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GATE 2025

AEROSPACE ENGINEERING

EXAM HELD ON
15th Feb, 2025
(Forenoon Session)
Organized by
IIT Roorkee

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QUESTIONS & SOLUTIONS

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OUR ACHIEVERS

GATE-2025 AE

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Sandip Univ, Nashik
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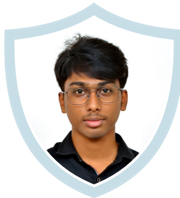
NEERAV GUPTA
IIST Trivandrum
AIR - 4

ALWIN THOMSON
SASTRA Univ, Thanjavur
AIR - 7

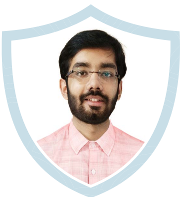
SHANTANU SAHA
IIST Trivandrum
AIR - 9



PRASANNA MATHAVAN
Amrita Univ, Coimbatore
AIR - 13

And Many More ....

GATE-2024 AE



K SUNIL
IIST TRIVANDRUM
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ACHARYA INSTITUTE, B'LORE
AIR - 6

HARIHARAN R
MIT, CHENNAI
AIR - 9

VIGNESH CG
IIST TRIVANDRUM
AIR - 11

ADITYA ANIL KUMAR
IIST TRIVANDRUM
AIR - 17

And Many More ....

GATE-2023 AE

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SSN COLLEGE CHENNAI
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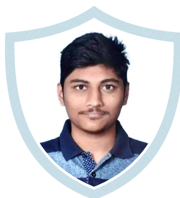
AKRITI
PEC, CHANDIGARH
AIR - 6

SHREYASHI SARKAR
IIEST, SHIBPUR
AIR - 8

YOKESH K
MIT, CHENNAI
AIR - 11



HRITHIK S PATIL
RVCE, BANGALORE
AIR - 14

And Many More ....

OUR PSU JOB ACHIEVERS

HAL DT ENGINEER 2023

S.S Sanjay Amrita Univ - Coimbatore	**Shashi Kanth M** Sastra Univ - Tanjore	**Vagicharla Dinesh** Lovely Professional Univ - Punjab

Anantha Krishan A.G
Amrita Univ - Coimbatore

HAL DT ENGINEER 2022

Fathima J MIT - Chennai	**Mohan Kumar H** MVJCE - Bangalore

HAL DT ENGINEER 2021

Arathy Anilkumar Nair Amrita Univ - Coimbatore	**Sadsivuni Tarun** Sastra Univ - Tanjore

DRDO & ADA Scientist B

Job Position for Recruitment (2021-24) Based on GATE AE score

Abhilash K Amrita Univ - Coimbatore	**Ajitha Nishma V** IIST - Trivendrum	**Dheeraj Sappa** IIEST - Shibpur	**Govarthan K** RVCE - Bangalore
F Jahangir MIT - Chennai	**Goutham** KCG College - Chennai	**M Kumar** MVJ College - Bangalore	**Sanjay S** Amrita Univ - Coimbatore
Mohit Kudal RTU - Kota	**Niladhari Pahari** IIEST - Shibpur	**Nitesh Singh** Sandip Univ - Nashik	**Snehasis C** IIEST - Shibpur
Ramanathan A Amrita Univ - Coimbatore	**Shruti S Rajpara** IIEST - Shibpur	**Ram Gopal Soni** GVIET - PUNJAB	**Yokesh K** MIT - Chennai

OUR PSU JOB ACHIEVERS

DGCA Air Safety & Worthiness Officer

Job Position for Recruitment (2023)

Abhishek Shukla
FGIET - Raebareli

Aishwarya PS
BMS College - Bangalore

Anil Kumar Nakkala
Malla Reddy College - Hyderabad

Ayush Boral
KIIT - Bhubaneswar

Dhiraj Rajendra Kapte
Priyadarshini College - Nagpur

Govardhan K
RVCE - Bangalore

R Selvaraj
Sri Ramakrishna College - Coimbatore

Rithik Gowda M
ACS College - Bangalore

Samhit Sumnampa
PEC - Chandigarh

Uttam Kumar Maurya
UPES - Dehradun

Thirthankar Majumdar
Amity University - Noida

IOCL & NPCIL

Nitish Patnaik
(Vivekanand ESIT- Mumbai)
Graduate Engineer- Instrumentation

NTPC

Milton Ghosh
Netaji Subhash Coll-kolakata
ET-NTPC

Surajit Rabi Das
Rerf-Kolkata
ET-NTPC

COAL INDIA

Prashanth P
R. V. College of Engineering - Bangalore

BEL

Vignesha M
MRS E-II CRL BEL

BDL

Vinay Kumar
Assistant Manager at BDL Hyderabbad

GET-ESS-AIESL 2023

S Komesh
Sathyabama University - Chennai

Shrenith Suhas
IIEST - Shibpur

Ankur Vats
School Of Aeronautics - Neemrana

GATE 2025
AEROSPACE ENGINEERING

General Aptitude – GA

Q. 1 – Q. 5 carry one mark each.

1. Courage : Bravery :: Yearning : _________

Select the most appropriate option to complete the analogy.

(A) Longing (C) Yawning
(B) Yelling (D) Glaring

2. We _________ tennis in the lawn when it suddenly started to rain.

Select the most appropriate option to complete the above sentence.

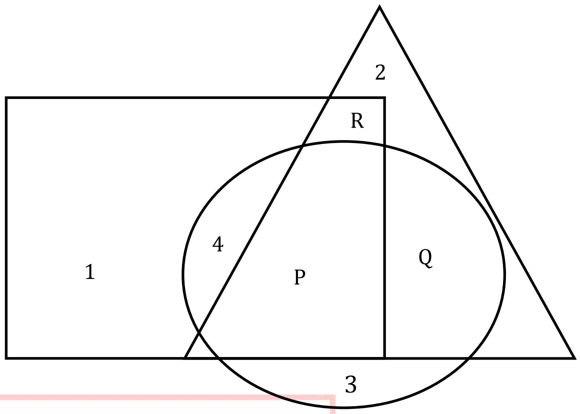
(A) have been playing
(B) had been playing
(C) would have been playing
(D) could be playing

3. A 4×4 digital image has pixel intensities (U) as shown in the figure. The number of pixels with $U \leq 4$ is:

0	1	0	2
4	7	3	3
5	5	4	4
6	7	3	2

(A) 3 (C) 11
(B) 8 (D) 9

4. In the given figure, the numbers associated with the rectangle, triangle, and ellipse are 1, 2, and 3, respectively. Which one among the given options is the most appropriate combination of P, Q, and R?



(A) P = 6; Q = 5; R = 3
(B) P = 5; Q = 6; R = 3
(C) P = 3; Q = 6; R = 6
(D) P = 5; Q = 3; R = 6

5. A rectangle has a length L and a width W, where L > W. If the width, W, is increased by 10%, which one of the following statements is correct for all values of L and W?

(A) Perimeter increases by 10%.
(B) Length of the diagonals increases by 10%.
(C) Area increases by 10%.
(D) The rectangle becomes a square.

6. Column-I has statements made by Shanthala; and, Column-II has responses given by Kanishk.

Column-I

P. This house is in a mess.

Q. I am not happy with the marks given to me.

R. Politics is a subject I avoid talking about.

S. I don't know what this word means.

Column-II

1. Alright, I won't bring it up during our conversations.
2. Well, you can easily look it up.
3. No problem, let me clear it up for you.
4. Don't worry, I will take it up with your teacher.

Identify the option that has the correct match between Column-I and Column-II.

(A) P – 2; Q – 3; R – 1; S – 4

(B) P – 3; Q – 4; R – 1; S – 2

(C) P – 4; Q – 1; R – 2; S – 3

(D) P – 1; Q – 2; R – 4; S – 3

7. Weight of a person can be expressed as a function of their age. The function usually varies from person to person. Suppose this function is identical for two brothers, and it monotonically increases till the age of 50 years and then it monotonically decreases. Let a_1 and a_2 (in years) denote the ages of the brothers and $a_1 < a_2$. Which one of the following statements is correct about their age on the day when they attain the same weight?

(A) $a_1 < a_2 < 50$

(B) $a_1 < 50 < a_2$

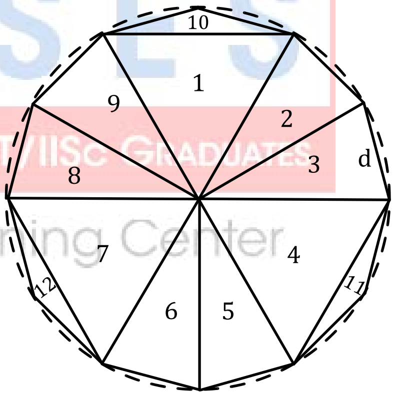
(C) $50 < a_1 < a_2$

(D) Either $a_1 = 50$ or $a_2 = 50$

8. A regular dodecagon (12-sided regular polygon) is inscribed in a circle of radius r cm as shown in the figure. The side of the dodecagon is d cm. All the triangles (numbered 1 to 12) in the figure are used to form squares of side r cm and each numbered triangle is used only once to form a square.

The number of squares that can be formed and the number of triangles required to form each square, respectively, are:

Note: The figure shown is representative.



(A) 3; 4

(B) 4; 3

(C) 3; 3

(D) 3; 2

9. If a real variable x satisfies $3^{x^2} = 27 \times 9^x$, then the value of $\frac{2^{x^2}}{(2^x)^2}$ is:

(A) 2^{-1}

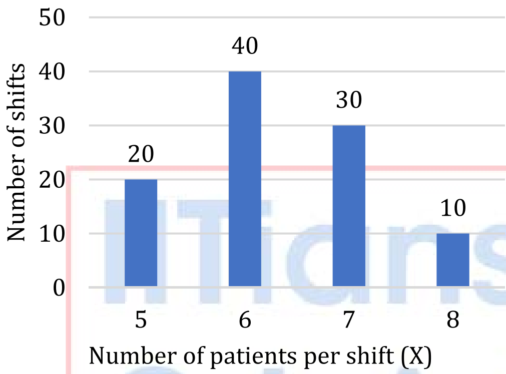
(B) 2^0

(C) 2^3

(D) 2^{15}

10. The number of patients per shift (X) consulting Dr. Gita in her past 100 shifts is shown in the figure. If the amount she earns is ₹ 1000(X − 0.2), what is the average amount (in ₹) she has earned per shift in the past 100 shifts?

Note: The figure shown is representative.



(A) 6,100 (C) 6,000

(B) 6,300 (D) 6,500

Aerospace Engineering – AE

Q. 11 – Q. 35 carry one mark each.

11. For any real symmetric matrix A, the transpose of A is ________.

(A) inverse of A (C) $-A$

(B) null matrix (D) A

12. $2x + 3y + z = 0$

$x + y = 0$

$y + z = 0$

The given system of equations has

(A) a unique solution.

(B) infinitely many solutions.

(C) no solution.

(D) a finite number of solutions.

13. The eigenvalues of the matrix $\begin{bmatrix} 1 & 2 \\ 0 & 3 \end{bmatrix}$ are ________.

(A) 0, 2 (C) 1, 3

(B) 2, 3 (D) 1, 2

14. The partial differential equation

$$\frac{\partial^2 u}{\partial x^2} + 4\frac{\partial^2 u}{\partial x\, \partial y} + 2\frac{\partial^2 u}{\partial y^2} = 0 \text{ is}\_\_\_\_\_\_\_\_.$$

(A) elliptic (C) parabolic

(B) hyperbolic (D) of mixed type

15. $f(x) = \begin{cases} A + x, & \text{if } x < 2 \\ 1 + x^2, & \text{if } x \geq 2 \end{cases}$

If the function f(x) is continuous at x = 2, the value of A is

(A) 2 (C) 3

(B) 2.5 (D) 3.5

16.

