Q. 1 – Q. 5 carry one mark each.

Q.1 Once the team of analysts identify the problem, we __________ in a better position to comment on the issue.

Which one of the following choices CANNOT fill the given blank?

(A) will be
(B) were to be
(C) are going to be
(D) might be

Q.2 A final examination is the __________ of a series of evaluations that a student has to go through.

(A) culmination
(B) consultation
(C) desperation
(D) insinuation

Q.3 If IMHO = JNIP; IDK = JEL; and SO = TP, then IDC = ____.

(A) JDE (B) JED (C) JDC (D) JCD

Q.4 The product of three integers X, Y and Z is 192. Z is equal to 4 and P is equal to the average of X and Y. What is the minimum possible value of P?

(A) 6 (B) 7 (C) 8 (D) 9.5

Q.5 Are there enough seats here? There are _________ people here than I expected.

(A) many (B) most (C) least (D) more

Q. 6 – Q. 10 carry two marks each.

Q.6 Fiscal deficit was 4% of the GDP in 2015 and that increased to 5% in 2016. If the GDP increased by 10% from 2015 to 2016, the percentage increase in the actual fiscal deficit is ___.

(A) 37.50 (B) 35.70 (C) 25.00 (D) 10.00

Q.7 Two pipes P and Q can fill a tank in 6 hours and 9 hours respectively, while a third pipe R can empty the tank in 12 hours. Initially, P and R are open for 4 hours. Then P is closed and Q is opened. After 6 more hours R is closed. The total time taken to fill the tank (in hours) is ____.

(A) 13.50 (B) 14.50 (C) 15.50 (D) 16.50

Q.8 While teaching a creative writing class in India, I was surprised at receiving stories from the students that were all set in distant places: in the American West with cowboys and in Manhattan penthouses with clinking ice cubes. This was, till an eminent Caribbean writer gave the writers in the once-colonised countries the confidence to see the shabby lives around them as worthy of being "told".

The writer of this passage is surprised by the creative writing assignments of his students, because ______________.

(A) Some of the students had written stories set in foreign places
(B) None of the students had written stories set in India
(C) None of the students had written about ice cubes and cowboys
(D) Some of the students had written about ice cubes and cowboys

Q.9 Mola is a digital platform for taxis in a city. It offers three types of rides – Pool, Mini and Prime. The Table below presents the number of rides for the past four months. The platform earns one US dollar per ride. What is the percentage share of revenue contributed by Prime to the total revenues of Mola, for the entire duration?

Type	**Month**			
	January	**February**	**March**	**April**
Pool	170	320	215	190
Mini	110	220	180	70
Prime	75	180	120	90

(A) 16.24 (B) 23.97 (C) 25.86 (D) 38.74

Q.10 X is an online media provider. By offering unlimited and exclusive online content at attractive prices for a loyalty membership, X is almost forcing its customers towards its loyalty membership. If its loyalty membership continues to grow at its current rate, within the next eight years more households will be watching X than cable television.

Which one of the following statements can be inferred from the above paragraph?

(A) Most households that subscribe to X's loyalty membership discontinue watching cable television
(B) Non-members prefer to watch cable television
(C) Cable television operators don't subscribe to X's loyalty membership
(D) The X is cancelling accounts of non-members

END OF THE QUESTION PAPER

XE-A: Q. 1 – Q. 7 carry one mark each & Q. 8 – Q. 11 carry two marks each.

Q.1 Let X be the Poisson random variable with parameter $\lambda = 1$. Then, the probability $P(2 \leq X \leq 4)$ equals

(A) $\frac{19}{24e}$ (B) $\frac{17}{24e}$ (C) $\frac{13}{24e}$ (D) $\frac{11}{24e}$

Q.2 For the series $\sum_{n=1}^{\infty} \frac{(x+1)^n}{n\, 2^n}, -\infty < x < \infty$, which of the following statements is **NOT** correct?

(A) The series converges at $x = -3$
(B) The series converges at $x = -1$
(C) The series converges at $x = 0$
(D) The series converges at $x = 1$

Q.3 Let $f(z) = \bar{z}e^{-|z|^2}$, where $\bar{z}$ is the complex conjugate of z. Then, it is differentiable on

(A) $|z| > 1$ (B) $|z| < 1$ (C) $|z| = 1$ (D) the entire complex plane $\mathbb{C}$

Q.4 If the transformation $u(x,t) = e^x v(x,t)$ reduces the partial differential equation $\frac{\partial^2 u}{\partial x^2} - 2\frac{\partial u}{\partial x} - \frac{\partial u}{\partial t} + u = 9$ to the equation $\frac{\partial v}{\partial t} - \frac{\partial^2 v}{\partial x^2} = 9\, f(x)$, then $f(x)$ equals

(A) $-e^{-x}$ (B) e^{-x} (C) $-2e^{-x}$ (D) $2e^{-x}$

Q.5 The value of α for which the system of equations

$$x - y - 3z = 3$$
$$2x + z = 0$$
$$-2y - 7z = \alpha$$

has a solution is _______ .

Q.6 The value of the line integral $\frac{2}{\pi}\oint_{\gamma}(-y^3dx + x^3dy)$, where γ is the circle $x^2 + y^2 = 1$ oriented counter clockwise, is _______ .

Q.7 Let $y_1(x)$ and $y_2(x)$ be two linearly independent solutions of the differential equation $x^2\frac{d^2y}{dx^2} + x\frac{dy}{dx} - 4y = 0, x > 0$. If $y_1(x) = x^2$, then $\lim_{x\to\infty} y_2(x)$ is _______ .

Q.8 If $Q = \begin{pmatrix} 3 & 2 & 4 \\ 2 & 0 & 2 \\ 4 & 2 & 3 \end{pmatrix}$ and $P = (\boldsymbol{v}_1 \quad \boldsymbol{v}_2 \quad \boldsymbol{v}_3)$ is the matrix where $\boldsymbol{v}_1, \boldsymbol{v}_2$ and $\boldsymbol{v}_3$ are linearly independent eigenvectors of the matrix Q, then the sum of the **absolute** values of all the elements of the matrix $P^{-1}QP$ is

(A) 6 (B) 10 (C) 14 (D) 22

Q.9 If $P(x) = ax^3 + bx^2 + cx + d$ is the polynomial obtained by Lagrange interpolation satisfying $P(0) = -8,\ P(1) = -7,\ P(2) = -6$ and $P(4) = 20$, then the value of $a - b + c$ is

(A) 1 (B) 3 (C) 5 (D) 7

Q.10 The number of critical points of the function $f(x, y) = x^3 + 3xy^2 - 15x - 12y$ at which there is neither maximum nor minimum is _______ .

Q.11 Let $I = \frac{10^5 i}{2\pi}\oint_{\gamma}\frac{dz}{(z-4)(z^7-1)}$, where $i = \sqrt{-1}$ and γ is the circle $|z| = 2$ oriented counter clockwise. Then, the value of I rounded off to one decimal place is _______ .

END OF THE QUESTION PAPER

XE -B: Q. 1 – Q. 9 carry one mark each

Q.1 For stable equilibrium of a floating body, which one of the following statements is correct?

(A) Centre of gravity must be located below the centre of buoyancy.
(B) Centre of buoyancy must be located below the centre of gravity.
(C) Metacentre must be located below the centre of gravity.
(D) Centre of gravity must be located below the metacentre.

Q.2 If u and v are the velocity components in the x- and y-directions respectively, the z-component of vorticity ω_z at a point in a flow field is

(A) $\frac{\partial v}{\partial x}+\frac{\partial u}{\partial y}$ (B) $\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}$ (C) $\frac{\partial v}{\partial y}+\frac{\partial u}{\partial x}$ (D) $\frac{\partial v}{\partial y}-\frac{\partial u}{\partial x}$

Q.3 In which one of the following devices the difference between static and total pressure is used to determine the flow velocity?

(A) Piezometer (B) Pitot static tube (C) Orificemeter (D) Venturimeter

Q.4 A golf ball is dimpled to make the flow turbulent and consequently to reduce the drag. Turbulent flow reduces the drag on the golf ball because

(A) skin friction coefficient is lower in a turbulent flow.
(B) skin friction coefficient is higher in a turbulent flow.
(C) turbulent flow has a lower tendency to separate.
(D) turbulent flow has a higher tendency to separate.

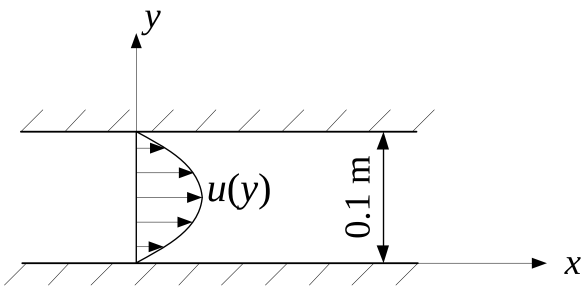
Q.5 For a steady laminar incompressible boundary layer flow over a sharp-edged flat plate at zero incidence,

(A) the edge of the boundary layer is a streamline.
(B) the edge of the boundary layer is a pathline.
(C) the skin friction coefficient decreases as the distance from the leading edge increases.
(D) the skin friction coefficient remains constant all along the plate.

Q.6 The power input P to a centrifugal pump is a function of the volume flow rate Q, impeller diameter D, rotational speed Ω, fluid density ρ, dynamic viscosity μ, and surface roughness ϵ. To carry out a dimensional analysis using Buckingham's π theorem, which one of the following sets can be taken as the set of repeating variables?

(A) Q, Ω, D (B) Q, ϵ, D (C) ϵ, D, ρ (D) D, ρ, Ω

Q.7 Consider the two-dimensional laminar flow of water (μ = 0.001 N.s/m^2) between two infinitely long parallel plates 0.1 m apart as shown in the figure below. The velocity profile at any location is given by $u(y) = 100(0.1y - y^2)$ m/s where y is in m. The magnitude of shear stress (in N/m^2, rounded off to 2 decimal places) acting on the bottom plate is _______



Q.8 The maximum velocity in a fully developed laminar incompressible flow through a circular pipe of constant cross-sectional area is 6 m/s. The average velocity (in m/s) of the flow is _______

Q.9 The theoretical discharge for the flow through an orificemeter is 40 m^3/s. If the measured discharge in an experiment is 32 m^3/s, then the discharge coefficient (rounded off to one decimal place) is _______

XE - B: Q. 10 – Q. 22 carry two marks each.

