GATE Aerospace Engineering

Sample Paper – 8

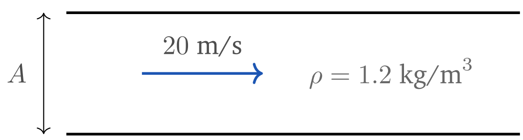
Duration: 128 Minutes **Maximum Marks: 72**

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. Air of density 1.2 kg/m^3 flows steadily through the straight duct shown at a mean velocity of 20 m/s. The cross-sectional area of the duct is 0.5 m^2. The mass flow rate through the duct is: **[1 mark]**



(A) 24 kg/s

(B) 10 kg/s

(C) 6 kg/s

(D) 12 kg/s

Q2. In the low-speed flow of air over an airfoil, the local velocity at a point on the surface is 1.2 times the freestream velocity. The pressure coefficient at that point, $C_p = 1 - \left(V/V_\infty\right)^2$, is: **[1 mark]**

(A) $+0.44$

(B) -0.44

(C) -1.44

(D) $+1.00$

Q3. A perfect gas ($\gamma = 1.4$) flows at a Mach number of 0.8 with a static pressure of 100 kPa. Using the compressible relation $q = \frac{\gamma}{2}\, p\, M^2$, the dynamic pressure of the flow is: **[1 mark]**

(A) 44.8 kPa

(B) 56.0 kPa

(C) 64.0 kPa

(D) 32.0 kPa

Q4. In the two-dimensional flow of air ($\rho = 1.225$ kg/m^3) at a freestream speed of 40 m/s, the circulation about an airfoil is $\Gamma = 20$ m^2/s. By the Kutta–Joukowski theorem the lift per unit span is $L' = \rho V_\infty \Gamma$. Its value is: **[1 mark]**

(A) 490 N/m

(B) 980 N/m

(C) 1960 N/m

(D) 800 N/m

Q5. An aircraft of mass 2000 kg has a wing planform area of 20 m^2. Taking $g = 9.81$ m/s^2, the wing loading W/S of the aircraft is nearest to: **[1 mark]**

(A) 1962 N/m^2

(B) 981 N/m^2

(C) 100 N/m^2

(D) 490 N/m^2

Q6. A finite wing has a zero-lift drag coefficient of 0.020, an aspect ratio of 6 and an Oswald span efficiency factor of 0.85. When operating at a lift coefficient of 0.90, the total drag coefficient $C_D = C_{D,0} + \dfrac{C_L^2}{\pi e\, AR}$ is nearest to: **[1 mark]**

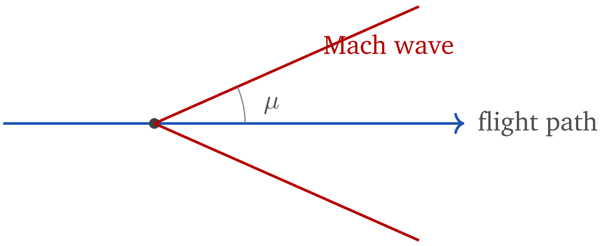
(A) 0.0506

(B) 0.0200

(C) 0.0706

(D) 0.0906

Q7. A slender body flies at a Mach number of 2.0 and generates the Mach wave shown. The Mach angle $\mu = \sin^{-1}(1/M)$ is: **[1 mark]**



(A) $60°$

(B) $45°$

(C) $26.6°$

(D) $30°$

Q8. Air ($\gamma = 1.4$) moves at a Mach number of 1.0. Using the isentropic relation $\dfrac{p_0}{p} = \left(1+\frac{\gamma-1}{2}M^2\right)^{\gamma/(\gamma-1)}$, the ratio of stagnation to static pressure is nearest to: **[1 mark]**

(A) 1.200

(B) 1.577

(C) 2.000

(D) 1.893

Q9. A perfect gas ($\gamma = 1.4$) flows at a Mach number of 2.0. Using the isentropic relation $\frac{\rho_0}{\rho} = \left(1 + \frac{\gamma-1}{2}M^2\right)^{1/(\gamma-1)}$, the ratio of stagnation to static density is nearest to: **[1 mark]**

(A) 1.80

(B) 3.24

(C) 4.35

(D) 5.00

Q10. A laminar boundary layer develops over a flat plate held parallel to the flow. At the trailing edge the Reynolds number based on plate length is $Re_L = 10^6$. The average skin-friction coefficient, using the Blasius result $C_f = \frac{1.328}{\sqrt{Re_L}}$, is: **[1 mark]**

(A) 1.328×10^{-3}

(B) 1.328×10^{-2}

(C) 5.0×10^{-3}

(D) 6.64×10^{-4}

Q11. At low speed a certain airfoil has a section lift coefficient of 0.50. When the same airfoil operates at a freestream Mach number of 0.60, the Prandtl–Glauert compressibility correction $c_\ell = \frac{c_{\ell,0}}{\sqrt{1 - M^2}}$ gives a corrected lift coefficient nearest to: **[1 mark]**

(A) 0.500

(B) 0.625

(C) 0.400

(D) 0.781

Q12. For a thin airfoil the theoretical lift-curve slope is $\dfrac{dc_\ell}{d\alpha} = 2\pi$ per radian. Expressed per degree of angle of attack, this slope is nearest to: **[1 mark]**

(A) 6.28 per degree

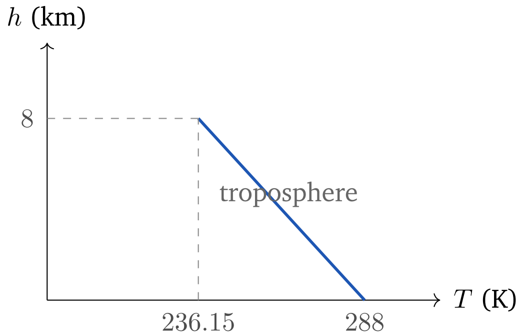
(B) 0.0175 per degree

(C) 0.110 per degree

(D) 0.220 per degree

Flight Mechanics & Space Dynamics

Q13. In the International Standard Atmosphere the sea-level temperature is 288.15 K and the tropospheric 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) 216.65 K

