Q. 1 – Q. 5 carry one mark each.

Q.1 Which of the following is **CORRECT** with respect to grammar and usage?

Mount Everest is ____________.

(A) the highest peak in the world

(B) highest peak in the world

(C) one of highest peak in the world

(D) one of the highest peak in the world

Q.2 The policeman asked the victim of a theft, “What did you _____?”

(A) loose (B) lose (C) loss (D) louse

Q.3 Despite the new medicine’s ______________ in treating diabetes, it is not ______________widely.

(A) effectiveness --- prescribed (B) availability --- used
(C) prescription --- available (D) acceptance --- proscribed

Q.4 In a huge pile of apples and oranges, both ripe and unripe mixed together, 15% are unripe fruits. Of the unripe fruits, 45% are apples. Of the ripe ones, 66% are oranges. If the pile contains a total of 5692000 fruits, how many of them are apples?

(A) 2029198 (B) 2467482 (C) 2789080 (D) 3577422

Q.5 Michael lives 10 km away from where I live. Ahmed lives 5 km away and Susan lives 7 km away from where I live. Arun is farther away than Ahmed but closer than Susan from where I live. From the information provided here, what is one possible distance (in km) at which I live from Arun’s place?

(A) 3.00 (B) 4.99 (C) 6.02 (D) 7.01

Q. 6 – Q. 10 carry two marks each.

Q.6 A person moving through a tuberculosis prone zone has a 50% probability of becoming infected. However, only 30% of infected people develop the disease. What percentage of people moving through a tuberculosis prone zone remains infected but does not show symptoms of disease?

(A) 15 (B) 33 (C) 35 (D) 37

Q.7 In a world filled with uncertainty, he was glad to have many good friends. He had always assisted them in times of need and was confident that they would reciprocate. However, the events of the last week proved him wrong.

Which of the following inference(s) is/are logically valid and can be inferred from the above passage?

(i) His friends were always asking him to help them.

(ii) He felt that when in need of help, his friends would let him down.

(iii) He was sure that his friends would help him when in need.

(iv) His friends did not help him last week.

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

Q.8 Leela is older than her cousin Pavithra. Pavithra's brother Shiva is older than Leela. When Pavithra and Shiva are visiting Leela, all three like to play chess. Pavithra wins more often than Leela does.

Which one of the following statements must be **TRUE** based on the above?

(A) When Shiva plays chess with Leela and Pavithra, he often loses.

(B) Leela is the oldest of the three.

(C) Shiva is a better chess player than Pavithra.

(D) Pavithra is the youngest of the three.

Q.9 If $q^{-a} = \frac{1}{r}$ and $r^{-b} = \frac{1}{s}$ and $s^{-c} = \frac{1}{q}$, the value of *abc* is ____.

(A) $(rqs)^{-1}$ (B) 0 (C) 1 (D) $r+q+s$

Q.10 **P**, **Q**, **R** and **S** are working on a project. **Q** can finish the task in 25 days, working alone for 12 hours a day. **R** can finish the task in 50 days, working alone for 12 hours per day. **Q** worked 12 hours a day but took sick leave in the beginning for two days. **R** worked 18 hours a day on all days. What is the ratio of work done by **Q** and **R** after 7 days from the start of the project?

(A) 10:11 (B) 11:10 (C) 20:21 (D) 21:20

END OF THE QUESTION PAPER

Q. 1 – Q. 25 carry one mark each.

Q.1 The solution to the system of equations

$$\begin{bmatrix} 2 & 5 \\ -4 & 3 \end{bmatrix} \begin{Bmatrix} x \\ y \end{Bmatrix} = \begin{Bmatrix} 2 \\ -30 \end{Bmatrix}$$

is

(A) $6,\ 2$ (B) $-6, 2$ (C) $-6, -2$ (D) $6, -2$

Q.2 If $f(t)$ is a function defined for all $t \geq 0$, its Laplace transform $F(s)$ is defined as