Q.10 Consider the flow between two infinitely long parallel plates of large width separated by a distance $2H$. The upper plate is moving with a constant velocity U while the lower plate is stationary. The volumetric flow rate per unit width of the plate is

(A) $0.25\ UH$ (B) $0.5\ UH$ (C) UH (D) $2\ UH$

Q.11 The velocity field in Cartesian coordinates in a two-dimensional steady incompressible flow of a fluid with density ρ is $\mathbf{V} = x\mathbf{i} - y\mathbf{j}$. Assuming no body and line forces, the magnitude of pressure gradient ∇p at point (1,1) is

(A) $\sqrt{2}\,\rho$ (B) ρ (C) $\rho/\sqrt{2}$ (D) $\rho/2$

Q.12 A two-dimensional velocity field in Cartesian coordinates is defined by $\mathbf{V} = y\mathbf{i} - x\mathbf{j}$. This flow is

(A) compressible and rotational (B) compressible and irrotational
(C) incompressible and rotational (D) incompressible and irrotational

Q.13 Assertion [a]: The streamlines in a free vortex flow are concentric circles.
Reasoning [r]: There exists only radial component for the velocity field in a free vortex flow.

(A) Both [a] and [r] are true and [r] is the correct reason for [a]
(B) Both [a] and [r] are true but [r] is not the correct reason for [a]
(C) [a] is true but [r] is false
(D) [a] is false but [r] is true

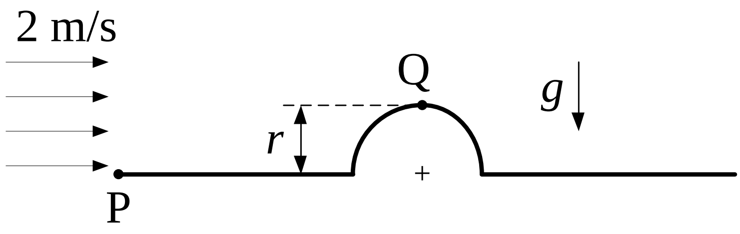
Q.14 The velocity components in Cartesian coordinates in a two-dimensional incompressible flow are $u = e^y \cos(x)$ and $v = e^y \sin(x)$. The magnitude of total acceleration at the point $(-1,1)$ is

(A) 0 (B) 1 (C) e (D) e^2

Q.15 For steady laminar flow at zero incidence over a flat plate, the component of velocity parallel to the plate in the boundary layer is given by $u(y) = a + by + cy^2$, where y is the distance measured normal to the flat plate. If μ is the coefficient of dynamic viscosity, U is the velocity parallel to the wall at the edge of the boundary layer and δ is the boundary layer thickness, the wall shear stress is given by

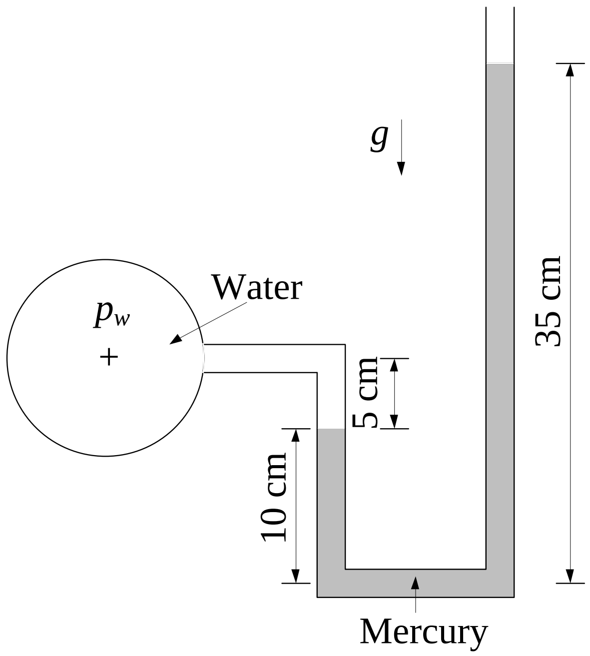
(A) $\mu U/\delta$ (B) $2\mu U/\delta$ (C) $2\mu(U/\delta)^2$ (D) $3\mu U/\delta$

Q.16 A fluid with constant density of 1 kg/m^3 flows past a semi-cylindrical structure with a freestream velocity of 2 m/s as shown in the figure below. The difference in static pressure between points P and Q is 10 N/m^2. If the gravitational acceleration g is 10 m/s^2 and the flow is assumed to be potential, what is the radius r (in m) of the semi-cylindrical structure?



(A) 1 (B) 0.8 (C) 0.6 (D) 0.4

Q.17 The mercury manometer shown in the figure below is connected to a water pipe at one end while the other end is open to the atmosphere. The density of water is 1000 kg/m^3, the specific gravity of mercury is 13.6 and the gravitational acceleration g is 10 m/s^2. The gauge pressure p_w (in kN/m^2, rounded off to 2 decimal places) in the water pipe is ________

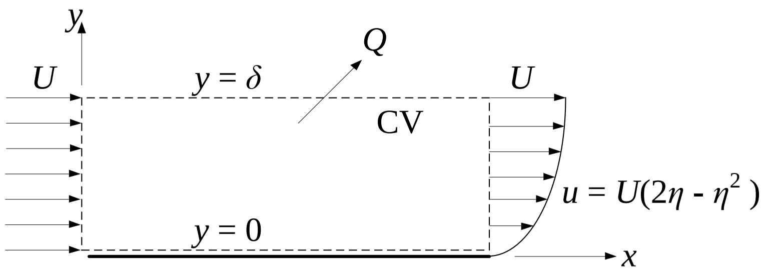


Q.18 Water (ρ = 1000 kg/m^3, μ = 0.001 N.s/m^2) flows through a smooth circular pipe of radius 0.05 m. If the flow Reynolds number is 1000, then the pressure drop (in N/m^2, rounded off to 2 decimal places) over a length of 5 m will be ________

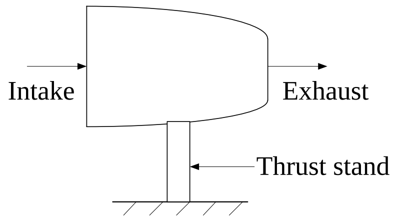
Q.19 A uniform flow with a velocity of 2 m/s in the x-direction approaches a line source placed on the x-axis at a distance of 0.1 m from the origin. If the origin is the stagnation point in the resulting flow, the strength of the source (in m^2/s, rounded off to 2 decimal places) is ________

Q.20 In a steady incompressible flow of a fluid past a smooth stationary sphere, the drag force F depends on the flow velocity U, diameter D, and the dynamic viscosity μ and density ρ of the fluid. Experiments are conducted on the same sphere at the same flow velocity using two different fluids. The density of the second fluid is two times that of the first fluid. The dynamic viscosity of the second fluid is n times that of the first fluid. If the non-dimensional force $F/(\rho U^2 D^2)$ remains the same in both the experiments, the value of n is ________

Q.21 An incompressible fluid flows past a flat plate as shown in the figure below with a uniform inlet velocity profile $u = U$ and a parabolic exit velocity profile $u = U(2\eta - \eta^2)$, where u is the component of velocity parallel to the wall, y is the normal distance from the plate and $\eta = y/\delta$. If the volume flow rate across the top surface of the control volume (CV) is $Q = pU\delta$ per unit width (perpendicular to the x-y plane) of the plate, the value of p (rounded off to 2 decimal places) is ________



Q.22 A jet engine is to be tested on a thrust stand as shown in the figure below. The conditions prevailing in a typical test are as follows: Axial intake air velocity = 100 m/s; axial exhaust gas velocity = 250 m/s; intake cross-sectional area = 1 m^2; intake static pressure = -22 kPa (gauge); exhaust static pressure = 0 kPa (gauge); mass flow rate through the engine = 100 kg/s. The anchoring force (in kN) in axial direction on the thrust stand is ________



END OF THE QUESTION PAPER

XE (C): Q. 1 – Q. 9 carry one mark each & Q. 10 – Q. 22 carry two marks each.

Q.1 On decreasing the objective aperture size in an optical microscope

(A) the spherical aberration increases
(B) the depth of field increases
(C) the diffraction-limited resolution increases
(D) the astigmatism increases

Q.2 Pilling-Bedworth ratios for oxides of some metals are given in the table.

Metal	Pilling-Bedworth Ratio
Li	0.57
Ce	1.16
Ta	2.33
W	3.40

Based on the criterion of Pilling-Bedworth ratio alone, which one of the following metals will be most protected from high temperature oxidation?

(A) Li (B) Ce (C) Ta (D) W

Q.3 In NaCl, the substitution of a Na^+ ion by a Ca^{2+} ion would most probably lead to

(A) the formation of a Na^+ vacancy
(B) the creation of a Cl^- interstitial
(C) the formation of a Cl^- vacancy
(D) the formation of a Na^+ and Cl^- vacancy pair

Q.4 Which one of the following is time-independent?

(A) Elastic deformation (B) Anelastic deformation
(C) Viscoelastic deformation (D) Creep deformation

Q.5 Copper is diffused into aluminium at 400 °C for 100 hours to obtain a certain concentration at a given depth. In another experiment conducted at 500 °C, to achieve the same concentration of copper at the same depth, the time required in hours is

(*Given: Diffusion coefficients of copper in aluminium at* 400 °*C and* 500 °*C are* 5×10^{-14} $m^2\, s^{-1}$ and 6×10^{-13} $m^2\, s^{-1}$, *respectively*)

(A) 7.33 (B) 8.33 (C) 9.33 (D) 10.33

Q.6 If carbon (C) in iron (Fe) is 6 percent by weight, then its atomic percent is approximately

(*Given: atomic weight C* = 12, *Fe* = 56)

(A) 13 (B) 23 (C) 30 (D) 50

Q.7 GaAs has advantage over silicon when used in intergrated circuits at low power because it has

(A) larger band gap
(B) more than one element
(C) higher electron mobility
(D) higher hole mobility

Q.8 Glass transition temperature of a polymer can be determined by

(A) Thermo-gravimetric analysis
(B) Raman spectroscopy
(C) NMR spectroscopy
(D) Differential scanning calorimetry

Q.9 The maximum wavelength of radiation to which Germanium (Ge) is opaque will be

(*Given: energy gap of Ge* = 0.67 *eV*, *Planck's constant* $h = 6.63 \times 10^{-34}$ *J s*, *velocity of light* $c = 3\times10^{8}$ $m\ s^{-1}$ *and* 1 *eV* = 1.6×10^{-19} *J*)

(A) 0.8 μm (B) 1.8 μm (C) 2.8 μm (D) 4.8 μm

Q.10 An alternating copolymer has number-averaged molecular weight of 10^5 g mol^{-1} and degree of polymerization of 2210. If one of the repeat units is ethylene, the other one is

(Given: atomic weight of H = *1*, C = *12*, F = *19 and* Cl = *35.5)*

(A) $-CH_2-CH(CH_3)-$
(B) $-CH_2-CHCl-$
(C) $-CF_2-CF_2-$
(D) $-CH_2-CH(C_6H_5)-$

Q.11 Match the sintering processes in **column I** with the most suitable products in **column II**.

