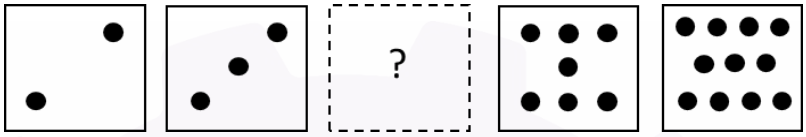
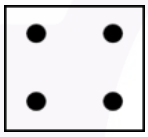
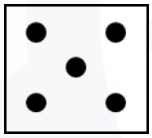
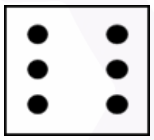
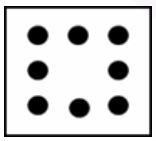
General Aptitude (GA)

Q.1 – Q.5 Carry ONE mark Each

Q.1	"He often _____ the numbers. False claims are not going to help. Honesty _____ trust", said the manager. Choose the option with the correct order of words to fill the blanks.
(A)	exaggerates; engenders
(B)	excels; encourages
(C)	aggravates; alleviates
(D)	diminishes; eliminates

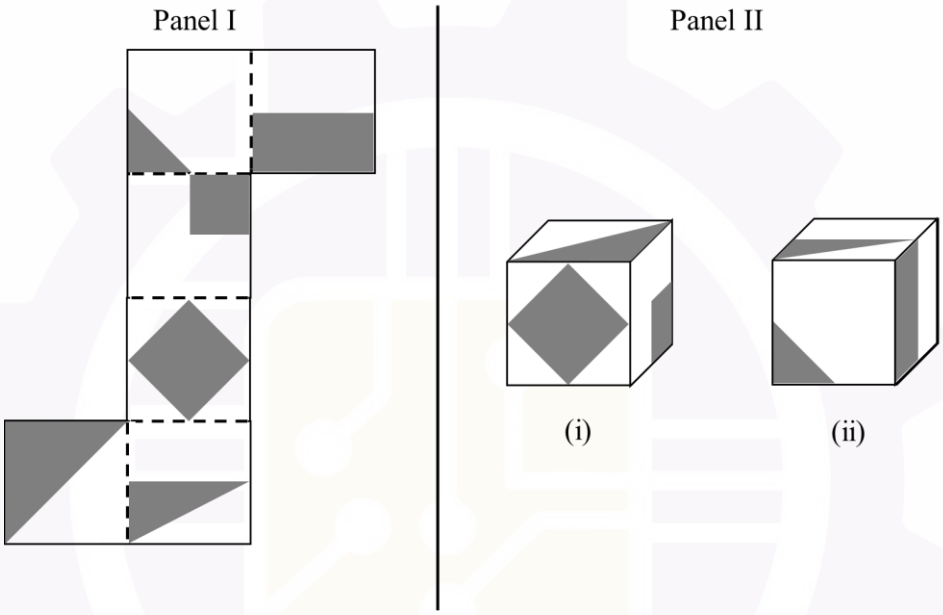
Q.2	In the sequence of tiles shown below, the missing tile indicated by the question mark should be 
(A)	
(B)	
(C)	
(D)	

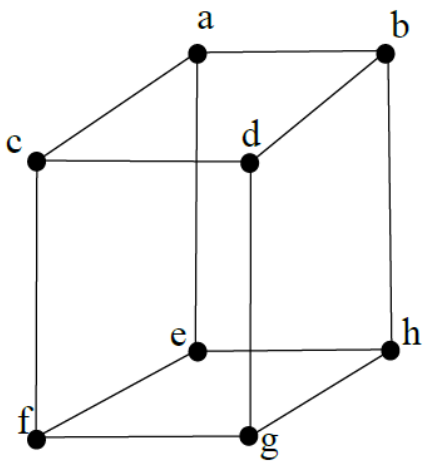
Q.3	A school has 100 students distributed among 1^{st} to 10^{th} standards. Based on this, which one of the following statements is always correct?
(A)	There are at least 10 students who belong to the same standard.
(B)	There is at least one student in each standard.
(C)	There are at most 10 students in 10^{th} standard.
(D)	The total number of students from 1^{st} to 5^{th} standards is at least 50.
Q.4	How many 3-digit numbers can be formed using three distinct single digit prime numbers?
(A)	64
(B)	24
(C)	12
(D)	4

Q.5	In a group of students, 10 students like Mathematics, 12 students like English, 4 students like both Mathematics and English, and 6 students like neither Mathematics nor English. The number of students in the group is ____
(A)	18
(B)	20
(C)	24
(D)	32