(A) $\int_0^\infty e^{st}\ f(t)\mathrm{d}t$ (B) $\int_0^\infty e^{-st}\ f(t)\mathrm{d}t$

(C) $\int_0^\infty e^{ist}\ f(t)\mathrm{d}t$ (D) $\int_0^\infty e^{-ist}\ f(t)\mathrm{d}t$

Q.3 $f(z) = u(x, y) + i\ v(x, y)$ is an analytic function of complex variable $z = x + i\ y$ where $i = \sqrt{-1}$. If $u(x, y) = 2\ xy$, then $v(x, y)$ may be expressed as

(A) $-x^2 + y^2 +$ constant (B) $x^2 - y^2 +$ constant

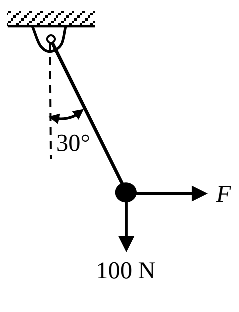
(C) $x^2 + y^2 +$ constant (D) $-(x^2 + y^2) +$ constant

Q.4 Consider a Poisson distribution for the tossing of a biased coin. The mean for this distribution is μ. The standard deviation for this distribution is given by

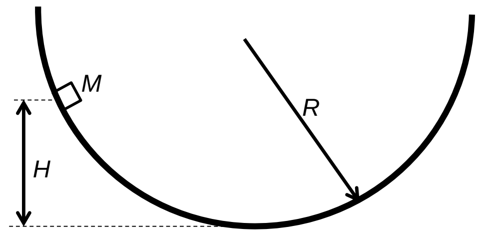
(A) $\sqrt{\mu}$ (B) μ^2 (C) μ (D) $1/\mu$

Q.5 Solve the equation $x = 10\cos(x)$ using the Newton-Raphson method. The initial guess is $x = \pi/4$. The value of the predicted root after the first iteration, up to second decimal, is ________

Q.6 A rigid ball of weight 100 N is suspended with the help of a string. The ball is pulled by a horizontal force F such that the string makes an angle of 30° with the vertical. The magnitude of force F (in N) is __________

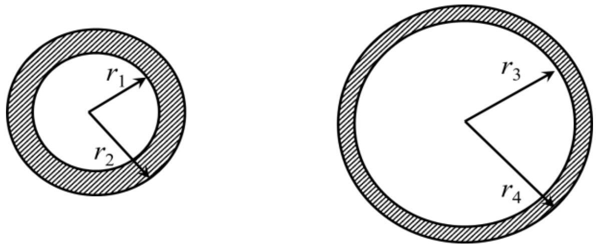


Q.7 A point mass M is released from rest and slides down a spherical bowl (of radius R) from a height H as shown in the figure below. The surface of the bowl is smooth (no friction). The velocity of the mass at the bottom of the bowl is



(A) $\sqrt{gH}$ (B) $\sqrt{2gR}$ (C) $\sqrt{2gH}$ (D) 0

Q.8 The cross sections of two hollow bars made of the same material are concentric circles as shown in the figure. It is given that $r_3 > r_1$ and $r_4 > r_2$, and that the areas of the cross-sections are the same. J_1 and J_2 are the torsional rigidities of the bars on the left and right, respectively. The ratio J_2/J_1 is



(A) > 1 (B) < 0.5 (C) =1 (D) between 0.5 and 1

Q.9 A cantilever beam having square cross-section of side a is subjected to an end load. If a is increased by 19%, the tip deflection decreases approximately by

(A) 19% (B) 29% (C) 41% (D) 50%

Q.10 A car is moving on a curved horizontal road of radius 100 m with a speed of 20 m/s. The rotating masses of the engine have an angular speed of 100 rad/s in clockwise direction when viewed from the front of the car. The combined moment of inertia of the rotating masses is 10 kg-m^2. The magnitude of the gyroscopic moment (in N-m) is __________

Q.11 A single degree of freedom spring mass system with viscous damping has a spring constant of 10 kN/m. The system is excited by a sinusoidal force of amplitude 100 N. If the damping factor (ratio) is 0.25, the amplitude of steady state oscillation at resonance is ________mm.