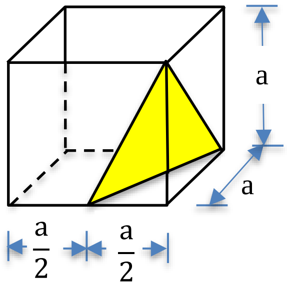
Column I	**Column II**
(P) Solid state sintering	(1) Carbon nanotube products
(Q) Liquid phase sintering	(2) Mixture of Cu and Zn powder products
(R) Spark plasma sintering	(3) Iron powder products
(S) Laser sintering	(4) 3D printed products

(A) P-4; Q-1; R-2; S-3
(B) P-3; Q-2; R-1; S-4
(C) P-3; Q-2; R-4; S-1
(D) P-2; Q-3; R-1; S-4

Q.12 Which one of the following conditions will NOT favour the separation of impurities in zone refining process?

(A) Increase in the gap between solidus and liquidus lines
(B) Increase in the solubility of impurities in solid as compared to that in liquid phase
(C) Agitation of melt
(D) Low cooling rate of melt

Q.13 A monochromatic X-ray beam of wavelength 0.154 nm is incident on a cubic crystal having lattice parameter a = 0.245 nm. The diffraction angle (2θ) for the first order reflection from a set of planes represented by the schematic plane below is ______degrees. *(round off to 1 decimal place)*



Q.14 Nickel corrodes at 298 K in a solution of 0.06 M nickel chloride having pH 4. Assuming complete dissociation of nickel chloride, the partial pressure of hydrogen required to stop the corrosion of nickel is _____ atm. *(round off to the nearest integer)*

(*Given: Standard reduction potential of nickel = − 0.25 V, Faraday's constant = 96500 C mol^{-1}, Universal gas constant = 8.314 J K^{-1}mol^{-1}*)

Q.15 The potential energy, U(r), of a pair of atoms spaced at a distance r in a solid is given by

$$\mathrm{U}(r) = -\frac{A}{r^3} + \frac{B}{r^7}.$$

The equilibrium distance between the atom pair is ______ nm.
(round off to 2 decimal places)

(*Given: Constants A = 6×10^{-20} J nm^3, B = 2.1×10^{-22} J nm^7*)

Q.16 Tensile true stress – true strain curve for plastic region of an alloy is given by
σ (MPa) $= 600\ \varepsilon^n$.
When true strain is 0.05, the true stress is 350 MPa. For the same alloy, when engineering strain is 0.12 then the engineering stress is ______MPa. *(round off to the nearest integer)*

Q.17 Box-S has 2 white and 4 black balls and box-T has 5 white and 3 black balls. A ball is drawn at random, from the box-S and put in box-T. Subsequently, the probability of drawing a white ball from box-T is ______. *(round off to 2 decimal places)*

Q.18 The zero point energy of an electron in a box of 0.2 nm width is ______ eV. *(round off to 1 decimal place)*

(Given: Planck's constant = 6.63×10^{-34} J s, electron mass = 9.11×10^{-31} kg and 1 eV = 1.6×10^{-19} J)

Q.19 The de Broglie wavelength of an electron accelerated across a 300 kV potential in an electron microscope is ______ $\times10^{-12}$ m. Ignore relativistic effects. *(round off to 2 decimal places)*

(Given: Planck's constant = 6.63×10^{-34} J s, electron rest mass = 9.11×10^{-31} kg, electron charge = 1.6×10^{-19} C)

Q.20 A stress of 17 MPa is applied to a polymer serving as a fastener in a complex assembly. At constant strain the stress drops to 16.6 MPa after 100 hours. The stress on the polymer must remain above 14.5 MPa in order for the assembly to function properly. The expected life of the assembly is ______ hours. *(round off to the nearest integer)*

Q.21 A piezoelectric material has a Young's modulus of 72 GPa. The stress required to change the polarization from 640 to 645 C m m^{-3} is ______ MPa. *(round off to the nearest integer)*

Q.22 An iron bar magnet having coercivity of 7000 A m^{-1} is to be demagnetized. The bar is introduced fully inside a 0.25 m long solenoid having 150 turns of wire. The electric current required to generate the necessary magnetic field is ______ A. *(round off to 1 decimal place)*

END OF THE QUESTION PAPER

XE -D: Q. 1 – Q. 9 carry one mark each

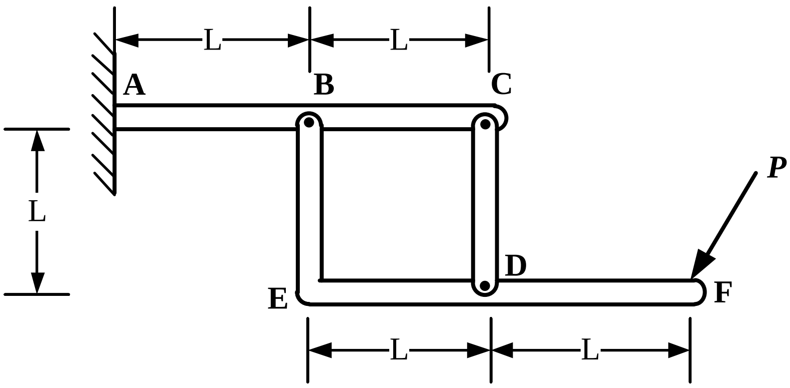
Q.1 For a pinned-pinned slender column of length L, with uniform circular cross section, and with second moment of cross sectional area I, the critical buckling load is P_{cr}. For a similar column, made of same material, having length $2L$ and second moment of cross sectional area $4I$, the critical buckling load is

(A) $4P_{cr}$ (B) $2P_{cr}$ (C) P_{cr} (D) $0.5P_{cr}$

Q.2 Two rods P and Q of uniform circular cross section are made of same material and are subjected to identical uniaxial tensile load. The length of rod P is twice the length of rod Q and the diameter of rod P is also twice the diameter of rod Q. The ratio of elastic strain energy stored in rod P to that stored in rod Q is

(A) 4:1 (B) 2:1 (C) 1:1 (D) 1:2

Q.3 The frame comprises members ABC, CD, and BEDF. This frame is fixed at A, and the connections between the three members are pins. Load P is applied at F. Which of the following statements is TRUE?



(A) ABC and CD are two-force members
(B) CD is the only two-force member
(C) BEDF and CD are two-force members
(D) ABC is the only two-force member

Q.4 When two spheres moving in a horizontal plane collide obliquely, which one of the following statements is ALWAYS TRUE?

(A) Energy of the two-sphere system is conserved
(B) Linear momentum of the two-sphere system is conserved along the normal to the plane of impact
(C) Linear momentum of each individual sphere is conserved along the normal to the plane of impact
(D) Linear momentum of each individual sphere is NOT conserved along the horizontal tangent to the plane of impact

Q.5 In a bending moment diagram of a simply supported beam, discontinuity in the bending moment occurs

(A) at the point of application of a couple
(B) at the point of application of a concentrated force
(C) at a point where the cross section of the beam changes abruptly
(D) at a point where shear force is zero

Q.6 For a solid circular shaft fixed at one end and a torque applied at the other end, which one of the following is TRUE?

(A) Every cross section of the shaft is subjected to the same internal torque
(B) The internal torque gradually increases from one end of the shaft to the other end
(C) Every cross section of the shaft is subjected to the same bending moment
(D) No cross section of the shaft rotates relative to another cross section

Q.7 Flexural stress occurs in a straight beam when

(A) it is subjected to pure torsion
(B) it is subjected to axial loads
(C) it is subjected to transverse loads
(D) it is subjected to combined axial and torsional loads

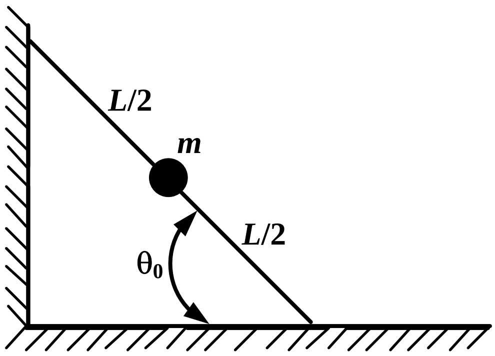
Q.8 The bending moment at a point in a beam changes its sign. Which one of the following is ALWAYS TRUE?

(A) The slope of the beam changes its sign at that point
(B) The deflection of the beam changes its sign at that point
(C) The shear force of the beam changes its sign at that point
(D) The curvature of the beam changes its sign at that point

Q.9 The state of stress at a point in a body under plane stress condition is given as $\sigma_x = 5$ MPa, $\sigma_y = -1$ MPa and $\tau_{xy} = 4$ MPa. If one of the principal stresses at that point is 7 MPa, then the other non-zero principal stress (in MPa) is __________

XE -D: Q. 10 – Q. 22 carry two marks each.

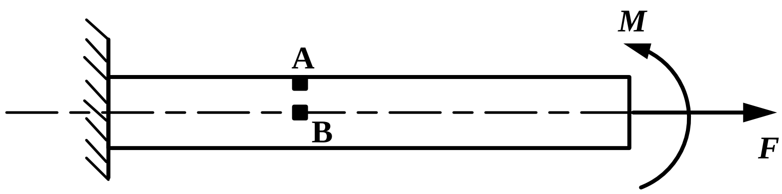
Q.10 A massless rod of length L having a concentrated mass m attached at its mid-point is held at rest between the smooth ground and the smooth wall when it makes an acute angle θ_0 with the ground as shown. The rod is then released. The acceleration due to gravity is g. At an instant when the angle between the rod and ground is θ, the velocity of the mass m is



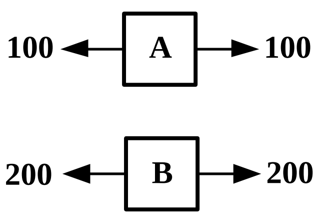
(A) $\sqrt{gL(\cos\theta - \cos\theta_0)}$ (B) $\sqrt{gL(\sin\theta_0 - \sin\theta)}$

(C) $\sqrt{gL(\cos\theta + \cos\theta_0)}$ (D) $\sqrt{gL(\sin\theta_0 + \sin\theta)}$

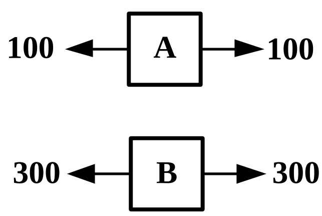
Q.11 A cantilever beam of constant cross section is subjected to a positive moment M and a positive axial force F as shown. The normal stress due to the axial force F is 200 MPa and the maximum compressive stress due to the moment M is 100 MPa. If the point A is located on the top surface and the point B is located on the centroidal axis of the beam, the stress elements at these points are (with stresses shown in MPa)



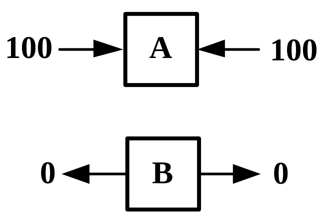
(A)



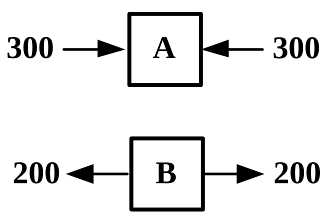
(B)