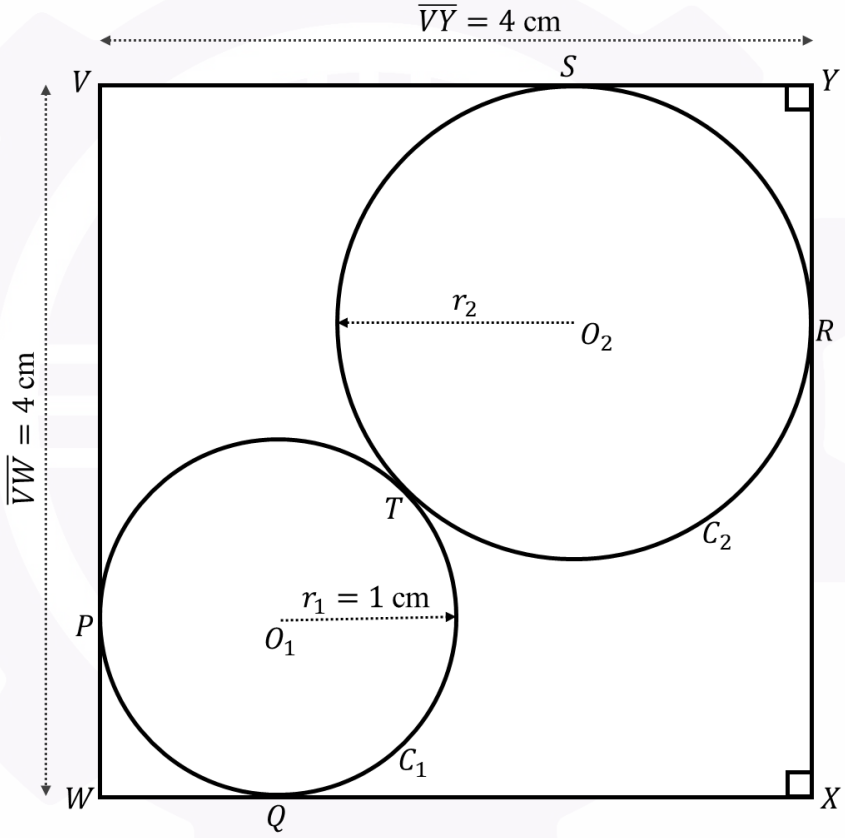
Q.6 – Q.10 Carry TWO marks Each

Q.6	Charity : P :: Retaliation : Q Choose the appropriate pair of words P and Q that fit the analogy.
(A)	P = Parsimonious; Q = Vengeful
(B)	P = Altruistic; Q = Amicable
(C)	P = Resentful; Q = Spiteful
(D)	P = Magnanimous; Q = Vindictive

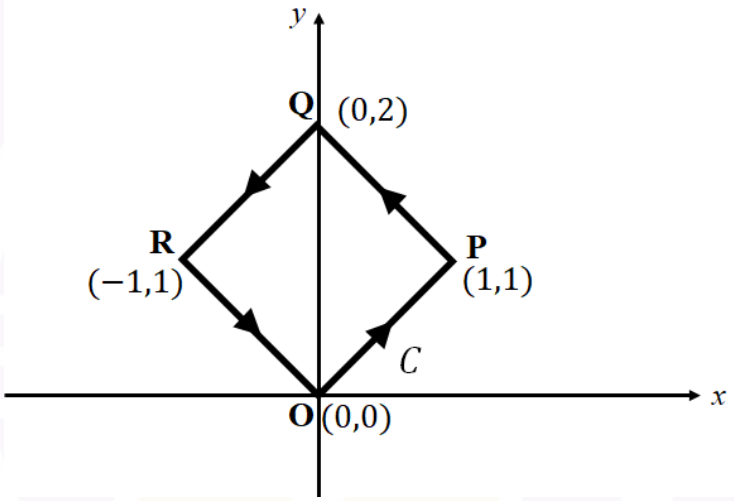
Q.7	A paper shown in Panel I is folded along the dashed lines (- - -) to construct a cube. The shaded regions shown in Panel I appear on the outer surface of the cube. Referring to cubes shown in Panel II, which one of the options is correct? 
(A)	Only (i) can correspond to the unfolded cube in Panel I.
(B)	Only (ii) can correspond to the unfolded cube in Panel I.
(C)	Both (i) and (ii) can correspond to the unfolded cube in Panel I.
(D)	Neither (i) nor (ii) can correspond to the unfolded cube in Panel I.

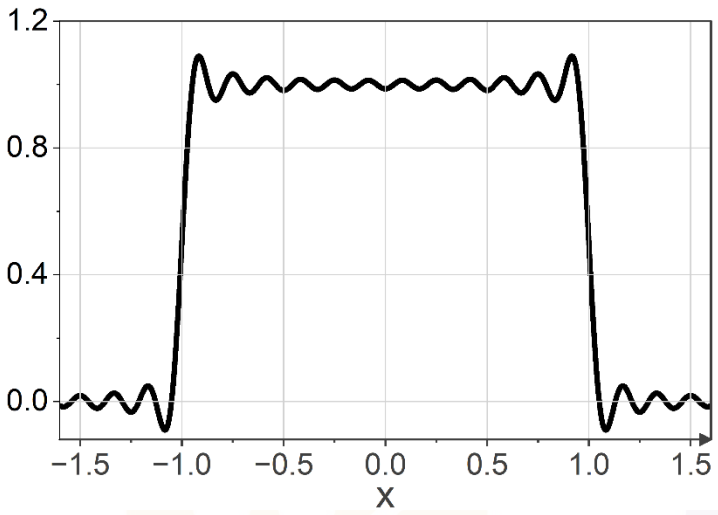
Q.8	Consider the cube shown below with its 8 corners labelled a, b, c, d, e, f, g, and h. The figure is representative. All corners are to be colored such that any two corners that are connected by an edge must be of different colors. The minimum number of colors required to achieve this is _____ 
(A)	8
(B)	4
(C)	3
(D)	2

Q.9	Four hills H1, H2, H3, and H4 are present in an area. The following observations are made about them: i. Neither H2 nor H3 is the easternmost hill. ii. Neither H2 nor H3 is the westernmost hill. iii. Neither the easternmost hill nor the westernmost hill is the southernmost hill. iv. Two hills are located to the west of H2. v. The southernmost hill has at least two hills to its east. The southernmost hill is _____.
(A)	H1
(B)	H2
(C)	H3
(D)	H4

Q.10	As shown in the figure, circle C_1 with center O_1 and radius r_1 touches the square $VWXY$ at points P and Q while circle C_2 with center O_2 and radius r_2 touches the square $VWXY$ at points R and S. The two circles touch each other at T. Given $r_1 = 1$ cm and $\overline{VY} = \overline{VW} = 4$ cm, r_2 = _____ cm. 
(A)	$4 - 3\sqrt{2}$
(B)	$1 + 2\sqrt{2}$
(C)	$7 - 4\sqrt{2}$
(D)	$5 + 3\sqrt{2}$

