Q. 1 – Q. 5 carry one mark each.

Q.1 The volume of a sphere of diameter 1 unit is ________ than the volume of a cube of side 1 unit.

(A) least (B) less (C) lesser (D) low

Q.2 The unruly crowd demanded that the accused be _____________ without trial.

(A) hanged (B) hanging (C) hankering (D) hung

Q.3 Choose the statement(s) where the underlined word is used correctly:

(i) A prone is a dried plum.
(ii) He was lying prone on the floor.
(iii) People who eat a lot of fat are prone to heart disease.

(A) (i) and (iii) only (B) (iii) only (C) (i) and (ii) only (D) (ii) and (iii) only

Q.4 **Fact:** If it rains, then the field is wet.

Read the following statements:
(i) It rains
(ii) The field is not wet
(iii) The field is wet
(iv) It did not rain

Which one of the options given below is **NOT** logically possible, based on the given fact?

(A) If (iii), then (iv). (B) If (i), then (iii).

(C) If (i), then (ii). (D) If (ii), then (iv).

Q.5 A window is made up of a square portion and an equilateral triangle portion above it. The base of the triangular portion coincides with the upper side of the square. If the perimeter of the window is 6 m, the area of the window in m^2 is ___________.

(A) 1.43 (B) 2.06 (C) 2.68 (D) 2.88

Q. 6 – Q. 10 carry two marks each.

Q.6 Students taking an exam are divided into two groups, **P** and **Q** such that each group has the same number of students. The performance of each of the students in a test was evaluated out of 200 marks. It was observed that the mean of group **P** was 105, while that of group **Q** was 85. The standard deviation of group **P** was 25, while that of group **Q** was 5. Assuming that the marks were distributed on a normal distribution, which of the following statements will have the highest probability of being **TRUE**?

(A) No student in group **Q** scored less marks than any student in group **P**.

(B) No student in group **P** scored less marks than any student in group **Q**.

(C) Most students of group **Q** scored marks in a narrower range than students in group **P**.

(D) The median of the marks of group **P** is 100.

Q.7 A smart city integrates all modes of transport, uses clean energy and promotes sustainable use of resources. It also uses technology to ensure safety and security of the city, something which critics argue, will lead to a surveillance state.

Which of the following can be logically inferred from the above paragraph?

(i) All smart cities encourage the formation of surveillance states.
(ii) Surveillance is an integral part of a smart city.
(iii) Sustainability and surveillance go hand in hand in a smart city.
(iv) There is a perception that smart cities promote surveillance.

(A) (i) and (iv) only (B) (ii) and (iii) only

(C) (iv) only (D) (i) only

Q.8 Find the missing sequence in the letter series.

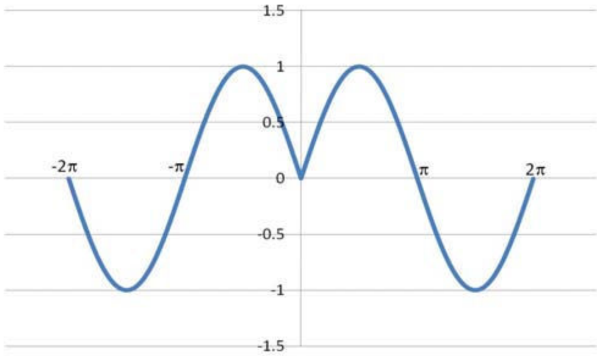
B, FH, LNP, _ _ _ _.

(A) SUWY (B) TUVW (C) TVXZ (D) TWXZ

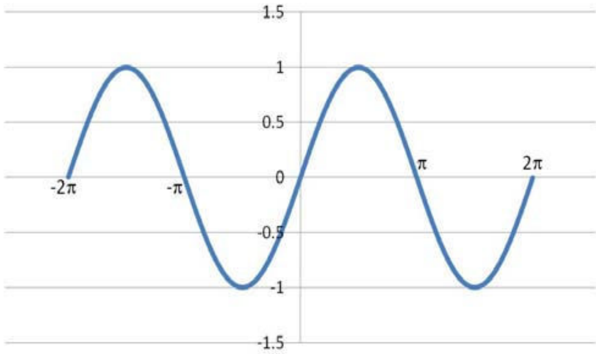
Q.9 The binary operation □ is defined as $a \square b = ab+(a+b)$, where a and b are any two real numbers. The value of the identity element of this operation, defined as the number x such that $a \square x = a$, for any a, is _____.