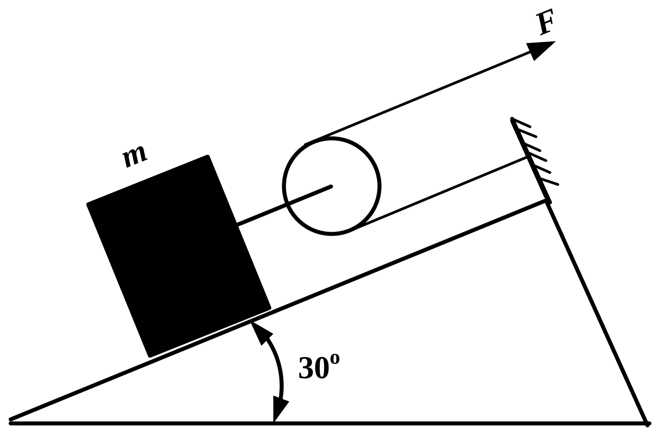
(C)



(D)

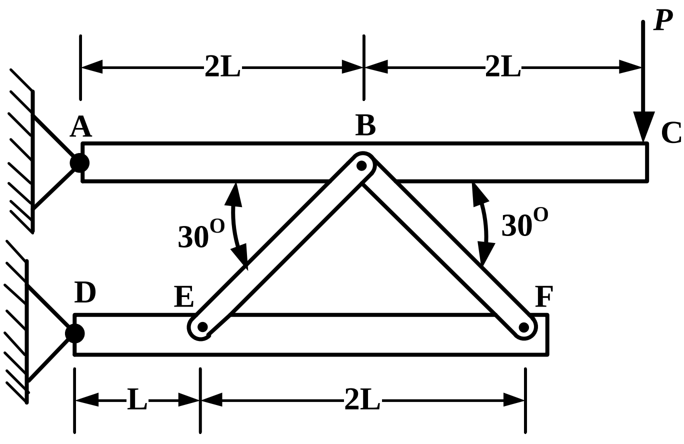


Q.12 The block of mass m = 10 kg is held in place along the incline by the force F applied via a pulley arrangement as shown. The coefficient of static friction between the block and incline is 0.65. The range of F (in N) for which the block will remain at rest is (use acceleration due to gravity $g = 10$ m/s^2)



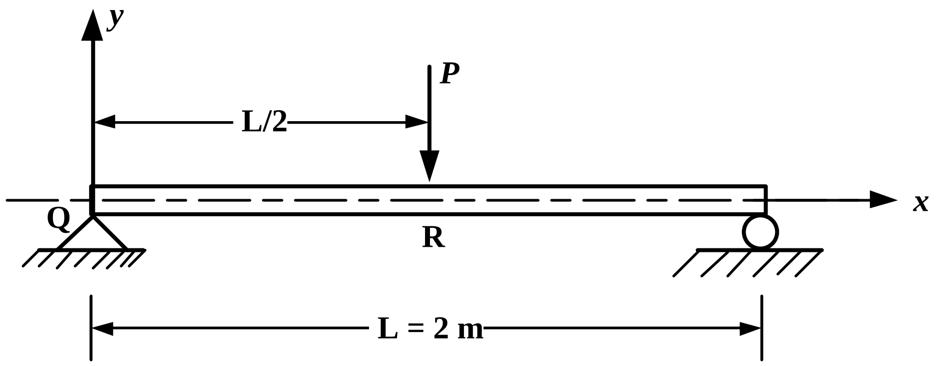
(A) 6.3 to 106.30 (B) 0 to 106.30 (C) 0 to 53.15 (D) 53.15 to 106.30

Q.13 The frame shown comprises members ABC, BE, BF, and DEF. It is pin supported at A and D. Members BE and BF are pin connected to ABC and DEF. The vertical load P is applied at C. The force in the member BF is



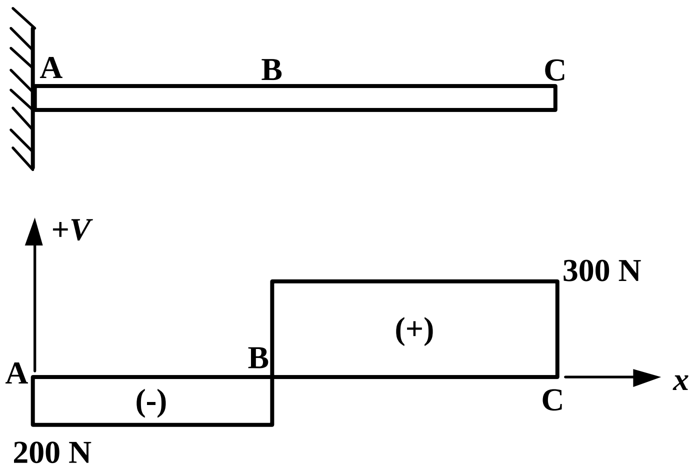
(A) compressive P (B) tensile P (C) compressive 2P (D) tensile 2P

Q.14 A simply supported beam is subjected to a concentrated force P = 48000 N at the mid-span as shown. The flexural rigidity of the beam is $EI = 11 \times 10^6$ N-m^2. The curvature of the beam between points Q and R is given as $\kappa = (Px/2EI)$. The magnitude of deflection (in mm) of the beam at $x = 0.5$ m is



(A) 0.5 (B) 1.0 (C) 1.5 (D) 2.0

Q.15 The shear force (V) diagram for a cantilever beam under certain loads applied at points B and C is shown. The magnitude of applied force at B (F_B), and the magnitude of applied force at C (F_C), are



(A) F_B = 500 N F_C = 300 N
(B) F_B = 200 N F_C = 300 N
(C) F_B = 300 N F_C = 200 N
(D) F_B = 300 N F_C = 500 N

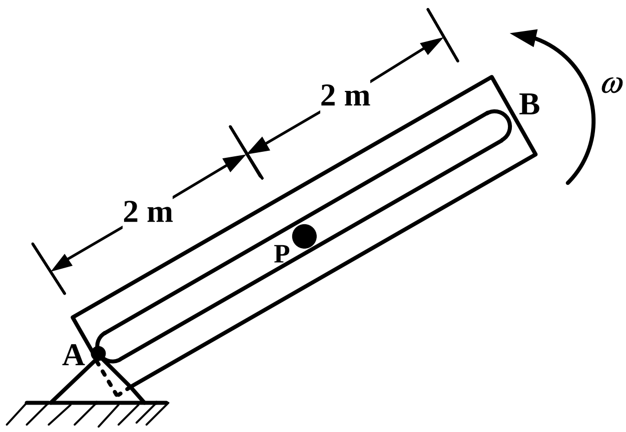
Q.16 A bar of length 1 m, having a uniform area of cross section 1000 mm^2, is fixed at one end and subjected to a uniaxial tensile load of 200 kN at the other end. Along with the tensile load, the rod also experiences a uniform temperature rise ΔT = 100 °C. The material of the rod has a Young's modulus E = 200 GPa and coefficient of thermal expansion $\alpha = 1\times10^{-5}$/ °C. The elongation of the rod (in mm) is _________

Q.17 A solid rod, with uniform circular cross section, of length 1000 mm and diameter 100 mm is subjected to a uniaxial tensile load. As a result, the increase in length of the rod is observed to be 1 mm while the reduction in diameter of the rod is observed to be 0.03 mm. If the Young's modulus of the material of the rod is 260 GPa, the shear modulus (in GPa) of the material of the rod is _________

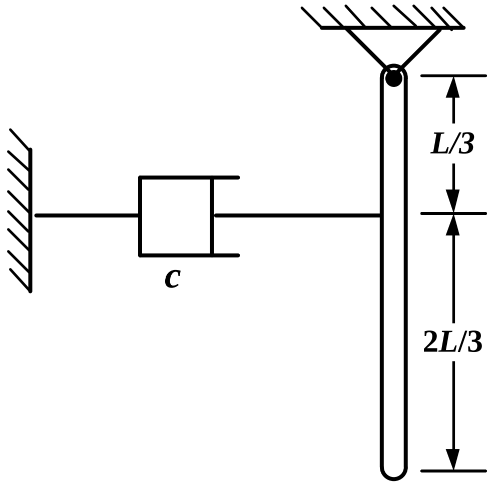
Q.18 A spherical pressure vessel has inner diameter of 4 m and wall thickness of 10 mm. It is made of a steel having tensile yield strength of 200 MPa. Neglecting radial stress and using the maximum shear stress theory, the maximum value of gauge pressure (in MPa) that the wall of the pressure vessel can withstand is _________ (rounded off to two decimal places)

Q.19 Two solid shafts P and Q made of same material transmit equal torque. Shaft P has a uniform circular cross section of area A and shaft Q has a uniform circular cross section of area $4A$. If the maximum torsional shear stress developed in shaft P is 160 MPa, the maximum torsional shear stress developed (in MPa) in shaft Q is _________

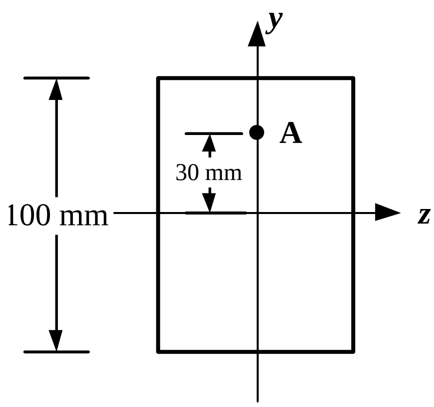
Q.20 The slotted arm AB rotates in the horizontal plane about point A at a constant angular speed $\omega = 10$ rad/sec. The particle P is released from rest, in the frictionless slot, at a distance of 2 m from end A. The magnitude of the velocity of the particle (in m/s) just before it hits end B is _________ (rounded off to two decimal places)



Q.21 The uniform pendulum rod, having mass 10 kg and length $L = 5$ m, is attached to a viscous damper having damping coefficient c. Use acceleration due to gravity $g = 10$ m/s^2. The least value of c (in N-s/m) such that small motions of the pendulum rod decay without oscillations is ________



Q.22 A beam having a constant solid rectangular cross section is subjected to pure bending. The longitudinal strain at a point A on the cross section is 3.0×10^{-5}. If the Young's modulus of the material of the beam is 200 GPa, the maximum tensile stress (in MPa) is ________



END OF THE QUESTION PAPER

XE-E: Q. 1 – Q. 9 carry one mark each & Q. 10 – Q. 22 carry two marks each.

Notations used:

c_p: Specific heat at constant pressure; c_v: Specific heat at constant volume; *h*: Specific enthalpy; *s*: Specific entropy; *v*: Specific volume; *P*: Pressure; *V*: Volume; *T*: Temperature; *R*: Gas constant; R_u : Universal Gas constant

Q.1 One kg of an ideal gas (molecular weight = X) occupies a certain volume *V* at temperature *T* and pressure P_1. Four kgs of another ideal gas (molecular weight = 2X) is added to the first gas keeping the volume *V* and temperature *T* same as before. The final pressure is

(A) 2 P_1 (B) 3 P_1 (C) 4 P_1 (D) 5 P_1

Q.2 Which of the following is an intensive thermodynamic property?