Q.12 The spring constant of a helical compression spring DOES NOT depend on

(A) coil diameter
(B) material strength
(C) number of active turns
(D) wire diameter

Q.13 The instantaneous stream-wise velocity of a turbulent flow is given as follows:

$$u(x, y, z, t) = \bar{u}(x, y, z) + u'(x, y, z, t)$$

The time-average of the fluctuating velocity $u'(x, y, z, t)$ is

(A) $u'/2$ (B) $-\bar{u}/2$ (C) zero (D) $\bar{u}/2$

Q.14 For a floating body, buoyant force acts at the

(A) centroid of the floating body
(B) center of gravity of the body
(C) centroid of the fluid vertically below the body
(D) centroid of the displaced fluid

Q.15 A plastic sleeve of outer radius r_0 = 1 mm covers a wire (radius r = 0.5 mm) carrying electric current. Thermal conductivity of the plastic is 0.15 W/m-K. The heat transfer coefficient on the outer surface of the sleeve exposed to air is 25 W/m^2-K. Due to the addition of the plastic cover, the heat transfer from the wire to the ambient will

(A) increase
(B) remain the same
(C) decrease
(D) be zero

Q.16 Which of the following statements are TRUE with respect to heat and work?

(i) They are boundary phenomena
(ii) They are exact differentials
(iii) They are path functions

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

Q.17 Propane (C_3H_8) is burned in an oxygen atmosphere with 10% deficit oxygen with respect to the stoichiometric requirement. Assuming no hydrocarbons in the products, the volume percentage of CO in the products is __________

Q.18 Consider two hydraulic turbines having identical specific speed and effective head at the inlet. If the speed ratio (N_1/N_2) of the two turbines is 2, then the respective power ratio (P_1/P_2) is ______________

Q.19 The INCORRECT statement about regeneration in vapor power cycle is that

(A) it increases the irreversibility by adding the liquid with higher energy content to the steam generator
(B) heat is exchanged between the expanding fluid in the turbine and the compressed fluid before heat addition
(C) the principle is similar to the principle of Stirling gas cycle
(D) it is practically implemented by providing feed water heaters

Q.20 The "Jominy test" is used to find

(A) Young's modulus
(B) hardenability
(C) yield strength
(D) thermal conductivity

Q.21 Under optimal conditions of the process the temperatures experienced by a copper work piece in fusion welding, brazing and soldering are such that

(A) $T_{welding} > T_{soldering} > T_{brazing}$
(B) $T_{soldering} > T_{welding} > T_{brazing}$
(C) $T_{brazing} > T_{welding} > T_{soldering}$
(D) $T_{welding} > T_{brazing} > T_{soldering}$

Q.22 The part of a gating system which regulates the rate of pouring of molten metal is

(A) pouring basin (B) runner (C) choke (D) ingate

Q.23 The non-traditional machining process that essentially requires vacuum is

(A) electron beam machining
(B) electro chemical machining
(C) electro chemical discharge machining
(D) electro discharge machining

Q.24 In an orthogonal cutting process the tool used has rake angle of zero degree. The measured cutting force and thrust force are 500 N and 250 N, respectively. The coefficient of friction between the tool and the chip is _________

Q.25 Match the following:

P. Feeler gauge	I. Radius of an object
Q. Fillet gauge	II. Diameter within limits by comparison
R. Snap gauge	III. Clearance or gap between components
S. Cylindrical plug gauge	IV. Inside diameter of straight hole

(A) P–III, Q–I, R–II, S–IV
(B) P–III, Q–II, R–I, S–IV
(C) P–IV, Q–II, R–I, S–III
(D) P–IV, Q–I, R–II, S–III

Q. 26 – Q. 55 carry two marks each.

Q.26 Consider the function $f(x) = 2x^3 - 3x^2$ in the domain $[-1, 2]$. The global minimum of $f(x)$ is _____________