Q14. An aircraft in steady, level flight has a total drag of 4000 N at a true airspeed of 100 m/s. The power required to maintain this flight condition, $P = DV$, is: **[1 mark]**

(A) 40 kW

(B) 4000 kW

(C) 200 kW

(D) 400 kW

Q15. An aircraft of weight 20,000 N flies at 50 m/s with an available thrust of 6000 N against a drag of 4000 N. The steady rate of climb, $R/C = \dfrac{(T-D)V}{W}$, is: **[1 mark]**

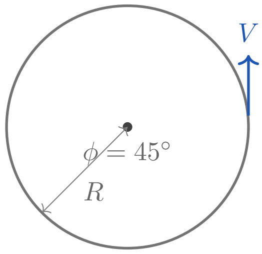
(A) 2.5 m/s

(B) 5.0 m/s

(C) 10.0 m/s

(D) 15.0 m/s

Q16. An aircraft performs a steady, level (co-ordinated) turn at a bank angle of 45° and a true airspeed of 100 m/s, as shown. Taking $g = 9.81$ m/s^2, the radius of the turn $R = \dfrac{V^2}{g\tan\phi}$ is nearest to: **[1 mark]**



(A) 1019 m

(B) 720 m

(C) 1440 m

(D) 510 m

Q17. A sailplane glides steadily at a lift-to-drag ratio of 20 with a forward (flight-path) speed of 40 m/s in still air. The rate of descent (sink rate), $V_s \approx \dfrac{V}{L/D}$, is: **[1 mark]**

(A) 2.0 m/s

(B) 4.0 m/s

(C) 1.0 m/s

(D) 20.0 m/s

Q18. For an airplane to possess directional (weathercock) static stability about its centre of gravity, the yawing-moment coefficient C_n must vary with the sideslip angle β such that: **[1 mark]**

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

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

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

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

Q19. An aircraft has a level-flight stalling speed of 50 m/s. In a co-ordinated turn the load factor is $n = 2$. The stalling speed in the turn, $V_{s,\text{turn}} = V_s\sqrt{n}$, is nearest to: **[1 mark]**

(A) 50.0 m/s

(B) 100.0 m/s

(C) 70.7 m/s

(D) 35.4 m/s

Q20. An aircraft has a static margin of 0.10 (i.e. 10% of the mean aerodynamic chord). If the neutral point lies at $0.35\,\bar{c}$ from the leading edge, the centre of gravity lies at: **[1 mark]**

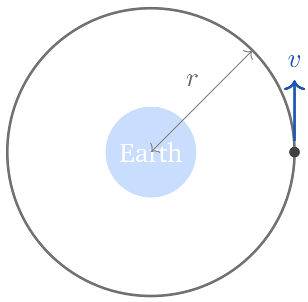
(A) $0.25\,\bar{c}$

(B) $0.45\,\bar{c}$

(C) $0.10\,\bar{c}$

(D) $0.35\,\bar{c}$

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



(A) 5829 s

(B) 2914 s

(C) 8640 s

(D) 5062 s

Q22. At a certain radius the circular orbital speed about the Earth is 7.5 km/s. At the same radius, the local escape speed, related to the circular speed by $v_{\text{esc}} = \sqrt{2}\, v_{\text{circ}}$, is nearest to: **[2 marks]**

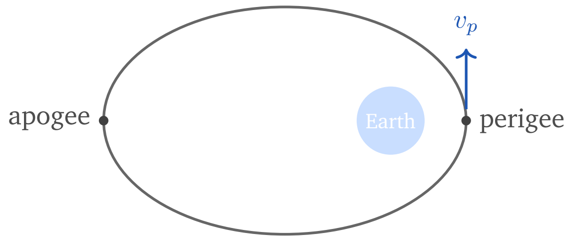
(A) 15.0 km/s

(B) 3.75 km/s

(C) 7.5 km/s

(D) 10.6 km/s

Q23. A satellite is in an elliptic orbit about the Earth with a perigee radius of 7000 km and a semi-major axis of 10,000 km, as shown. Using the vis-viva relation $v = \sqrt{\mu\left(\frac{2}{r} - \frac{1}{a}\right)}$ with $\mu = 3.986 \times 10^{14}$ m^3/s^2, the speed at perigee is nearest to: **[2 marks]**



(A) 7.55 km/s

(B) 5.34 km/s

(C) 10.2 km/s

(D) 8.60 km/s

Aerospace Structures

Q24. A cylindrical pin of diameter 20 mm is loaded in single shear and carries a transverse force of 10 kN. The average shear stress in the pin, $\tau = F/A$, is nearest to: **[2 marks]**

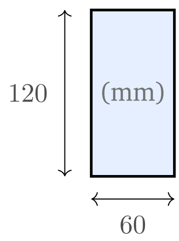
(A) 31.8 MPa

(B) 63.7 MPa

(C) 15.9 MPa

(D) 25.0 MPa

Q25. A beam has the solid rectangular cross-section shown, of width 60 mm and depth 120 mm. The elastic section modulus about the horizontal centroidal axis, $Z = \dfrac{bd^2}{6}$, is: **[2 marks]**



(A) 8.64×10^5 mm^3

(B) 7.20×10^4 mm^3

(C) 1.44×10^5 mm^3

(D) 2.88×10^5 mm^3

Q26. A solid circular shaft of diameter 50 mm and length 2 m is made of a material with shear modulus 80 GPa and transmits a torque of 2 kN·m. Using $\theta = \dfrac{TL}{GJ}$ with $J = \dfrac{\pi d^4}{32}$, the angle of twist over the full length, expressed in degrees, is nearest to: **[2 marks]**