Q.11 – Q.35 Carry ONE mark Each

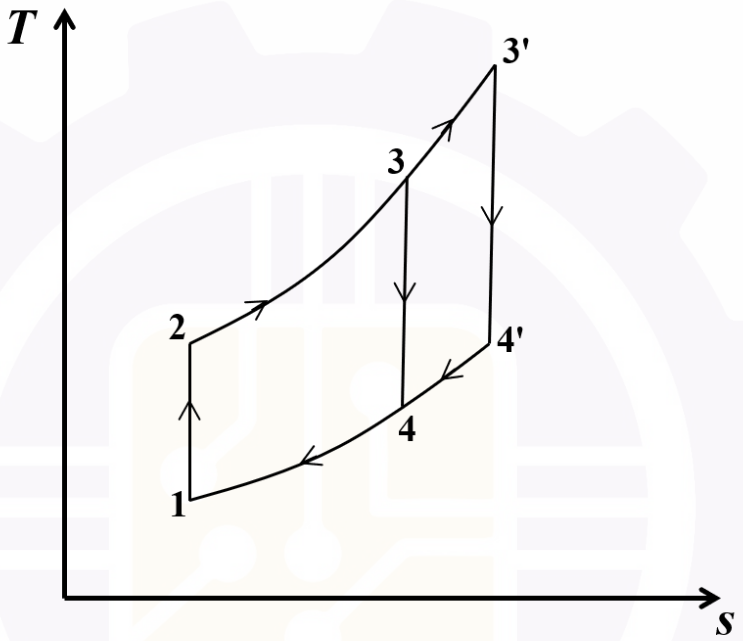
Q.11	Consider the contour C shown in the figure below. For the vector $\vec{F} = (x + 2y)\hat{e}_x + (2x + 4y)\hat{e}_y$, the integral $\oint_C \vec{F} \cdot d\vec{l}$ =_____. Here $d\vec{l}$ represents an infinitesimal length along the contour C. 
(A)	0
(B)	2
(C)	4
(D)	6

Q.12	The Fourier series representation of a square wave is shown in the figure below. The fluctuations seen near $x = \pm 1$ are named after which one of the following scientists? 
(A)	Cauchy
(B)	Fourier
(C)	Gibbs
(D)	Laplace

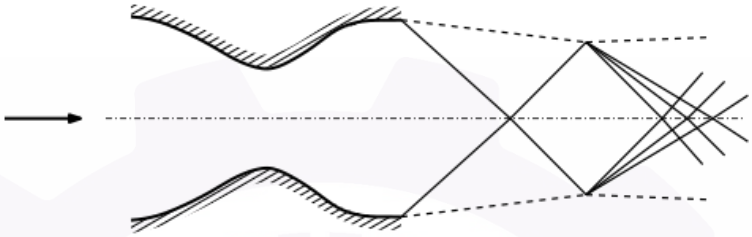
Q.13	The following equation with respect to $\varphi(x,t)$, where a is a non-zero constant, represents _____. $$\frac{\partial \varphi}{\partial t} + a\frac{\partial \varphi}{\partial x} = 0$$
(A)	linear wave propagation
(B)	transient heat conduction
(C)	Newton's law of cooling
(D)	radiative transfer
Q.14	Which one of the following makes an ideal air-standard Stirling cycle?
(A)	Two reversible isobars, and two reversible adiabatics
(B)	Two reversible isotherms, and two reversible isobars
(C)	Two reversible isotherms, and two reversible isochores
(D)	Isentropic compression, constant volume heat addition, isentropic expansion, and constant volume heat rejection

Q.15	In fluid dynamics, d'Alembert's paradox refers to which one of the following?
(A)	Deviation of drag from $D \propto v^2$ at very low speeds
(B)	Deviation of drag from $D \propto v^2$ at high subsonic speeds
(C)	Prediction of zero drag by potential flow theory
(D)	Presence of shocks in transonic flows
Q.16	The number of independent elastic constants that a fully anisotropic linear elastic material can have is _____.
(A)	36
(B)	21
(C)	10
(D)	2

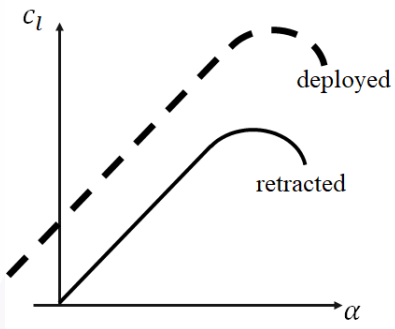
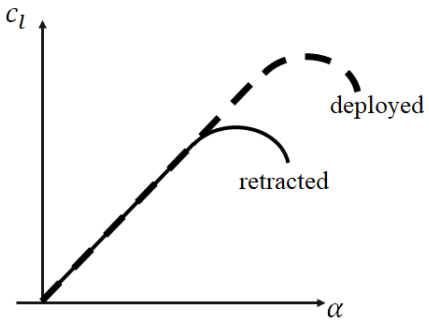
Q.17	A cantilever beam with an unsymmetric cross-section is subjected to a transverse shear force (P) at its free end. P acts at the shear center of the beam cross-section. Which one of the following statements is TRUE about the deformation of this beam?
(A)	The beam undergoes only torsion
(B)	The beam undergoes only bending
(C)	The beam undergoes both torsion and bending
(D)	The beam undergoes neither torsion nor bending

Q.18	The figure below depicts two ideal gas turbine cycles, cycle 1-2-3-4-1 and cycle 1-2-3'-4'-1, on a ***T-s*** diagram. Which one the following statements is FALSE? 
(A)	The thermal efficiency of the two cycles is the same
(B)	The specific work of the two cycles is the same
(C)	The processes 2-3 and 2-3' are isobaric
(D)	The amount of heat added in the combustion process is greater for the cycle 1-2-3'-4'-1

