. Using $F = \dot{m}(V_e - V_0) + (p_e - p_a)A_e$, the net thrust is: **[2 marks]**

(A) 16.0 kN

(B) 18.5 kN

(C) 21.0 kN

(D) 2.5 kN

Q37. A jet engine produces a thrust of 20 kN while burning fuel at a rate of 0.4 kg/s. Using the fuel-based specific impulse $I_{sp} = \dfrac{F}{\dot{m}_f\, g_0}$ with $g_0 = 9.81\ \text{m/s}^2$, the specific impulse is nearest to: **[2 marks]**

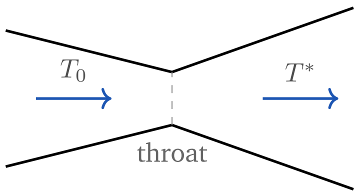
(A) 2548 s

(B) 10000 s

(C) 4000 s

(D) 5096 s

Q38. Air ($\gamma = 1.4$) expands from a chamber at a stagnation temperature of 600 K through the convergent–divergent nozzle shown and chokes at the throat ($M = 1$). Using $T^* = T_0 \dfrac{2}{\gamma + 1}$, the throat static temperature is: **[2 marks]**



(A) 500 K

(B) 480 K

(C) 333 K

(D) 600 K

Q39. For air ($\gamma = 1.4$) expanding to a choked throat ($M = 1$), the ratio of the throat static temperature to the stagnation temperature, $T^*/T_0 = \dfrac{2}{\gamma + 1}$, is nearest to: **[2 marks]**

(A) 0.528

(B) 0.833

(C) 0.634

(D) 0.667

Q40. In an axial-flow compressor stage the mean blade speed is 250 m/s and the whirl (tangential) component of the absolute velocity increases by 180 m/s across the rotor. Taking $c_p = 1005$ J/kg $\cdot$ K, the stagnation temperature rise $\left(\Delta T_0 = U\,\Delta C_w/c_p\right)$ across the stage is nearest to: **[2 marks]**

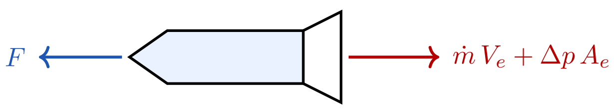
(A) 15.0 K

(B) 30.0 K

(C) 22.4 K

(D) 44.8 K

Q41. A rocket engine expels propellant at a mass flow rate of 200 kg/s with an exhaust velocity of 2500 m/s. The nozzle is under-expanded with a pressure-thrust term $(p_e - p_a)A_e = 20$ kN, as shown. Using $F = \dot{m}\,V_e + (p_e - p_a)A_e$, the thrust produced is: **[2 marks]**



(A) 500 kN

(B) 480 kN

(C) 520 kN

(D) 200 kN

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

(A) 300 s

(B) 350 s

(C) 288 s

(D) 254.8 s

Q43. A single-stage rocket must produce an ideal velocity increment of 5000 m/s using an engine of specific impulse 300 s ($g_0 = 9.81$ m/s^2). Using the Tsiolkovsky equation $\Delta v = I_{sp} g_0 \ln(m_0/m_f)$, the required initial-to-final mass ratio m_0/m_f is nearest to: **[2 marks]**

(A) 3.00

(B) 5.47

(C) 2.72

(D) 7.39

Q44. A hydrocarbon fuel has a stoichiometric air–fuel ratio of 15. A combustor runs lean at an equivalence ratio of 0.6. Using $\phi = \dfrac{(A/F)_{\text{stoich}}}{(A/F)_{\text{actual}}}$, the actual air–fuel ratio supplied is: **[2 marks]**

(A) 25

(B) 9

(C) 15

(D) 20

Q45. A jet engine has a thermal efficiency of 0.40 and a propulsive efficiency of 0.75. The overall efficiency $\left(\eta_0 = \eta_{th}\, \eta_p\right)$ of the engine is: **[2 marks]**

(A) 0.40

(B) 0.75

(C) 0.30

(D) 0.53

Q46. The turbine of a gas-turbine engine expands gas isentropically from a stagnation temperature of 1200 K through an expansion (pressure) ratio of 8 ($\gamma = 1.4$). Using $\dfrac{T_{02}}{T_{01}} = \left(\dfrac{1}{r_p}\right)^{(\gamma-1)/\gamma}$, the turbine-exit stagnation temperature is nearest to: **[2 marks]**

(A) 1200 K

(B) 480 K

(C) 543 K

(D) 662.5 K

Detailed Solutions

Q1.

Solution

Concept – Mach number from the local speed of sound: $M = \dfrac{V}{a}$, where $a = \sqrt{\gamma RT}$ is evaluated at the local static temperature.