Q.27 If $y = f(x)$ satisfies the boundary value problem $y'' + 9y = 0$, $y(0) = 0$, $y(\pi/2) = \sqrt{2}$, then $y(\pi/4)$ is ________

Q.28 The value of the integral

$$\int_{-\infty}^{\infty} \frac{\sin x}{x^2 + 2x + 2}\,\mathrm{d}x$$

evaluated using contour integration and the residue theorem is

(A) $-\pi \sin(1)/\mathrm{e}$ (B) $-\pi \cos(1)/\mathrm{e}$ (C) $\sin(1)/\mathrm{e}$ (D) $\cos(1)/\mathrm{e}$

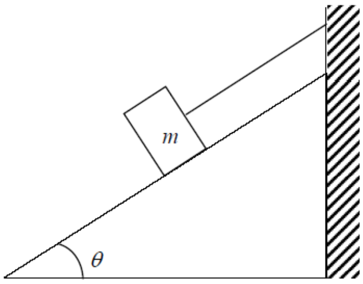
Q.29 Gauss-Seidel method is used to solve the following equations (as per the given order):

$x_1 + 2x_2 + 3x_3 = 5$
$2x_1 + 3x_2 + x_3 = 1$
$3x_1 + 2x_2 + x_3 = 3$

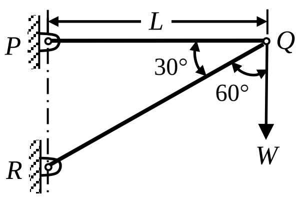
Assuming initial guess as $x_1 = x_2 = x_3 = 0$, the value of x_3 after the first iteration is __________

Q.30 A block of mass *m* rests on an inclined plane and is attached by a string to the wall as shown in the figure. The coefficient of static friction between the plane and the block is 0.25. The string can withstand a maximum force of 20 N. The maximum value of the mass (*m*) for which the string will not break and the block will be in static equilibrium is ____________ kg.
Take $\cos\theta = 0.8$ and $\sin\theta = 0.6$.

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

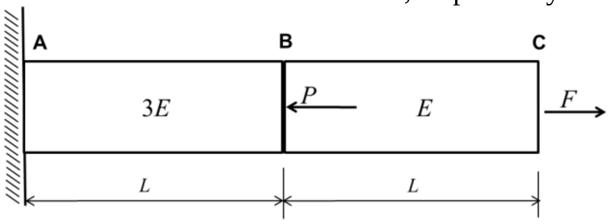


Q.31 A two-member truss *PQR* is supporting a load *W*. The axial forces in members *PQ* and *QR* are respectively



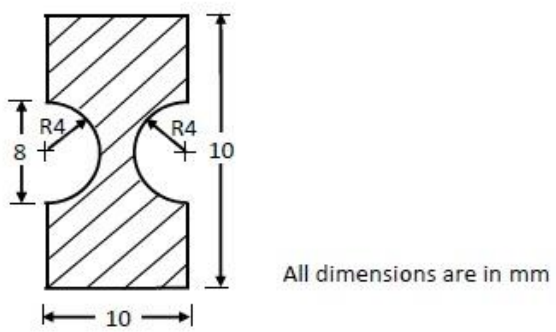
(A) $2W$ tensile and $\sqrt{3}W$ compressive
(B) $\sqrt{3}W$ tensile and $2W$ compressive
(C) $\sqrt{3}W$ compressive and $2W$ tensile
(D) $2W$ compressive and $\sqrt{3}W$ tensile

Q.32 A horizontal bar with a constant cross-section is subjected to loading as shown in the figure. The Young's moduli for the sections AB and BC are $3E$ and E, respectively.