(A) 0 (B) 1 (C) 2 (D) 10

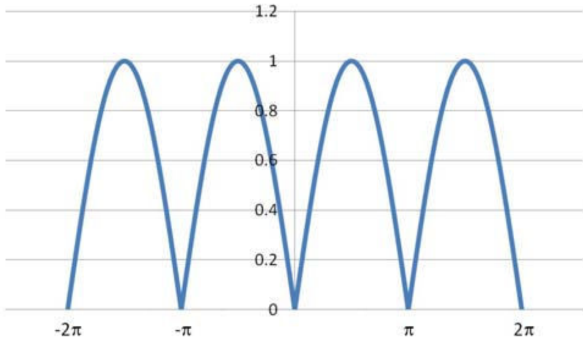
Q.10 Which of the following curves represents the function $y = \ln(|e^{[|\sin(|x|)|]}|)$ for $|x| < 2\pi$? Here, x represents the abscissa and y represents the ordinate.



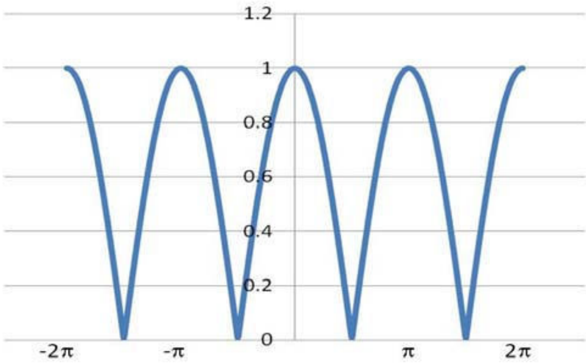
(A)



(B)



(C)



(D)

END OF THE QUESTION PAPER

Q. 1 – Q. 25 carry one mark each.

Q.1 The condition for which the eigenvalues of the matrix

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

are positive, is

(A) $k > 1/2$ (B) $k > -2$ (C) $k > 0$ (D) $k < -1/2$

Q.2 The values of x for which the function

$$f(x) = \frac{x^2 - 3x - 4}{x^2 + 3x - 4}$$

is **NOT** continuous are

(A) 4 and -1 (B) 4 and 1 (C) -4 and 1 (D) -4 and -1

Q.3 Laplace transform of $\cos(\omega t)$ is

(A) $\frac{s}{s^2 + \omega^2}$

(B) $\frac{\omega}{s^2 + \omega^2}$

(C) $\frac{s}{s^2 - \omega^2}$

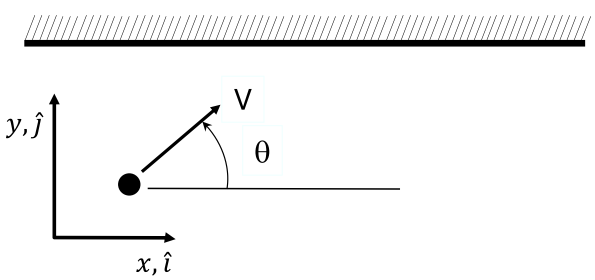
(D) $\frac{\omega}{s^2 - \omega^2}$

Q.4 A function f of the complex variable $z = x + i\,y$, is given as $f(x, y) = u(x, y) + i\,v(x, y)$, where $u(x, y) = 2kxy$ and $v(x, y) = x^2 - y^2$. The value of k, for which the function is analytic, is _____

Q.5 Numerical integration using trapezoidal rule gives the best result for a single variable function, which is

(A) linear (B) parabolic (C) logarithmic (D) hyperbolic

Q.6 A point mass having mass M is moving with a velocity V at an angle θ to the wall as shown in the figure. The mass undergoes a perfectly elastic collision with the smooth wall and rebounds. The total change (final minus initial) in the momentum of the mass is



(A) $-2MV\cos\theta\,\hat{j}$ (B) $2MV\sin\theta\,\hat{j}$ (C) $2MV\cos\theta\,\hat{j}$ (D) $-2MV\sin\theta\,\hat{j}$

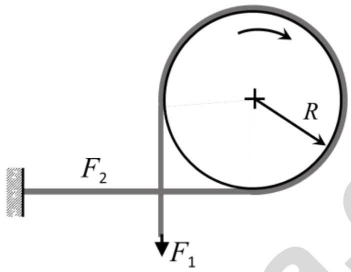
Q.7 A shaft with a circular cross-section is subjected to pure twisting moment. The ratio of the maximum shear stress to the largest principal stress is

(A) 2.0 (B) 1.0 (C) 0.5 (D) 0

Q.8 A thin cylindrical pressure vessel with closed-ends is subjected to internal pressure. The ratio of circumferential (hoop) stress to the longitudinal stress is