Step 1 – list the data: $V = 634$ m/s, $T = 250$ K, $\gamma = 1.4$, $R = 287$ J/kg · K.

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

Step 3 – multiply by the temperature: $\gamma RT = 401.8 \times 250 = 100450$

Step 4 – take the square root for the speed of sound: $a = \sqrt{100450} = 316.9$ m/s

Step 5 – divide the airspeed by the speed of sound: $M = \dfrac{634}{316.9}$

Step 6 – evaluate: $M = 2.00$

Step 7 – avoid the trap: Using the sea-level speed of sound 340.3 m/s gives $634/340.3 = 1.86$ (option A), which is wrong because a must be taken at the local temperature.

Final Answer: $M \approx 2.0 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q1

Q2.

Solution

Concept – incompressible pressure coefficient: $C_p = 1 - \left(\dfrac{V}{V_\infty}\right)^2$.

Step 1 – list the data: $\dfrac{V}{V_\infty} = 1.5$.

Step 2 – square the velocity ratio: $\left(\dfrac{V}{V_\infty}\right)^2 = 1.5^2 = 2.25$

Step 3 – subtract from one: $C_p = 1 - 2.25$

Step 4 – evaluate: $C_p = -1.25$

Step 5 – interpret the sign: The local velocity exceeds the freestream value, so the flow accelerates and the pressure coefficient is negative (a suction).

Final Answer: $C_p = -1.25 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q2

Q3.

Solution

Concept – compressible dynamic pressure: $q = \frac{\gamma}{2}\, p\, M^2$, a convenient form that uses static pressure and Mach number.

Step 1 – list the data: $\gamma = 1.4$, $p = 50$ kPa $= 50000$ Pa, $M = 1.0$.

Step 2 – evaluate $\frac{\gamma}{2}$**:** $\frac{1.4}{2} = 0.7$

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

Step 4 – multiply the terms: $q = 0.7 \times 50000 \times 1.0$

Step 5 – evaluate: $q = 35000$ Pa $= 35.0$ kPa

Final Answer: $q = 35.0$ kPa $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q3

Q4.

Solution

Concept – lift from the lift equation: $L = \frac{1}{2}\rho V^2 S\, C_L$.

Step 1 – list the data: $\rho = 1.225$ kg/m^3, $V = 60$ m/s, $S = 20$ m^2, $C_L = 0.5$.

Step 2 – square the velocity: $V^2 = 60^2 = 3600$

Step 3 – compute the dynamic pressure: $q = \frac{1}{2}\rho V^2 = 0.6125 \times 3600$

$q = 2205$ Pa

Step 4 – multiply by the wing area: $q\, S = 2205 \times 20 = 44100$ N

Step 5 – multiply by the lift coefficient: $L = 44100 \times 0.5$

Step 6 – evaluate: $L = 22050$ N

Final Answer: $L = 22050$ N $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q4

Q5.

Solution

Concept – taper ratio of a wing: $\lambda = \frac{c_t}{c_r}$, the ratio of tip chord to root chord.

Step 1 – list the data: $c_r = 4$ m, $c_t = 1$ m.

Step 2 – form the ratio: $\lambda = \frac{1}{4}$

Step 3 – evaluate: $\lambda = 0.25$

Final Answer: $\lambda = 0.25 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q5

Q6.

Solution

Concept – drag polar of a finite wing: $C_D = C_{D,0} + \dfrac{C_L^2}{\pi e\, AR}$.

Step 1 – list the data: $C_{D,0} = 0.020$, $C_L = 0.5$, $e = 0.8$, $AR = 5$.

Step 2 – square the lift coefficient: $C_L^2 = 0.5^2 = 0.25$

Step 3 – form the denominator $\pi e\, AR$: $\pi e\, AR = 3.1416 \times 0.8 \times 5$

$= 12.566$

Step 4 – compute the induced-drag term: $\dfrac{0.25}{12.566} = 0.0199$

Step 5 – add the zero-lift drag: $C_D = 0.020 + 0.0199$

Step 6 – evaluate: $C_D = 0.0399$

Final Answer: $C_D \approx 0.0399 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q6

Q7.

Solution

Concept – Mach angle: $\sin\mu = \dfrac{1}{M}$, the half-angle of the Mach cone in supersonic flow.

Step 1 – list the data: $M = 2.0$.

Step 2 – form the sine of the Mach angle: $\sin\mu = \dfrac{1}{2.0} = 0.5$

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

Step 4 – evaluate: $\mu = 30^\circ$

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

Answer: (B) Go Back to Q7

Q8.

Solution

Concept – static pressure ratio across a normal shock: $\frac{p_2}{p_1} = 1 + \frac{2\gamma}{\gamma+1}\left(M_1^2 - 1\right)$.

Step 1 – list the data: $\gamma = 1.4$, $M_1 = 2.0$.