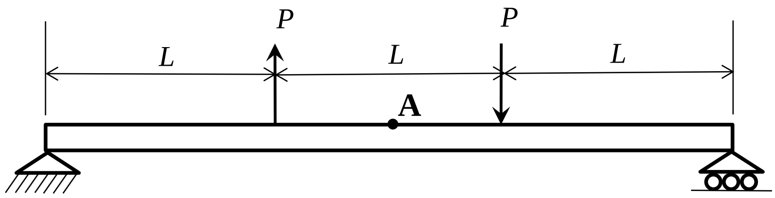


For the deflection at C to be zero, the ratio P/F is ____________

Q.33 The figure shows cross-section of a beam subjected to bending. The area moment of inertia (in mm^4) of this cross-section about its base is __________



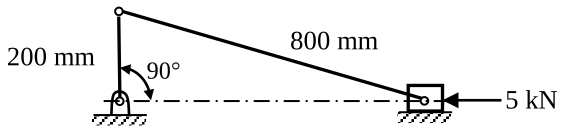
Q.34 A simply-supported beam of length $3L$ is subjected to the loading shown in the figure.



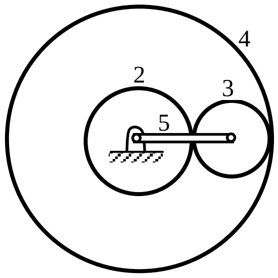
It is given that P = 1 N, L = 1 m and Young's modulus E = 200 GPa. The cross-section is a square with dimension 10 mm × 10 mm. The bending stress (in Pa) at the point **A** located at the top surface of the beam at a distance of $1.5L$ from the left end is _____________

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

Q.35 A slider crank mechanism with crank radius 200 mm and connecting rod length 800 mm is shown. The crank is rotating at 600 rpm in the counterclockwise direction. In the configuration shown, the crank makes an angle of 90° with the sliding direction of the slider, and a force of 5 kN is acting on the slider. Neglecting the inertia forces, the turning moment on the crank (in kN-m) is __________

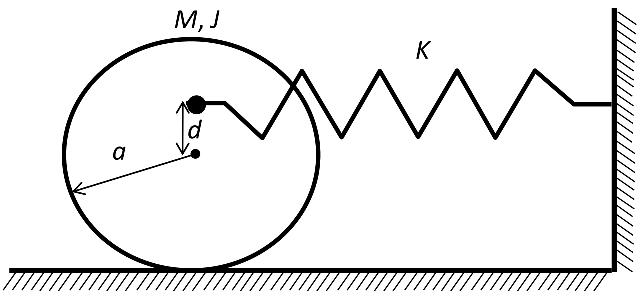


Q.36 In the gear train shown, gear 3 is carried on arm 5. Gear 3 meshes with gear 2 and gear 4. The number of teeth on gear 2, 3, and 4 are 60, 20, and 100, respectively. If gear 2 is fixed and gear 4 rotates with an angular velocity of 100 rpm in the counterclockwise direction, the angular speed of arm 5 (in rpm) is



(A) 166.7 counterclockwise (B) 166.7 clockwise
(C) 62.5 counterclockwise (D) 62.5 clockwise

Q.37 A solid disc with radius a is connected to a spring at a point d above the center of the disc. The other end of the spring is fixed to the vertical wall. The disc is free to roll without slipping on the ground. The mass of the disc is M and the spring constant is K. The polar moment of inertia for the disc about its centre is $J = Ma^2/2$.



The natural frequency of this system in rad/s is given by

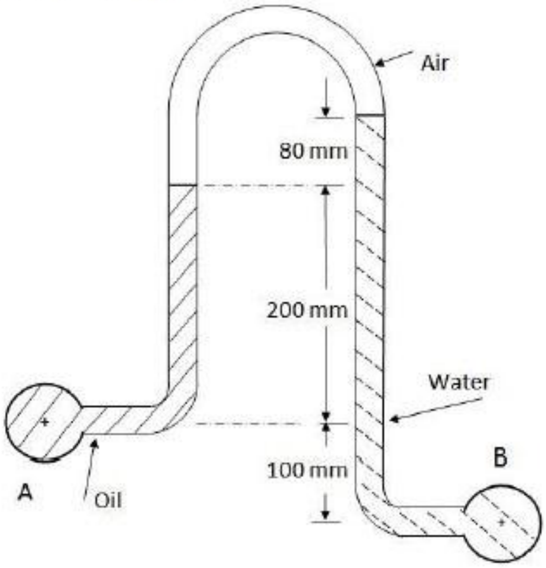
(A) $\sqrt{\frac{2\,K\,(a+d)^2}{3\,M\,a^2}}$ (B) $\sqrt{\frac{2\,K}{3\,M}}$ (C) $\sqrt{\frac{2\,K\,(a+d)^2}{M\,a^2}}$ (D) $\sqrt{\frac{K\,(a+d)^2}{M\,a^2}}$