(A) 0.25 (B) 0.50 (C) 1.0 (D) 2.0

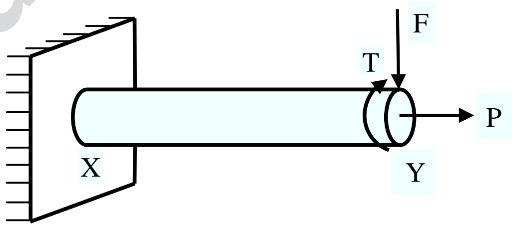
Q.9 The forces F_1 and F_2 in a brake band and the direction of rotation of the drum are as shown in the figure. The coefficient of friction is 0.25. The angle of wrap is $3\pi/2$ radians. It is given that R = 1 m and F_2 = 1 N. The torque (in N-m) exerted on the drum is _________



Q.10 A single degree of freedom mass-spring-viscous damper system with mass m, spring constant k and viscous damping coefficient q is critically damped. The correct relation among m, k, and q is

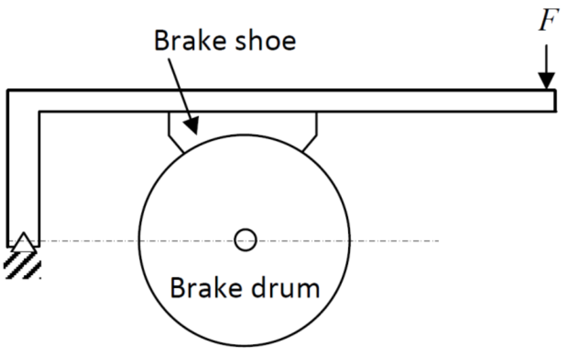
(A) $q = \sqrt{2\,k\,m}$ (B) $q = 2\sqrt{k\,m}$ (C) $q = \sqrt{\frac{2\,k}{m}}$ (D) $q = 2\sqrt{\frac{k}{m}}$

Q.11 A machine element XY, fixed at end X, is subjected to an axial load P, transverse load F, and a twisting moment T at its free end Y. The most critical point from the strength point of view is



(A) a point on the circumference at location Y
(B) a point at the center at location Y
(C) a point on the circumference at location X
(D) a point at the center at location X

Q.12 For the brake shown in the figure, which one of the following is TRUE?



(A) Self energizing for clockwise rotation of the drum
(B) Self energizing for anti-clockwise rotation of the drum
(C) Self energizing for rotation in either direction of the drum
(D) Not of the self energizing type

Q.13 The volumetric flow rate (per unit depth) between two streamlines having stream functions ψ_1 and ψ_2 is

(A) $|\psi_1+\psi_2|$ (B) $\psi_1\psi_2$ (C) ψ_1/ψ_2 (D) $|\psi_1-\psi_2|$

Q.14 Assuming constant temperature condition and air to be an ideal gas, the variation in atmospheric pressure with height calculated from fluid statics is

(A) linear (B) exponential (C) quadratic (D) cubic

Q.15 A hollow cylinder has length L, inner radius r_1, outer radius r_2, and thermal conductivity k. The thermal resistance of the cylinder for radial conduction is

(A) $\dfrac{\ln(r_2/r_1)}{2\pi kL}$ (B) $\dfrac{\ln(r_1/r_2)}{2\pi kL}$ (C) $\dfrac{2\pi kL}{\ln(r_2/r_1)}$ (D) $\dfrac{2\pi kL}{\ln(r_1/r_2)}$

Q.16 Consider the radiation heat exchange inside an annulus between two very long concentric cylinders. The radius of the outer cylinder is R_o and that of the inner cylinder is R_i. The radiation view factor of the outer cylinder onto itself is

(A) $1-\sqrt{\frac{R_i}{R_o}}$ (B) $\sqrt{1-\frac{R_i}{R_o}}$ (C) $1-\left(\frac{R_i}{R_o}\right)^{1/3}$ (D) $1-\frac{R_i}{R_o}$

Q.17 The internal energy of an ideal gas is a function of

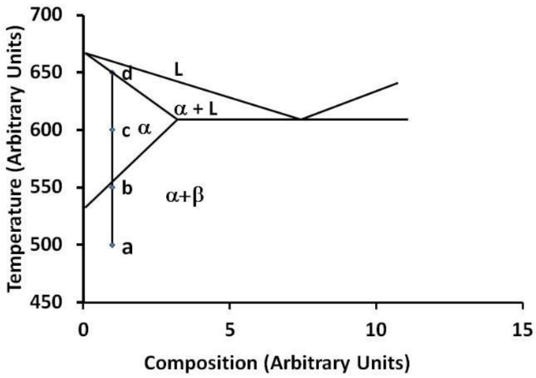
(A) temperature and pressure
(B) volume and pressure
(C) entropy and pressure
(D) temperature only

Q.18 The heat removal rate from a refrigerated space and the power input to the compressor are 7.2 kW and 1.8 kW, respectively. The coefficient of performance (COP) of the refrigerator is ______

Q.19 Consider a simple gas turbine (Brayton) cycle and a gas turbine cycle with perfect regeneration. In both the cycles, the pressure ratio is 6 and the ratio of the specific heats of the working medium is 1.4. The ratio of minimum to maximum temperatures is 0.3 (with temperatures expressed in K) in the regenerative cycle. The ratio of the thermal efficiency of the simple cycle to that of the regenerative cycle is _________

Q.20 In a single-channel queuing model, the customer arrival rate is 12 per hour and the serving rate is 24 per hour. The expected time that a customer is in queue is _______ minutes.