If $i = \sqrt{-1}, \dfrac{(i+1)^2}{i-1} =$ ________.

(A) 2 (C) $(i + 1)$

(B) -2 (D) $(i - 1)$

17. For a two-dimensional incompressible flow over a flat plate, the laminar boundary layer thickness at a distance x from the leading edge is δ. If Re_x is the Reynolds number defined based on length scale x,(δ/x) is proportional to ________.

(A) $Re_x^{-1/2}$ (C) $Re_x^{-3/2}$

(B) Re_x^{-1} (D) Re_x^{-2}

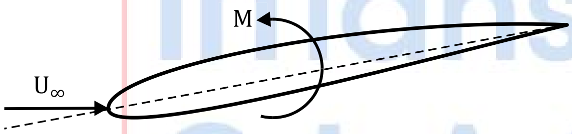
18. For a NACA 4415 airfoil, the location of maximum camber, as a fraction of the chord length from the leading edge, is ________.

(A) 0.44 (C) 0.15

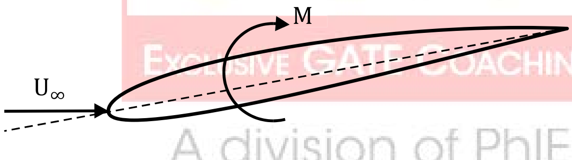
(B) 0.40 (D) 0.04

19. A positively cambered airfoil is placed in a uniform flow (velocity, U_∞) at its zero-lift angle of attack. M is the corresponding pitching moment. Which one of the following representations accurately describes this scenario?

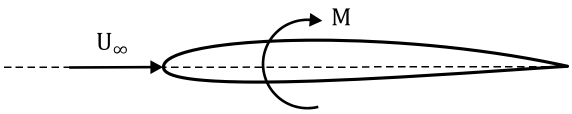
(A)



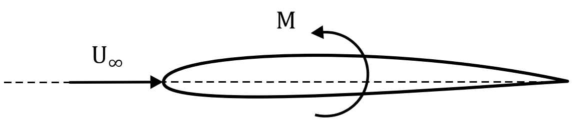
(B)



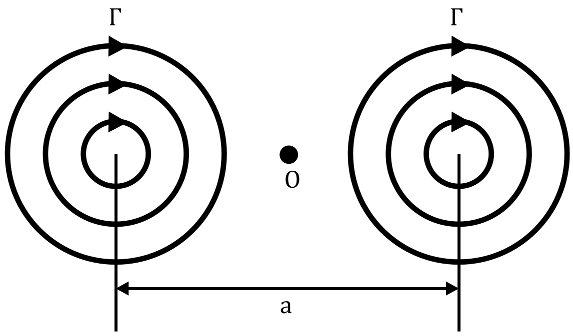
(C)



(D)



20. Consider a pair of point vortices with clockwise circulation Γ each. The distance between their centers is a, as shown in the figure. Assume two-dimensional, incompressible, inviscid flow. Which one of the following options is correct?



(A) The vortices translate downwards together with a velocity $\Gamma/2\pi a$.

(B) The vortices translate upwards together with a velocity $\Gamma/2\pi a$.

(C) The vortices rotate clockwise around each other about their centroid O.

(D) The vortices rotate counter-clockwise around each other about their centroid O.

21. In a fluid flow, Mach number is an estimate of ________.

(A) $\sqrt{\dfrac{\text{inertia force}}{\text{viscous force}}}$ (C) $\sqrt{\dfrac{\text{elastic force}}{\text{viscous force}}}$

(B) $\sqrt{\dfrac{\text{inertia force}}{\text{elastic force}}}$ (D) $\sqrt{\dfrac{\text{viscous force}}{\text{inertia force}}}$

22. A general aviation airplane is in steady and level flight. The airplane is prone to adverse yaw. Which one of the following options best describes the deflections of aileron and rudder to achieve a coordinated right turn?

(A) Left aileron: down; Right aileron: up; Rudder: left
(B) Left aileron: down; Right aileron: up; Rudder: right
(C) Left aileron: up; Right aileron: down; Rudder: left
(D) Left aileron: up; Right aileron: down; Rudder: right

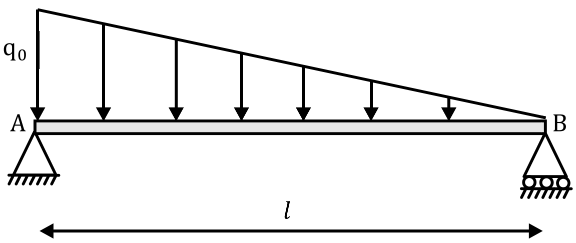
23. For a general aviation airplane, which one of the following has a destabilizing effect on its static roll stability?
(A) Wing with a positive dihedral angle
(B) Fuselage with a high wing
(C) Fuselage with a low wing
(D) Swept back wing

24. A general aviation airplane is flying at an altitude of 5000 m. The indicated airspeed is 250 km/h. Assume that there are no instrument errors and position errors. Neglecting compressibility effects, which one of the following options is FALSE?
(A) The true airspeed is greater than 250 km/h.
(B) The calibrated airspeed is 250 km/h.
(C) The true airspeed is 250 km/h.
(D) The equivalent airspeed is 250 km/h.

25. To achieve longitudinal static stability of a general aviation airplane, which one of the following conditions should be satisfied?
(A) The center of gravity of the airplane should be aft of the neutral point.
(B) The center of gravity of the airplane should be forward of the neutral point.
(C) The stability coefficient $\frac{\partial C_m}{\partial \alpha}$ (C_m is the airplane pitching moment coefficient and α is the angle of attack) is positive.
(D) The static margin is negative.

26. For a homogeneous, isotropic material, the relation between the shear modulus (G), Young's modulus (E), and Poisson's ratio (ν) is ________.
(A) $G = 2E(1 + \nu)$
(B) $2G = E(1 + \nu)$
(C) $E = 2G(1 + \nu)$
(D) $2E = G(1 + \nu)$

27. A simply supported horizontal beam is subjected to a distributed transverse load varying linearly from q_0 at A to zero at B, as shown in the figure. Which one of the following options is correct?



(A) The magnitude of the vertical reaction force at A is larger than that at B.

(B) The magnitude of the vertical reaction force at B is larger than that at A.

(C) The magnitudes of the vertical reaction forces at A and B are equal.

(D) The reactions at points A and B are indeterminate.

28. A stress field is given by $\sigma_{xx} = \sigma_{zz} = C_1 y$; $\sigma_{yy} = C_2 y$; $\tau_{xy} = \tau_{yz} = \tau_{zx} = 0$, where C_1 and C_2 are non-zero constants. If the stress field satisfies equilibrium, which one of the following options is correct?

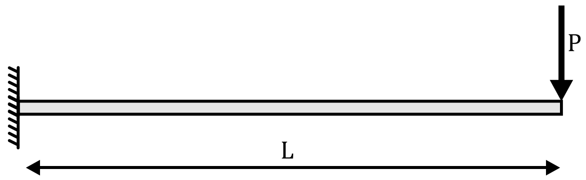
(A) There is no body force per unit volume.

(B) There is a constant body force per unit volume in the y-direction.

(C) The body force per unit volume varies linearly in the y-direction.

(D) The direction of the body force per unit volume depends on the value of C_1.

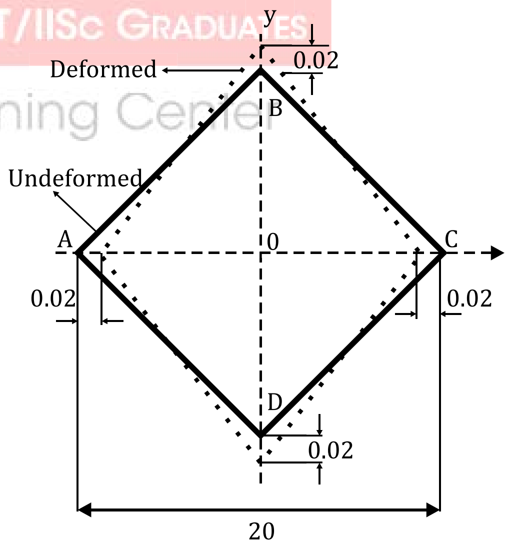
29. A uniform symmetric cross-section cantilever beam of length L is subjected to a transverse force P at the free end, as shown in the figure. The Young's modulus of the material is E and the moment of inertia is I. Ignoring the contributions due to transverse shear, the strain energy stored in the beam is ________.



(A) $\frac{P^2L^3}{6EI}$ (C) $\frac{PL^3}{6EI}$

(B) $\frac{PL^3}{3EI}$ (D) $\frac{P^2L^3}{3EI}$

30. In the given figure, plate ABCD in its undeformed configuration (solid line) is a rhombus with all the internal angles being 90°. The lengths of the undeformed diagonals are 20 cm. ABCD deforms as shown by the dotted lines. Upon deformation, diagonal AC reduces to 19.96 cm and BD increases to 20.04 cm. In the given x-y coordinate system, the engineering shear strain γ_{xy} is equal to ________.



(A) 0 (C) 0.004

(B) 0.002 (D) −0.004

31. δQ and δW are the heat and work interactions of a system with its surroundings, and dU is the change in the internal energy of the system. For an adiabatic process in a closed, constant pressure combustor, which one of the following options is correct?
(A) $|\delta Q| = |dU| \neq 0$ and $|\delta W| = 0$
(B) $|\delta Q| = |\delta W| = 0$ and $|dU| \neq 0$
(C) $|\delta Q| = |\delta W| = |dU| = 0$
(D) $|\delta W| = |dU| \neq 0$ and $|\delta Q| = 0$

32. An ideal two-stage rocket has identical specific impulse and structural coefficient for its two stages. For an optimized rocket, the two stages have identical payload ratio as well. The payload is 2 tons and the initial mass of the rocket is 200 tons. The mass of the second stage of the rocket (including the final payload mass) is ________ tons.
(A) 100 (C) 20
(B) 10 (D) 50

33. A gaseous fuel mixture comprising 3 moles of methane and 2 moles of ammonia is combusted in X moles of pure oxygen in stoichiometric amount. Assuming complete combustion, with only CO_2, H_2O and N_2 in the product gases, the value of X is ________.
$3\,CH_4 + 2\,NH_3 + X\,O_2$
$\rightarrow$ Products (CO_2, H_2O, N_2)
(A) 7.5 (C) 8.5
(B) 5.5 (D) 9.5

34. The lift per unit span for a spinning circular cylinder in a potential flow is 6 N/m. The free-stream velocity is 30 m/s, and the density of air is 1.225 kg/m^3. The circulation around the cylinder is ________ m^2/s (rounded off to two decimal places).

35. In a centrifugal compressor, the eye tip diameter is 10 cm. For a shaft rotational speed of 490 rotations per second, the tangential speed at the inducer tip is ________ m/s (rounded off to one decimal place).

Q. 36 – Q. 65 carry two marks each.

36. A lifting surface has a spanwise circulation distribution of $\Gamma(\theta) = A \sin 3\theta$ (where $A \neq 0$) over its span $-\frac{b}{2} \leq y \leq \frac{b}{2}$, and $y = -\frac{b}{2}\cos\theta$ is the spanwise coordinate. Furthermore, the downwash varies along the span as $w(\theta) = V_\infty \left(\frac{3A\sin 3\theta}{\sin\theta}\right)$, where V_∞ is the freestream velocity. Which one of the following options represents the total lift (L) and induced drag (D_i)?
(A) $L = 0$ and $D_i = 0$
(B) $L = 0$ and $D_i \neq 0$
(C) $L \neq 0$ and $D_i = 0$
(D) $L \neq 0$ and $D_i \neq 0$

37. A 1 m long rod is to be designed to support an axial tensile load P (P >> weight of the rod). The material for the

rod is to be chosen from one of the four provided in the table. Using strength-based failure criterion for design, which material results in the lowest weight of the rod?