(A) Enthalpy (B) Internal energy (C) Entropy (D) Pressure

Q.3 A thermodynamic process for a substance is represented as a constant pressure process on a *P*-*V* diagram, and a constant temperature process on a *T*-*V* diagram. Which of the following statements is **TRUE**?

(A) The substance is an ideal gas.
(B) The substance is a van der Waals gas.
(C) The substance undergoes a phase change.
(D) Such a process is not possible.

Q.4 Addition of a reheat process to a simple Rankine cycle will always

(A) increase both efficiency and work output of the cycle.
(B) increase efficiency but not necessarily work output of the cycle.
(C) increase work output but not necessarily efficiency of the cycle.
(D) decrease both efficiency and work output of the cycle.

Q.5 A Carnot cycle implemented using an ideal gas in a piston-cylinder system will have

(A) work transfer in two parts of the cycle and heat transfer in the other two parts of the cycle.
(B) work transfer in all four parts of the cycle and heat transfer in two parts of the cycle.
(C) work transfer in two parts of the cycle and heat transfer in all four parts of the cycle.
(D) work transfer in all four parts of the cycle and heat transfer in all four parts of the cycle.

Q.6 The “degrees of freedom” for a pure substance at its triple point is

(A) 3 (B) 2 (C) 1 (D) 0

Q.7 The differential of the Gibbs function (g) for a simple compressible system can be represented as $dg = v\,dP - s\,dT$. Using the appropriate Maxwell relation derived from the above equation, the quantity, $\left[-\left(\frac{\partial s}{\partial P}\right)_T\right]$ for an ideal gas is

(A) $\frac{R}{T}$ (B) $\frac{R}{P}$ (C) $\frac{P}{R}$ (D) $\frac{T}{R}$

Q.8 A Carnot engine receives 2000 kJ heat from a source at 1200 K and rejects 500 kJ heat to sink. The sink temperature (K) is __________.

Q.9 A closed vessel contains a pure substance with 0.1 m^3 of saturated liquid and 0.9 m^3 of saturated vapor. The specific volume of the liquid and vapor phases are 0.000843 m^3/kg and 0.02671 m^3/kg respectively. The **percentage** of vapor in the mixture on mass basis (rounded off to two decimal places) is __________.

Q.10 A gas obeys the van der Waals equation of state $\left(P + \frac{a}{v^2}\right)(v - b) = R\,T$, where a and b are van der Waals constants. The compressibility factor $\left[Z = \frac{P\,v}{R\,T}\right]$ in the limit of high specific volume ($b \ll v$) is

(A) $1 + \frac{1}{v}\left(b - \frac{a}{R\,T}\right)$ (B) $1 + \frac{1}{v}\left(b + \frac{a}{R\,T}\right)$ (C) $1 - \frac{1}{v}\left(b + \frac{a}{R\,T}\right)$ (D) $1 - \frac{1}{v}\left(b - \frac{a}{R\,T}\right)$

Q.11 Consider the thermodynamic relation, $\left(\frac{\partial c_p}{\partial P}\right)_T = -T\left(\frac{\partial^2 v}{\partial T^2}\right)_P$. For a certain gas, if the isobaric thermal expansion coefficient, $\alpha = \frac{1}{T}$ (where T is the temperature measured in K), then the value of $\left(\frac{\partial c_p}{\partial P}\right)_T$ is,

(A) 0 (B) 1 (C) 2 (D) $\frac{v}{T}$

Q.12 A piston-cylinder system has an initial volume of 0.1 m^3 and contains an ideal gas ($c_v = 0.74$ kJ/kg.K, $R = 0.288$ kJ/kg.K) at 1.5 bar and 298 K. The piston is moved to compress the gas until the pressure and temperature reach 10 bar and 423 K respectively. During this process, 20 kJ of work is done on the gas. The magnitude of heat transfer (**kJ**) during this process is

(A) 134.8 (B) 36.2 (C) 8.2 (D) 3.8

Q.13 A reversible cyclic device absorbs 400 kJ/s heat from a reservoir maintained at 265 K and rejects heat to another reservoir at 298 K. The magnitude of the rate of work done (**kW)** by the device is

(A) 849.81 (B) 449.81 (C) 355.70 (D) 49.81

Q.14 In a reversible process, an ideal gas ($c_p = 1.04$ kJ/kg.K, R = 0.297 kJ/kg.K) at 293 K, is compressed in a cylinder from 100 kPa to 500 kPa. During this compression process, the relation between pressure and volume is expressed as, $Pv^{1.3}$ = constant.
In the following options, mark the closest value for the entropy change per kilogram **(J/kg.K)**.

(A) -91 (B) 91 (C) -864 (D) 864

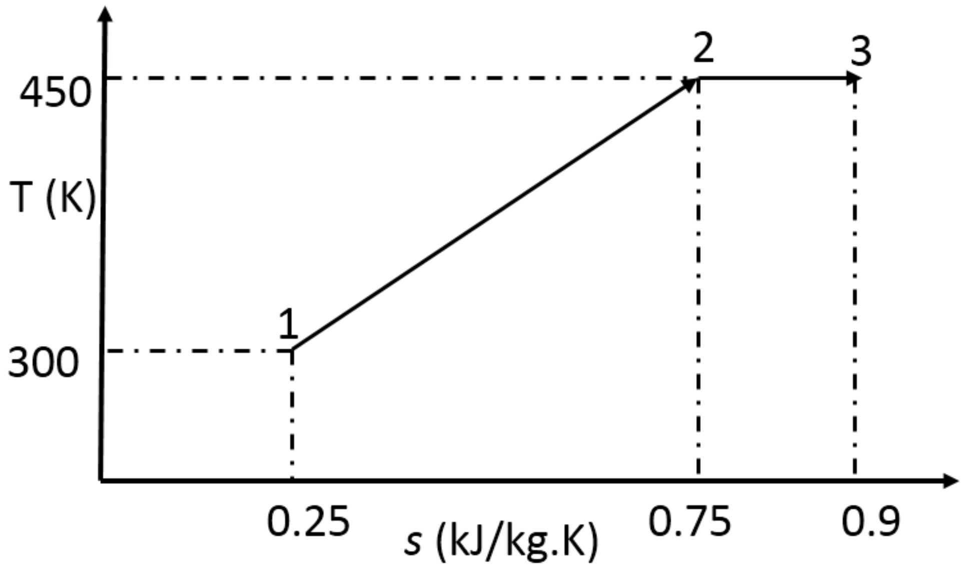
Q.15 The sublimation pressure of water vapor at 233 K is 13 Pa. Assume the water vapor to behave as an ideal gas (R = 0.46 kJ/kg.K), and the latent heat of sublimation is 2840 kJ/kg. The sublimation pressure of water vapor at 213 K, (rounded off to 2 decimal places), is _____________ **Pa.**

Q.16 In a heating and humidification process, dry air ($d.a$) with relative humidity of 10% at ambient temperature of 10°C, is mixed with superheated steam at temperature 'T'. The resultant mixture is at 25°C with relative humidity of 50%. The total pressure before and after the process remains the same at 102 kPa. The saturated pressure of water vapor (v) at 10°C and 25°C are 1.2281 kPa, and 3.1698 kPa, respectively. The specific humidity in grams of water vapour per kg of dry air, can be calculated using $\omega = 622 \frac{p_v}{p_{d.a}}$, where p_v and $p_{d.a}$ are the partial pressures of water vapour and dry air respectively. The quantity of steam in **grams (**rounded off to 2 decimal places) added per kg of dry air is _______________.

Q.17 In a vapor compression system, a refrigerant leaves the evaporator and enters the compressor in saturated vapor condition at 0°C. The specific enthalpies of the saturated liquid and the saturated vapor at 0°C are 50 kJ/kg and 250 kJ/kg, respectively. The refrigerant leaves the compressor with a specific enthalpy of 300 kJ/kg. From the exit of the condenser, the refrigerant is throttled to the evaporator pressure. If the coefficient of performance (COP) of the refrigerator is 2.8 then the **dryness fraction** of the refrigerant entering the evaporator is __________.

Q.18 Hot air, assumed as an ideal gas (c_p = 1000 J/kg.K, γ = 1.4) enters a gas turbine at 10 bar, 1000 K and leaves at a pressure of 5 bar. Subsequently it expands in a nozzle to a pressure of 1 bar. Assume both these processes to be reversible and adiabatic. If the inlet velocity of the air to the nozzle is negligible, the final velocity (**m/s**, rounded off to 1 decimal place) of air at the exit of the nozzle is __________.

Q.19



The "*T*-*s* diagram" for a thermodynamic process is shown in the figure. The heat transferred (**kJ/kg**) during the reversible process 1-3 is __________.

Q.20 In a simple Rankine cycle, superheated steam enters the turbine at 100 bar, 500°C (h = 3375.1 kJ/kg, s = 6.5995 kJ/kg.K) at a rate of 1000 kg/s. It expands isentropically in the turbine to the condenser pressure. The temperature in the condenser is 30°C (h_f = 125.74 kJ/kg, s_f = 0.4368 kJ/kg.K, h_g = 2555.6 kJ/kg, s_g = 8.4520 kJ/kg.K). Saturated water from the condenser is pumped back to the boiler. Neglecting the pump work, the efficiency (in **percentage,** rounded off to 1 decimal) of the cycle is __________.

Q.21 A rigid, adiabatic container has two parts (A) and (B) separated by a piston. Initially, part (A) is filled with 1 kg of an ideal gas (c_v = 750 J/kg.K, R = 500 J/kg.K) at 1 bar, 600 K. The part (B) is filled with 1 kg of the same ideal gas at 2 bar, 400 K. The piston is now removed. In the final state, the pressure **(bar,** rounded off to two decimal places) will be _______________.

Q.22 In a steady flow process, superheated steam at 70 bar and 450°C, is throttled to 30 bar in an insulated valve, at a rate of 2 kg/s. The changes in the kinetic energy and potential energy during the process are assumed to be zero. The rate of entropy generation **(kJ/s.K** rounded off to three decimal places**)** during the throttling process is __________.

The thermodynamic property data for superheated steam at 70 bar and 450°C:
h = 3288.3 kJ/kg, s = 6.6353 kJ/kg.K
The thermodynamic property data for superheated steam at 30 bar are given in the following table.

T (°C)	*h* (kJ/kg)	*s* (kJ/kg K)
400	3231.7	6.9235
450	3344.9	7.0856

END OF THE QUESTION PAPER

XE-A: Q. 1 – Q. 7 carry one mark each & Q. 8 – Q. 11 carry two marks each.