Q.21 In the phase diagram shown in the figure, four samples of the same composition are heated to temperatures marked by a, b, c and d.



At which temperature will a sample get solutionized the fastest?

(A) a (B) b (C) c (D) d

Q.22 The welding process which uses a blanket of fusible granular flux is

(A) tungsten inert gas welding (B) submerged arc welding
(C) electroslag welding (D) thermit welding

Q.23 The value of true strain produced in compressing a cylinder to half its original length is

(A) 0.69 (B) − 0.69 (C) 0.5 (D) − 0.5

Q.24 The following data is applicable for a turning operation. The length of job is 900 mm, diameter of job is 200 mm, feed rate is 0.25 mm/rev and optimum cutting speed is 300 m/min. The machining time (in min) is __________

Q.25 In an ultrasonic machining (USM) process, the material removal rate (MRR) is plotted as a function of the feed force of the USM tool. With increasing feed force, the MRR exhibits the following behavior:

(A) increases linearly
(B) decreases linearly
(C) does not change
(D) first increases and then decreases

Q. 26 – Q. 55 carry two marks each.

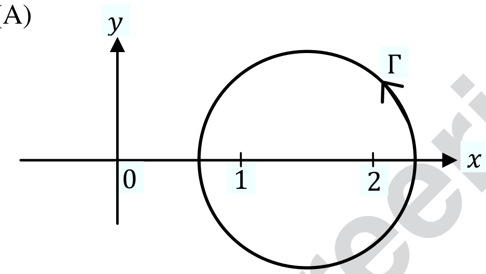
Q.26 A scalar potential φ has the following gradient: $\nabla\varphi = yz\hat{\imath} + xz\hat{\jmath} + xy\hat{k}$. Consider the integral

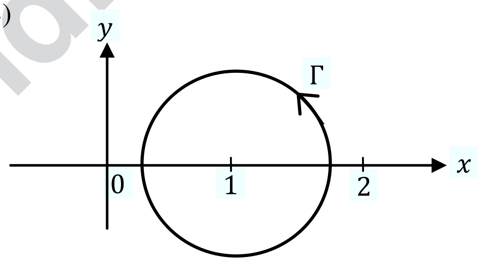
$\int_C \nabla\varphi . d\vec{r}$ on the curve $\vec{r} = x\hat{\imath} + y\hat{\jmath} + z\hat{k}$.

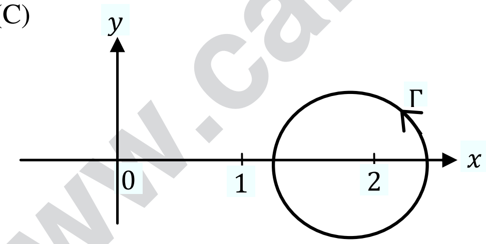
The curve C is parameterized as follows: $\begin{cases} x = t \\ y = t^2 \\ z = 3t^2 \end{cases}$ and $1 \le t \le 3$.

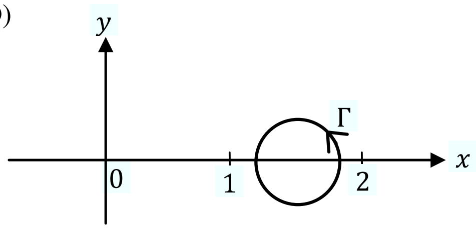
The value of the integral is ________

Q.27 The value of $\oint_\Gamma \frac{3\,z-5}{(z-1)\,(z-2)}\,dz$ along a closed path Γ is equal to $(4\,\pi\,i)$, where $z = x + iy$ and $i = \sqrt{-1}$. The correct path Γ is

(A)


(B)


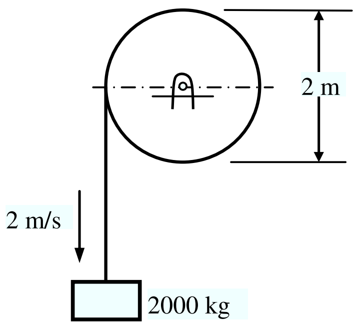
(C)


(D)