Properties	Material α	Material β	Material γ	Material δ
Density (kg/m^3)	2700	4500	7800	9000
Young's modulus (GPa)	70	115	200	130
Yield Strength (MPa)	270	900	520	540

(A) Material α
(B) Material β
(C) Material γ
(D) Material δ

38. A general aviation airplane is initially in steady and level flight. The stability Coefficient $\frac{\partial C_m}{\partial q}$ (C_m is the airplane pitching moment coefficient and q is the pitch rate) is negative. The airplane is perturbed with a small nose-up constant pitch rate. Assume that the horizontal tail does not stall during the perturbation, and unsteady effects are neglected. When compared to steady and level flight condition, which of the following statements is/are true during the perturbed motion?

(A) The angle of attack of the horizontal tail increases.
(B) The contribution of the horizontal tail to the airplane's pitching moment about the center of gravity is more stabilizing.
(C) The lift generated by the horizontal tail increases.
(D) The contribution of the horizontal tail to the airplane's pitching moment about the center of gravity is less stabilizing.

39. A general aviation airplane is gliding with a speed V_g at minimum glide angle. Which of the following statements is/are true?

(A) V_g is equal to the speed corresponding to the maximum lift to drag ratio of the airplane.
(B) V_g increases with decreasing wing loading when all other parameters remain constant.
(C) V_g increases with decreasing altitude when all other parameters remain constant.
(D) V_g increases with increasing altitude when all other parameters remain constant.

40. The maximum value of the function $f(x) = (x-1)(x-2)(x-3)$ in the domain [0, 3] occurs at x = ________ (rounded off to two decimal places).

41.
$$\lim_{x\to 0} \frac{1-\cos(2x)}{x^2}$$
= ________ (answer in integer).

42. The equation of a closed curve in two-dimensional polar coordinates is given by $r = \frac{2}{\sqrt{\pi}}(1-\sin\theta)$. The area enclosed by the curve is ________(answer in integer).

43. Consider the ordinary differential equation:
$\frac{1}{2}\frac{dy}{dx} + \frac{y}{x} = 1$. If $y = \frac{2}{3}$ at $x = 1$,
then the value of y at x = 3 is ________ rounded off to the nearest integer).

44. An approximate solution of the equation $x^3 - 17 = 0$ is to be obtained using the Newton-Raphson method. If the initial guess is $x_0 = 2$, the value at the end of the first iteration is $x_1 =$________ (rounded off to two decimal places).

45. $\hat{i}$ and $\hat{j}$ denote unit vectors in the x and y directions, respectively. The outward flux of the two-dimensional vector field $\vec{v} = x\hat{i} + y\hat{j}$ over the unit circle centered at the origin is ________ (rounded off to two decimal places).

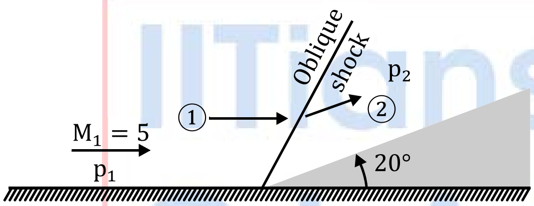
46. An aircraft is flying at an altitude of 4500 m above sea level, where the ambient pressure, temperature and density are 57 kPa, 259 K and 0.777 kg/m^3, respectively. The speed of the aircraft (V) is 230 m/s. Gas constant R= 287 J/kg/K, and specific heat ratio $\gamma = 1.4$. If the stagnation pressure is P_0, and static pressure is p, the value of $\left[\frac{p_0 - p}{\frac{1}{2}\rho V^2}\right]$ is ________ (rounded off to two decimal places).

47. A rectangular wing of 1.2 m chord length and aspect ratio 5 is tested in a wind tunnel at an air speed of 60 m/s. The density and the dynamic viscosity of air are 1.3 kg/m^3 and 1.8×10^{-5} kg/m-s, respectively. A second rectangular wing of the same span, but with an aspect ratio of 6, is to be tested in the same tunnel at the same Reynolds number. The air speed at which the second test should be performed is ________ m/s (answer in integer).

48. In a low-speed airplane, a venturimeter with 1.3:1 area ratio is used for airspeed measurement. The airplane's maximum speed at sea level is 90 m/s. If the density of air at sea level is 1.225 kg/m^3, the maximum pressure difference between

the inlet and the throat of the venturimeter is _______ kPa (rounded off to two decimal places).

49. A supersonic stream of an ideal gas at Mach number $M_1 = 5$ is turned by a ramp, as shown in the figure. The ramp angle is 20°. The pressure ratio is $\frac{p_2}{p_1} = 7.125$ and the specific heat ratio is $\gamma = 1.4$. The pressure coefficient on the ramp surface is ________ (rounded off to two decimal places).



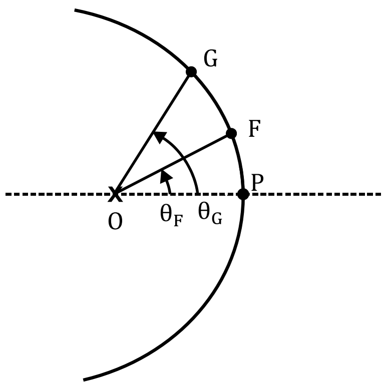
50. A perfect gas flows through a frictionless constant-area duct with heat addition. The inlet conditions are as follows: pressure 100 kPa, density 1 kg/m^3, and velocity 100 m/s. At a particular downstream location, the gas velocity is 200 m/s. The static pressure at the downstream location is ________ kPa (answer in integer).

51. The mass flow rate in a supersonic wind tunnel is 2 kg/s when the stagnation pressure and stagnation temperature are 1 MPa and 800 K, respectively. If the stagnation pressure and stagnation temperature are changed to 3 MPa and 200 K, the mass flow rate in the tunnel changes to________ kg/s (answer in integer).

52. A jet-powered airplane is steadily climbing at a rate of 10 m/s. The air density is 0.8 kg/m^3, and the thrust force is aligned with the flight path. Using the information provided in the table below, the airplane's thrust to weight ratio is ________ (rounded off to one decimal place).

Airplane speed	80 m/s
Lift coefficient, C_L	0.8
Aspect ratio	6
Oswald efficiency factor	0.8
Zero-lift drag coefficient	0.02

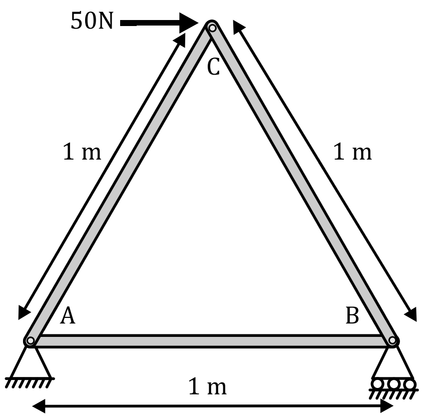
53. F and G denote two points on a spacecraft's orbit around a planet, as indicated in the figure. O is the center of the planet, P is the periapsis, and the angles are as indicated in the figure. If OF = 8000 km, OG = 10000 km, $\theta_F = 0$ deg, and $\theta_G = 60$ deg, the eccentricity of the spacecraft's orbit is ________ (rounded off to two decimal places).



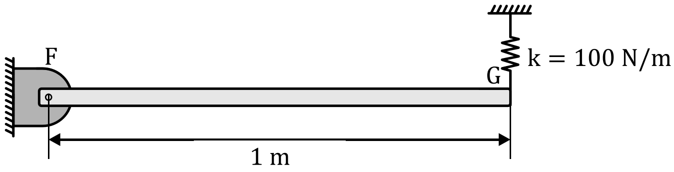
54. While taking off, the net external force acting on an airplane during the ground roll segment can be assumed to be constant. The airplane starts from rest. S_{LO} and V_{LO} are the ground roll distance and the lift-off speed, respectively. αV_{LO} ($\alpha > 0$) denotes the airplane speed at $0.5\ S_{LO}$. Neglecting changes in the airplane mass during the ground roll segment, the value of α is ________ (rounded off to two decimal places).

55. A 1 m long rod of 1 cm × 1 cm cross section is subjected to an axial tensile force of 35 kN. The Young's modulus of the material is 70 GPa. The cross-section of the deformed rod is 0.998 cm × 0.998 cm. The Poisson's ratio of the material is ________ (rounded off to one decimal place).

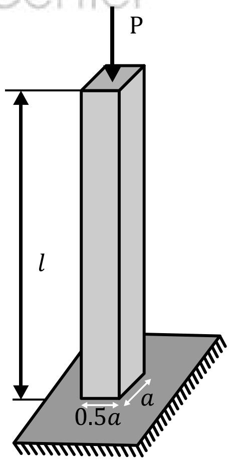
56. For a three-bar truss loaded as shown in the figure, the magnitude of the force in the horizontal member AB is ________ N (answer in integer).



57. A uniform rigid bar of mass 3 kg is hinged at point F, and supported by a spring of stiffness k=100 N/m, as shown in the figure. The natural frequency of free vibration of the system is ________ rad/s (answer in integer).



58. A prismatic vertical column of cross-section a × 0.5a and length l is rigidly fixed at the bottom and free at the top. A compressive force P is applied along the centroidal axis at the top surface. The Young's modulus of the material is 200 GPa and the uniaxial yield stress is 400 MPa. If the critical value of P for yielding and for buckling of the column are equal, the value of (l/a) is ________ (rounded off to one decimal place).

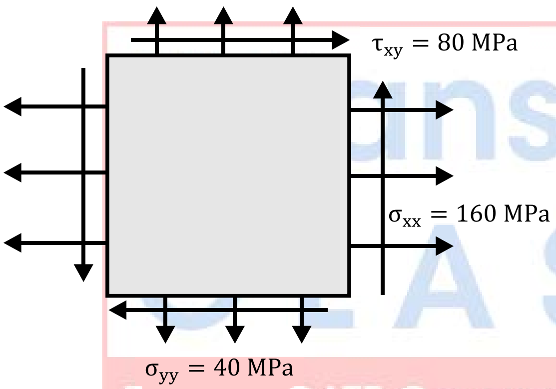


59. A thin flat plate is subjected to the following stresses:

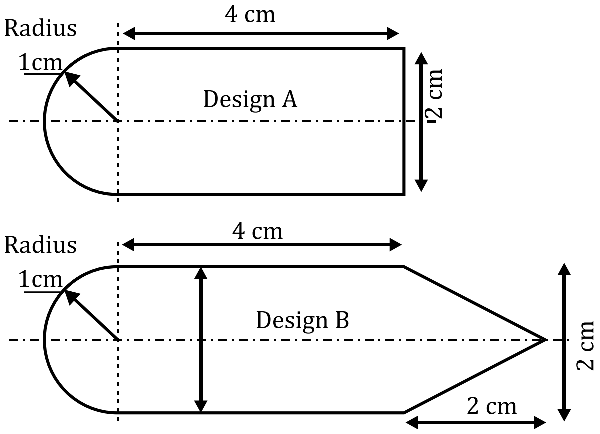
$\sigma_{xx} = 160$ MPa; $\sigma_{yy} = 40$ MPa;

$\tau_{xy} = 80$ MPa.

Factor of safety is defined as the ratio of the yield stress to the applied stress. The yield stress of the material under uniaxial tensile load is 250 MPa. The factor of safety for the plate assuming that material failure is governed by the von Mises criterion is ________ (rounded off to two decimal places).