Step 2 – evaluate the coefficient $\frac{2\gamma}{\gamma+1}$**:** $\frac{2 \times 1.4}{1.4+1} = \frac{2.8}{2.4} = 1.1667$

Step 3 – evaluate $M_1^2 - 1$**:** $2.0^2 - 1 = 4 - 1 = 3$

Step 4 – multiply the two: $1.1667 \times 3 = 3.5$

Step 5 – add one: $\frac{p_2}{p_1} = 1 + 3.5 = 4.5$

Final Answer: $p_2/p_1 = 4.5 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q8

Q9.

Solution

Concept – density ratio across a normal shock: $\frac{\rho_2}{\rho_1} = \frac{(\gamma+1)M_1^2}{(\gamma-1)M_1^2 + 2}$.

Step 1 – list the data: $\gamma = 1.4$, $M_1 = 2.0$, so $M_1^2 = 4$.

Step 2 – evaluate the numerator: $(\gamma+1)M_1^2 = 2.4 \times 4 = 9.6$

Step 3 – evaluate the denominator: $(\gamma-1)M_1^2 = 0.4 \times 4 = 1.6$

$1.6 + 2 = 3.6$

Step 4 – form the ratio: $\frac{\rho_2}{\rho_1} = \frac{9.6}{3.6}$

Step 5 – evaluate: $\frac{\rho_2}{\rho_1} = 2.667$

Final Answer: $\rho_2/\rho_1 \approx 2.67 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q9

Q10.

Solution

Concept – laminar displacement thickness: $\delta^* = \frac{1.721\,x}{\sqrt{Re_x}}$.

Step 1 – list the data: $x = 1$ m, $Re_x = 10^6$.

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

Step 3 – substitute into the formula: $\delta^* = \dfrac{1.721 \times 1}{1000}$

Step 4 – evaluate: $\delta^* = 0.001721$ m

Step 5 – convert to millimetres: $\delta^* = 1.721$ mm

Final Answer: $\delta^* \approx 1.72$ mm $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q10

Q11.

Solution

Concept – drag force: $D = \frac{1}{2}\rho V^2 S\, C_D$.

Step 1 – list the data: $\rho = 1.225$ kg/m^3, $V = 40$ m/s, $S = 2$ m^2, $C_D = 0.03$.

Step 2 – square the velocity: $V^2 = 40^2 = 1600$

Step 3 – compute the dynamic pressure: $q = 0.6125 \times 1600 = 980$ Pa

Step 4 – multiply by the area: $q\, S = 980 \times 2 = 1960$ N

Step 5 – multiply by the drag coefficient: $D = 1960 \times 0.03$

Step 6 – evaluate: $D = 58.8$ N

Final Answer: $D = 58.8$ N $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q11

Q12.

Solution

Concept – lift-curve slope in degrees: The thin-airfoil slope is 2π per radian; converting to a per-degree value uses 1 rad $= 57.2958°$.

Step 1 – state the per-radian slope: $a_0 = 2\pi = 6.2832$ per radian.

Step 2 – divide by the number of degrees in a radian: $a_0 = \dfrac{6.2832}{57.2958}$

Step 3 – evaluate: $a_0 = 0.1097$ per degree

Step 4 – round: $a_0 \approx 0.110$ per degree

Step 5 – note the traps: Option B (6.28) is the per-radian value, and D (57.3) is the radian-to-degree factor itself, not the slope.

Final Answer: $a_0 \approx 0.110$ per degree $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q12

Q13.

Solution

Concept – ISA temperature in the troposphere: $T(h) = T_0 - Lh$, with $T_0 = 288.15$ K and $L = 6.5$ K/km.

Step 1 – list the data: $T_0 = 288.15$ K, $L = 6.5$ K/km, $h = 8$ km.

Step 2 – compute the temperature drop: $Lh = 6.5 \times 8 = 52$ K

Step 3 – subtract from the sea-level value: $T = 288.15 - 52$

Step 4 – evaluate: $T = 236.15$ K

Final Answer: $T = 236.15 \text{ K} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q13

Q14.

Solution

Concept – steady climb angle: Along the flight path the excess thrust drives the climb, $\sin\gamma = \dfrac{T-D}{W}$.

Step 1 – list the data: $T = 6$ kN, $D = 4$ kN, $W = 20$ kN.

Step 2 – form the excess thrust: $T - D = 6 - 4 = 2$ kN

Step 3 – divide by the weight: $\sin\gamma = \dfrac{2}{20} = 0.1$

Step 4 – take the inverse sine: $\gamma = \sin^{-1}(0.1)$

Step 5 – evaluate: $\gamma = 5.74°$

Final Answer: $\gamma \approx 5.74° \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q14

Q15.