Q.28 The probability that a screw manufactured by a company is defective is 0.1. The company sells screws in packets containing 5 screws and gives a guarantee of replacement if one or more screws in the packet are found to be defective. The probability that a packet would have to be replaced is _________

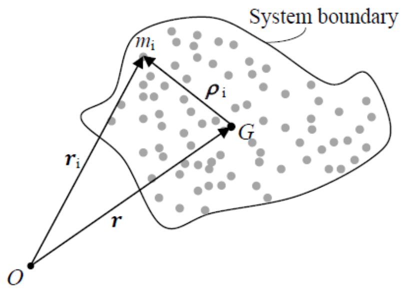
Q.29 The error in numerically computing the integral $\int_0^{\pi}(\sin x + \cos x)\, dx$ using the trapezoidal rule with three intervals of equal length between 0 and π is ___________

Q.30 A mass of 2000 kg is currently being lowered at a velocity of 2 m/s from the drum as shown in the figure. The mass moment of inertia of the drum is 150 kg-m^2. On applying the brake, the mass is brought to rest in a distance of 0.5 m. The energy absorbed by the brake (in kJ) is __________



Q.31 A system of particles in motion has mass center G as shown in the figure. The particle i has mass m_i and its position with respect to a fixed point O is given by the position vector $\mathbf{r}_i$. The position of the particle with respect to G is given by the vector $\boldsymbol{\rho}_i$. The time rate of change of the angular momentum of the system of particles about G is

(The quantity $\ddot{\boldsymbol{\rho}}_i$ indicates second derivative of $\boldsymbol{\rho}_i$ with respect to time and likewise for $\boldsymbol{r}_i$).



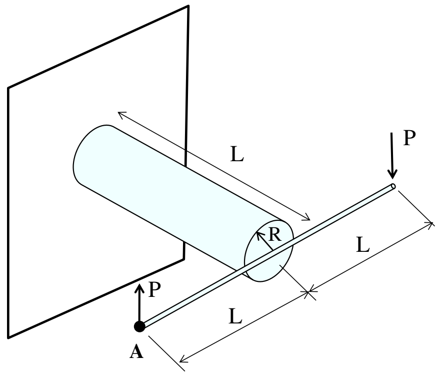
(A) $\sum_i \boldsymbol{r}_i \times m_i \ddot{\boldsymbol{\rho}}_i$

(B) $\sum_i \boldsymbol{\rho}_i \times m_i \ddot{\boldsymbol{r}}_i$

(C) $\sum_i \boldsymbol{r}_i \times m_i \ddot{\boldsymbol{r}}_i$

(D) $\sum_i \boldsymbol{\rho}_i \times m_i \ddot{\boldsymbol{\rho}}_i$

Q.32 A rigid horizontal rod of length 2L is fixed to a circular cylinder of radius R as shown in the figure. Vertical forces of magnitude P are applied at the two ends as shown in the figure. The shear modulus for the cylinder is G and the Young's modulus is E.



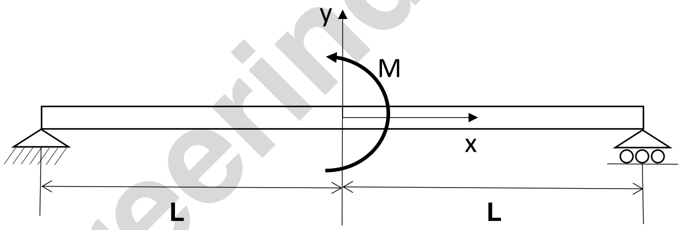
The vertical deflection at point **A** is

(A) $PL^3/(\pi R^4 G)$ (B) $PL^3/(\pi R^4 E)$ (C) $2PL^3/(\pi R^4 E)$ (D) $4PL^3/(\pi R^4 G)$

Q.33 A simply supported beam of length 2L is subjected to a moment M at the mid-point x = 0 as shown in the figure. The deflection in the domain $0 \le x \le L$ is given by

$$w = \frac{-Mx}{12\,EIL}(L-x)(x+c),$$

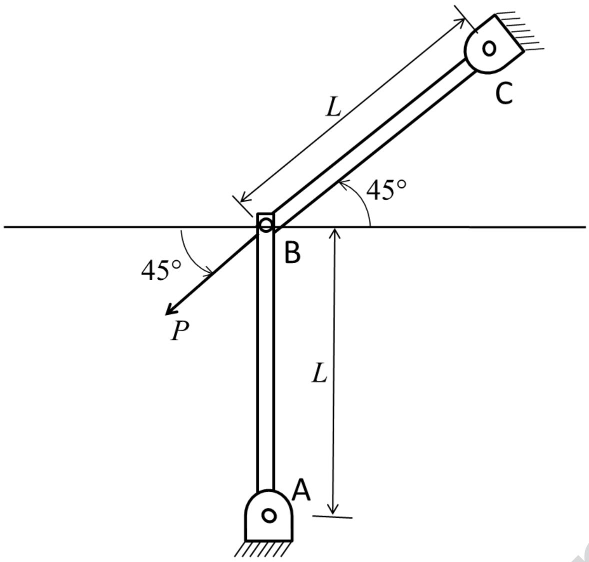
where E is the Young's modulus, I is the area moment of inertia and c is a constant (to be determined) .