60. Two designs A and B, shown in the figure, are proposed for a thin-walled closed section that is expected to carry only torque. Both A and B have a semi-circular nose, and are made of the same material with a wall thickness of 1 mm. With strength as the only criterion for failure, the ratio of maximum torque that B can support to the maximum torque that A can support is ________ (rounded off to two decimal places).



61. An ideal turbofan with a bypass ratio of 5 has core mass flow rate, $\dot{m}_{a,c} = 100$ kg/s. The core and the fan exhausts are separate and optimally expanded. The core exhaust speed is 600 m/s and the fan exhaust speed is 120 m/s. If the fuel mass flow rate is negligible in comparison to $\dot{m}_{a,c}$, the static specific thrust $(T/\dot{m}_{a,c})$ developed by the engine is ________ Ns/kg (rounded off to the nearest integer).

62. Air at temperature 300 K is compressed isentropically from a pressure of 1 bar to 10 bar in a compressor. Eighty percent of the compressed air is supplied to a combustor. In the combustor, 0.88 MJ of heat is added per kg of air. The specific heat at constant pressure is $C_p = 1005$ J/kg/K and the specific heat ratio is $\gamma = 1.4$. The temperature of the air leaving the combustor is ________ K (rounded off to one decimal place).

63. A monopropellant liquid rocket engine has 800 injectors of diameter 4 mm each, and with a discharge coefficient of 0.65. The liquid propellant of density 1000 kg/m^3 flows through the injectors. There is a pressure difference of 10 bar across the injectors. The specific impulse of the rocket is 1500 m/s. The thrust generated by the rocket is ________ kN (rounded off to one decimal place).

64. An ideal ramjet with an optimally expanded exhaust is travelling at Mach 3. The ambient temperature and pressure are 260 K and 60 kPa, respectively. The inlet air mass flow rate is 50 kg/s. Exit temperature of the exhaust gases is 700 K. Fuel mass flow rate is negligible compared to air mass flow rate. Gas constant is R= 287 J/kg/K, and specific heat ratio is $\gamma = 1.4$. The thrust generated by the engine is ________ kN (rounded off to one decimal place).

65. A single-stage axial compressor, with a 50 % degree of reaction, runs at a mean blade speed of 250 m/s. The overall pressure ratio developed is 1.3. Inlet pressure and temperature are 1 bar and 300 K, respectively. Axial velocity is 200 m/s. Specific heat at constant pressure, $C_p = 1005$ J/kg/K and specific heat ratio, $\gamma = 1.4$. The rotor blade angle at the outlet is ________ degrees (rounded off to two decimal places).

******

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Answer Keys GATE 2025 - Aerospace Engineering

General Aptitude – GA

1	A	6	B
2	B	7	B
3	C	8	A
4	A	9	C
5	C	10	A

Aerospace Engineering – AE

11	D	31	D	51	12 to 12
12	B	32	C	52	0.2 to 0.2
13	C	33	A	53	0.66 to 0.67
14	B	34	0.16 to 0.17	54	0.70 to 0.71
15	C	35	151.0 to 154.0	55	0.4 to 0.4
16	A	36	B	56	25 to 25
17	A	37	B	57	10 to 10
18	B	38	A;B;C	58	5.0 to 5.1
19	A	39	A;D	59	1.25 to 1.25
20	C	40	1.41 to 1.43	60	1.20 to 1.22
21	B	41	2 to 2	61	1200 to 1200
22	B	42	6 to 6	62	1454.0 to 1455.0
23	C	43	2 to 2	63	430.0 to 442.0
24	C	44	2.75 to 2.75	64	30.9 to 31.2
25	B	45	6.20 to 6.30	65	21.00 to 22.00
26	C	46	1.08 to 1.14		
27	A	47	72 to 72		
28	B	48	3.20 to 3.45		
29	A	49	0.31 to 0.37		
30	A	50	90 to 90		

Explanations GATE 2025 - Aerospace Engineering

General Aptitude – GA

1. **[Ans. A]**

In an analogy, the relationship between the first pair of words should be mirrored in the second pair.

- **Courage** and **Bravery** are synonyms, both representing the ability to face fear with confidence.
- **Yearning** conveys a deep emotional longing for something, and **Longing** is its closest synonym.
- Other options like **Yelling**, **Yawning**, and **Glaring** do not share this meaning and are unrelated.

Conclusion: The correct answer is **"Longing"**, as it best preserves the synonym relationship like the first pair.

2. **[Ans. B]**

The past perfect continuous tense (**had been + verb-ing**) is used for an action that was ongoing in the past and got interrupted (it suddenly started to rain).

3. **[Ans. C]**

Counting the number of pixels with values ≤ 4 in the given matrix, we get **11 pixels**.

4. **[Ans. A]**

P = Rectangle + Triangle + Ellipse

$= 1 + 2 + 3 = 6$

Q = Ellipse + Triangle

$= 3 + 2 = 5$

R = Rectangle + Triangle

$= 1 + 2 = 3$

So, $P = 6, Q = 5, R = 3$

5. **[Ans. C]**

$A = LW \to L(1.1LW)$

$$\% \text{ Change} = \frac{1.1\text{ LW} - \text{LW}}{\text{LW}} \times 100$$

$= 10\%$ Increase

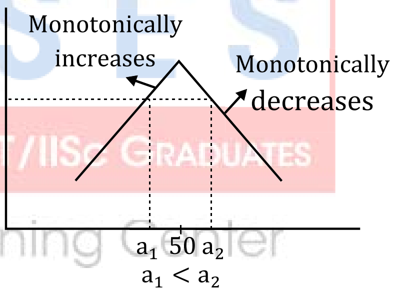
6. **[Ans. B]**

$P = 3; Q = 4; R = 1; S = 2$

7. **[Ans. B]**

weight $= f(\text{age})$

$\Rightarrow a_1 < 50 < a_2$



8. **[Ans. A]**

$$y = \frac{180 - 150}{2} = 15$$

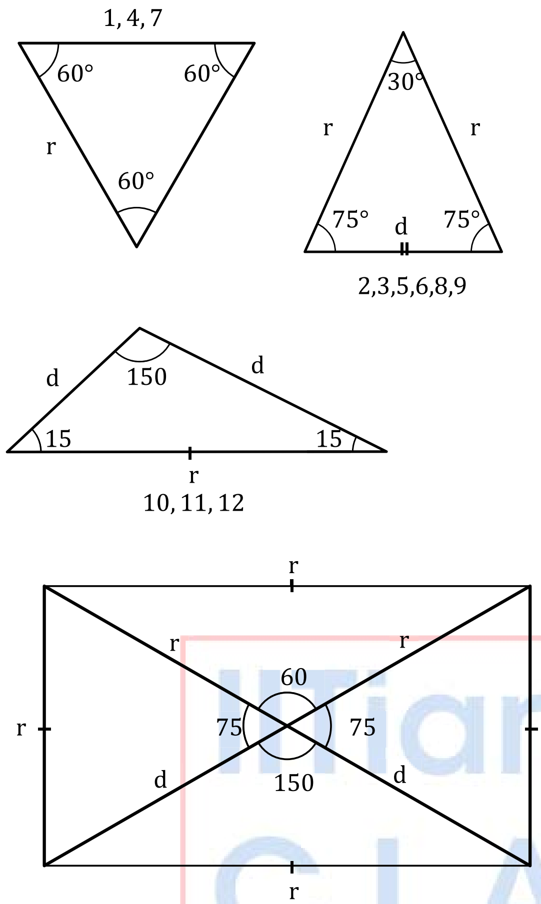
$150 + 60 + 75 + 75 = 360$

1 sq = 1qg + 1 obt + 2 acute

= 4 triangle

Total = 12 triangle

$$\text{Sq} = \frac{12}{4} = 3$$



9. **[Ans. C]**

$3^{x^2} = 3^3 \times (3^2)^x$

$= 3^3 \cdot 3^{2x}$

$3^{x^2} = 3^{3+2x}$

$\frac{3^{x^2}}{3^{2x}} = 3^3$

$3^{x^2-2x} = 3^3$

Same base $\Rightarrow x^2 - 2x = 3$

$\frac{2^{x^2}}{2^{2x}} = 2^{x^2-2x}$

$= 2^3$

10. **[Ans. A]**

$x = 5: 1000\,(x - 0.2) = 1000(5 - 0.2) = 4800$

$\rightarrow 20$ No of shift

$x = 6: 1000\,(6 - 0.2) = 5800 \rightarrow 40$ No of shift

$x = 7: 1000\,(7 - 0.2) = 6800 \rightarrow 30$ No of shift

$x = 8: 1000\,(8 - 0.2) = 6800 \rightarrow 10$ No of shift

$\Rightarrow$ Average

$$= \frac{4800 \times 20 + 5800 \times 40 + 6800 \times 30 + 7800 \times 10}{(20 + 40 + 30 + 10)}$$

$= 960 + 2320 + 2040 + 780$

Average $= 6100$

Aerospace Engineering – AE

11. **[Ans. D]**

Identity: $A^T = A$ and $a_{ij} = a_{ji}$

$$A = \begin{bmatrix} 1 & 4 & 5 \\ 4 & 2 & 6 \\ 5 & 6 & 3 \end{bmatrix}$$

$$A^T = \begin{bmatrix} 1 & 4 & 5 \\ 4 & 2 & 6 \\ 5 & 6 & 3 \end{bmatrix} = A$$

12. **[Ans. B]**

$Ax = 0$

$$\underset{A}{\begin{bmatrix} 2 & 3 & 1 \\ 1 & 1 & 0 \\ 0 & 1 & 1 \end{bmatrix}} \underset{x}{\begin{bmatrix} x \\ y \\ z \end{bmatrix}} = \underset{0}{\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}}$$

$|A| = 2[1 - 0] - 3[1 - 0] + 1[1 - 0]$

$|A| = 0$ (Infinite solution)

13. **[Ans. C]**

$$A = \begin{bmatrix} 1 & 2 \\ 0 & 3 \end{bmatrix}$$

$\Rightarrow |A - \lambda I| = 0$

$$\Rightarrow \begin{vmatrix} (1 - \lambda) & 2 \\ 0 & (3 - \lambda) \end{vmatrix} = 0$$

$(1 - \lambda)(3 - \lambda) = 0$

$\lambda = 1$ and 3

14. **[Ans. B]**

General form of a 2nd order PDE

$Au_{xx} + Bu_{xy} + Cu_{yy} = f(x, y, u, u_x, u_y)$

$B^2 - 4AC = (4)^2 - 4(1)(2) = 16 - 8$

$= 8 > 0$ (Hyperbolic)

15. **[Ans. C]**

$$f(x) = \begin{cases} A + x, & \text{if } x < 2 \\ 1 + x^2, & \text{if } x \geq 2 \end{cases}$$

$x_0 = 2$

$LHL = \lim_{x\to 2^-} f(x) = \lim_{x\to 2^-} (A + x) = A + 2$

$RHL = \lim_{x\to 2^+} f(x) = \lim_{x\to 2^+} (1 + x^2) = 1 + 4$

$= 5$

$f(x_0) = f(2) = 1 + 4 = 5$

So for $f(x)$ to be continuous at $x = 2$,

$\lim_{x\to 2^-} f(x) = \lim_{x\to 2^+} f(x) = f(2)$

$A + 2 = 5$

$A = 3$

16. **[Ans. A]**

$$\frac{(1+i)^3}{(i-1)}$$

$$= \frac{(1)^3 + (i)^3 + 3(1)^2(i) + 3(1)(i)^2}{(i-1)}$$

$$= \frac{1 - i + 3i - 3}{i - 1}$$

$$= \frac{-2 + 2i}{i - 1}$$

$$= 2\frac{(i-1)}{(i-1)}$$

$$\frac{(1+i)^3}{(i-1)} = 2$$

17. **[Ans. A]**

Blasius solution

$$\frac{\delta}{x} = \frac{4.9}{\sqrt{Re_x}}$$

$$\frac{\delta}{x} \propto \frac{1}{\sqrt{Re_x}}$$

$$\frac{\delta}{x} \propto (Re_x)^{-1/2}$$

18. **[Ans. B]**

NACA 4415

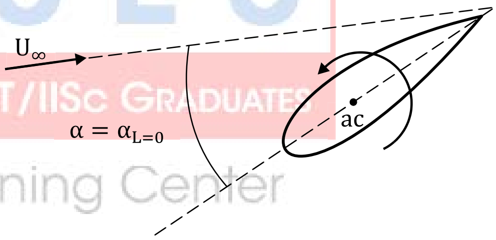
Second digit represent the Location of maximum chamber along the chord from the leading edge.