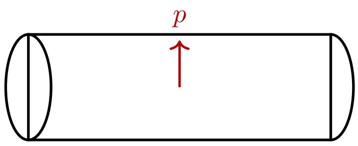
(A) 2.33°

(B) 9.34°

(C) $1.17°$

(D) $4.67°$

Q27. A thin-walled cylindrical pressure vessel of internal diameter 1.2 m and wall thickness 8 mm carries an internal gauge pressure of 1.5 MPa, as shown. The longitudinal (axial) stress in the wall, $\sigma_l = \dfrac{pd}{4t}$, is: **[2 marks]**



$d = 1.2$ m, $t = 8$ mm

(A) 112.5 MPa

(B) 56.25 MPa

(C) 28.1 MPa

(D) 225.0 MPa

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

(A) 987.0 kN

(B) 246.7 kN

(C) 61.7 kN

(D) 3948.0 kN

Q29. At a point in a loaded structural member the plane-stress components are $\sigma_x = 100$ MPa, $\sigma_y = 40$ MPa and $\tau_{xy} = 0$. The von Mises equivalent stress, $\sigma_v = \sqrt{\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2}$, is nearest to: **[2 marks]**

(A) 87.2 MPa

(B) 100.0 MPa

(C) 76.0 MPa

(D) 60.8 MPa

Q30. At a point in a loaded member the direct stress is 200 MPa and the material's Young's modulus is 200 GPa. The strain-energy density (resilience) stored at the point, $u = \dfrac{\sigma^2}{2E}$, is: **[2 marks]**

(A) 200 kJ/m^3

(B) 100 kJ/m^3

(C) 50 kJ/m^3

(D) 400 kJ/m^3

Q31. A single-degree-of-freedom spring–mass system has a stiffness of 1000 N/m and a mass of 4 kg. The undamped natural period of oscillation, $T = 2\pi\sqrt{m/k}$, is nearest to: **[2 marks]**

(A) 2.52 s

(B) 0.0632 s

(C) 0.397 s

(D) 15.9 s

Q32. A thin-walled closed tube encloses an area of 0.02 m^2 and carries a torque of 800 N·m. Using the Bredt–Batho theory, the shear flow around the wall, $q = \dfrac{T}{2A_m}$, is: **[2 marks]**

(A) 40 kN/m

(B) 20 kN/m

(C) 10 kN/m

(D) 5 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 $I = 5 \times 10^6$ mm^4. The mid-span deflection $\delta = \dfrac{PL^3}{48EI}$ is nearest to: **[2 marks]**

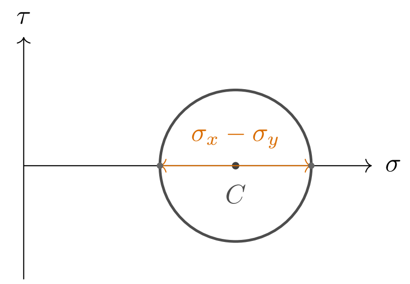
(A) 1.33 mm

(B) 0.167 mm

(C) 0.333 mm

(D) 0.667 mm

Q34. At a point in a thin skin the plane-stress components are $\sigma_x = 60$ MPa and $\sigma_y = 20$ MPa with no shear. Using the Mohr's-circle construction shown, the centre of the circle (the average normal stress) $\dfrac{\sigma_x + \sigma_y}{2}$ is: **[2 marks]**



(A) 40 MPa

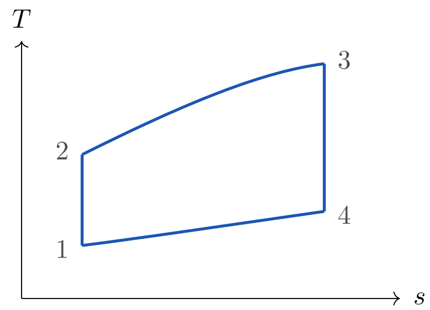
(B) 20 MPa

(C) 80 MPa

(D) 30 MPa

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. The thermal efficiency $\eta = 1 - r_p^{-(\gamma-1)/\gamma}$ is nearest to: **[2 marks]**



(A) 51.8%

(B) 60.0%

(C) 37.5%

(D) 48.2%

Q36. A turbojet ingests air at a mass flow rate of 40 kg/s. The flight (inlet) velocity is 250 m/s and the exhaust jet velocity is 550 m/s. Neglecting the fuel mass flow and pressure-thrust terms, the net thrust $F = \dot{m}(V_e - V_0)$ is: **[2 marks]**

(A) 22 kN

(B) 12 kN

(C) 10 kN

(D) 32 kN

Q37. The turbojet of the previous type produces a net thrust of 12 kN while ingesting air at a mass flow rate of 40 kg/s. The specific thrust of the engine, $F/\dot{m}_{\text{air}}$, is: **[2 marks]**

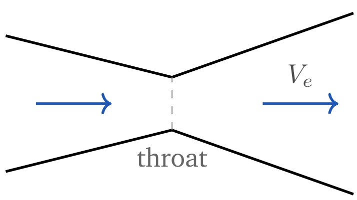
(A) $550\ \text{N} \cdot \text{s/kg}$

(B) $300\ \text{N} \cdot \text{s/kg}$

(C) $250\ \text{N} \cdot \text{s/kg}$

(D) $480\ \text{N} \cdot \text{s/kg}$

Q38. Combustion gas expands through the convergent–divergent nozzle shown. The static temperature drops by 300 K from the chamber to the exit. Taking $c_p = 1005$ J/kg $\cdot$ K and negligible inlet velocity, the exit velocity $V_e = \sqrt{2c_p\,\Delta T}$ is nearest to: **[2 marks]**



(A) 549 m/s

(B) 1553 m/s

(C) 388 m/s

(D) 777 m/s

Q39. Air ($\gamma = 1.4$) is accelerated in a nozzle until the flow is just choked at the throat ($M = 1$). The ratio of the static temperature at the throat to the stagnation temperature, $\dfrac{T^*}{T_0} = \dfrac{2}{\gamma + 1}$, is nearest to: **[2 marks]**