Solution

Concept – level-flight speed: $L = W = \frac{1}{2}\rho V^2 S\, C_L$, so $V = \sqrt{\dfrac{2W}{\rho S\, C_L}}$.

Step 1 – list the data: $W = 22000$ N, $\rho = 1.225$ kg/m^3, $S = 16$ m^2, $C_L = 0.5$.

Step 2 – form the numerator $2W$: $2W = 2 \times 22000 = 44000$

Step 3 – form the denominator $\rho S\, C_L$: $1.225 \times 16 = 19.6$

$19.6 \times 0.5 = 9.8$

Step 4 – divide: $\dfrac{44000}{9.8} = 4489.8$

Step 5 – take the square root: $V = \sqrt{4489.8} = 67.0$ m/s

Final Answer: $V \approx 67.0$ m/s $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q15

Q16.

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: $V^2 = 100^2 = 10000$

Step 3 – evaluate the tangent: $\tan 45° = 1$

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

Step 5 – divide: $R = \dfrac{10000}{9.81}$

Step 6 – evaluate: $R = 1019$ m

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

Answer: (A) Go Back to Q16

Q17.

Solution

Concept – sink rate in a glide: For a shallow glide the rate of descent is the forward speed divided by the glide ratio, $V_{sink} = \dfrac{V}{L/D}$.

Step 1 – list the data: $V = 50$ m/s, $L/D = 10$.

Step 2 – divide the speed by the glide ratio: $V_{sink} = \dfrac{50}{10}$

Step 3 – evaluate: $V_{sink} = 5$ m/s

Step 4 – interpret: A higher L/D would give a slower sink rate; here the aircraft loses 5 m of height each second.

Final Answer: $V_{sink} = 5$ m/s $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q17

Q18.

Solution

Concept – directional (weathercock) static stability: Stability in yaw requires that a disturbance producing a sideslip angle β generates a restoring yawing moment that turns the nose back into the wind.

Step 1 – set up the disturbance: A positive sideslip β (nose to the left of the relative wind) must produce a yawing moment that reduces β.

Step 2 – restoring-moment condition: This restoring moment corresponds to a positive slope of the yawing-moment coefficient with sideslip, $\dfrac{dC_n}{d\beta} > 0$.

Step 3 – role of the vertical tail: The vertical fin supplies this positive slope, much as a weathercock aligns with the wind.

Why the other options are wrong:

- B, $dC_n/d\beta < 0$: gives a diverging (destabilising) yaw, so the aircraft is directionally unstable.
- C, $dC_n/d\beta = 0$: neutral directional stability, not stable.
- D, $dC_l/d\beta > 0$: this concerns roll due to sideslip (dihedral effect), not directional stability.

Final Answer: $\dfrac{dC_n}{d\beta} > 0 \Rightarrow \boxed{\text{A}}$

$\boxed{\textbf{Answer: (A)}}$ Go Back to Q18

Q19.

Solution

Concept – turn radius from load factor: $R = \dfrac{V^2}{g\sqrt{n^2 - 1}}$.

Step 1 – list the data: $n = 2.0$, $V = 100$ m/s, $g = 9.81$ m/s^2.

Step 2 – evaluate $n^2 - 1$: $n^2 - 1 = 2.0^2 - 1 = 4 - 1 = 3$

Step 3 – take the square root: $\sqrt{3} = 1.732$

Step 4 – square the speed: $V^2 = 100^2 = 10000$

Step 5 – form the denominator $g\sqrt{n^2 - 1}$: $9.81 \times 1.732 = 16.99$

Step 6 – divide: $R = \dfrac{10000}{16.99}$

$R = 588.5$ m

Final Answer: $R \approx 588.5 \text{ m} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q19

Q20.

Solution

Concept – horizontal-tail volume coefficient: $V_H = \dfrac{l_t\,S_t}{S_w\,\bar{c}}$, a non-dimensional measure of tail effectiveness.

Step 1 – list the data: $l_t = 6$ m, $S_t = 4$ m^2, $S_w = 20$ m^2, $\bar{c} = 1.5$ m.

Step 2 – form the numerator $l_t\,S_t$**:** $l_t\,S_t = 6 \times 4 = 24$

Step 3 – form the denominator $S_w\,\bar{c}$**:** $S_w\,\bar{c} = 20 \times 1.5 = 30$

Step 4 – divide: $V_H = \dfrac{24}{30}$

Step 5 – evaluate: $V_H = 0.8$

Final Answer: $V_H = 0.8 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q20

Q21.

Solution

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

Step 1 – list the data: $r = 7000$ km $= 7.0 \times 10^6$ m, $\mu = 3.986 \times 10^{14}$ m^3/s^2.