Location of maximum camber $= \frac{4}{10}C$

$= 0.4\ C$

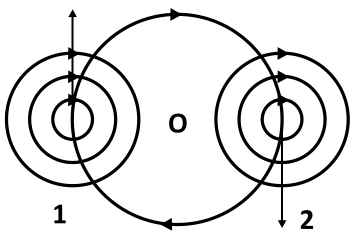
19. **[Ans. A]**

For positively cambered airfoil, $\alpha = \alpha_{L=0} < 0$



C_{mac} =Constant and less than zero for +ve cambered airfoil at aerodynamics center (Nose down moment)

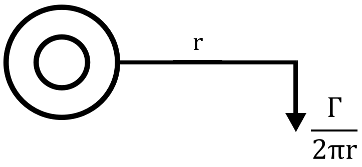
20. **[Ans. C]**



$V_{12} = -\frac{\Gamma}{2\pi a}$, Velocity induced by the vortices 1 on 2; the negative sign indicates that the velocity vector points in the negative y direction.

$V_{21} = \frac{\Gamma}{2\pi a}$, Velocity induced by the vortices 1 on 2: The velocity vector points in the negative y direction.

The vortices rotate in clockwise direction about their centroid O.



21. **[Ans. B]**

$M = \frac{V}{a}$

$a = \sqrt{\frac{dp}{d\rho}}$

Bulk modulus $(K) = \rho \frac{dp}{d\rho}$

$a = \sqrt{\frac{K}{\rho}}$

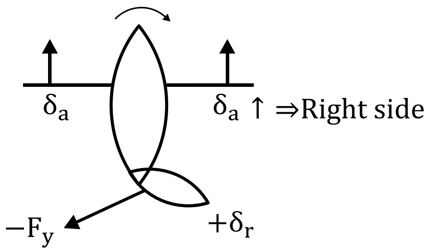
$M^2 = \frac{V^2}{\frac{K}{\rho}}$

$= \frac{\rho v^2 A}{K\,A}$ $\begin{matrix} \rightarrow \text{Inertial force} \\ \rightarrow \text{Elastic force} \end{matrix}$

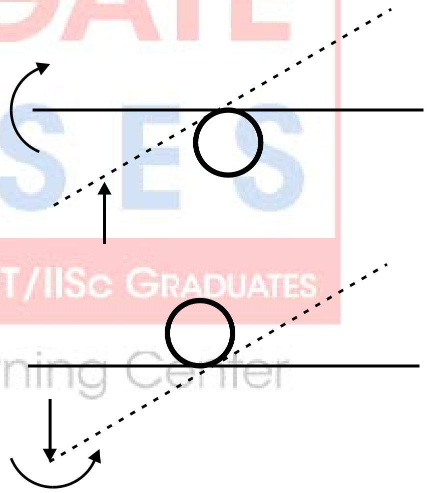
So $M = \sqrt{\frac{\rho v^2 A}{K\,A}} = \sqrt{\frac{\text{Inertia force}}{\text{Elastic force}}}$

22. **[Ans. B]**

For a right-coordinated turn, the left aileron should be deflected downward and the right aileron should be deflected upward. This in turn results in an increase in induced drag on the left wing and a decrease in induced drag on the right wing. The difference in drag induces the negative yaw. To counteract this, the rudder must be deflected toward the right.



23. **[Ans. C]**



Low-wing aircraft provide a destabilizing contribution to lateral stability. To make low-wing aircraft stable, a positive dihedral angle is provided.

24. **[Ans. C]**

$T_{AS} > I_{AS}$

$T_{AS} = I_{AS} \times \sqrt{\frac{\rho_0}{\rho}}$ $(\because \rho_0 > \rho)$

25. **[Ans. B]**

For longitudinal static stability

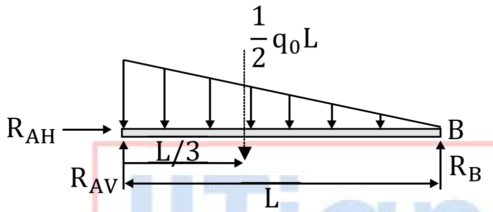
$SM = \bar{X}_{np} - \bar{X}_{CG} > 0$

$\frac{dc_m}{d\alpha} < 0$

26. **[Ans. C]**

$E = 2G(1+\nu)$

27. **[Ans. A]**



$\Sigma F_x = 0$

$R_{AH} = 0$

$\Sigma F_y = 0 \quad \uparrow +ve$

$R_{AV} + R_B - \frac{1}{2}\, q_0\, L = 0$

$R_{AV} + R_B = \frac{1}{2} q_0 L \rightarrow$ ①

$\Sigma M_A = 0$ (clockwise +ve)

$+\left(\frac{1}{2}\, q_0 L\right)\left(\frac{L}{3}\right) - R_B\,(L) = 0$

$R_B = \frac{q_0 L}{6}$

From equation ①

$R_{AV} = \frac{1}{2}\, q_0\, L - \frac{q_0 L}{6} = \frac{q_0 L}{3}$

$R_{AV} > R_B$

28. **[Ans. B]**

$\frac{\partial \sigma_{yy}}{\partial y} = C_2$

$\sigma_{xx} = \sigma_{zz} = yC_1$

$\sigma_{yy} = yC_2$

$\tau_{xy} = \tau_{yz} = \tau_{zx} = 0$

From equilibrium equation

$\cancelto{0}{\frac{\partial \sigma_{xx}}{\partial x}} + \cancelto{0}{\frac{\partial(\tau_{xy})}{\partial y}} + \cancelto{0}{\frac{\partial(\tau_{yz})}{\partial z}} + f(x) = 0$

$f(x) = 0$

in y direction

$\frac{\partial \sigma_{yy}}{\partial y} + \cancelto{0}{\frac{\partial(\tau_{xy})}{\partial x}} + \cancelto{0}{\frac{\partial(\tau_{yz})}{\partial z}} + f(y) = 0$

$C2 + f(y) = 0$

$f(y) = -C_2$

f(x) and f(y) are the body forces per unit volume in x and y direction respectively.

29. **[Ans. A]**

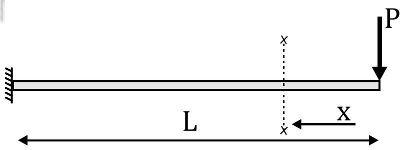
$M_{xx} = -P(x)$

$u_{Bending} = \int_0^L \frac{(M_{xx})^2 dx}{2EI}$

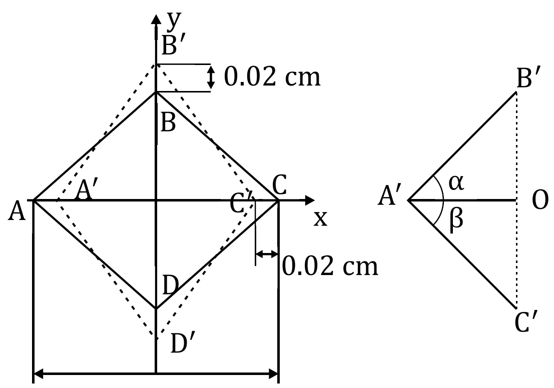
$u_{Bending} = \int_0^L \frac{(-P(x))^2 dx}{2EI}$

$= \frac{P^2}{2EI}\left[\frac{x^3}{3}\right]_0^L$

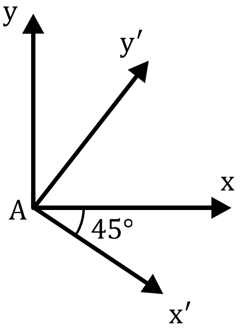
$= \frac{P^2 L^3}{6EI}$



30. **[Ans. A]**



At point A,



$$\tan\alpha = \frac{OB'}{OA'} = \frac{10.02}{9.98}$$

$$\alpha = \tan^{-1}\frac{10.02}{9.98} = 45.114^\circ$$

$$\beta = \tan^{-1}\frac{10.02}{9.98} = 45.114^\circ$$

$$\gamma_{x'y'} = 90^\circ - (\alpha + \beta)$$

$$\gamma_{x'y'} = -0.004 \text{ radian}$$

$$\varepsilon_{x'} = \frac{A'D' - AD}{AD}$$

$$= \frac{\sqrt{10.02^2 + 9.98^2} - \sqrt{200}}{\sqrt{200}}$$

$$= 1.99 \times 10^{-6}$$

$$\varepsilon_{y'} = \frac{A'B' - AB}{AB}$$

$$= \frac{\sqrt{10.02^2 + 9.98^2} - \sqrt{200}}{\sqrt{200}}$$

$$= 1.99 \times 10^{-6}$$

$$\begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \frac{\gamma_{xy}}{2} \end{bmatrix}$$

$$= \begin{bmatrix} \cos\theta^2 & \sin\theta^2 & 2\cos\theta\sin\theta \\ \sin\theta^2 & \cos\theta^2 & -2\cos\theta\sin\theta \\ -\cos\theta\sin\theta & \cos\theta\sin\theta & \cos\theta^2 - \sin\theta^2 \end{bmatrix} \begin{bmatrix} \varepsilon_{x'} \\ \varepsilon_{y'} \\ \frac{\gamma_{x'y'}}{2} \end{bmatrix}$$

$$\theta = 45^\circ$$

$$\frac{\gamma_{xy}}{2} = -\frac{1}{2}\varepsilon_{x'} + \frac{1}{2}\varepsilon_{y'} + \left(\frac{1}{2} - \frac{1}{2}\right)\frac{\gamma_{x'y'}}{2} = 0$$

Method 2:

The initial angle between OB and OA is 90°. After deformation, the angle between OB' and OC' is 90°. Change the orientation of the x-y axis after deformation is zero. Therefore, shear strain is zero. $\gamma_{xy} = 0$

31. **[Ans. D]**

$$W = mP(\nu_2 - \nu_1)$$

$\delta Q = dU + \delta W$ (1st law of thermodynamics)

$\delta Q = 0$ (Adiabatic process)

$$dU = \delta W \neq 0$$

32. **[Ans. C]**

Method 1:

$$m_{L2} = 2 \text{ ton}$$

$$m_{01} = 200 \text{ ton}$$

$$m_{L1} = m_{02}$$

$$\varepsilon_1 = \varepsilon_2$$

$$\varepsilon_i = \frac{m_{S\,i}}{m_{0i} - m_{Li}}$$

$$= \frac{m_{S,i}}{m_{Pi} + m_{S\,i}}$$

$$m_{0i} = m_{Pi} + m_{Si} + m_{Li}$$

$$m_{01} = 200 \text{ ton}$$

$$m_{L2} = 2 \text{ ton}$$

$$\lambda_1 = \lambda_2$$

$$\lambda_i = \frac{m_{Li}}{m_{0i} - m_{Li}}$$

$$\lambda_i = \frac{m_{Li}}{m_{Pi} + m_{Si}}$$

$$\frac{m_{L2}}{m_{01}} = \lambda_* = \prod_{i=1}^{n}\left(\frac{\lambda_i}{\lambda_i + 1}\right)$$

$$= \left(\frac{\lambda_1}{1 + \lambda_1}\right)\left(\frac{\lambda_2}{1 + \lambda_2}\right) = \left(\frac{\lambda_2}{1 + \lambda_2}\right)^2$$

$$\frac{m_{L2}}{m_{01}} = \left(\frac{\lambda_2}{1 + \lambda_2}\right)^2 = 0.01$$