Q.38 The principal stresses at a point inside a solid object are σ_1 = 100 MPa, σ_2 = 100 MPa and σ_3 = 0 MPa. The yield strength of the material is 200 MPa. The factor of safety calculated using Tresca (maximum shear stress) theory is n_T and the factor of safety calculated using von Mises (maximum distortional energy) theory is n_V. Which one of the following relations is TRUE?

(A) $n_T = (\sqrt{3}/2)n_V$
(B) $n_T = (\sqrt{3})n_V$
(C) $n_T = n_V$
(D) $n_V = (\sqrt{3})n_T$

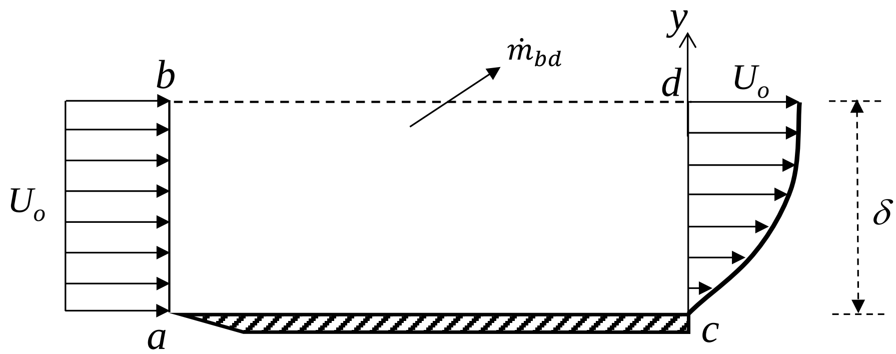
Q.39 An inverted U-tube manometer is used to measure the pressure difference between two pipes A and B, as shown in the figure. Pipe A is carrying oil (specific gravity = 0.8) and pipe B is carrying water. The densities of air and water are 1.16 kg/m^3 and 1000 kg/m^3, respectively. The pressure difference between pipes A and B is __________kPa.

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



Q.40 Oil (kinematic viscosity, $\nu_{oil} = 1.0 \times 10^{-5}$ m^2/s) flows through a pipe of 0.5 m diameter with a velocity of 10 m/s. Water (kinematic viscosity, $\nu_w = 0.89 \times 10^{-6}$ m^2/s) is flowing through a model pipe of diameter 20 mm. For satisfying the dynamic similarity, the velocity of water (in m/s) is __________

Q.41 A steady laminar boundary layer is formed over a flat plate as shown in the figure. The free stream velocity of the fluid is U_o. The velocity profile at the inlet *a*-*b* is uniform, while that at a downstream location *c*-*d* is given by $u = U_o\left[2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2\right]$.

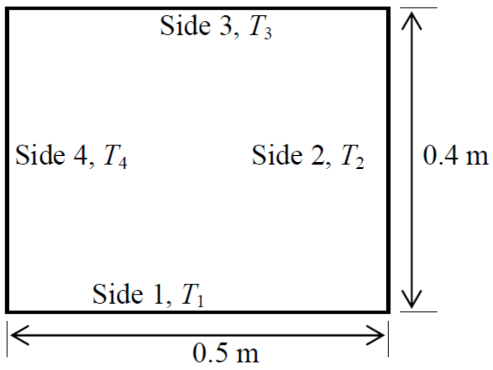


The ratio of the mass flow rate, $\dot{m}_{bd}$, leaving through the horizontal section *b*-*d* to that entering through the vertical section *a*-*b* is ___________