(A) 0.833

(B) 0.528

(C) 0.634

(D) 1.200

Q40. In an axial-flow compressor stage the specific work input to the air is 30 kJ/kg. Taking $c_p = 1005$ J/kg · K, the stagnation-temperature rise across the stage, $\Delta T_0 = \dfrac{w}{c_p}$, is nearest to: **[2 marks]**

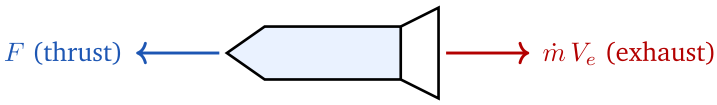
(A) 15.0 K

(B) 60.0 K

(C) 29.85 K

(D) 45.0 K

Q41. A rocket engine expels propellant at a mass flow rate of 120 kg/s with an effective exhaust velocity of 2500 m/s, as shown by the thrust free-body. For a perfectly expanded (pressure-matched) nozzle, the thrust $F = \dot{m}\, V_e$ is: **[2 marks]**



(A) 300 kN

(B) 200 kN

(C) 3000 kN

(D) 100 kN

Q42. The rocket engine of the previous problem has an effective exhaust velocity of 2500 m/s. Taking $g_0 = 9.81$ m/s^2, the specific impulse $I_{sp} = \dfrac{V_e}{g_0}$ is nearest to: **[2 marks]**

(A) 300 s

(B) 350 s

(C) 288 s

(D) 255 s

Q43. A single-stage rocket has a specific impulse of 250 s (with $g_0 = 9.81$ m/s^2) and an initial-to-final mass ratio of 4. Using the Tsiolkovsky rocket equation $\Delta v = I_{sp}\, g_0 \ln(\text{MR})$, the ideal velocity increment is nearest to: **[2 marks]**

(A) 2452 m/s

(B) 6800 m/s

(C) 3400 m/s

(D) 1700 m/s

Q44. A gas-turbine combustor burns a hydrocarbon fuel whose stoichiometric air–fuel ratio is 15. In operation the actual air–fuel ratio supplied is also 15. The equivalence ratio $\phi = \dfrac{(A/F)_{\text{stoich}}}{(A/F)_{\text{actual}}}$ of the mixture is: **[2 marks]**

(A) 0.75

(B) 1.33

(C) 1.00

(D) 0.50

Q45. A jet engine has a propulsive efficiency of 0.60 and a thermal (energy-conversion) efficiency of 0.50. The overall efficiency of the engine, $\eta_o = \eta_p\, \eta_{th}$, is: **[2 marks]**

(A) 0.60

(B) 0.50

(C) 0.55

(D) 0.30

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

(A) 663 K

(B) 543 K

(C) 480 K

(D) 750 K

Detailed Solutions

Q1.

Solution

Concept – mass flow rate through a duct: The mass flow rate is $\dot{m} = \rho A V$.

Step 1 – list the data: $\rho = 1.2$ kg/m^3, $A = 0.5$ m^2, $V = 20$ m/s.

Step 2 – write the formula: $\dot{m} = \rho A V$

Step 3 – multiply density by area: $\rho A = 1.2 \times 0.5 = 0.6$

Step 4 – multiply by the velocity: $\dot{m} = 0.6 \times 20$

Step 5 – evaluate: $\dot{m} = 12$ kg/s

Final Answer: $\dot{m} = 12$ kg/s $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q1

Q2.

Solution

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

Step 1 – list the data: $\dfrac{V}{V_\infty} = 1.2$.

Step 2 – square the velocity ratio: $\left(\dfrac{V}{V_\infty}\right)^2 = 1.2^2 = 1.44$

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 C_p is negative (a suction, i.e. below freestream pressure).

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

Answer: (B) Go Back to Q2

Q3.

Solution

Concept – compressible dynamic pressure: $q = \dfrac{\gamma}{2}\, p\, M^2$.

Step 1 – list the data: $\gamma = 1.4$, $p = 100$ kPa $= 100000$ Pa, $M = 0.8$.

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

Step 3 – square the Mach number: $M^2 = 0.8^2 = 0.64$

Step 4 – combine the factors: $q = 0.7 \times 100000 \times 0.64$

Step 5 – multiply step by step: $0.7 \times 100000 = 70000$

$70000 \times 0.64 = 44800$ Pa

Step 6 – convert to kilopascals: $q = 44.8$ kPa

Final Answer: $q = 44.8 \text{ kPa} \Rightarrow \boxed{\text{A}}$

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: $\rho = 1.225 \text{ kg/m}^3$, $V_\infty = 40$ m/s, $\Gamma = 20 \text{ m}^2/\text{s}$.

Step 2 – multiply density by velocity: $\rho V_\infty = 1.225 \times 40 = 49$

Step 3 – multiply by the circulation: $L' = 49 \times 20$

Step 4 – evaluate: $L' = 980$ N/m

Final Answer: $L' = 980 \text{ N/m} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q4

Q5.

Solution

Concept – wing loading: Wing loading is the weight divided by wing area, W/S, with $W = mg$.

Step 1 – list the data: $m = 2000$ kg, $g = 9.81 \text{ m/s}^2$, $S = 20 \text{ m}^2$.

Step 2 – compute the weight: $W = 2000 \times 9.81 = 19620$ N

Step 3 – divide by the wing area: $\dfrac{W}{S} = \dfrac{19620}{20}$

Step 4 – evaluate: $\dfrac{W}{S} = 981 \text{ N/m}^2$

Final Answer: $W/S = 981 \text{ N/m}^2 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q5

Q6.

Solution

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

Step 1 – list the data: $C_{D,0} = 0.020$, $C_L = 0.90$, $e = 0.85$, $AR = 6$.