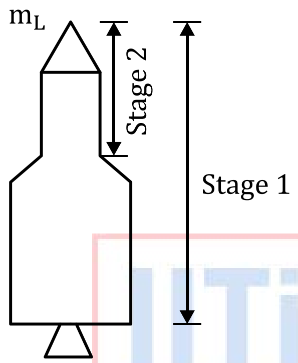
$$\left(\frac{\lambda_2}{1+\lambda_2}\right) = 0.1$$

$$\Rightarrow \lambda_2 = 0.111 = \frac{m_{L2}}{m_{02} - m_{L2}} = \frac{2}{m_{02} - 2}$$

$$0.111 = \frac{2}{m_{02} - 2}$$

$$m_{02} - 2 = \frac{2}{0.111}$$

$$m_{02} = 20 \text{ tons}$$



Method 2:

$$\lambda_1 = \frac{m_{02}}{m_{01} - m_{02}}$$

$$\lambda_2 = \frac{m_{L2}}{m_{02} - m_{L2}}$$

$$\lambda_2 = \lambda_1$$

$$\frac{m_{02}}{200 - m_{02}} = \frac{2}{m_{02} - 2}$$

$$m_{02}(m_{02} - 2) = 2(200 - m_{02})$$

$$m_{02}^{\,2} = 400$$

$$m_{02} = 20 \text{ tons}$$

33. **[Ans. A]**

$3\,CH_4 + 2\,NH_3 + X\,O_2 \longrightarrow aCO_2 + bH_2O + cN_2$

$a = 3, b = 9$ and c=1

$$O = 3 \times 2 + 9 \times 1 = 15$$

$$O_2 = \frac{15}{2} = 7.5$$

34. **[Ans. *] Range: 0.16 to 0.17**

$L' = 6$ N/m

$V_\infty = 30$ m/s

$\rho_\infty = 1.225$ kg/m^3

Kutta Joukowski Theorem

$$L' = \rho_\infty V_\infty \Gamma$$

$$\Gamma = \frac{L'}{\rho_\infty V_\infty} = \frac{6}{30 \times 1.225} = 0.163 \text{ m}^2/\text{s}$$

$$\Gamma = 0.163 \text{ m}^2/\text{s}$$

35. **[Ans. *] Range: 151.0 to 154.0**

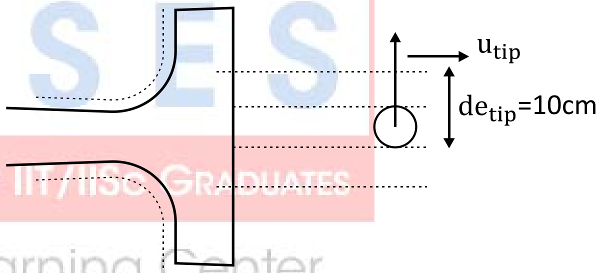
$\omega = 2\pi f$ rad/sec

$|u| = |\omega||r| \sin\theta$

Where, $\theta = 90^\circ$

$$u = 2\pi \times 490 \times \left(\frac{10}{2} \times 10^{-2}\right)$$

$$u = 153.9 \text{ m/s}$$



36. **[Ans. B]**

$$\Gamma(\theta) = A \sin 3\theta$$

$$L = \int_{-b/2}^{b/2} \rho_\infty V_\infty \Gamma(y)\,dy$$

$$y = -\frac{b}{2}\cos\theta \;;\; dy = \frac{b}{2}\sin\theta$$

$$L = \rho_\infty V_\infty \int_0^\pi \frac{b}{2}\, \Gamma(\theta) \sin\theta \, d\theta$$

$$L = \rho_\infty V_\infty \frac{b}{2} A \int_0^\pi \sin 3\theta \sin\theta \; d\theta$$

$$L = 0$$

$$Di = L\alpha i(y)$$

$$= \int_{-b/2}^{b/2} \frac{L(-w(y))}{V_\infty} dy$$

$$= \int_{-b/2}^{b/2} \frac{\rho_\infty V_\infty \Gamma(y)dy\,(-w(y))}{V_\infty} dy$$

$$= -\rho_\infty V_\infty \frac{b}{2} \int_0^\pi \Gamma(\theta)\, w(\theta) \sin\theta\, d\theta$$

$$= -3\rho_\infty A^2 \frac{b}{2} V_\infty \int_0^\pi \sin 3\theta \frac{\sin 3\theta}{\sin\theta} \sin\theta\ d\theta\ \ (n = m)$$

$$= -3\rho_\infty A^2 \frac{b}{2} V_\infty \int_0^\pi \sin 3\theta^2\ d\theta$$

$$= -3\rho_\infty A^2 \frac{b}{4} V_\infty \pi$$

$Di \neq 0$

37. **[Ans. B]**

$\sigma_{max} \leq \sigma_{yield}$

$\frac{P}{A} = \sigma_{yield}$

$P = [\sigma_{yield} \times A] \rightarrow$ Eq ①

$(W)_{weight} = mg$

$= (Volume)\,\rho g$

$W = (A \times l)\rho g \rightarrow$ equation ②

$$\frac{Eq\ ①}{Eq\ ②} = \frac{\sigma_{yield}}{\rho(l \times g)}$$

1. For Material (α)

$$\left(\frac{P}{W}\right)_\alpha = \frac{270}{2700(l \times g)} = \frac{0.1}{g}$$

2. For material (β)

$$\left(\frac{P}{W}\right)_\beta = \frac{900}{4500(l \times g)} = \frac{0.2}{g}$$

3. Material (γ)

$$\left(\frac{P}{W}\right)_\gamma = \frac{520}{7800(l \times g)} = \frac{0.067}{g}$$

4. Material (δ)

$$\left(\frac{P}{W}\right)_\delta = \frac{540}{9000\,g} = \frac{0.06}{g}$$

38. **[Ans. A, B, C]**

Option A: Nose-up perturbation increases the angle of attack (AOA) of the horizontal tail.

Option B and C: CL of H-tail is a function of the angle of attack of the H-tail, elevator deflection angle, and trim tab deflection angle. An increase in AOA results in increases in the lift of the H-tail, which in turn generates a nose-down pitching moment (restoring moment) about the CG of the aircraft.

39. **[Ans. A, D]**

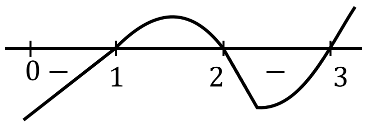
$\theta_g = \tan^{-1}\left(\frac{D}{L}\right)$

$\theta_{gmin} = \tan^{-1}\left(\frac{1}{(L/D)_{max}}\right)$

$Vglide = V_\infty \times \sin\theta_g$

$Vglide \Rightarrow V_\infty \propto \frac{1}{\sqrt{\rho}}$

40. **[Ans. *] Range: 1.41 to 1.43**



$f(0) = -1 \times -2 \times -3$

$= -6$

$f(1) = 0, f(2) = 0, f(3) = 0$

$f(1.5) = 0.5 \times (-0.5) \times (1.5) > 0$

$f(x) = (x-1)(x-2)(x-3)$

$$f'(x) = (x-2)(x-3) + (x-1)(x-3) + (x-1)(x-2)$$
$$= x^2 - 5x + 6 + x^2 - 4x + 3 + x^3 - 3x + 2 = 0$$
$$f'(x) = 3x^2 - 12x + 11 = 0$$
$$x = \frac{12 \pm \sqrt{(-12)^2 - 4(3)(11)}}{2(3)}$$
$$x = \frac{12 \pm \sqrt{12}}{6}$$
$$x = 2 \pm \frac{1}{\sqrt{3}}$$
$$x_1 = 2 + \frac{1}{\sqrt{3}} > 2$$
$$x_2 = 2 - \frac{1}{\sqrt{3}} \rightarrow \text{between } 1 < 2$$
$f''(x) < 0$, for maxima
$$f''(x) = 6(x) - 12$$
$$f(x_2 = 1.42) = -3.48 < 0$$
$$x_2 \rightarrow \text{Maxima}$$
$$x_2 = 1.42$$

41. **[Ans. *] Range: 2 to 2**

$$\lim_{x\to 0} \frac{1-\cos(0)}{(0)^2} = \frac{0}{0} \text{ form}$$

L'Hôpital's rule

$$\lim_{x\to 0} \frac{[\sin 2x](2)}{2x} \Rightarrow \frac{0}{0} \text{form}$$
$\rightarrow$ Differentiate again
$$\lim_{x\to 0} \frac{4\cos(2x)}{2} \Rightarrow 2(1) = 2$$

42. **[Ans. *] Range: 6 to 6**

$$r = \frac{2}{\sqrt{\pi}}(1 - \sin\theta)$$
$$0 \le \theta \le 2\pi$$
$$A = \int_{\theta=0}^{2\pi} \int r dr\, d\theta$$
$$A = \int_{\theta=0}^{2\pi} \frac{1}{2} r^2 d\theta$$
$$= \frac{1}{2}\int_0^{2\pi} \frac{4}{\pi}(1-\sin\theta)^2 d\theta$$
$$= \frac{2}{\pi}\int_0^{2\pi} [1 + \sin^2\theta - 2\sin\theta] d\theta$$
$$= \frac{2}{\pi}\left[\int_0^{2\pi} d\theta + \int_0^{2\pi} \sin^2\theta d\theta - 2\int_0^{2\pi} \sin\theta d\theta\right] \quad (\sin\theta\, d\theta \text{ term} \rightarrow 0)$$
$$= \frac{2}{\pi}\left[(2\pi) + \int_0^{2\pi} \frac{(1-\cos 2\theta)}{2} d\theta\right]$$
$$= 4 + \frac{1}{\pi}\left[\int_0^{2\pi} d\theta - \int_0^{2\pi} \cos 2\theta\, d\theta\right] \quad (\cos 2\theta\, d\theta \text{ term} \rightarrow 0)$$
$$= 4 + \frac{1}{\pi}(2\pi)$$
$$A = 6$$

43. **[Ans. *] Range: 2 to 2**

General form of linear first order ODE

$$\frac{dy}{dx} + P(x)y = q(x)$$

The integrating factor (IF) $= e^{\int (p(x)dx}$
$$= e^{\int \frac{2}{x} dx}$$
$$= e^{\ln x^2}$$
$$IF = x^2$$
$$y(IF) = \int q(x)(IF)dx + C$$
$$y(x^2) = \int 2x^2 dx + C$$
$$x^2 y = \frac{2}{3}x^3 + C$$
Given $y(1) = \frac{2}{3}$
$$(1)^2\left(\frac{2}{3}\right) = \frac{2}{3}(1)^3 + C$$
$$C = 0$$
$$y = \frac{2}{3}x \Rightarrow \text{for } x = 3 \rightarrow \ y = \frac{2}{3}(3) = 2$$