XE (B to H): Q. 1 – Q. 9 carry one mark each & Q. 10 – Q. 22 carry two marks each.

Q.1 The functionality of allyl alcohol (CH_2=CH-CH_2OH) for condensation reaction with terephthalic acid is

(A) 0 (B) 1 (C) 2 (D) 3

Q.2 Which of the following polymers can be synthesized by ring opening polymerization?

(A) Poly(vinyl alcohol)
(B) Nylon 66
(C) Poly(ethylene terephthalate)
(D) Poly(ε-caprolactone)

Q.3 The weather resistant polymer among the following is

(A) natural rubber
(B) styrene butadiene rubber
(C) nitrile rubber
(D) silicone rubber

Q.4 If a combination of sodium and naphthalene is used to initiate polymerization of styrene, then the most likely mechanism of polymerization is

(A) free radical
(B) cationic
(C) anionic
(D) olefin metathesis

Q.5 Hypalon is the trade name for

(A) chlorosulfonated polyethylene
(B) chlorinated polyethylene
(C) ultra high molecular weight polyethylene
(D) cross-linked polyethylene

Q.6 The copolymer(s) among high density polyethylene (HDPE), low density polyethylene (LDPE) and linear low density polyethylene (LLDPE) is/are

(A) LDPE only
(B) LLDPE only
(C) LDPE and LLDPE
(D) HDPE and LDPE

Q.7 The polymer which lacks the ability to exhibit tacticity among the following is

(A) polypropylene
(B) polystyrene
(C) polyisobutylene
(D) poly(methyl methacrylate)

Q.8 The correct order of glass transition temperature (T_g) for the polymers listed below is (PC = polycarbonate; PET = poly(ethylene terephthalate); PE = polyethylene; PP = polypropylene)

(A) PC > PET > PP > PE
(B) PC > PET > PE > PP
(C) PET > PC > PE > PP
(D) PET > PC > PP > PE

Q.9 Polystyrene coffee cup can be most economically manufactured by

(A) thermoforming
(B) injection molding
(C) compression molding
(D) blow molding

Q.10 Match the following rubber additives to their function:

Additive	**Function**
P. Tetramethyl thiuram disulfide	1. Peptizer
Q. Xylyl mercaptan	2. Antiozonant
R. Sulfur	3. Accelerator
S. Microcrystalline wax	4. Cross-linking agent

(A) P-4, Q-1, R-3, S-2
(B) P-3, Q-1, R-4, S-2
(C) P-3, Q-2, R-4, S-1
(D) P-4, Q-2, R-3, S-1

Q.11 Match the following polymers with their characteristic infrared (IR) stretching frequency:

Polymer	**IR stretching frequency (cm^{-1})**
P. Polystyrene	1. ~2242
Q. Polyacrylonitrile	2. ~1733
R. Poly(ethylene terephthalate)	3. ~3392
S. Poly(vinyl alcohol)	4. ~3100

(A) P-2, Q-3, R-1, S-4
(B) P-2, Q-1, R-4, S-3
(C) P-4, Q-2, R-3, S-1
(D) P-4, Q-1, R-2, S-3

Q.12 Match the following products to the most suitable polymer for their manufacture:

Product	**Polymer**
P. Electrical cables	1. Polyurethane
Q. Electrical switches	2. Poly(methyl methacrylate)
R. Optical lenses	3. Cross-linked polyethylene
S. Shoe soles	4. Phenol formaldehyde resin

(A) P-3, Q-2, R-1, S-4
(B) P-3, Q-4, R-2, S-1
(C) P-4, Q-3, R-1, S-2
(D) P-2, Q-3, R-1, S-4

Q.13 The order of limiting oxygen index for the following polymers is (polypropylene=PP; PTFE=polytetrafluoroethylene; PVC=poly(vinyl chloride))

(A) PP < PTFE < Nylon 6 < PVC
(B) PP < PVC < Nylon 6 < PTFE
(C) PP < Nylon 6 < PVC < PTFE
(D) PP < Nylon 6 < PTFE < PVC

Q.14 Match the following plastic additives to their function:

Additive	**Function**
P. Molybdenum disulfide	1. Heat stabilizer
Q. Glycerol monostearate	2. UV-absorber
R. Tribasic lead sulphate	3. Antistatic agent
S. 2-Hydroxybenzophenone	4. Solid layer lubricant

(A) P-3, Q-1, R-2, S-4
(B) P-3, Q-4, R-1, S-2
(C) P-4, Q-3, R-2, S-1
(D) P-4, Q-3, R-1, S-2

Q.15 Match the material classification in Column A with the appropriate one in Column B: (PS=polystyrene, PPO=polyphenylene oxide, PDMS=poly(dimethyl siloxane), PP=polypropylene, PE=polyethylene, PP-g-MA= maleic anhydride grafted PP)

Column A	**Column B**
P. Miscible blend	1. PDMS + Fumed silica
Q. Immiscible blend	2. Nylon 6 + PP-g-MA + PP
R. Compatibilized blend	3. PS + PPO
S. Polymer composite	4. PE + PP

(A) P-3, Q-4, R-2, S-1
(B) P-4, Q-3, R-2, S-1
(C) P-3, Q-4, R-1, S-2
(D) P-4, Q-3, R-1, S-2

Q.16 A linear amorphous polymer has a T_g of +10 °C. At 28 °C, it has a melt viscosity of 4×10^8 poise. The viscosity of the polymer at its T_g is _______ $\times 10^{13}$ poise (round off to one decimal place).

Q.17 A polypropylene (PP) bar with a 10 mm × 10 mm square section is 225 mm long. The modulus of PP bar is 861 MN m^{-2}. It is pinned at both ends and an axial compressive load of 140 N is applied. The strain due to the applied load experienced by the PP bar is ___ % (round off to two decimal places).

Q.18 In a unidirectional carbon fibre/vinyl ester composite, the ratio of the moduli of the carbon fibre to that of vinyl ester is 35 and the fibres take up 50% of the cross-section. The percentage of applied force taken up by the fibres is ______ % (round off to one decimal place).

Q.19 A 3 mm thick layer of softened poly(methyl methacrylate) at 190 °C is sandwiched between two flat parallel plates. A shear stress of 100 kPa is applied to the softened polymer. Assuming the softened polymer as a Newtonian fluid with an apparent viscosity of 3.9×10^4 Pa s, the relative sliding velocity between the two plates is ____ mm s^{-1} (round off to one decimal place).

Q.20 For AIBN initiated polymerization of styrene, if both the monomer and initiator concentration are doubled, then the rate of polymerization increases by a factor of ________ (round off to two decimal places).

Q.21 If 49 moles of hexamethylene diamine is reacted with 50 moles of adipic acid to prepare Nylon 66, then the number average molecular weight, $\bar{M}_n$ of the resulting polymer at 99.5% conversion (ignoring contribution from end groups) is________ g mol^{-1} (round off to 2 decimal places).

Q.22 A single screw extruder is to be used to manufacture a nylon rod of 0.5 cm diameter at a production rate of 2.5 cm s^{-1}. The density of solid nylon and nylon melt are 1.140 g cm^{-3} and 0.790 g cm^{-3}, respectively. The melt flow rate through the die is _______ cm^3 s^{-1} (round off to two decimal places).

END OF THE QUESTION PAPER

Q. 1 – Q. 9 carry one mark each & Q. 10 – Q. 22 carry two marks each.

Q.1 Colloidal stability of milk casein is because of the highly hydrated carbohydrate residues in _________.

(A) α_{s1} casein (B) α_{s2} casein (C) β casein (D) κ casein

Q.2 Rice bran is stabilized prior to oil extraction to protect it from the activity of ________.

(A) Polyphenol oxidase
(B) Peroxidase
(C) Lipase
(D) Lipoxygenase

Q.3 Sticking of powder to wall of the chamber during spray drying of fruit juice is due to ____.

(A) Low glass transition temperature of the compounds in juice
(B) High glass transition temperature of the compounds in juice
(C) Improper processing parameters of spray dryer
(D) Presence of gums in feed material

Q.4 Thearubigins and theaflavins in black tea are formed by the oxidation and dimerization of ___________.

(A) Quercetin (B) Catechins (C) Gallic acid (D) Kaempferol

Q.5 Ratio of Schmidt number to Lewis number is __________.

(A) Prandtl number
(B) Reynolds number
(C) Nusselt number
(D) Sherwood number

Q.6 'Red dog' is one of the byproducts during milling of ________.

(A) Corn (B) Rice (C) *Ragi* (D) Wheat

Q.7 An ice cream mix of 870 g L^{-1} has been used to prepare ice cream which yielded a finished product of 490 g L^{-1}. The per cent over run is _________ (*round off to 1 decimal place*).

Q.8 Impeller in a fruit juice mixing tank is rotating at 200 rpm with a Reynolds number $>10^4$. Density of juice is 1045 kg m^{-3}. If diameter of the impeller is doubled and other conditions remained constant, the power requirement of mixing will increase by a factor of ________.

Q.9 Paddy consisting of 20% husk has been milled to remove 6% bran during polishing. Assuming no other losses, yield (per cent) of polished rice from the paddy is _______ (*round off to 1 decimal place*).

Q.10 Match the following laws in Column I with corresponding phenomenon in Column II.

	Column I		**Column II**
P	Newton's law	1	Size reduction
Q	Hertz constant stress theory	2	Substance cooling
R	Fick's law	3	Damage of fruits and vegetables
S	Bond's law	4	Molecular diffusion

(A) P-2, Q-3, R-4, S-1
(B) P-3, Q-2, R-4, S-1
(C) P-3, Q-1, R-4, S-2
(D) P-4, Q-3, R-2, S-1

Q.11 Match the mold in Column I with its asexual/sexual spore shown in Column II.

	Column I		**Column II**
P	*Aspergillus*	1	Arthrospore
Q	*Geotrichum*	2	Oospores
R	*Rhizopus*	3	Conidia
S	*Oomycetes*	4	Sporangiospores

(A) P-3, Q-1, R-4, S-2
(B) P-1, Q-4, R-3, S-2
(C) P-4, Q-3, R-1, S-2
(D) P-4, Q-1, R-2, S-3

Q.12 Match the foods given in Column I with their specific usage given in Column II.

	Column I		**Column II**
P	Egg yolk	1	Ice cream
Q	Pregelatinised starch	2	Mayonnaise
R	Gum	3	Baking powder
S	Starch	4	Baby food

(A) P-2, Q-4, R-1, S-3
(B) P-4, Q-1, R-2, S-3
(C) P-2, Q-3, R-1, S-4
(D) P-1, Q-4, R-1, S-3

Q.13 Match the bioactive compounds in Column I with their botanical source given in Column II.

	Column I		**Column II**
P	Isoflavones	1	Corn
Q	Resistant starch	2	Grapes
R	Xanthophyll	3	Soybean
S	Resveratrol	4	Plantain (culinary banana)

(A) P-2, Q-4, R-1, S-3
(B) P-3, Q-4, R-1, S-2
(C) P-4, Q-1, R-2, S-3
(D) P-4, Q-3, R-2, S-1

Q.14 Match the following microbial species in Column I with related disease caused by them as listed in Column II.