Step 2 – cube the radius: $a^3 = (7.0 \times 10^6)^3 = 3.43 \times 10^{20}$ m^3

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

$= 8.605 \times 10^5$ s^2

Step 4 – take the square root: $\sqrt{8.605 \times 10^5} = 927.6$ s

Step 5 – multiply by 2π**:** $T = 2\pi \times 927.6$

$T = 6.2832 \times 927.6$

Step 6 – evaluate: $T = 5829$ s

Final Answer: $T \approx 5829$ s $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q21

Q22.

Solution

Concept – vis-viva equation: $v = \sqrt{\mu\left(\frac{2}{r} - \frac{1}{a}\right)}$, evaluated at the perigee radius.

Step 1 – form the perigee and apogee radii: $r_p = 6378 + 200 = 6578$ km $= 6.578 \times 10^6$ m

$r_a = 6378 + 2000 = 8378$ km $= 8.378 \times 10^6$ m

Step 2 – compute the semi-major axis: $a = \frac{r_p + r_a}{2} = \frac{6578 + 8378}{2} = 7478$ km $= 7.478 \times 10^6$ m

Step 3 – evaluate $\frac{2}{r_p}$**:** $\frac{2}{6.578 \times 10^6} = 3.0404 \times 10^{-7}$

Step 4 – evaluate $\frac{1}{a}$**:** $\frac{1}{7.478 \times 10^6} = 1.3373 \times 10^{-7}$

Step 5 – take the difference: $3.0404 \times 10^{-7} - 1.3373 \times 10^{-7} = 1.7031 \times 10^{-7}$

Step 6 – multiply by μ**:** $3.986 \times 10^{14} \times 1.7031 \times 10^{-7} = 6.789 \times 10^7$

Step 7 – take the square root: $v = \sqrt{6.789 \times 10^7} = 8239$ m/s

Step 8 – convert to km/s: $v = 8.24$ km/s

Final Answer: $v \approx 8.24$ km/s $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q22

Q23.

Solution

Concept – eccentricity from apogee and perigee radii: $e = \frac{r_a - r_p}{r_a + r_p}$.

Step 1 – list the data: $r_p = 6578$ km, $r_a = 8378$ km.

Step 2 – form the numerator: $r_a - r_p = 8378 - 6578 = 1800$ km

Step 3 – form the denominator: $r_a + r_p = 8378 + 6578 = 14956$ km

Step 4 – divide: $e = \frac{1800}{14956}$

Step 5 – evaluate: $e = 0.1203$

Final Answer: $e \approx 0.120 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q23

Q24.

Solution

Concept – axial elongation of a bar: $\delta = \dfrac{PL}{AE}$.

Step 1 – list the data (consistent units): $P = 100$ kN $= 100000$ N, $L = 2$ m $= 2000$ mm, $A = 500$ mm^2, $E = 200000$ N/mm^2.

Step 2 – form the numerator PL**:** $PL = 100000 \times 2000 = 2 \times 10^8$

Step 3 – form the denominator AE**:** $AE = 500 \times 200000 = 1 \times 10^8$

Step 4 – divide: $\delta = \dfrac{2 \times 10^8}{1 \times 10^8}$

Step 5 – evaluate: $\delta = 2$ mm

Final Answer: $\delta = 2$ mm $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q24

Q25.

Solution

Concept – bending stress in a solid circular section: $\sigma = \dfrac{32M}{\pi d^3}$, since the section modulus is $Z = \dfrac{\pi d^3}{32}$.

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

Step 2 – cube the diameter: $d^3 = 50^3 = 125000$ mm^3

Step 3 – form the denominator πd^3**:** $\pi d^3 = 3.1416 \times 125000 = 392699$

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

Step 5 – divide: $\sigma = \dfrac{6.4 \times 10^7}{392699}$

Step 6 – evaluate: $\sigma = 163.0$ MPa

Final Answer: $\sigma \approx 163$ MPa $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q25

Q26.

Solution

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

Step 1 – list the data (consistent units): $T = 500$ N $\cdot$ m $= 5 \times 10^5$ N $\cdot$ mm, $L = 1$

m $= 1000$ mm, $G = 80000$ N/mm^2, $d = 40$ mm.

Step 2 – compute the polar moment J: $d^4 = 40^4 = 2560000$

$J = \dfrac{\pi \times 2560000}{32} = 251327$ mm^4

Step 3 – form the numerator TL: $TL = 5 \times 10^5 \times 1000 = 5 \times 10^8$

Step 4 – form the denominator GJ: $GJ = 80000 \times 251327 = 2.0106 \times 10^{10}$

Step 5 – divide: $\theta = \dfrac{5 \times 10^8}{2.0106 \times 10^{10}}$

Step 6 – evaluate: $\theta = 0.0249$ rad

Final Answer: $\theta \approx 0.0249$ rad $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q26

Q27.