44. **[Ans. *] Range: 2.75 to 2.75**

$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)} \quad f(x) = x^3 - 17, \quad f'(x) = 3x^2$$

$$x_0 = 2, f(x_0) = (2)^3 - 17 = 8 - 17 = -9$$

$$f'(x_0) = 3(2)^2 = 12$$

$$x_1 = 2 - \frac{-9}{12} = 2 + \frac{3}{4}$$

$$x_1 = 2.75$$

45. **[Ans. *] Range: 6.20 to 6.30**

Flux form of Green's theorem

$$\vec{V} = f(x,y)\hat{\imath} + g(x,y)\hat{\jmath}$$

$$\oint_C \vec{V}.\hat{n}ds = \iint_R (\nabla\cdot\vec{V})dA = \iint_R \left[\frac{\partial f}{\partial x} + \frac{\partial g}{\partial y}\right]dA$$

$$\vec{V} = x\hat{\imath} + y\hat{\jmath} \rightarrow \nabla\cdot\vec{V} = \frac{d}{dx}(x) + \frac{d}{dy}(y) = 1 + 1 = 2$$

$$\text{Total outward flux} = \oint \vec{V}\cdot\hat{n}\,ds = \iint_R 2\,dA = 2\iint_R dA = 2\pi(1)^2$$

$$\oint \vec{V}\cdot\hat{n}ds = 6.28$$

46. **[Ans. *] Range: 1.08 to 1.14**

$$q_\infty = \frac{\gamma}{2}P \times M_\infty^2$$

$$M_\infty = \frac{V}{\sqrt{\gamma RT}} = \frac{230}{\sqrt{1.4 \times 287 \times 259}}$$

$M_\infty = 0.712$ (compressible flow)

$$\frac{P_o - P}{\frac{1}{2}\rho V^2} = \frac{P_o - P}{q_\infty} = \frac{P_o - P}{\frac{\gamma}{2}P M_\infty^2} = \frac{\frac{P_o}{P} - 1}{\frac{\gamma}{2}M_\infty^2} = \frac{\left(1 + \frac{\gamma - 1}{2}M_\infty^2\right)^{\frac{\gamma}{\gamma-1}} - 1}{\frac{\gamma}{2}M_\infty^2}$$

$$\frac{P_o - P}{\frac{1}{2}\rho V^2} = 1.13 > 1$$

47. **[Ans. *] Range: 72 to 72**

Case-I

$AR_1 = 5$

$V_1 = 60$ m/s

$AR_1 = \frac{b}{c}$

$C_1 = 1.2$ m

$b_1 = AR_1 \times C = 6$ m

Case II

$AR_2 = 6$

$b_2 = 6$ m

$C_2 = 1$ m

$$Re_1 = Re_2$$

$$\frac{\rho_1 V_1 C_1}{\mu_1} = \frac{\rho_2 V_2 C_2}{\mu_2}$$

$$V_2 = \frac{V_1 C_1}{C_2}$$

$$V_2 = \frac{60 \times 1.2}{1} = 72 \text{ m/s}$$

$$V_2 = 72 \text{ m/s}$$

48. **[Ans. *] Range: 3.20 to 3.45**

$$\frac{A_1}{A_2} = 1.3 \quad V_1 = 90 \text{ m/s}$$

$$A_1V_1 = A_2V_2$$

$$V_2 = \frac{A_1}{A_2} V_1 = 117 \text{ m/s}$$

$$P_1 + \frac{1}{2}\rho V_1^2 = P_2 + \frac{1}{2}\rho V_2^2$$

$$\Delta P = P_1 - P_2 = \frac{1}{2}\rho (V_2^2 - V_1^2)$$

$$= \frac{1}{2}(1.225)((117)^2 - (90)^2)$$

$$\Delta P = 3.42 \text{ kPa}$$

49. **[Ans. *] Range: 0.31 to 0.37**

$$C_P = \frac{P - P_\infty}{q_\infty}$$

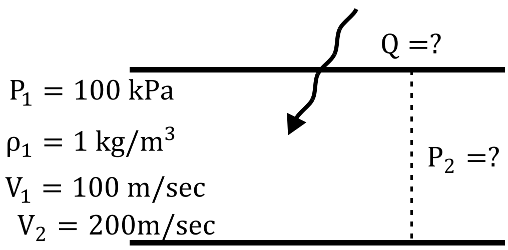
$$C_P = \frac{P_2 - P_1}{q_1} \qquad q_1 = \frac{1}{2}\rho_1 V_1^2 = \frac{\gamma}{2} P_1 M_1^2$$

$$C_P = \frac{\frac{P_2}{P_1} - 1}{\frac{\gamma}{2} M_1^2}$$

$$C_P = \frac{7.125 - 1}{\frac{1.4}{2} \times (5)^2}$$

$$C_P = 0.35$$

50. **[Ans. *] Range: 90 to 90**



Continuity Equation

$$\rho_1 V_1 = \rho_2 V_2$$

$$\rho_2 = \frac{\rho_1 V_1}{V_2} = \frac{1 \times 100}{200}$$

$$= 0.5 \text{ kg/m}^3$$

Momentum equation

$$P_1 + \rho_1 V_1^2 = P_2 + \rho_2 V_2^2$$

$$P_2 = 100 \times 10^3 + 1 \times (100)^2 - 0.5 \times (200)^2$$

$$P_2 = 90 \text{ kPa}$$

51. **[Ans. *] Range: 12 to 12**

$$\dot{m} = \frac{P_0 A^*}{\sqrt{RT_0}} f(R, \gamma) \qquad \dot{m}_1 = 2\text{kg/s}$$

$$\dot{m} \propto \frac{P_0}{\sqrt{T_0}}$$

$$\frac{\dot{m}_1}{\dot{m}_2} = \frac{P_{01}}{P_{02}} \sqrt{\frac{T_{02}}{T_{01}}}$$

$$\frac{\dot{m}_1}{\dot{m}_2} = \frac{1}{3} \times \sqrt{\frac{200}{800}} = \frac{1}{6}$$

$$\dot{m}_2 = 6 \times 2 = 12\text{kg/s}$$

52. **[Ans. *] Range: 0.2 to 0.2**

$$V_C = 10 \text{ m/sec}$$

$$\rho = 0.8 \text{ kg/m}^3$$

$$V = 80 \text{ m/s}$$

$$C_L = 0.8$$

$$A.R = 6$$

$$e = 0.8$$

$$C_{D_0} = 0.02$$

$$\sin\gamma = \frac{V_C}{V} = 0.125$$

$$C_D = C_{D_0} + KC_L{}^2$$

$$C_D = 0.02 + \frac{1}{\pi e AR}(0.8)^2$$

$$C_D = 0.0624$$

$$L = W = \frac{1}{2}\rho V^2 S C_L$$

$$T = D + W\sin\gamma$$

$$\frac{T}{W} = \frac{D}{W} + \sin\gamma$$

$$\frac{T}{W} = 0.078 + 0.125 = 0.203$$

$$\frac{T}{W} = 0.2$$

53. **[Ans. *] Range: 0.66 to 0.67**

$$r = \frac{h^2/\mu}{1 + e\cos\theta} \quad h$$

= Specific angular momentum; $\mu = GM$

$$r_F = \frac{h^2/\mu}{1 + e\cos\theta} = \frac{h^2/\mu}{1 + e} = 8000$$

$$r_G = \frac{h^2/\mu}{1 + e\cos 60} = \frac{h^2/\mu}{1 + 0.5e} = 10000$$

$$\frac{r_G}{r_F} = \frac{1 + e}{1 + 0.5e} = \frac{10000}{8000} = \frac{10}{8}$$

$$8 + 8e = 10 + 5e$$

$$3e = 2$$

$$e = \frac{2}{3} = 0.67$$

54. **[Ans. *] Range: 0.70 to 0.71**

Approach1:

1. Work done = $\Delta kE \Rightarrow$ Force $\times$ displacement $= \frac{1}{2}mV^2 - \frac{1}{2}mU^2$

Approach 2:

2. $V^2 = U^2 + 2aS$

(a) $V_{L_0}^2 = 2a\,S_{L0}$

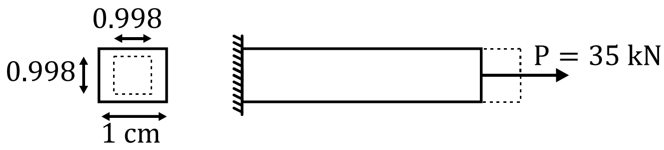
(b) $\left(\alpha V_{L_0}\right)^2 = 2a(0.5)S_{L0}$

$$\frac{\alpha^2 V_{Lo}^2}{V_{Lo}^2} = \frac{2a\ 0.5\ S_{Lo}}{2a\ S_{Lo}}$$

$$\alpha^2 = 0.5$$

$$\alpha = 0.707 = 0.71$$

55. **[Ans. *] Range: 0.4 to 0.4**



$$\delta l = \frac{Pl}{AE}$$

$$\delta l = \frac{35 \times 1000 \times [1 \times 1000]}{10 \times 10 \times 70 \times 10^3}$$

$$\delta l = 5\text{ mm}$$

Lateral strain

$$= \frac{\Delta(\text{Lateral dimension})}{\text{Original Lateral dimension}}$$

$$= \frac{[0.998 - 1]}{1} = -2 \times 10^{-3}$$

$$\mu = \frac{-\text{Lateral strain}}{\text{Linear strain}} = \frac{+2 \times 10^{-3}}{5 \times 10^{-3}}$$

$$\mu = \frac{2}{5} = 0.4$$

56. **[Ans. *] Range: 25 to 25**

$\Sigma F_x = 0 \quad \overset{+ve}{\longrightarrow}$

$50 - R_{AH} = 0$

$R_{AH} = 50N$

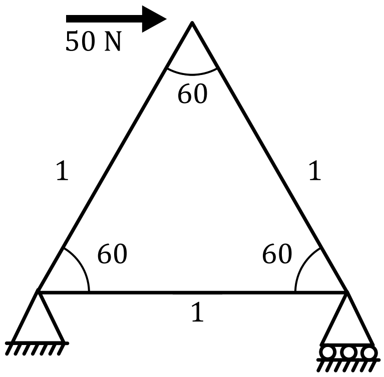
$\Sigma F_y = 0 \quad \uparrow +ve$

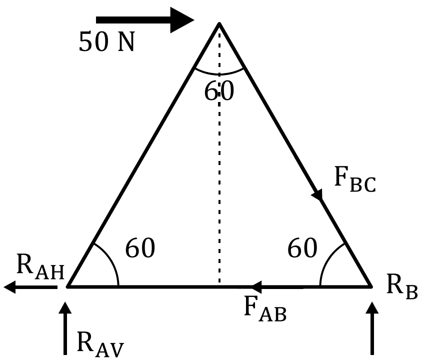
$R_B = -R_{Av}$

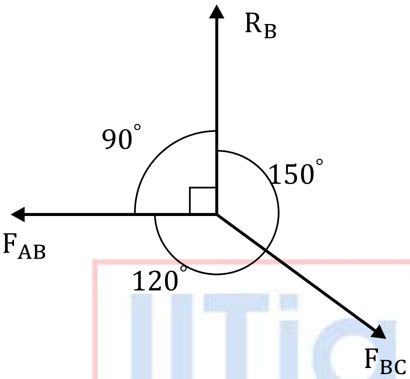
$\Sigma M_A = 0$

$$50 \times \frac{\sqrt{3}}{2} - R_B \times 1 = 0$$

$$R_B = 25\sqrt{3}\text{ N}$$







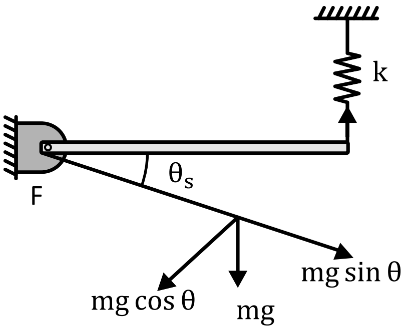
By sine rule

$$\frac{F_{AB}}{\sin(150)} = \frac{25\sqrt{3}}{\sin 120}$$

$$F_{AB} = \frac{25\sqrt{3} \times [1/2]}{\sqrt{3}/2} = 25\text{ N}$$

$$F_{AB} = 25\text{ N}$$

57. **[Ans. *] Range: 10 to 10**



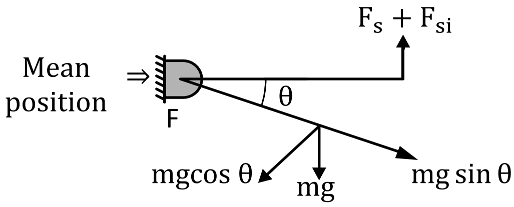
$m = 3$ kg; $k = 100$ N/m

at mean position

$$mg\cos\theta_s\left(\frac{l}{2}\right) = F_{si}(l)$$

$\theta_s \approx$ small

$$mg\left(\frac{l}{2}\right) = F_{si}(l) \rightarrow eq(1)$$



$F_s = ky$

$y = l\theta$

$[l = 1m]$

$\sum T_{net} = I_F\alpha$

$$-[F_s + F_{si}][l] + mg\left[\frac{l}{2}\right] = \left[\frac{ml^2}{3}\right]\ddot{\theta}$$