The slope at the center x = 0 is

(A) $ML/(2EI)$ (B) $ML/(3EI)$ (C) $ML/(6EI)$ (D) $ML/(12EI)$

Q.34 In the figure, the load P = 1 N, length L = 1 m, Young's modulus E = 70 GPa, and the cross-section of the links is a square with dimension 10 mm × 10 mm. All joints are pin joints.

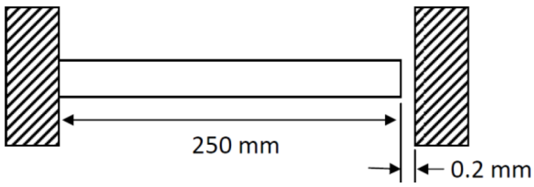


The stress (in Pa) in the link AB is ___________

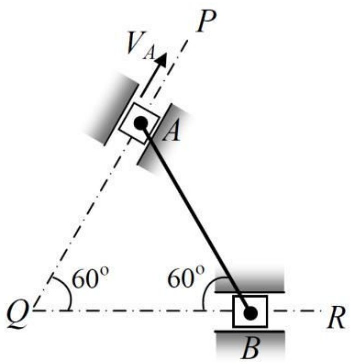
(Indicate compressive stress by a negative sign and tensile stress by a positive sign.)

Q.35 A circular metallic rod of length 250 mm is placed between two rigid immovable walls as shown in the figure. The rod is in perfect contact with the wall on the left side and there is a gap of 0.2 mm between the rod and the wall on the right side. If the temperature of the rod is increased by 200^{o} C, the axial stress developed in the rod is __________ MPa.

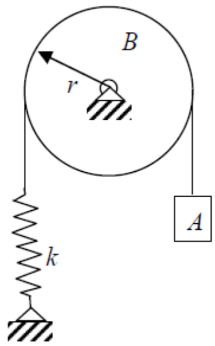
Young's modulus of the material of the rod is 200 GPa and the coefficient of thermal expansion is 10^{-5} per ^{o}C.



Q.36 The rod AB, of length 1 m, shown in the figure is connected to two sliders at each end through pins. The sliders can slide along QP and QR. If the velocity V_A of the slider at A is 2 m/s, the velocity of the midpoint of the rod at this instant is ___________ m/s.



Q.37 The system shown in the figure consists of block A of mass 5 kg connected to a spring through a massless rope passing over pulley B of radius r and mass 20 kg. The spring constant k is 1500 N/m. If there is no slipping of the rope over the pulley, the natural frequency of the system is_____________ rad/s.



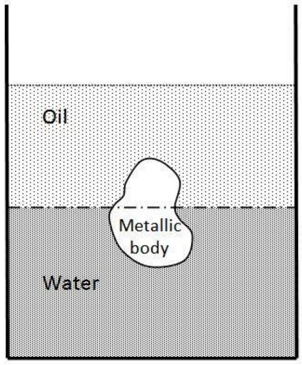
Q.38 In a structural member under fatigue loading, the minimum and maximum stresses developed at the critical point are 50 MPa and 150 MPa, respectively. The endurance, yield, and the ultimate strengths of the material are 200 MPa, 300 MPa and 400 MPa, respectively. The factor of safety using modified Goodman criterion is

(A) $\frac{3}{2}$ (B) $\frac{8}{5}$ (C) $\frac{12}{7}$ (D) 2

Q.39 The large vessel shown in the figure contains oil and water. A body is submerged at the interface of oil and water such that 45 percent of its volume is in oil while the rest is in water. The density of the body is _________ kg/m^3.

The specific gravity of oil is 0.7 and density of water is 1000 kg/m^3.

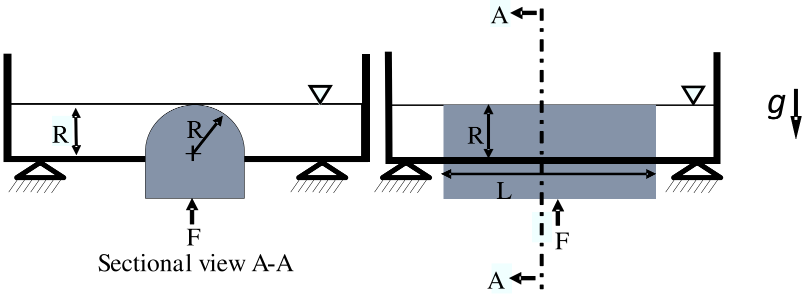
Acceleration due to gravity g = 10 m/s^2.