Solution

Concept – membrane stress in a thin sphere: $\sigma = \dfrac{p\,d}{4t}$; the sphere carries the same stress in every direction.

Step 1 – list the data: $p = 1.5$ MPa, $d = 2$ m $= 2000$ mm, $t = 10$ mm.

Step 2 – form the numerator $p\,d$: $p\,d = 1.5 \times 2000 = 3000$

Step 3 – form the denominator $4t$: $4t = 4 \times 10 = 40$

Step 4 – divide: $\sigma = \dfrac{3000}{40}$

Step 5 – evaluate: $\sigma = 75$ MPa

Step 6 – compare with a cylinder: A cylinder of the same p, d, t would carry a hoop stress $pd/2t = 150$ MPa, twice as high, which is why spherical vessels are more weight-efficient.

Final Answer: $\sigma = 75$ MPa $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q27

Q28.

Solution

Concept – Euler buckling of a fixed–free column: $P_{cr} = \dfrac{\pi^2 EI}{L_e^2}$, with the effective length $L_e = 2L$ for a fixed–free (cantilever) column.

Step 1 – list the data (consistent units): $E = 200000$ N/mm^2, $I = 2 \times 10^6$ mm^4, $L = 2$ m $= 2000$ mm.

Step 2 – form the effective length: $L_e = 2L = 2 \times 2000 = 4000$ mm

Step 3 – form the numerator $\pi^2 EI$: $\pi^2 = 9.8696$

$\pi^2 EI = 9.8696 \times 200000 \times 2 \times 10^6$

$= 9.8696 \times 4 \times 10^{11}$

$= 3.9478 \times 10^{12}$

Step 4 – form the denominator L_e^2: $L_e^2 = 4000^2 = 1.6 \times 10^7$ mm^2

Step 5 – divide: $P_{cr} = \dfrac{3.9478 \times 10^{12}}{1.6 \times 10^7}$

$P_{cr} = 246738$ N

Step 6 – convert to kN: $P_{cr} = 247$ kN

Final Answer: $P_{cr} \approx 247$ kN $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q28

Q29.

Solution

Concept – minor principal stress: $\sigma_2 = \dfrac{\sigma_x + \sigma_y}{2} - \sqrt{\left(\dfrac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}.$

Step 1 – list the data: $\sigma_x = 60$ MPa, $\sigma_y = 20$ MPa, $\tau_{xy} = 20$ MPa.

Step 2 – compute the mean (centre of Mohr's circle): $\dfrac{\sigma_x + \sigma_y}{2} = \dfrac{60 + 20}{2} = 40$ MPa

Step 3 – compute the half-difference: $\dfrac{\sigma_x - \sigma_y}{2} = \dfrac{60 - 20}{2} = 20$ MPa

Step 4 – compute the radius: $R = \sqrt{20^2 + 20^2} = \sqrt{400 + 400}$

$R = \sqrt{800} = 28.28$ MPa

Step 5 – subtract the radius from the mean: $\sigma_2 = 40 - 28.28$

Step 6 – evaluate: $\sigma_2 = 11.72$ MPa

Final Answer: $\sigma_2 \approx 11.72$ MPa $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q29

Q30.

Solution

Concept – maximum transverse shear stress in a rectangular section: The parabolic distribution peaks at the neutral axis, $\tau_{\max} = \frac{3V}{2A} = 1.5\,\frac{V}{A}$.

Step 1 – list the data: $V = 30$ kN $= 30000$ N, $b = 50$ mm, $d = 100$ mm.

Step 2 – compute the cross-sectional area: $A = b\,d = 50 \times 100 = 5000$ mm^2

Step 3 – form the average shear stress: $\frac{V}{A} = \frac{30000}{5000} = 6$ N/mm^2

Step 4 – multiply by the factor 1.5: $\tau_{\max} = 1.5 \times 6$

Step 5 – evaluate: $\tau_{\max} = 9$ MPa

Final Answer: $\tau_{\max} = 9$ MPa $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q30

Q31.

Solution

Concept – damping ratio: $\zeta = \frac{c}{c_c}$, where the critical damping is $c_c = 2\sqrt{km}$.

Step 1 – list the data: $m = 10$ kg, $k = 10000$ N/m, $c = 200$ N $\cdot$ s/m.

Step 2 – form the product km: $km = 10000 \times 10 = 100000$

Step 3 – take the square root: $\sqrt{km} = \sqrt{100000} = 316.23$

Step 4 – form the critical damping: $c_c = 2 \times 316.23 = 632.46$ N $\cdot$ s/m

Step 5 – divide the actual damping by the critical value: $\zeta = \frac{200}{632.46}$

Step 6 – evaluate: $\zeta = 0.316$

Final Answer: $\zeta \approx 0.316 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q31

Q32.