	Column I		**Column II**
P	*Vibrio sp.*	1	Gastroenteritis
Q	*Shigella sp.*	2	Typhoid
R	*E. coli*	3	Cholera
S	*Salmonella typhi*	4	Bacillary dysentery

(A) P-1, Q-3, R-4, S-2
(B) P-2, Q-3, R-4, S-1
(C) P-3, Q-1, R-4, S-2
(D) P-3, Q-4, R-1, S-2

Q.15 Buffalo milk having density of 1030 kg m^{-3} is homogenized with a pressure of 30 MPa. Given, acceleration due to gravity as 9.81 m s^{-2} and assuming no pressure loss, the velocity (m s^{-1}) of the milk flowing through the homogenizer valve will be _______ (*round off to 2 decimal places*).

Q.16 Potato slices have been dehydrated from an initial solid content of 12% to a final solid content of 94%. If the peeling and other losses are to the tune of 10%, final yield (per cent) of the dried chips per ton of fresh potato taken is ________ (*round off to 2 decimal places*).

Q.17 A mixed fruit beverage with 12 °Brix having specifc heat of 4298 J kg^{-1} K^{-1} is being heated from 30 °C to 95 °C for pasteurization at a flow rate of 1000 L h^{-1} in a tubular heat exchanger. Steam at 100 °C is used as heating medium which is converted into condensate at 100 °C. If the density of beverage is 1075 kg m^{-3} and the latent heat of steam at the given temeparture is 2257 kJ kg^{-1}, the mass flow rate of steam (kg min^{-1}) is ______ (*round off to 2 decimal places*).

Q.18 Fruit juice was cooled in a tubular heat exchanger from 50 °C to 7 °C using water at 2 °C, which gets heated to 5 °C. Assume, Pr = 0.72, Re = 20000 and thermal conductivity = 0.6 W m^{-1} $°C^{-1}$ and no viscous effect. If pipe diameter was 10 cm, the convective heat transfer coefficient (W m^{-2} $°C^{-1}$) is ____________ (*round off to 1 decimal place*).

Q.19 Room air is at 40 °C with 60% relative humidity. Saturated vapour pressure of water at 40 °C is 7.375 kPa. Volume of humid air (m^3 per kg of dry air) is ____________ (*round off to 3 decimal places*).

Q.20 A shallow-bed horizontal belt type solvent extractor is operating on 0.3 mm thick soybean flakes with 0.5 m bed depth and a forward speed of 0.8 m min^{-1} with miscella flux rate of 0.25 m min^{-1}. If porosity of the flakes is 60%, the distance between washing nozzle and miscella collecting receptacle (cm) is ____________ (*round off to 1 decimal place*).

Q.21 An extruded snack food is packed in a barrier film having water vapour transmission rate of 0.02 mL m^{-2} day^{-1}. Pack surface area is 0.0012 m^2 per gram of dry food solids, EMC of the food is 6% (d.b.), initial moisture content is 2% (d.b.), critical moisture content is 5% (d.b.) and slope of moisture sorption isotherm is 3.4% (d.b.) per unit water activity (a_w). Sealed pack is stored at 30 °C. Assume that the vapor pressure of pure water at 30 °C is 31.7 torr. Time required for the food to reach the critical moisture content (days) is ____________ (*round off to 1 decimal place*).

Q.22 Freezing of 100 mm spherical meat ball with 60% moisture at 35 °C is being done in an air blast freezer maintained at -45 °C. Given, latent heat of fusion for water is 333.2 kJ kg^{-1}, thermal conductivity of meat is 1.5 W m^{-1} °C^{-1}, convective heat transfer coefficient is 40 W m^{-2} °C^{-1}, density of frozen meat is 980 kg m^{-3} and initial freezing temperature of meat ball is -10 °C. Using Plank's equation, freezing time (h) is ____________ (*round off to 2 decimal places*).

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XE-A: Q. 1 – Q. 7 carry one mark each & Q. 8 – Q. 11 carry two marks each.

XE (B to H): Q. 1 – Q. 9 carry one mark each & Q. 10 – Q. 22 carry two marks each.

XL-P: Q. 1 – Q. 5 carry one mark each & Q. 6 – Q. 15 carry two marks each

XL (Q to U): Q. 1 – Q. 10 carry one mark each & Q. 11 – Q. 20 carry two marks each.

Q.1 In the equatorial belt, the Madden-Julian Oscillation (MJO) propagates

(A) northward (B) southward (C) eastward (D) westward

Q.2 Potential temperature increases with height in an atmosphere. Upon adiabatic vertical displacement, a parcel of dry air is

(A) stable (B) absolutely unstable
(C) neutral (D) conditionally unstable

Q.3 Oxygen minimum zones in the ocean are formed in the layers where

(A) Photosynthesis is dominant
(B) Sunlight is maximum
(C) Decomposition of organic matter is dominant
(D) Iron availability is maximum

Q.4 Water level in an estuary rises and falls in response to tidal forces. Assume that the only tidal period in an estuary is 12 hours. The speed of the ebb current in that estuary would be maximum

(A) At high tide
(B) At low tide
(C) About 3 hours after high tide
(D) About 6 hours after low tide

Q.5 The most abundant ions in seawater are

(A) Sodium and chloride ions
(B) Magnesium and chloride ions
(C) Calcium and chloride ions
(D) Magnesium and sulphide ions

Q.6 Which among the following statements is true with respect to the axis of the Indian monsoon trough

(A) Relative vorticity is cyclonic at 850 hPa
(B) Relative vorticity is anticyclonic at 850 hPa
(C) It shifts to the south during break monsoon
(D) It moves to the head Bay of Bengal when a monsoon depression is present over the Indian subcontinent

Q.7 A student considered the following possibilities regarding trade wind inversion:

(P) Zonal component of wind is westerly
(Q) Zonal component of wind is easterly
(R) Meridional component of wind is poleward
(S) Meridional component of wind is equatorward

The only combination of correct statements is

(A) P,S (B) Q,S (C) Q,R (D) P,R

Q.8 Which of the following statements about thermal wind is **NOT** correct:

(A) Flow is in geostrophic balance
(B) Horizontal temperature gradient is non-zero
(C) Wind speed varies with height
(D) Flow is quasi-geostrophic

Q.9 A numerical weather forecasting model follows sigma (σ) coordinate system in the vertical. At two locations A and B, the surface pressure is 1000 hPa and 500 hPa respectively. The values of pressure at A and B (in that order) for σ = 0.5 are:

(A) 2000 hPa, 1000 hPa (B) 500 hPa, 250 hPa
(C) 999.5 hPa, 499.5 hPa (D) 500 hPa, 0 hPa

Q.10 At a given temperature and pressure, equilibrium vapor pressure over the surface of a rain droplet compared to that over a flat surface of pure water is

(A) Always less
(B) Always more
(C) Always equal
(D) Can be less, equal to or more depending on the size and chemical composition of the cloud condensation nuclei, and droplet radius

Q.11 Velocity field in a geophysical flow is given by $u = -5x$, $v = 4y$, $w = 0$ where u, v, w are zonal, meridional and vertical components of velocity, and x and y refer to eastward and northward distance. Which among the following statements is **NOT** true for the flow at 45^{o}N:

(A) Flow is incompressible
(B) Relative vorticity is zero
(C) Potential vorticity is positive
(D) Flow is compressible

Q.12 The distance between Mars and Earth is 0.52 times the distance between Sun and Earth. If the solar constant on Earth is 1370 W m^{-2}, then the solar constant on Mars is __________ W m^{-2}. (Round off to one decimal place.)

Q.13 Ideal gas equation for dry air is expressed as $p = \rho_d R_d T$, where p is pressure, ρ_d is density, T is temperature and R_d is gas constant. If CO_2 concentration in Earth's atmosphere quadruples due to fossil fuel burning, then the new gas constant is __________ J kg^{-1} K^{-1}. (Round off to two decimal places.)
Take the universal gas constant (R^*) = 8.314 J K^{-1} $mole^{-1}$, molecular weight of CO_2 = 44, and present value of R_d = 287 J kg^{-1} K^{-1}, present concentration of CO_2 = 500 mg kg^{-1}.

Q.14 On a calm evening under a clear sky, the lowest 20 m of the atmosphere is continuously losing energy at a rate of 10 W m^{-2} due to radiative cooling. Sensible and latent heat flux exchange with the ground is zero. If air temperature and dew point depression at 6 p.m. are 25^{o}C and 8^{o}C, respectively, the probability of fog formation at midnight is __________ %. (Round off to the nearest integer.)
Take C_p = 1005 J kg^{-1} K^{-1}, density of air = 1.15 kg m^{-3}

Q.15 The dynamical core of a general circulation model uses 256 spherical harmonic waves to cover the globe in east-west direction. If two grids of the model exactly resolve the shortest of those waves, then the grid spacing at the equator is __________ km. (Round off to one decimal place.)
Take radius of the earth (R_E) = 6400 km.

Q.16 It rains 10 cm in a day over an ocean with a mixed layer depth of 5 m and initial salinity 30 g kg^{-1}. The rain water uniformly mixes with the existing mixed layer water. The final salinity after the rain is __________ g kg^{-1}. (Round off to one decimal place.)

Q.17 A moist air parcel is lifted adiabatically to 800 hPa level. Initial temperature and pressure of the parcel are 300 K and 1010 hPa, and the partial pressure of water vapor is 10 hPa. The partial pressure of the water vapor at the new location is __________ hPa. (Round off to one decimal place.)
Take saturation vapor pressure of water at temperature T as

$$e_s(T) = Ae^{-\frac{B}{T}},$$

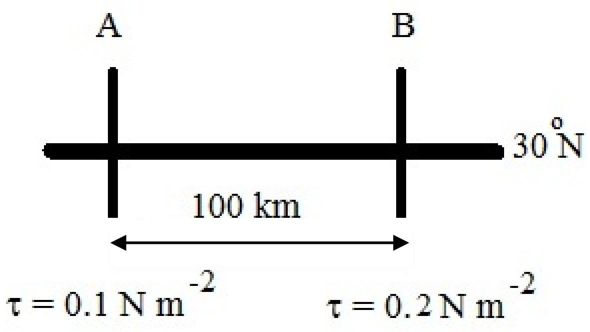
where $A = 2.53 \times 10^9$ hPa, $B = 5420$ K, gas constant (R) = 287 J kg^{-1} K^{-1}, and C_p = 1005 J kg^{-1} K^{-1}.

Q.18 In steady state, global mean precipitation P is equal to global mean evaporation E from the surface of the earth. If P is 2.8 mm day^{-1}, then global mean surface latent heat flux is __________ W m^{-2}. (Round off to the nearest integer).