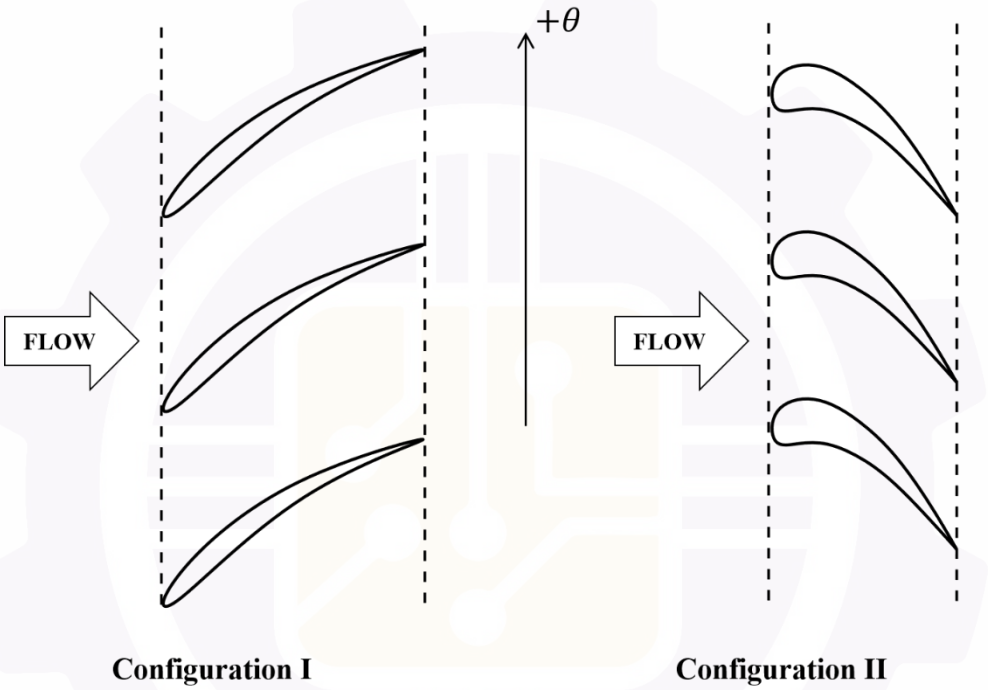
Q.19	The velocity potential function (φ) given below represents which one of the following? $$\varphi = 5x - 12y$$
(A)	Doublet
(B)	Irrotational vortex
(C)	Source
(D)	Uniform flow
Q.20	The fundamental purpose of the Kutta condition in the thin airfoil theory is _____.
(A)	to determine the total strength of the source distribution
(B)	to determine the speed of the uniform flow
(C)	to incorporate the essential effect of viscosity in the potential flow theory
(D)	to incorporate the concept of induced drag in the inviscid theory

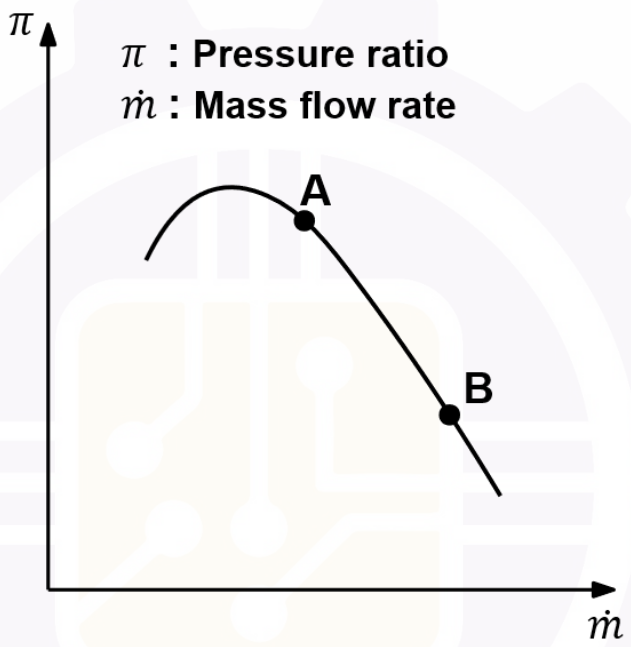
Q.21	In the figure shown below, the flow at the nozzle exit is _____. 
(A)	overexpanded
(B)	underexpanded
(C)	ideally expanded
(D)	subsonic
Q.22	An $n \times n$ square matrix A satisfies $A^T = A^{-1}$. The determinant of this matrix may take which of the following value(s)?
(A)	$+1$
(B)	-1
(C)	n
(D)	0

Q.23	Which of the following statements is/are TRUE about the stability of an aircraft?
(A)	Static stability of an aircraft is sufficient to guarantee its dynamic stability
(B)	Static stability of an aircraft is related only to its initial tendency to return towards the equilibrium position from which it is disturbed
(C)	An aircraft may be dynamically unstable even if it is statically stable
(D)	Dynamic stability is related to the time history of aircraft motion after being disturbed from its equilibrium position
Q.24	For a given air-standard power, the propulsive efficiency of a turbofan engine is more than that of a turbojet engine. Which of the following is/are the reason(s) for this?
(A)	The mass flow rate is more for a turbofan engine
(B)	The exit velocity is lower for a turbofan engine
(C)	A turbofan engine operates at a lower altitude
(D)	The fan of a turbofan engine consumes lesser power

Q.25	Shown below are qualitative illustrations of the lift curve for an airfoil when two different control surfaces are in their respective retracted and deployed configurations. Which of the following is/are TRUE?  **Figure P**  **Figure Q**
(A)	Figure P is for a flap
(B)	Figure P is for a slat
(C)	Figure Q is for a slat
(D)	Figure Q is for a flap

Q.26	The state of stress at a point in a 2-D body, in the *x*-*y* Cartesian coordinate system, is represented in matrix form as [σ]. The transformation matrix [Q] rotates the coordinate system to a new *x'*-*y'* Cartesian coordinate system. Select the CORRECT option(s) that represent(s) the state of stress in the new coordinate system.
(A)	$[Q]\,[\sigma]\,[Q]^{T}$
(B)	$[Q]\,[\sigma]\,[Q]^{-1}$
(C)	$([Q]^{-1})^{T}\,[\sigma]\,[Q]^{T}$
(D)	$[Q]^{-1}\,[\sigma]\,[Q]$

Q.27	The figure below shows the blading of the rotors of two different axial turbomachines under their typical operating conditions, labelled as Configuration I and Configuration II. Which of the following statements is/are TRUE? 
(A)	Configuration I corresponds to the rotor of a compressor and Configuration II corresponds to the rotor of a turbine
(B)	Configuration I corresponds to the rotor of a turbine and Configuration II corresponds to the rotor of a compressor
(C)	The rotor blades of the turbomachine in Configuration I move along the $+\theta$ direction
(D)	The rotor blades of the turbomachine in Configuration II move along the $+\theta$ direction