Solution

Concept – shear flow in a thin closed tube: $q = \frac{T}{2A_m}$, the shear force per unit length of wall (Bredt–Batho).

Step 1 – list the data (SI units): $T = 800$ N $\cdot$ m, $A_m = 0.02$ m^2.

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

Step 3 – divide the torque: $q = \dfrac{800}{0.04}$

Step 4 – evaluate: $q = 20000$ N/m

Step 5 – convert to N/mm: $q = \dfrac{20000}{1000} = 20$ N/mm

Final Answer: $q = 20$ N/mm $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q32

Q33.

Solution

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

Step 1 – list the data (consistent units): $P = 10$ kN $= 10000$ N, $L = 2$ m $= 2000$ mm, $E = 200000$ N/mm^2, $I = 5 \times 10^6$ mm^4.

Step 2 – cube the span: $L^3 = 2000^3 = 8 \times 10^9$ mm^3

Step 3 – form the numerator PL^3: $PL^3 = 10000 \times 8 \times 10^9 = 8 \times 10^{13}$

Step 4 – form the denominator $48EI$: $48EI = 48 \times 200000 \times 5 \times 10^6$

$= 48 \times 1 \times 10^{12}$

$= 4.8 \times 10^{13}$

Step 5 – divide: $\delta = \dfrac{8 \times 10^{13}}{4.8 \times 10^{13}}$

Step 6 – evaluate: $\delta = 1.667$ mm

Final Answer: $\delta \approx 1.67$ mm $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q33

Q34.

Solution

Concept – orientation of the principal plane: $\tan 2\theta_p = \dfrac{2\tau_{xy}}{\sigma_x - \sigma_y}$.

Step 1 – list the data: $\sigma_x = 50$ MPa, $\sigma_y = 10$ MPa, $\tau_{xy} = 20$ MPa.

Step 2 – form the numerator $2\tau_{xy}$: $2\tau_{xy} = 2 \times 20 = 40$

Step 3 – form the denominator $\sigma_x - \sigma_y$: $\sigma_x - \sigma_y = 50 - 10 = 40$

Step 4 – form the tangent: $\tan 2\theta_p = \dfrac{40}{40} = 1$

Step 5 – take the inverse tangent: $2\theta_p = \tan^{-1}(1) = 45°$

Step 6 – halve the angle: $\theta_p = 22.5°$

Final Answer: $\theta_p = 22.5° \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q34

Q35.

Solution

Concept – ideal Brayton-cycle thermal efficiency: $\eta = 1 - \dfrac{1}{r_p^{(\gamma-1)/\gamma}}$.

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: $10^{0.2857} = 1.9307$

Step 4 – take the reciprocal: $\dfrac{1}{1.9307} = 0.5180$

Step 5 – subtract from one: $\eta = 1 - 0.5180 = 0.4820$

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

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

Answer: (C) Go Back to Q35

Q36.

Solution

Concept – net thrust with a pressure-thrust term: $F = \dot{m}\,(V_e - V_0) + (p_e - p_a)A_e$.

Step 1 – list the data: $\dot{m} = 40$ kg/s, $V_e = 600$ m/s, $V_0 = 200$ m/s, $(p_e - p_a)A_e = 2500$ N.

Step 2 – take the velocity difference: $V_e - V_0 = 600 - 200 = 400$ m/s

Step 3 – form the momentum thrust: $\dot{m}\,(V_e - V_0) = 40 \times 400 = 16000$ N

Step 4 – add the pressure thrust: $F = 16000 + 2500$

Step 5 – evaluate: $F = 18500$ N $= 18.5$ kN

Final Answer: $F = 18.5$ kN $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q36

Q37.

Solution

Concept – fuel-based specific impulse: $I_{sp} = \dfrac{F}{\dot{m}_f\, g_0}$.

Step 1 – list the data: $F = 20$ kN $= 20000$ N, $\dot{m}_f = 0.4$ kg/s, $g_0 = 9.81$ m/s^2.

Step 2 – form the denominator $\dot{m}_f\, g_0$**:** $\dot{m}_f\, g_0 = 0.4 \times 9.81 = 3.924$

Step 3 – divide the thrust: $I_{sp} = \dfrac{20000}{3.924}$

Step 4 – evaluate: $I_{sp} = 5096$ s

Final Answer: $I_{sp} \approx 5096$ s $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q37

Q38.

Solution

Concept – throat static temperature at choking: $T^* = T_0 \dfrac{2}{\gamma+1}$, the static temperature where $M = 1$.

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

Step 2 – form the ratio $\dfrac{2}{\gamma+1}$**:** $\dfrac{2}{1.4+1} = \dfrac{2}{2.4} = 0.8333$

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

Step 4 – evaluate: $T^* = 500$ K

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

Answer: (A) Go Back to Q38

Q39.