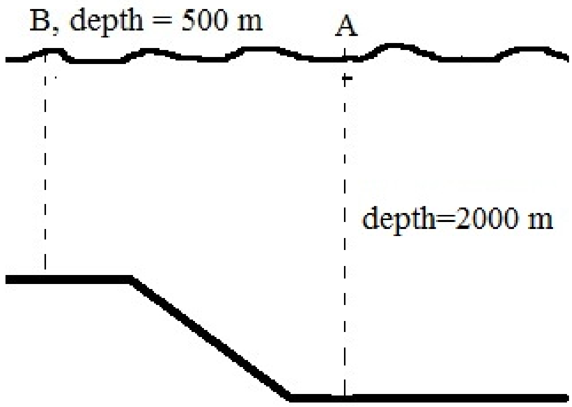
Take latent heat of evaporation of water as 2.5×10^6 J kg^{-1}.

Q.19 A column of seawater from surface to 1000 m depth is initially at rest at the equator. The column is moved to 30°N with no change in column depth. In the absence of friction, the vertical component of relative vorticity of the water in the column at 30°N is __________ $\times10^{-5}$ s^{-1}. (Round off to one decimal place.)

Q.20 Consider two north-south (i.e. meridional) sections A and B in the ocean, separated by 100 km; section B is to the east of section A (as shown in figure below). The steady northward wind stress at A and B are 0.1 N/m^2 and 0.2 N/m^2, respectively; zonal wind stress is zero everywhere. Density of seawater is 1000 kg m^{-3}. At 30°N, the vertical velocity at the base of the Ekman layer is __________ meters per day. (Round off to one decimal place.)



Q.21 A tsunami is a long gravity wave, i.e. its wavelength is much larger than the depth of the ocean. A tsunami moves from point A to point B (see figure below); water depth at A is 2000 m, and water depth at B is 500 m. Assume no frictional losses. By energy conservation, C_g <E> is constant, where C_g is group speed and <E> is the total (potential plus kinetic) energy density of the wave field. If the amplitude of the tsunami at point A is 1 m, its amplitude at B is __________ m. (Round off to two decimal places.)



Q.22 At mid-latitudes, long Rossby waves obey the dispersion relation $\sigma = - \beta k / L^{-2}$, where σ is frequency, k is zonal wavenumber, β is rate of change of Coriolis parameter with northward distance (units m^{-1} s^{-1}), and L is Rossby radius. If $L = 100$ km, the speed of the long Rossby wave at 45°N is __________ m s^{-1}. (Round off to two decimal places.) Take radius of the earth as 6400 km.

END OF THE QUESTION PAPER

Q.No.	Type	Section	Key/Range	Marks
1	MCQ	GA	B	1
2	MCQ	GA	A	1
3	MCQ	GA	B	1
4	MCQ	GA	B	1
5	MCQ	GA	D	1
6	MCQ	GA	A	2
7	MCQ	GA	B	2
8	MCQ	GA	B	2
9	MCQ	GA	B	2
10	MCQ	GA	A	2
1	MCQ	XE-A	B	1
2	MCQ	XE-A	D	1
3	MCQ	XE-A	C	1
4	MCQ	XE-A	A	1
5	NAT	XE-A	6 to 6	1
6	NAT	XE-A	3 to 3	1
7	NAT	XE-A	0 to 0	1
8	MCQ	XE-A	B	2
9	MCQ	XE-A	D	2
10	NAT	XE-A	2 to 2	2
11	NAT	XE-A	6.0 to 6.2	2
1	MCQ	XE-B	D	1
2	MCQ	XE-B	B	1

Q.No.	Type	Section	Key/Range	Marks
3	MCQ	XE-B	B	1
4	MCQ	XE-B	C	1
5	MCQ	XE-B	C	1
6	MCQ	XE-B	D	1
7	NAT	XE-B	0.01 to 0.01	1
8	NAT	XE-B	3 to 3	1
9	NAT	XE-B	0.8 to 0.8	1
10	MCQ	XE-B	C	2
11	MCQ	XE-B	A	2
12	MCQ	XE-B	C	2
13	MCQ	XE-B	C	2
14	MCQ	XE-B	D	2
15	MCQ	XE-B	B	2
16	MCQ	XE-B	D	2
17	NAT	XE-B	33.25 to 33.75	2
18	NAT	XE-B	0.15 to 0.17	2
19	NAT	XE-B	1.25 to 1.27	2
20	NAT	XE-B	2 to 2	2
21	NAT	XE-B	0.32 to 0.34	2
22	NAT	XE-B	37 to 37	2
1	MCQ	XE-C	B	1
2	MCQ	XE-C	B	1
3	MCQ	XE-C	A	1

Q.No.	Type	Section	Key/Range	Marks
4	MCQ	XE-C	A	1
5	MCQ	XE-C	B	1
6	MCQ	XE-C	B	1
7	MCQ	XE-C	C	1
8	MCQ	XE-C	D	1
9	MCQ	XE-C	B	1
10	MCQ	XE-C	B	2
11	MCQ	XE-C	B	2
12	MCQ	XE-C	B	2
13	NAT	XE-C	100.0 to 102.0	2
14	NAT	XE-C	45 to 52	2
15	NAT	XE-C	0.28 to 0.32	2
16	NAT	XE-C	360 to 364	2
17	NAT	XE-C	0.58 to 0.61	2
18	NAT	XE-C	9.2 to 9.6	2
19	NAT	XE-C	2.10 to 2.35	2
20	NAT	XE-C	666 to 670	2
21	NAT	XE-C	560 to 565	2
22	NAT	XE-C	11.0 to 12.5	2
1	MCQ	XE-D	C	1
2	MCQ	XE-D	D	1
3	MCQ	XE-D	B	1
4	MCQ	XE-D	B	1

Q.No.	Type	Section	Key/Range	Marks
5	MCQ	XE-D	A	1
6	MCQ	XE-D	A	1
7	MCQ	XE-D	C	1
8	MCQ	XE-D	D	1
9	NAT	XE-D	-3.0 to -3.0	1
10	MCQ	XE-D	B	2
11	MCQ	XE-D	A	2
12	MCQ	XE-D	C	2
13	MCQ	XE-D	D	2
14	MCQ	XE-D	A	2
15	MCQ	XE-D	A	2
16	NAT	XE-D	2.0 to 2.0	2
17	NAT	XE-D	100 to 100	2
18	NAT	XE-D	1.90 TO 2.10	2
19	NAT	XE-D	19.0 TO 21.0	2
20	NAT	XE-D	52.00 TO 54.00	2
21	NAT	XE-D	102.0 TO 106.0	2
22	NAT	XE-D	10.0 to 10.0	2
1	MCQ	XE-E	B	1
2	MCQ	XE-E	D	1
3	MCQ	XE-E	C	1
4	MCQ	XE-E	C	1
5	MCQ	XE-E	B	1

Q.No.	Type	Section	Key/Range	Marks
6	MCQ	XE-E	D	1
7	MCQ	XE-E	B	1
8	NAT	XE-E	300 to 300	1
9	NAT	XE-E	22.00 to 22.30	1
10	MCQ	XE-E	A	2
11	MCQ	XE-E	A	2
12	MCQ	XE-E	D	2
13	MCQ	XE-E	D	2
14	MCQ	XE-E	A	2
15	NAT	XE-E	1.05 to 1.15	2
16	NAT	XE-E	8.50 to 9.50	2
17	NAT	XE-E	0.3 to 0.3	2
18	NAT	XE-E	770.0 to 785.0	2
19	NAT	XE-E	255 to 255	2
20	NAT	XE-E	41.0 to 43.5	2
21	NAT	XE-E	1.25 to 1.25	2
22	NAT	XE-E	0.700 to 0.750	2
1	MCQ	XE-F	B	1
2	MCQ	XE-F	D	1
3	MCQ	XE-F	D	1
4	MCQ	XE-F	C	1
5	MCQ	XE-F	A	1
6	MCQ	XE-F	B	1

Q.No.	Type	Section	Key/Range	Marks
7	MCQ	XE-F	C	1
8	MCQ	XE-F	A	1
9	MCQ	XE-F	A	1
10	MCQ	XE-F	B	2
11	MCQ	XE-F	D	2
12	MCQ	XE-F	B	2
13	MCQ	XE-F	C	2
14	MCQ	XE-F	D	2
15	MCQ	XE-F	A	2
16	NAT	XE-F	1.2 to 1.4	2
17	NAT	XE-F	0.15 to 0.17	2
18	NAT	XE-F	97.0 to 97.5	2
19	NAT	XE-F	7.6 to 7.8	2
20	NAT	XE-F	2.80 to 2.84	2
21	NAT	XE-F	7497.72 to 7517.72	2
22	NAT	XE-F	0.69 to 0.73	2
1	MCQ	XE-G	D	1
2	MCQ	XE-G	C	1
3	MCQ	XE-G	A	1
4	MCQ	XE-G	B	1
5	MCQ	XE-G	D	1
6	MCQ	XE-G	D	1
7	NAT	XE-G	77.4 to 77.6	1

Q.No.	Type	Section	Key/Range	Marks
8	NAT	XE-G	32 to 32	1
9	NAT	XE-G	74.8 to 75.6	1
10	MCQ	XE-G	A	2
11	MCQ	XE-G	A	2
12	MCQ	XE-G	A	2
13	MCQ	XE-G	B	2
14	MCQ	XE-G	D	2
15	NAT	XE-G	240.00 to 242.00	2
16	NAT	XE-G	11.45 to 11.55	2
17	NAT	XE-G	2.16 to 2.25	2
18	NAT	XE-G	339.1 to 342.9	2
19	NAT	XE-G	0.924 to 0.930	2
20	NAT	XE-G	95.0 to 100.0	2
21	NAT	XE-G	58.1 to 62.9	2
22	NAT	XE-G	1.06 to 1.09	2
1	MCQ	XE-H	C	1
2	MCQ	XE-H	A	1
3	MCQ	XE-H	C	1
4	MCQ	XE-H	C	1
5	MCQ	XE-H	A	1
6	MCQ	XE-H	A	1
7	MCQ	XE-H	B	1
8	MCQ	XE-H	D	1

Q.No.	Type	Section	Key/Range	Marks
9	MCQ	XE-H	B	1
10	MCQ	XE-H	D	2
11	MCQ	XE-H	A	2
12	NAT	XE-H	592.8 to 593.2	2
13	NAT	XE-H	286.40 to 287.30	2
14	NAT	XE-H	99 to 100	2
15	NAT	XE-H	78.4 to 78.6	2
16	NAT	XE-H	29.3 to 29.5	2
17	NAT	XE-H	7.8 to 8.1	2
18	NAT	XE-H	75 to 85	2
19	NAT	XE-H	-7.6 to -7.0	2
20	NAT	XE-H	1.1 to 1.3	2
21	NAT	XE-H	1.30 to 1.50	2
22	NAT	XE-H	0.13 to 0.19	2