Step 2 – square the lift coefficient: $C_L^2 = 0.90^2 = 0.81$

Step 3 – form the denominator: $\pi e\, AR = 3.1416 \times 0.85 \times 6$

$3.1416 \times 0.85 = 2.6704$

$2.6704 \times 6 = 16.02$

Step 4 – compute the induced-drag term: $\dfrac{C_L^2}{\pi e\, AR} = \dfrac{0.81}{16.02} = 0.0506$

Step 5 – add the zero-lift drag: $C_D = 0.020 + 0.0506 = 0.0706$

Final Answer: $C_D \approx 0.0706 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q6

Q7.

Solution

Concept – Mach angle of a weak wave: $\mu = \sin^{-1}\left(\dfrac{1}{M}\right)$.

Step 1 – list the data: $M = 2.0$.

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

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

Step 4 – evaluate: $\mu = 30^\circ$

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

Answer: (D) Go Back to Q7

Q8.

Solution

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

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

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

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: $\frac{\gamma}{\gamma-1} = \frac{1.4}{0.4} = 3.5$

Step 6 – raise the bracket to that power: $\frac{p_0}{p} = 1.2^{3.5}$

$1.2^{3.5} = 1.893$

Final Answer: $\frac{p_0}{p} \approx 1.893 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q8

Q9.

Solution

Concept – isentropic stagnation density ratio: $\frac{\rho_0}{\rho} = \left(1 + \frac{\gamma-1}{2}M^2\right)^{1/(\gamma-1)}$.

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

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

Step 3 – square the Mach number: $M^2 = 2.0^2 = 4$

Step 4 – form the bracket: $1 + 0.2 \times 4 = 1 + 0.8 = 1.8$

Step 5 – evaluate the exponent: $\frac{1}{\gamma-1} = \frac{1}{0.4} = 2.5$

Step 6 – raise the bracket to that power: $\frac{\rho_0}{\rho} = 1.8^{2.5}$

$1.8^{2.5} = 4.35$

Final Answer: $\frac{\rho_0}{\rho} \approx 4.35 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q9

Q10.

Solution

Concept – average laminar skin-friction coefficient (Blasius): $C_f = \frac{1.328}{\sqrt{Re_L}}$.

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

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

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

Step 4 – evaluate: $C_f = 1.328 \times 10^{-3}$

Final Answer: $C_f = 1.328 \times 10^{-3} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q10

Q11.

Solution

Concept – Prandtl–Glauert compressibility correction: $c_\ell = \dfrac{c_{\ell,0}}{\sqrt{1-M^2}}$.

Step 1 – list the data: $c_{\ell,0} = 0.50$, $M = 0.60$.

Step 2 – square the Mach number: $M^2 = 0.60^2 = 0.36$

Step 3 – form the term under the root: $1 - M^2 = 1 - 0.36 = 0.64$

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

Step 5 – divide: $c_\ell = \dfrac{0.50}{0.8} = 0.625$

Final Answer: $c_\ell = 0.625 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q11

Q12.

Solution

Concept – thin-airfoil lift-curve slope: $\dfrac{dc_\ell}{d\alpha} = 2\pi$ per radian; to convert to a per-degree slope, divide by 57.3 (degrees per radian).

Step 1 – write the slope per radian: $2\pi = 6.2832$ per radian

Step 2 – note the conversion factor: 1 rad $= 57.3°$

Step 3 – divide the per-radian slope by 57.3: $\dfrac{dc_\ell}{d\alpha} = \dfrac{6.2832}{57.3}$

Step 4 – evaluate: $\dfrac{dc_\ell}{d\alpha} = 0.1097 \approx 0.110$ per degree

Final Answer: $\dfrac{dc_\ell}{d\alpha} \approx 0.110$ per degree $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q12

Q13.

Solution

Concept – ISA temperature in the troposphere: $T(h) = T_0 - Lh$, where $T_0 = 288.15$ 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 – power required in level flight: The power needed to overcome drag is $P = DV$.

Step 1 – list the data: $D = 4000$ N, $V = 100$ m/s.

Step 2 – write the formula: $P = DV$

Step 3 – substitute the numbers: $P = 4000 \times 100$

Step 4 – evaluate: $P = 400000$ W

Step 5 – convert to kilowatts: $P = 400$ kW

Final Answer: $P = 400\text{ kW} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q14

Q15.

Solution

Concept – steady rate of climb: $R/C = \dfrac{(T-D)V}{W}$, where $(T-D)V$ is the excess power available.

Step 1 – list the data: $T = 6000$ N, $D = 4000$ N, $V = 50$ m/s, $W = 20000$ N.

Step 2 – find the excess thrust: $T - D = 6000 - 4000 = 2000$ N

Step 3 – multiply by the flight speed: $(T-D)V = 2000 \times 50 = 100000$ W

Step 4 – divide by the weight: $R/C = \dfrac{100000}{20000}$

Step 5 – evaluate: $R/C = 5.0$ m/s

Final Answer: $R/C = 5.0\text{ m/s} \Rightarrow \boxed{\text{B}}$

Answer: (B) 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 of the bank angle: $\tan 45° = 1$

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

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 steady glide: For a shallow glide the sink rate is $V_s \approx \dfrac{V}{L/D}$, since $\tan\gamma \approx \dfrac{1}{L/D}$ and $V_s = V\sin\gamma \approx V\tan\gamma$.

Step 1 – list the data: $L/D = 20$, $V = 40$ m/s.

Step 2 – write the formula: $V_s = \dfrac{V}{L/D}$

Step 3 – substitute the numbers: $V_s = \dfrac{40}{20}$

Step 4 – evaluate: $V_s = 2.0$ m/s

Final Answer: $V_s = 2.0$ m/s $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q17

Q18.

Solution

Concept – directional (weathercock) static stability: A disturbance in sideslip β must generate a restoring yawing moment that turns the nose back into the wind. In coefficient form this requires the yaw-moment slope with sideslip to be positive.