Solution

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

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

Step 2 – form the denominator $\gamma + 1$**:** $\gamma + 1 = 1.4 + 1 = 2.4$

Step 3 – divide: $\dfrac{T^*}{T_0} = \dfrac{2}{2.4}$

Step 4 – evaluate: $\dfrac{T^*}{T_0} = 0.8333$

Step 5 – note the trap: Option A (0.528) is the critical *pressure* ratio p^*/p_0, not the temperature ratio.

Final Answer: $T^*/T_0 \approx 0.833 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q39

Q40.

Solution

Concept – stagnation temperature rise across a compressor stage: The Euler work is $w = U\,\Delta C_w$, and the temperature rise follows from $w = c_p\,\Delta T_0$, so $\Delta T_0 = \dfrac{U\,\Delta C_w}{c_p}$.

Step 1 – list the data: $U = 250$ m/s, $\Delta C_w = 180$ m/s, $c_p = 1005$ J/kg · K.

Step 2 – form the Euler work: $w = U\,\Delta C_w = 250 \times 180$

$= 45000$ J/kg

Step 3 – divide by c_p: $\Delta T_0 = \dfrac{45000}{1005}$

Step 4 – evaluate: $\Delta T_0 = 44.8$ K

Final Answer: $\Delta T_0 \approx 44.8\text{ K} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q40

Q41.

Solution

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

Step 1 – list the data: $\dot{m} = 200$ kg/s, $V_e = 2500$ m/s, $(p_e - p_a)A_e = 20$ kN $= 20000$ N.

Step 2 – form the momentum thrust: $\dot{m}\,V_e = 200 \times 2500$

$= 500000$ N

Step 3 – add the pressure thrust: $F = 500000 + 20000$

Step 4 – evaluate: $F = 520000$ N $= 520$ kN

Final Answer: $F = 520\text{ kN} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q41

Q42.

Solution

Concept – specific impulse of a rocket: $I_{sp} = \dfrac{F}{\dot{m}\, g_0}$.

Step 1 – list the data: $F = 100$ kN $= 100000$ 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: $I_{sp} = \dfrac{100000}{392.4}$

Step 4 – evaluate: $I_{sp} = 254.8$ s

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

Answer: (D) Go Back to Q42

Q43.

Solution

Concept – Tsiolkovsky rocket equation (solved for mass ratio): $\Delta v = I_{sp}\, g_0 \ln\left(\dfrac{m_0}{m_f}\right)$, so $\dfrac{m_0}{m_f} = \exp\left(\dfrac{\Delta v}{I_{sp}\, g_0}\right)$.

Step 1 – list the data: $\Delta v = 5000$ m/s, $I_{sp} = 300$ s, $g_0 = 9.81$ m/s^2.

Step 2 – form the effective exhaust velocity $I_{sp}\, g_0$**:** $I_{sp}\, g_0 = 300 \times 9.81 = 2943$ m/s

Step 3 – form the exponent $\dfrac{\Delta v}{I_{sp}\, g_0}$**:** $\dfrac{5000}{2943} = 1.699$

Step 4 – take the exponential: $\dfrac{m_0}{m_f} = e^{1.699}$

Step 5 – evaluate: $\dfrac{m_0}{m_f} = 5.47$

Final Answer: $m_0/m_f \approx 5.47 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q43

Q44.

Solution

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

Step 1 – list the data: $(A/F)_{\text{stoich}} = 15$, $\phi = 0.6$.

Step 2 – divide by the equivalence ratio: $(A/F)_{\text{actual}} = \dfrac{15}{0.6}$

Step 3 – evaluate: $(A/F)_{\text{actual}} = 25$

Step 4 – interpret: Since $\phi < 1$, more air is supplied than the stoichiometric amount, giving an air–fuel ratio (25) larger than the stoichiometric value (15); the mixture is lean.

Final Answer: $(A/F)_{\text{actual}} = 25 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q44

Q45.

Solution

Concept – overall (thermal) efficiency of a jet engine: $\eta_0 = \eta_{th}\,\eta_p$, the product of thermal and propulsive efficiencies.

Step 1 – list the data: $\eta_{th} = 0.40$, $\eta_p = 0.75$.

Step 2 – multiply the two efficiencies: $\eta_0 = 0.40 \times 0.75$

Step 3 – evaluate: $\eta_0 = 0.30$

Final Answer: $\eta_0 = 0.30 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q45

Q46.

Solution

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

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 – divide the inlet temperature by this factor: $T_{02} = \dfrac{1200}{1.8114}$

Step 5 – evaluate: $T_{02} = 662.5$ K

Final Answer: $T_{02} \approx 662.5\text{ K} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q46

Answer Key

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