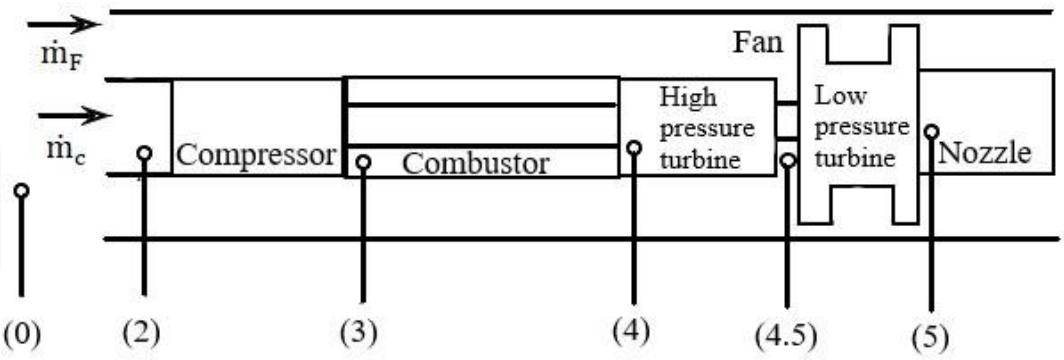
Q.28	A multi-stage axial compressor can be operated at two points, A and B, both of which lie on the same speed line, as shown in the figure below. If η is the isentropic efficiency of the compressor, select the statements that is/are TRUE. 
(A)	$\eta_A > \eta_B$
(B)	$\eta_B > \eta_A$
(C)	In comparison to point B, point A is closer to the surge point
(D)	In comparison to point A, point B is closer to the choke point

Q.29	Which of the following statements is/are TRUE regarding critical and drag divergence Mach numbers of a wing?
(A)	Critical Mach number is the minimum freestream Mach number for which sonic condition is attained somewhere over the wing
(B)	Drag divergence Mach number is always higher than the critical Mach number
(C)	Drag divergence Mach number is the local Mach number over the wing at which the drag increases drastically
(D)	Critical Mach number is independent of the angle of attack
Q.30	A flow is steady, inviscid and one-dimensional, with no shaft work or body forces. Which of the following is/are possible under the given conditions?
(A)	Oblique shocks
(B)	Sound propagation
(C)	Rayleigh flow
(D)	Fanno flow

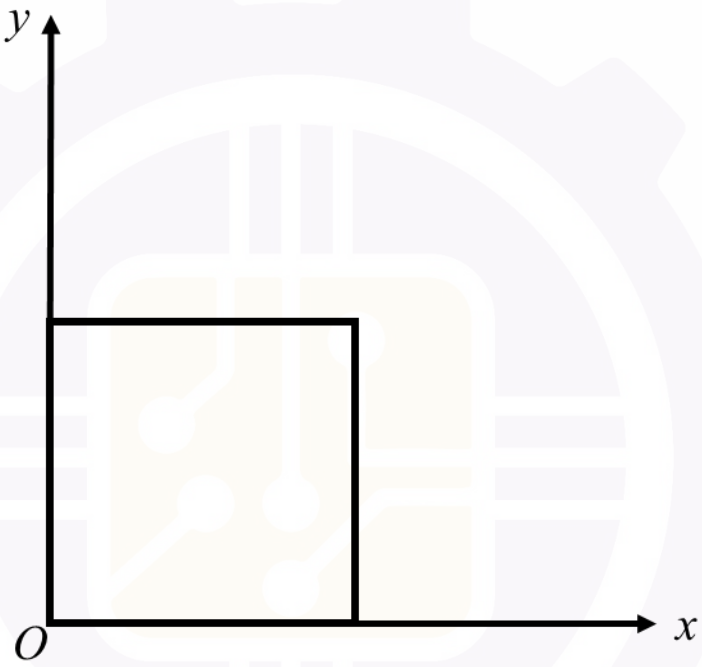
Q.31	An aircraft starts gliding in power-off condition at an altitude of 4 km. Given that the maximum lift to drag ratio of the aircraft is 15, the maximum glide range that the aircraft can cover, measured along the ground, is _____ km (*rounded off to the nearest integer*).
Q.32	If a matrix can be written as $A = uv^T$, where both u and v are n-dimensional real-valued non-zero column vectors, then the rank of the matrix A is _____ (*answer in integer*).
Q.33	The response $x(t)$ of a freely vibrating single degree of freedom underdamped system is given below. In the equation, A and ϕ are constants. The damping ratio of the system is _____ (*rounded off to 3 decimal places*). $$x(t) = A\mathrm{e}^{-5t}\sin(10t + \phi)$$
Q.34	The vortex shedding frequency behind a landing gear model is found to be 50 Hz when tested in a wind tunnel operating at 5 m/s. If the actual landing gear size is 10 times that of the model, and it is designed to operate at 50 m/s, then the expected vortex shedding frequency behind it is _____ Hz (*rounded off to the nearest integer*).
Q.35	An elliptic wing has a span of 6 m and a planform area of 6 m^2. When generating a lift coefficient of 0.6, the induced drag it incurs is _____ $\times 10^{-3}$ (*rounded off to 1 decimal place*).