Step 1 – state the stability condition: $\dfrac{dC_n}{d\beta} > 0$

Step 2 – reason physically: A positive sideslip (nose left of the relative wind) must produce a positive (nose-right) yawing moment, driving β back to zero; that is a positive slope.

Step 3 – reject the other options: A negative or zero slope gives divergent or neutral yaw behaviour; $dC_\ell/d\beta$ describes roll (lateral) stability, not directional stability.

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

Answer: (C) Go Back to Q18

Q19.

Solution

Concept – stalling speed in a turn: At a load factor n the required lift is n times the weight, so the stall speed rises by $\sqrt{n}$: $V_{s,\text{turn}} = V_s\sqrt{n}$.

Step 1 – list the data: $V_s = 50$ m/s, $n = 2$.

Step 2 – take the square root of the load factor: $\sqrt{n} = \sqrt{2} = 1.414$

Step 3 – multiply the level-flight stall speed: $V_{s,\text{turn}} = 50 \times 1.414$

Step 4 – evaluate: $V_{s,\text{turn}} = 70.7$ m/s

Final Answer: $V_{s,\text{turn}} \approx 70.7$ m/s $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q19

Q20.

Solution

Concept – static margin: The static margin is the distance (in chord fractions) between the neutral point and the centre of gravity: SM $= x_{NP} - x_{CG}$.

Step 1 – list the data: SM $= 0.10$, $x_{NP} = 0.35\,\bar{c}$.

Step 2 – rearrange for the CG position: $x_{CG} = x_{NP} -$ SM

Step 3 – substitute the numbers: $x_{CG} = 0.35 - 0.10$

Step 4 – evaluate: $x_{CG} = 0.25\,\bar{c}$

Final Answer: $x_{CG} = 0.25\,\bar{c} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q20

Q21.

Solution

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

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

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

Step 3 – divide by μ: $\dfrac{r^3}{\mu} = \dfrac{3.43 \times 10^{20}}{3.986 \times 10^{14}} = 8.605 \times 10^5$

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

Step 5 – multiply by 2π: $T = 2\pi \times 927.6 = 6.2832 \times 927.6$

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 – escape speed from circular speed: At any radius $v_{\text{esc}} = \sqrt{2}\, v_{\text{circ}}$, because escape energy needs twice the kinetic energy of a circular orbit.

Step 1 – list the data: $v_{\text{circ}} = 7.5$ km/s.

Step 2 – write the square-root factor: $\sqrt{2} = 1.4142$

Step 3 – multiply: $v_{\text{esc}} = 1.4142 \times 7.5$

Step 4 – evaluate: $v_{\text{esc}} = 10.6$ km/s

Final Answer: $v_{\text{esc}} \approx 10.6$ km/s $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q22

Q23.

Solution

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

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

Step 2 – evaluate $\dfrac{2}{r_p}$: $\dfrac{2}{7 \times 10^6} = 2.857 \times 10^{-7}$

Step 3 – evaluate $\frac{1}{a}$**:** $\frac{1}{1\times10^7} = 1.0\times10^{-7}$

Step 4 – subtract: $2.857\times10^{-7} - 1.0\times10^{-7} = 1.857\times10^{-7}$

Step 5 – multiply by μ**:** $3.986\times10^{14}\times1.857\times10^{-7} = 7.402\times10^{7}$

Step 6 – take the square root: $v = \sqrt{7.402\times10^7} = 8603$ m/s

Step 7 – convert to km/s: $v \approx 8.60$ km/s

Final Answer: $v \approx 8.60$ km/s $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q23

Q24.

Solution

Concept – average shear stress in single shear: $\tau = \frac{F}{A}$, with $A = \frac{\pi d^2}{4}$ the pin cross-section.

Step 1 – list the data: $d = 20$ mm $= 0.02$ m, $F = 10$ kN $= 10000$ N.

Step 2 – compute the cross-sectional area: $A = \frac{\pi(0.02)^2}{4} = \frac{\pi\times4\times10^{-4}}{4}$

$A = \pi\times1\times10^{-4} = 3.1416\times10^{-4}$ m^2

Step 3 – divide the force by the area: $\tau = \frac{10000}{3.1416\times10^{-4}}$

Step 4 – evaluate: $\tau = 3.183\times10^{7}$ Pa

Step 5 – convert to megapascals: $\tau = 31.8$ MPa

Final Answer: $\tau \approx 31.8$ MPa $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q24

Q25.

Solution

Concept – elastic section modulus of a rectangle: $Z = \frac{bd^2}{6}$, with b the width and d the depth.

Step 1 – list the data: $b = 60$ mm, $d = 120$ mm.

Step 2 – square the depth: $d^2 = 120^2 = 14400$ mm^2

Step 3 – multiply by the width: $bd^2 = 60\times14400 = 864000$ mm^3

Step 4 – divide by 6: $Z = \frac{864000}{6} = 144000$ mm^3

Step 5 – express in scientific notation: $Z = 1.44\times10^5$ mm^3

Final Answer: $Z = 1.44 \times 10^5$ mm^3 $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q25

Q26.

Solution

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

Step 1 – list the data: $T = 2000$ N·m, $L = 2$ m, $G = 80 \times 10^9$ Pa, $d = 0.05$ m.

Step 2 – compute the polar second moment J**:** $d^4 = 0.05^4 = 6.25 \times 10^{-6}$ m^4

$J = \dfrac{\pi \times 6.25 \times 10^{-6}}{32} = \dfrac{1.9635 \times 10^{-5}}{32}$

$J = 6.136 \times 10^{-7}$ m^4

Step 3 – form the numerator TL**:** $TL = 2000 \times 2 = 4000$

Step 4 – form the denominator GJ**:** $GJ = 80 \times 10^9 \times 6.136 \times 10^{-7} = 49088$

Step 5 – divide to get the twist in radians: $\theta = \dfrac{4000}{49088} = 0.08148$ rad

Step 6 – convert to degrees: $\theta = 0.08148 \times 57.3 = 4.67^\circ$

Final Answer: $\theta \approx 4.67^\circ \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q26

Q27.