Q.40 Consider fluid flow between two infinite horizontal plates which are parallel (the gap between them being 50 mm). The top plate is sliding parallel to the stationary bottom plate at a speed of 3 m/s. The flow between the plates is solely due to the motion of the top plate. The force per unit area (magnitude) required to maintain the bottom plate stationary is _________ N/m^2.

Viscosity of the fluid μ = 0.44 kg/m-s and density ρ = 888 kg/m^3.

Q.41 Consider a frictionless, massless and leak-proof plug blocking a rectangular hole of dimensions $2R \times L$ at the bottom of an open tank as shown in the figure. The head of the plug has the shape of a semi-cylinder of radius R. The tank is filled with a liquid of density ρ up to the tip of the plug. The gravitational acceleration is g. Neglect the effect of the atmospheric pressure.



The force F required to hold the plug in its position is

(A) $2\rho R^2 gL\left(1-\frac{\pi}{4}\right)$ (B) $2\rho R^2 gL\left(1+\frac{\pi}{4}\right)$

(C) $\pi R^2 \rho gL$ (D) $\frac{\pi}{2}\rho R^2 gL$

Q.42 Consider a parallel-flow heat exchanger with area A_p and a counter-flow heat exchanger with area A_c. In both the heat exchangers, the hot stream flowing at 1 kg/s cools from 80 °C to 50 °C. For the cold stream in both the heat exchangers, the flow rate and the inlet temperature are 2 kg/s and 10 °C, respectively. The hot and cold streams in both the heat exchangers are of the same fluid. Also, both the heat exchangers have the same overall heat transfer coefficient. The ratio A_c/A_p is _________

Q.43 Two cylindrical shafts A and B at the same initial temperature are simultaneously placed in a furnace. The surfaces of the shafts remain at the furnace gas temperature at all times after they are introduced into the furnace. The temperature variation in the axial direction of the shafts can be assumed to be negligible. The data related to shafts A and B is given in the following Table.

Quantity	Shaft A	Shaft B
Diameter (m)	0.4	0.1
Thermal conductivity (W/m-K)	40	20
Volumetric heat capacity (J/m^3-K)	2×10^6	2×10^7

The temperature at the centerline of the shaft A reaches 400 °C after two hours. The time required (in hours) for the centerline of the shaft B to attain the temperature of 400 °C is _______

Q.44 A piston-cylinder device initially contains 0.4 m^3 of air (to be treated as an ideal gas) at 100 kPa and 80 °C. The air is now isothermally compressed to 0.1 m^3. The work done during this process is ________ kJ.

(Take the sign convention such that work done on the system is negative)

Q.45 A reversible cycle receives 40 kJ of heat from one heat source at a temperature of 127 °C and 37 kJ from another heat source at 97 °C. The heat rejected (in kJ) to the heat sink at 47 °C is __________

Q.46 A refrigerator uses R-134a as its refrigerant and operates on an ideal vapour-compression refrigeration cycle between 0.14 MPa and 0.8 MPa. If the mass flow rate of the refrigerant is 0.05 kg/s, the rate of heat rejection to the environment is _________ kW.

Given data:
At P = 0.14 MPa, h = 236.04 kJ/kg, s = 0.9322 kJ/kg-K
At P = 0.8 MPa, h = 272.05 kJ/kg (superheated vapour)
At P = 0.8 MPa, h = 93.42 kJ/kg (saturated liquid)

Q.47 The partial pressure of water vapour in a moist air sample of relative humidity 70% is 1.6 kPa, the total pressure being 101.325 kPa. Moist air may be treated as an ideal gas mixture of water vapour and dry air. The relation between saturation temperature (T_s in K) and saturation pressure (p_s in kPa) for water is given by $\ln(p_s/p_o) = 14.317 - 5304/T_s$, where $p_o = 101.325$ kPa. The dry bulb temperature of the moist air sample (in °C) is __________

Q.48 In a binary system of A and B, a liquid of 20% A (80% B) is coexisting with a solid of 70% A (30% B). For an overall composition having 40% A, the fraction of solid is

(A) 0.40 (B) 0.50 (C) 0.60 (D) 0.75

Q.49 Gray cast iron blocks of size 100 mm × 50 mm × 10 mm with a central spherical cavity of diameter 4 mm are sand cast. The shrinkage allowance for the pattern is 3%. The ratio of the volume of the pattern to volume of the casting is _________