Q.36 – Q.65 Carry TWO marks Each

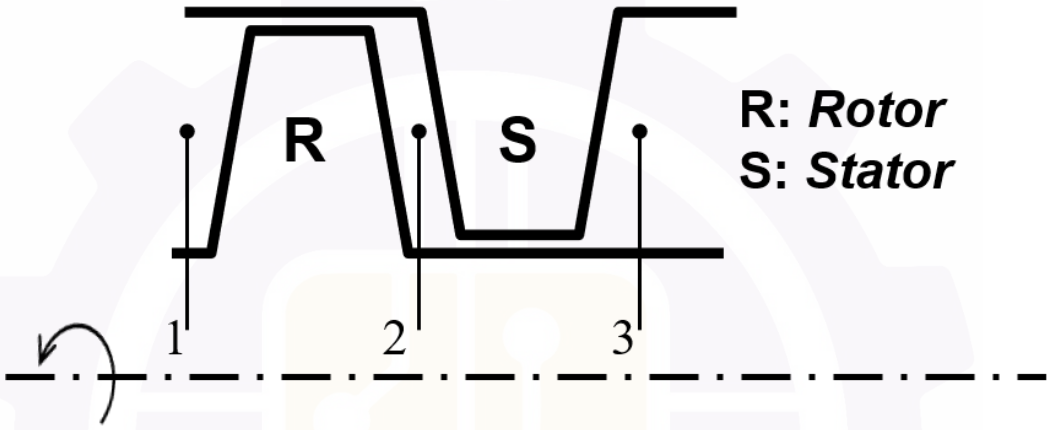
Q.36	An earth satellite has the instantaneous position vector $\vec{r}$ and velocity vector $\vec{v}$ as given below. Here $\hat{p}$ and $\hat{q}$ denote the unit vectors along the x and y axes of the perifocal frame, respectively. Assume that the value of gravitational parameter is 398600 km^3/s^2. Which one of the following trajectories does the satellite follow? $\vec{r} = (8000\hat{p} + 9000\hat{q})$ km and $\vec{v} = (-6\hat{p} + 6\hat{q})$ km/s
(A)	Circle
(B)	Hyperbola
(C)	Parabola
(D)	Straight line
Q.37	For the matrix $A = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$, if the relation $a + b = c + d$ holds and $a, b, c, d \neq 0$, then which one of the following statements about A is FALSE?
(A)	$\begin{bmatrix} 1 \\ 1 \end{bmatrix}$ is an eigenvector
(B)	$\lambda = a + b$ is an eigenvalue
(C)	$\lambda = d - b$ is an eigenvalue
(D)	$\lambda = d + b$ is an eigenvalue

Q.38	In an ideal turbofan engine shown in the figure below, the compressor is driven by the high pressure turbine, and the fan is driven by the low pressure turbine. The stations 0, 2, 3, 4, 4.5, and 5 refer to free-stream, compressor inlet, compressor outlet, combustor exit, high pressure turbine exit, and low pressure turbine exit, respectively, and the subscript 't' refers to the total condition. Also, $\tau_r = T_{t0}/T_0$, $\tau_c = T_{t3}/T_{t2}$ and $\tau_\lambda = T_{t4}/T_0$. The total temperature ratio of the high pressure turbine $(T_{t4.5}/T_{t4})$ is given by _____. 
(A)	$1 - \frac{\tau_r}{\tau_\lambda}(\tau_c - 1)$
(B)	$1 + \frac{\tau_r}{\tau_\lambda}(\tau_c + 1)$
(C)	$1 - \frac{\tau_r}{\tau_\lambda}(\tau_c + 1)$
(D)	$1 + \frac{\tau_r}{\tau_\lambda}(\tau_c - 1)$

Q.39	An ideal rocket has characteristic exhaust velocity of 1200 m/s, mass flow rate of 75 kg/s, thrust coefficient of 1.5, and nozzle throat area of 0.025 m^2. The chamber pressure in kPa and the specific impulse due to gravity in seconds are _____, respectively. Assume that the acceleration due to gravity is 9.8 m/s^2.
(A)	3600 and 183.67
(B)	4600 and 190.51
(C)	3600 and 175.23
(D)	3500 and 183.67

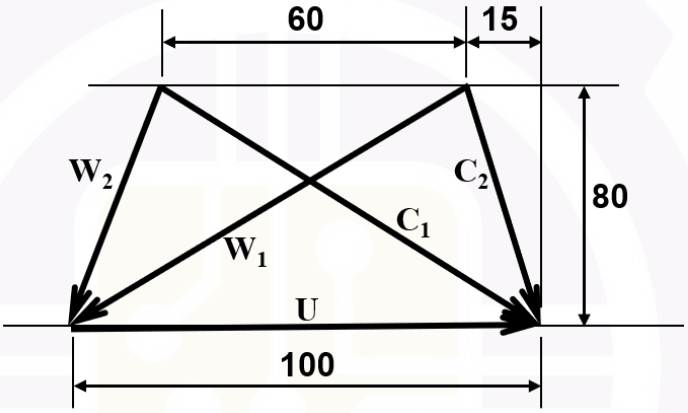
Q.40	Consider a unit square body as shown in the figure below. The body is subjected to the deformation field $u = -ay$ and $v = ax$, where 'a' is a constant. Due to the application of this deformation field, the body undergoes _____ in the x-y plane. 
(A)	biaxial deformation
(B)	pure shear
(C)	pure bending
(D)	rigid body rotation

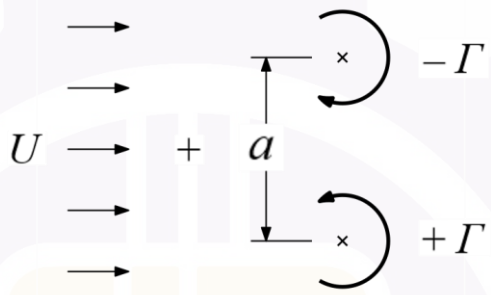
Q.41	Consider a launch vehicle of mass 10 tons being launched vertically. The vehicle has 8 tons of propellant, which burns completely at a constant rate over 50 s. If the engine specific impulse is 250 s, and the acceleration due to gravity at sea level is g_0, the acceleration experienced by the vehicle at lift-off is _____.
(A)	g_0
(B)	$2g_0$
(C)	$3g_0$
(D)	$4g_0$

Q.42	The figure below shows a compressor stage with station numbers 1, 2, and 3 as indicated. If p_{0i}, T_{0i}, and C_i refer to the average values of total pressure, total temperature, and absolute flow speed, respectively, at the i^{th} station, select the CORRECT option considering losses. 
(A)	$p_{01} < p_{02},\ p_{02} > p_{03}\ ;\ \ T_{01} < T_{02},\ T_{02} \approx T_{03}\ ;\ \ C_1 < C_2,\ C_2 > C_3$
(B)	$p_{01} < p_{02},\ p_{02} = p_{03}\ ;\ \ T_{01} < T_{02},\ T_{02} \approx T_{03}\ ;\ \ C_1 < C_2,\ C_2 = C_3$
(C)	$p_{01} < p_{02},\ p_{02} > p_{03}\ ;\ \ T_{01} < T_{02},\ T_{02} < T_{03}\ ;\ \ C_1 > C_2,\ C_2 > C_3$
(D)	$p_{01} < p_{02},\ p_{02} < p_{03}\ ;\ \ T_{01} < T_{02}, T_{02} < T_{03}\ ;\ \ C_1 = C_2 = C_3$