Solution

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

Step 1 – list the data: $p = 1.5 \times 10^6$ Pa, $d = 1.2$ m, $t = 0.008$ m.

Step 2 – form the numerator pd**:** $pd = 1.5 \times 10^6 \times 1.2 = 1.8 \times 10^6$

Step 3 – form the denominator $4t$**:** $4t = 4 \times 0.008 = 0.032$

Step 4 – divide: $\sigma_l = \dfrac{1.8 \times 10^6}{0.032}$

Step 5 – evaluate: $\sigma_l = 5.625 \times 10^7$ Pa

Step 6 – convert to megapascals: $\sigma_l = 56.25$ MPa

Final Answer: $\sigma_l = 56.25$ MPa $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q27

Q28.

Solution

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

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

Step 2 – compute the effective length and its square: $2L = 4$ m

$(2L)^2 = 16$ m^2

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

Step 4 – multiply by π^2: $\pi^2 = 9.8696$

$\pi^2 EI = 9.8696 \times 4 \times 10^5 = 3.9478 \times 10^6$

Step 5 – divide by $(2L)^2$: $P_{cr} = \dfrac{3.9478 \times 10^6}{16}$

Step 6 – evaluate: $P_{cr} = 246738$ N $= 246.7$ kN

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

Answer: (B) Go Back to Q28

Q29.

Solution

Concept – von Mises stress in plane stress: With $\tau_{xy} = 0$, $\sigma_v = \sqrt{\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2}$.

Step 1 – list the data: $\sigma_x = 100$ MPa, $\sigma_y = 40$ MPa, $\tau_{xy} = 0$.

Step 2 – square the first stress: $\sigma_x^2 = 100^2 = 10000$

Step 3 – form the cross term: $\sigma_x\sigma_y = 100 \times 40 = 4000$

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

Step 5 – combine under the root: $10000 - 4000 + 1600 = 7600$

Step 6 – take the square root: $\sigma_v = \sqrt{7600} = 87.2$ MPa

Final Answer: $\sigma_v \approx 87.2$ MPa $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q29

Q30.

Solution

Concept – strain-energy density (resilience): $u = \dfrac{\sigma^2}{2E}$.

Step 1 – list the data: $\sigma = 200 \times 10^6$ Pa, $E = 200 \times 10^9$ Pa.

Step 2 – square the stress: $\sigma^2 = (200 \times 10^6)^2 = 4 \times 10^{16}$

Step 3 – form the denominator $2E$**:** $2E = 2 \times 200 \times 10^9 = 4 \times 10^{11}$

Step 4 – divide: $u = \dfrac{4 \times 10^{16}}{4 \times 10^{11}}$

Step 5 – evaluate: $u = 1 \times 10^5$ J/m^3 $= 100$ kJ/m^3

Final Answer: $u = 100$ kJ/m^3 $\Rightarrow \boxed{\text{B}}$

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: $k = 1000$ N/m, $m = 4$ kg.

Step 2 – form the ratio m/k**:** $\dfrac{m}{k} = \dfrac{4}{1000} = 0.004$

Step 3 – take the square root: $\sqrt{0.004} = 0.06325$

Step 4 – multiply by 2π**:** $T = 2\pi \times 0.06325 = 6.2832 \times 0.06325$

Step 5 – evaluate: $T = 0.397$ s

Final Answer: $T \approx 0.397$ s $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q31

Q32.

Solution

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

Step 1 – list the data: $T = 800$ N·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 – express in kN/m: $q = 20$ kN/m

Final Answer: $q = 20$ kN/m $\Rightarrow \boxed{\text{B}}$

Answer: (B) 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: $P = 2000$ N, $L = 2$ m, $E = 200 \times 10^9$ Pa, $I = 5 \times 10^{-6}$ m^4.

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

Step 3 – form the numerator PL^3: $PL^3 = 2000 \times 8 = 16000$

Step 4 – form EI: $EI = 200 \times 10^9 \times 5 \times 10^{-6} = 1 \times 10^6$

Step 5 – form the denominator $48EI$: $48EI = 48 \times 1 \times 10^6 = 4.8 \times 10^7$

Step 6 – divide: $\delta = \dfrac{16000}{4.8 \times 10^7} = 3.333 \times 10^{-4}$ m

Step 7 – convert to millimetres: $\delta = 0.333$ mm

Final Answer: $\delta \approx 0.333$ mm $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q33

Q34.

Solution

Concept – centre of Mohr's circle: The centre lies at the average normal stress, $\sigma_{\text{avg}} = \dfrac{\sigma_x + \sigma_y}{2}$.

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

Step 2 – add the two normal stresses: $\sigma_x + \sigma_y = 60 + 20 = 80$

Step 3 – divide by 2: $\sigma_{\text{avg}} = \dfrac{80}{2}$

Step 4 – evaluate: $\sigma_{\text{avg}} = 40$ MPa

Final Answer: $\sigma_{\text{avg}} = 40$ MPa $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q34

Q35.

Solution

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

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 the negative power: $r_p^{-0.2857} = 10^{-0.2857} = 0.5179$

Step 4 – subtract from 1: $\eta = 1 - 0.5179 = 0.4821$

Step 5 – 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 – net thrust of a turbojet: Neglecting fuel flow and pressure thrust, $F = \dot{m}(V_e - V_0)$.

Step 1 – list the data: $\dot{m} = 40$ kg/s, $V_e = 550$ m/s, $V_0 = 250$ m/s.

Step 2 – find the velocity increase: $V_e - V_0 = 550 - 250 = 300$ m/s

Step 3 – multiply by the mass flow rate: $F = 40 \times 300$

Step 4 – evaluate: $F = 12000$ N $= 12$ kN

Final Answer: $F = 12$ kN $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q36

Q37.