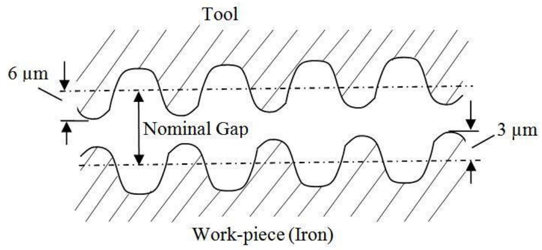
Q.50 The voltage-length characteristic of a direct current arc in an arc welding process is $V = (100 + 40l)$, where l is the length of the arc in mm and V is arc voltage in volts. During a welding operation, the arc length varies between 1 and 2 mm and the welding current is in the range 200-250 A. Assuming a linear power source, the short circuit current is_________ A.

Q.51 For a certain job, the cost of metal cutting is Rs. $18C/V$ and the cost of tooling is Rs. $270C/(TV)$, where C is a constant, V is the cutting speed in m/min and T is the tool life in minutes. The Taylor's tool life equation is $VT^{0.25} = 150$. The cutting speed (in m/min) for the minimum total cost is _______

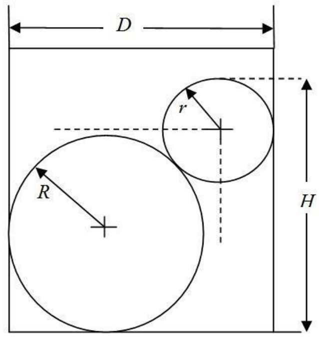
Q.52 The surface irregularities of electrodes used in an electrochemical machining (ECM) process are 3 µm and 6 µm as shown in the figure. If the work-piece is of pure iron and 12V DC is applied between the electrodes, the largest feed rate is ___________mm/min.

Conductivity of the electrolyte	0.02 $ohm^{-1}mm^{-1}$
Over-potential voltage	1.5 V
Density of iron	7860 kg/m^3
Atomic weight of iron	55.85 gm

Assume the iron to be dissolved as Fe^{+2} and the Faraday constant to be 96500 Coulomb.



Q.53 For the situation shown in the figure below the expression for H in terms of r, R and D is



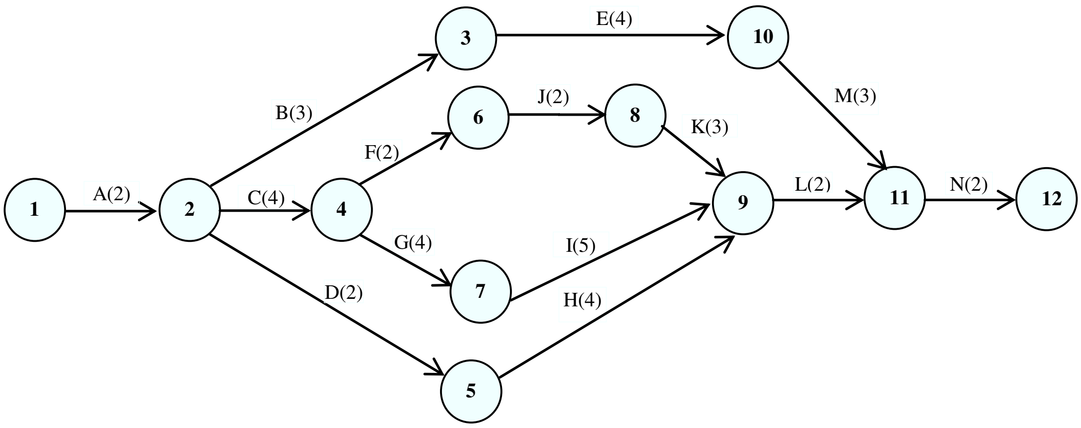
(A) $H = D + \sqrt{r^2 + R^2}$
(B) $H = (R + r) + (D + r)$
(C) $H = (R + r) + \sqrt{D^2 - R^2}$
(D) $H = (R + r) + \sqrt{2D(R + r) - D^2}$

Q.54 A food processing company uses 25,000 kg of corn flour every year. The quantity-discount price of corn flour is provided in the table below:

Quantity (kg)	Unit price (Rs/kg)
1-749	70
750-1499	65
1500 and above	60

The order processing charges are Rs. 500/order. The handling plus carry-over charge on an annual basis is 20% of the purchase price of the corn flour per kg. The optimal order quantity (in kg) is _____________

Q.55 A project consists of 14 activities, A to N. The duration of these activities (in days) are shown in brackets on the network diagram. The latest finish time (in days) for node 10 is __________



END OF THE QUESTION PAPER