Q.43	An experimental study is planned to map out the low-Reynolds number incompressible steady two-dimensional aerodynamic characteristics of a promising novel airfoil. The operational parameters of the problem are the speed, density and viscosity of the freestream, the chord of the airfoil and its angle of attack. If the objective is to achieve this with the minimum number of test runs N_{min} while taking 10 equally-spaced test values of each independent parameter of the problem in a suitable range, then N_{min} is _____.
(A)	10
(B)	100
(C)	10,000
(D)	1,00,000
Q.44	Which of the following process(es) is/are involved in the compression of air in an ideal ramjet engine?
(A)	oblique shock
(B)	mechanical compression
(C)	normal shock
(D)	subsonic diffusion

Q.45	The deformation of an open-section bar subjected to pure torsion can be solved by choosing an appropriate Prandtl stress function. Which of the following statements is/are true about the Prandtl stress function?
(A)	It satisfies the equilibrium equation
(B)	It is zero on the lateral surfaces of the bar
(C)	It satisfies the compatibility equation
(D)	It does not satisfy the equilibrium equation

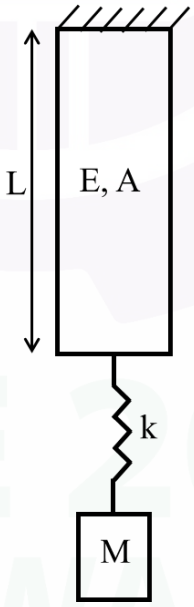
Q.46	The figure below shows the velocity triangles at the inlet and outlet of the rotor of a low hub-to-tip ratio axial compressor at the mid-span of the blade. The absolute and relative velocities of the flow are denoted by **C** and **W**, respectively. The subscripts 1 and 2 refer to the locations before and after the rotor, respectively. The blade velocity is denoted by **U**. Select the CORRECT statement(s) for this device.  All values are in m/s.
(A)	The axial velocity is constant across the rotor
(B)	The flow coefficient is 0.6
(C)	The blade loading coefficient is 0.6
(D)	If the acoustic velocity at the rotor inlet is 350 m/s, then the inlet relative Mach number is 0.333

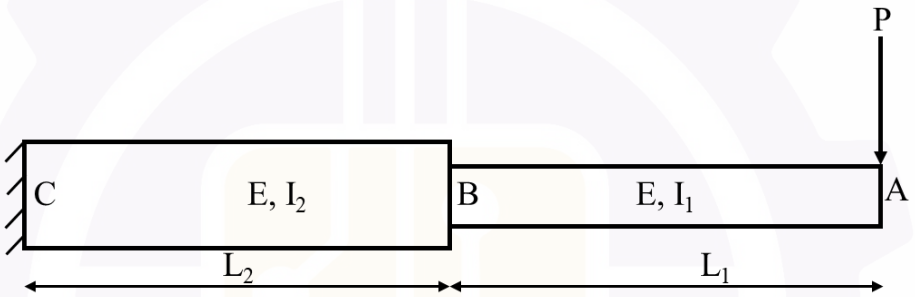
Q.47	Consider the flow over an oval modeled using the elementary potential flows as shown below. U represents uniform flow velocity and Γ represents circulation around an irrotational line vortex.  Which of the following statements is/are TRUE for this model?
(A)	Increasing U enlarges the oval
(B)	Increasing Γ enlarges the oval
(C)	Interchanging the sense of the two vortices does not alter the oval
(D)	Moving the vortices too far apart causes the oval to break up

Q.48	What is/are the use(s) of the single horseshoe vortex model of finite wing aerodynamic theory?
(A)	It can approximate the wing pitching moment coefficient
(B)	It can approximate the wing induced drag coefficient
(C)	It can approximate the effect of the wing on the induced drag coefficient of a typical horizontal tail
(D)	It can approximate the aerodynamic benefit/penalty of formation flight compared to isolated flight
Q.49	Consider the differential equation with the initial conditions given below. If $y(x)$ is the solution of the equation, the value of the slope, $\frac{dy}{dx}$, at $x = \ln(2)$ is _____ (*rounded off to three decimal places*). $$\frac{d^2y}{dx^2} + 2\frac{dy}{dx} + y = 0 \quad \text{with } y\big\vert_{x=0} = 0 \text{ and } \left.\frac{dy}{dx}\right\vert_{x=0} = 1$$
Q.50	An object of mass 1 kg is launched with an initial speed of v_o into a large tank filled with a viscous liquid. The liquid exerts a resistive force (drag) of the form $D = \alpha v$ on any object that is moving inside it, where v is the instantaneous speed of the object and $\alpha = 1$ kg/s. If the effect of gravity is ignored, the time taken by the object to slow down to the speed $v_o/2$ is _____ s (*rounded off to 2 decimal places*). Assume that the tank is sufficiently large for the above deceleration to happen inside the tank.

<table>
<tr><td>Q.51</td><td>The minimum value of the function $f(x) = |x| + |2x + 3|$ for real x is _____ (rounded off to 1 decimal place).</td></tr>
<tr><td>Q.52</td><td>Isobutane (C_4H_{10}) is burnt completely in pure oxygen as per the reaction given below. Given that the standard heats of formation (in kcal/mole) of isobutane, carbon dioxide, and water vapour are –31.489, –94.052, and –60.150, respectively, the heat of reaction is _____ kcal (rounded off to 2 decimal places).