Solution

Concept – specific thrust: $\dfrac{F}{\dot{m}_{\text{air}}}$ is the thrust delivered per unit mass flow of air.

Step 1 – list the data: $F = 12000$ N, $\dot{m}_{\text{air}} = 40$ kg/s.

Step 2 – write the formula: $\dfrac{F}{\dot{m}_{\text{air}}}$

Step 3 – substitute the numbers: $\dfrac{12000}{40}$

Step 4 – evaluate: $= 300$ N $\cdot$ s/kg

Final Answer: $F/\dot{m} = 300\ \mathrm{N \cdot s/kg} \Rightarrow \boxed{\mathrm{B}}$

Answer: (B) Go Back to Q37

Q38.

Solution

Concept – nozzle exit velocity from energy conservation: With negligible inlet velocity, $V_e = \sqrt{2c_p\,\Delta T}$.

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

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

$2010 \times 300 = 603000$

Step 3 – take the square root: $V_e = \sqrt{603000}$

Step 4 – evaluate: $V_e = 776.5\ \mathrm{m/s} \approx 777\ \mathrm{m/s}$

Final Answer: $V_e \approx 777\ \mathrm{m/s} \Rightarrow \boxed{\mathrm{D}}$

Answer: (D) Go Back to Q38

Q39.

Solution

Concept – critical (choked) temperature ratio: 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 2 by that value: $\dfrac{T^*}{T_0} = \dfrac{2}{2.4}$

Step 4 – evaluate: $\dfrac{T^*}{T_0} = 0.833$

Final Answer: $\dfrac{T^*}{T_0} \approx 0.833 \Rightarrow \boxed{\mathrm{A}}$

Answer: (A) Go Back to Q39

Q40.

Solution

Concept – stagnation-temperature rise across a compressor stage: $\Delta T_0 = \frac{w}{c_p}$, where w is the specific work input.

Step 1 – list the data: $w = 30$ kJ/kg $= 30000$ J/kg, $c_p = 1005$ J/kg $\cdot$ K.

Step 2 – write the formula: $\Delta T_0 = \frac{w}{c_p}$

Step 3 – substitute the numbers: $\Delta T_0 = \frac{30000}{1005}$

Step 4 – evaluate: $\Delta T_0 = 29.85$ K

Final Answer: $\Delta T_0 \approx 29.85\text{ K} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q40

Q41.

Solution

Concept – thrust of a pressure-matched rocket: For a perfectly expanded nozzle the pressure term vanishes and $F = \dot{m}\,V_e$.

Step 1 – list the data: $\dot{m} = 120$ kg/s, $V_e = 2500$ m/s.

Step 2 – write the formula: $F = \dot{m}V_e$

Step 3 – substitute the numbers: $F = 120 \times 2500$

Step 4 – evaluate: $F = 300000$ N $= 300$ kN

Final Answer: $F = 300\text{ kN} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q41

Q42.

Solution

Concept – specific impulse from effective exhaust velocity: $I_{sp} = \frac{V_e}{g_0}$.

Step 1 – list the data: $V_e = 2500$ m/s, $g_0 = 9.81$ m/s^2.

Step 2 – write the formula: $I_{sp} = \frac{V_e}{g_0}$

Step 3 – substitute the numbers: $I_{sp} = \frac{2500}{9.81}$

Step 4 – evaluate: $I_{sp} = 254.8\text{ s} \approx 255\text{ s}$

Final Answer: $I_{sp} \approx 255\text{ s} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q42

Q43.

Solution

Concept – Tsiolkovsky rocket equation: $\Delta v = I_{sp}\, g_0\, \ln(\mathrm{MR})$.

Step 1 – list the data: $I_{sp} = 250$ s, $g_0 = 9.81$ m/s^2, $\mathrm{MR} = 4$.

Step 2 – form the effective exhaust velocity $I_{sp}g_0$: $I_{sp}g_0 = 250 \times 9.81 = 2452.5$ m/s

Step 3 – take the natural logarithm of the mass ratio: $\ln 4 = 1.3863$

Step 4 – multiply: $\Delta v = 2452.5 \times 1.3863$

Step 5 – evaluate: $\Delta v = 3400$ m/s

Final Answer: $\Delta v \approx 3400$ m/s $\Rightarrow \boxed{\mathrm{C}}$

Answer: (C) Go Back to Q43

Q44.

Solution

Concept – equivalence ratio: $\phi = \dfrac{(A/F)_{\text{stoich}}}{(A/F)_{\text{actual}}}$; $\phi = 1$ marks a stoichiometric mixture.

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

Step 2 – form the ratio: $\phi = \dfrac{15}{15}$

Step 3 – evaluate: $\phi = 1.00$

Step 4 – interpret: Since $\phi = 1$, the mixture is exactly stoichiometric (neither lean nor rich).

Final Answer: $\phi = 1.00 \Rightarrow \boxed{\mathrm{C}}$

Answer: (C) Go Back to Q44

Q45.

Solution

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

Step 1 – list the data: $\eta_p = 0.60$, $\eta_{th} = 0.50$.

Step 2 – write the formula: $\eta_o = \eta_p \eta_{th}$

Step 3 – multiply: $\eta_o = 0.60 \times 0.50$

Step 4 – evaluate: $\eta_o = 0.30$

Final Answer: $\eta_o = 0.30 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q45

Q46.

Solution

Concept – isentropic turbine expansion temperature: $T_{02} = \dfrac{T_{01}}{r_p^{(\gamma-1)/\gamma}}$.

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: $T_{02} = \dfrac{1200}{1.8114}$

Step 5 – evaluate: $T_{02} = 662.5 \text{ K} \approx 663 \text{ K}$

Final Answer: $T_{02} \approx 663 \text{ K} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q46

Answer Key

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