From equation (1)

$$-F_s(l) = \frac{ml^2}{3}\ddot{\theta}$$

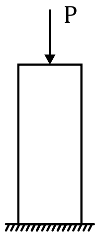
$$\frac{ml^2}{3}\ddot{\theta} + kl^2\theta = 0$$

$$\ddot{\theta} + \left(\frac{kl^2}{\frac{ml^2}{3}}\right)\theta = 0$$

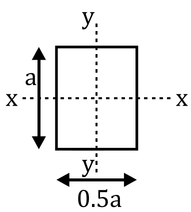
$$\omega_n = \sqrt{\frac{3kl^2}{ml^2}} = \sqrt{\frac{3k}{m}}$$

$\omega_n = 10$ rad/sec

58. **[Ans. *] Range: 5.0 to 5.1**



For fixed-free column $k = 2$



$$I_y(\min) = \frac{a \times (0.5a)^3}{12}$$

$$P_{Buckling} = \frac{\pi^2 EI_{min}}{(kl)^2}$$

$$P_B = \frac{\pi^2 EI_{min}}{4l^2}$$

$$P_B = \frac{\pi^2 E[a \times 0.5^3 a^3]}{12 \times 4l^2}$$

$$P_{Yielding} = \sigma_y \times A$$

$$P_Y = 400 \times [0.5 \times 1]a^2$$

$$\frac{\pi^2 E[0.5^3 a^4]}{48l^2} = 400 \times 0.5a^2$$

$$\frac{\pi^2 \times 200 \times 100 \times 0.5^3 a^4}{48l^2} = 400 \times 0.5a^2$$

$$\left(\frac{l}{a}\right) = 5.07$$

59. **[Ans. *] Range: 1.25 to 1.25**

$$\sigma_{eq} = \frac{\sigma_{yt}}{FOS}$$

$$= \sqrt{\frac{1}{2}\left[\begin{matrix}(\sigma_{xx} - \sigma_{yy})^2 + (\sigma_{yy} - \sigma_{zz})^2 + \\ (\sigma_{xx} - \sigma_{zz})^2 + 6[\tau_{xy}^2 + \tau_{yz}^2 + \tau_{zx}^2]\end{matrix}\right]}$$

$$\sigma_{xx} = 160 \text{ MPa}$$

$$\sigma_{yy} = 40 \text{ MPa}, \tau_{xy} = 80 \text{ MPa}$$

$$\frac{\sigma_{yt}}{FOS} = \sqrt{\sigma_{xx}^2 + \sigma_{yy}^2 - \sigma_{xx}\,\sigma_{yy} + 3(\tau_{xy})^2}$$

$$\frac{250}{FOS} = \sqrt{(160)^2 + 40^2 - (160 \times 40) + 3(80)^2}$$

$$FOS = 1.25$$

60. **[Ans. *] Range: 1.20 to 1.22**

$$T = 2Aq \;;\; q_{max} = \tau_{max}\, t_{min}$$

$$T_{max} = 2A_{C/S}\, q_{max}$$

$$= 2\, A_{C/S} \tau_{max}\, t_{min}$$

$$= 2\, A\tau_{allow} t$$

$$\frac{T_{max2}}{T_{max1}} = \frac{2A_2 \tau_{allow} t}{2A_1 \tau_{allow} t}$$

$$= \frac{A_2}{A_1}$$

$$= \frac{\left(\frac{\pi}{2}(1)^2 + 4 \times 2 + \frac{1}{2} \times 2 \times 2\right)}{\left(\frac{\pi}{2}(1)^2 + 4 \times 2\right)}$$

$$= 1.2089$$

61. **[Ans. *] Range: 1200 to 1200**

$$\dot{m}_{cold} = \frac{\beta \times \dot{m}_{ac}}{\beta + 1}$$

$$\dot{m}_{hot} = \frac{\dot{m}_{ac}}{1 + \beta}$$

$$T = \dot{m}_{hot} C_{jh} + \dot{m}_{cold} C_{jc} - \dot{m}_{ac} C_i + (\text{Pressure Thrust})$$

$$\frac{T}{\dot{m}_{ac}} = \frac{1}{\beta + 1} C_{jh} + \frac{\beta}{\beta + 1} C_{jc}$$

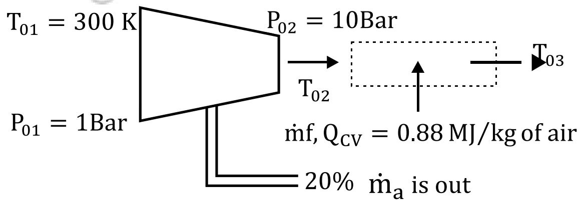
$$\frac{T}{\dot{m}_{ac}} = \frac{1}{6} \times 600 + \frac{5}{6} \times 120$$

$$\frac{T}{\dot{m}_{hot}} = (\beta + 1)\left(\frac{T}{\dot{m}_{ac}}\right)$$

$$= 1 \times 600 + 120 \times 5$$

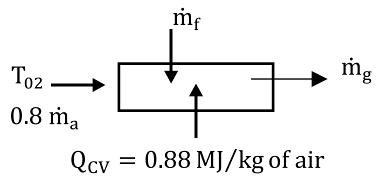
$$= 1200 \text{ Ns/kg}$$

62. **[Ans. *] Range: 1454.0 to 1455.0**



$$\eta_{is} = 100\%$$

$$\frac{T_{02}}{T_{01}} = \left(\frac{P_{02}}{P_{01}}\right)^{\frac{\gamma - 1}{\gamma}} \Rightarrow T_{02} = 579.209 \text{ K}$$



$$\dot m_g C_{Pg} T_{03} = 0.8 \times \dot m_a C_p T_{02} + \dot m_a \eta_{comb} Q_{CV} \text{(Per kg of air)}$$

$$\dot m_f << \dot m_a \Rightarrow \dot m_g = \dot m_a$$

$$C_{Pg} T_{03} = C_{Pa} T_{02} + \eta Q_{CV}$$

$$T_{03} = T_{02} + \frac{Q_{CV}}{C_P}$$

$$T_{03} = 579.209 + \frac{0.88 \times 10^6}{1005}$$

$$T_{03} = 1454.83 \text{ K}$$

63. **[Ans. *] Range: 430.0 to 442.0**

$N = 800$

$d_{in} = 4 \times 10^{-3} m$

$\rho_{prop} = 1000 \text{ kg/m}^3$

$\Delta P = 10 \text{ bar} = 10 \times 10^5 \text{Pa}$

$$\dot m_P = \sum_{i=1}^{800} \dot m_{pi} \times Cd$$

$$(\dot m_P)_{actual} = Cd \times (\dot m_P)_{theory}$$

$$= Cd \times N \times \rho A V$$

$$= Cd \times 800 \times \frac{\rho(\pi d_{in}^2)}{4} V$$

Where, $V = \sqrt{\frac{2\Delta P}{\rho}}$

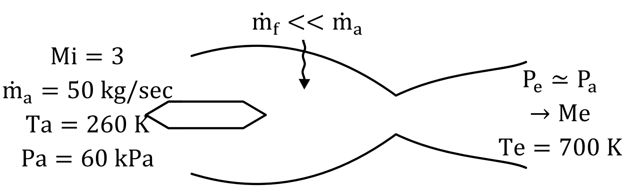
$$\dot m_P = Cd \times 800 \times \frac{(\pi d_{in}{}^2)}{4} \sqrt{2\rho\Delta P}$$

$$\dot m_P = 292.239 \text{ kg/sec}$$

$$F = \dot m_P \times I_{SP} \times g_0$$

$$F = 438 \text{ kN}$$

64. **[Ans. *] Range: 30.9 to 31.2**



$$F = \dot m_g Cj - \dot m_a Ci$$

$$\dot m_f \ll 1 \quad \dot m_g = \dot m_a$$

$$Me = Mi$$

$$F = \dot m_a Ci \left(\sqrt{\frac{Te}{Ta}} - 1\right) \quad \frac{Cj}{\sqrt{\gamma R Te}}$$

$$= \frac{Ci}{\sqrt{\gamma R Ta}}$$

$$M_i = \frac{C_i}{\sqrt{\gamma R Ta}} \quad Cj = Ci\sqrt{\frac{Te}{Ta}}$$

$$C_i = Mi\sqrt{\gamma R Ta}$$

$$F = \dot m_a \sqrt{\gamma R Ta}\ Mi\left(\sqrt{\frac{Te}{Ta}} - 1\right)$$

$$F = 31.0687 \text{ kN}$$

$$F = 31.1 \text{ kN}$$

65. **[Ans. *] Range: 21.00 to 22.00**

$R = 0.5 = \frac{1}{2}$

$\alpha_1 = \beta_2, \beta_1 = \alpha_2$

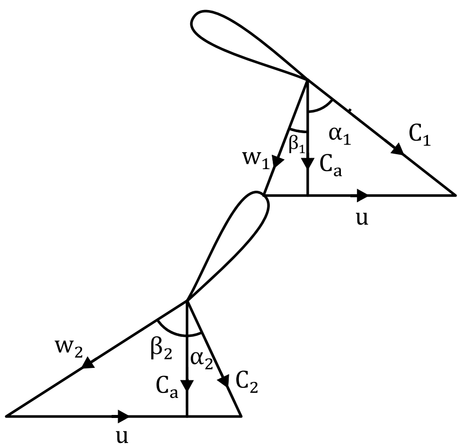
$c_1 = w_2, w_1 = c_2$

$u = 250 \text{ m/sec}$

$c_a = 200 \text{ m/sec}$

$\pi_{pr} = 1.3 \quad \gamma = 1.4$

$Cp = 1005 \text{ J/kg K}$



$$\frac{1}{2} = R = \frac{c_a}{2u}(\tan\beta_1 + \tan\beta_2)$$

$$\frac{u}{c_a} = \tan\beta_1 + \tan\beta_2$$

$$Cp(\Delta T_0) = W = uc_a(\tan\beta_1 - \tan\beta_2)$$

$$100\% = \eta_c = \frac{T_{01}\left(\pi_c^{\frac{\gamma-1}{\gamma}} - 1\right)}{\Delta T_0}$$

$$\tan\beta_1 - \tan\beta_2 = \frac{Cp\Delta T_0}{uc_a}$$

$$= \frac{Cp}{uc_a}\left(T_{01}\left(\pi_c^{\frac{\gamma-1}{\gamma}} - 1\right)\right)$$

$$\tan\beta_1 - \tan\beta_2 = 0.4694$$

$$\tan\beta_1 = 0.4692 + \tan\beta_2$$

$$\frac{u}{c_a} = \tan\beta_1 + \tan\beta_2$$

$$= 0.4694 + 2\tan\beta_2$$

$$\beta_2 = \tan^{-1}\left(\frac{\frac{u}{c_a} - 0.4694}{2}\right)$$

$$\beta_2 = 21.32^{\circ}$$

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