$C_4H_{10} + 6.5\ O_2 \rightarrow 4\ CO_2 + 5\ H_2O$</td></tr>
<tr><td>Q.53</td><td>A furnace of 250 MW rating is used to melt and raise the temperature of aluminium from 25 ^oC to 900 ^oC. Aluminium has a solid-state specific heat, latent heat, and liquid-state specific heat of 0.9 kJ/kg-K, 390 kJ/kg, and 1.108 kJ/kg-K, respectively, and the furnace has 70% efficiency. The melting point of aluminium is 660 ^oC. The amount of aluminium that can be processed per hour is _____ kg (rounded off to 1 decimal place).</td></tr>
<tr><td>Q.54</td><td>For an airfoil section the pitching moment coefficient is determined about a reference point that is 0.3 times the chord behind the leading edge. It varies with the lift coefficient as shown in the table below. The distance of the aerodynamic center from the leading edge of the airfoil as a fraction of the chord is _____ (rounded off to one decimal place).
<table>
<tr><td>c_l</td><td>0.2</td><td>0.4</td><td>0.6</td><td>0.8</td></tr>
<tr><td>c_m</td><td>– 0.02</td><td>0</td><td>0.02</td><td>0.04</td></tr>
</table>
</td></tr>
<tr><td>Q.55</td><td>An earth satellite moves in an elliptical orbit with a perigee altitude of 300 km and an apogee altitude of 3000 km. Assume that the radius of the earth is 6378 km. The eccentricity of the orbit is _____ (rounded off to three decimal places).</td></tr>
<tr><td>Q.56</td><td>Consider a finite wing of aspect ratio 10 with span effectiveness factor 0.95. Its airfoil section has a lift slope of 0.106 per degree and a zero-lift angle of attack of –1.5°. The lift coefficient of the wing at an angle of attack of 3.5° is _____ (rounded off to 2 decimal places).</td></tr>
</table>

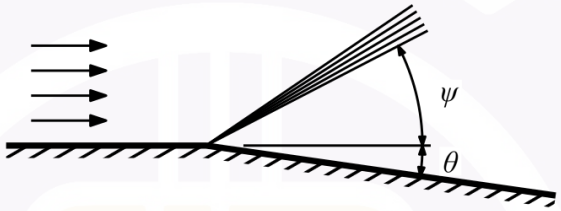
Q.57	W_A and W_B are the respective maximum take-off weights of an aircraft for two ambient air conditions given below. Condition A: $p = 1$ bar, $T = 50\,^{o}$C; Condition B: $p = 0.66$ bar, $T = -30\,^{o}$C If all other parameters relevant for take-off are kept the same in these two conditions, the ratio W_B/W_A is _____ (*rounded off to 3 decimal places*).
Q.58	A thin-walled circular tube is made of a material whose magnitude of the ultimate strength, both in tension and compression, is 200 MPa. The mean radius of the tube is 0.2 m and the wall thickness is 0.004 m. Based on the maximum stress criteria, the maximum torque that the tube can sustain is _____ kN-m (*round off to the nearest integer*).
Q.59	A system comprising a bar, spring and mass is shown in the figure below. The bar, having negligible mass, is made of a material having Young's modulus E = 200 GPa, cross-sectional area A = 100 mm^2, and length L = 100 mm. The spring stiffness k = 200 kN/mm and the mass M = 100 kg. The natural frequency of free vibration of the system is _____ rad/s (*rounded off to the nearest integer*). 

Q.60	A stepped cantilever beam, made of a material having Young's modulus E = 200 GPa, is shown in the figure below. The length and the moment of inertia of the beam from point A to B are L_1 = 100 mm and I_1 = 100 mm^4, respectively. The length and the moment of inertia of the beam from point B to C are L_2 = 100 mm and I_2 = 700 mm^4, respectively. A shear force P = 30 N is applied at point A of the beam. The magnitude of the deflection of the beam at point A is _____ mm (*rounded off to 1 decimal place*). 
Q.61	A centrifugal compressor has a constant-width radial diffuser. The diameters at the diffuser inlet and outlet are 0.2 m and 0.3 m, respectively. The flow at the diffuser inlet and outlet is assumed to be steady and uniform. The average velocity at the diffuser inlet and outlet are $(60\ \hat{\mathbf{e}}_\mathbf{r} + 75\ \hat{\mathbf{e}}_\boldsymbol{\theta})$ m/s and $(u\ \hat{\mathbf{e}}_\mathbf{r} + 50\ \hat{\mathbf{e}}_\boldsymbol{\theta})$ m/s, respectively. If the flow through the diffuser is treated as steady and incompressible, the value of u is _____ (*rounded off to the nearest integer*).
Q.62	A gas mixture at a pressure of 800 kPa and a density of 5 kg/m^3 enters a turbine stage. The temperature of the gas at the nozzle exit and the stage exit are 790 K and 750 K, respectively. Assume the specific heats are constant for the gas mixture in the range of temperatures considered. The specific heat at constant pressure is 0.72 kJ/kg-K and the ratio of specific heats is 1.33. The value of the degree of reaction of the turbine stage is _____ (*rounded off to 2 decimal places*).
Q.63	Thin airfoil theory predicts the zero-lift angle of attack $\alpha_{L=0}$ of NACA 2412 airfoil as $-2.1°$. The corresponding prediction of $\alpha_{L=0}$ for NACA 5410 airfoil is _____ degrees (*rounded off to 1 decimal place*).

Q.64

Consider a centered Prandtl-Meyer expansion fan at a $\theta = 4°$ corner in a Mach 1.78 air flow, as shown in the figure below. The angle ψ (see figure) made by the ending wave of the fan with respect to the incoming stream is _____ degrees (*rounded off to 1 decimal place*).

An excerpt from the table of Prandtl-Meyer function for air is provided below.



M	ν [deg]	M	ν [deg]	M	ν [deg]
1.72	18.40	1.82	21.30	1.92	24.15
1.74	18.98	1.84	21.88	1.94	24.71
1.76	19.56	1.86	22.45	1.96	25.27
1.78	20.15	1.88	23.02	1.98	25.83
1.80	20.73	1.90	23.59	2.00	26.38

Q.65

A Mach 1.5 air flow enters a round duct of length 20 cm and diameter 3 cm. If the flow exits with Mach number 1.1, the average Fanning friction factor f of the duct is _____ $\times 10^{-3}$ (*rounded off to 1 decimal place*).

An excerpt from the Fanno flow table for air is given below.

M	1.1	1.2	1.3	1.4	1.5	1.6
$\frac{4fL^*}{D} \times 10^4$	99.35	336.4	648.3	997.4	1361	1724