Q.42 A steel ball of 10 mm diameter at 1000 K is required to be cooled to 350 K by immersing it in a water environment at 300 K. The convective heat transfer coefficient is 1000 W/m^2-K. Thermal conductivity of steel is 40 W/m-K. The time constant for the cooling process τ is 16 s. The time required (in s) to reach the final temperature is __________

Q.43 An infinitely long furnace of 0.5 m × 0. 4 m cross-section is shown in the figure below. Consider all surfaces of the furnace to be black. The top and bottom walls are maintained at temperature $T_1 = T_3 = 927$ $^{\circ}$C while the side walls are at temperature $T_2 = T_4 = 527$ $^{\circ}$C. The view factor, $F_{1\text{-}2}$ is 0.26. The net radiation heat loss or gain on side 1 is_________ W/m.

Stefan-Boltzmann constant = 5.67×10^{-8} W/m^2-K^4



Q.44 A fluid (Prandtl number, Pr = 1) at 500 K flows over a flat plate of 1.5 m length, maintained at 300 K. The velocity of the fluid is 10 m/s. Assuming kinematic viscosity, $\nu = 30 \times 10^{-6}$ m^2/s, the thermal boundary layer thickness (in mm) at 0.5 m from the leading edge is __________

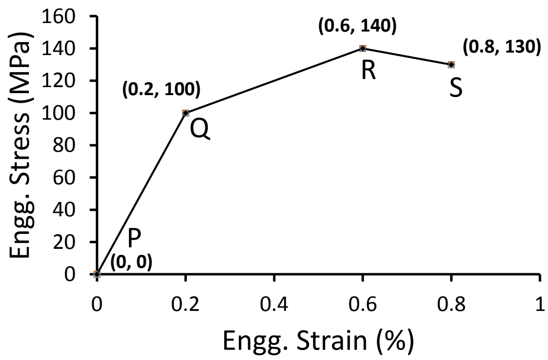
Q.45 For water at 25 °C, $\mathrm{d}p_s/\mathrm{d}T_s$ = 0.189 kPa/K (p_s is the saturation pressure in kPa and T_s is the saturation temperature in K) and the specific volume of dry saturated vapour is 43.38 m^3/kg. Assume that the specific volume of liquid is negligible in comparison with that of vapour. Using the Clausius-Clapeyron equation, an estimate of the enthalpy of evaporation of water at 25 °C (in kJ/kg) is __________

Q.46 An ideal gas undergoes a reversible process in which the pressure varies linearly with volume. The conditions at the start (subscript 1) and at the end (subscript 2) of the process with usual notation are: p_1 = 100 kPa, V_1 = 0.2 m^3 and p_2 = 200 kPa, V_2 = 0.1 m^3 and the gas constant, R = 0.275 kJ/kg-K. The magnitude of the work required for the process (in kJ) is ________

Q.47 In a steam power plant operating on an ideal Rankine cycle, superheated steam enters the turbine at 3 MPa and 350 °C. The condenser pressure is 75 kPa. The thermal efficiency of the cycle is ________ percent.

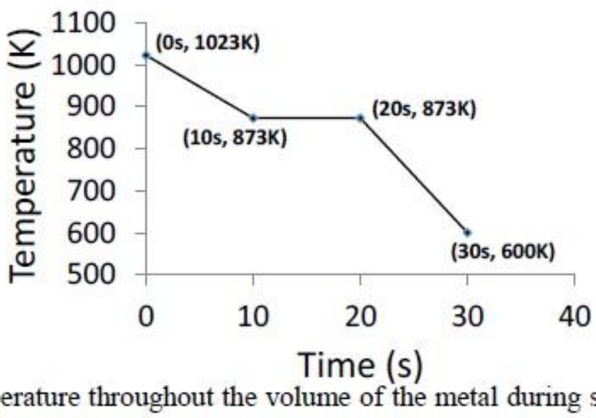
Given data:
For saturated liquid, at P = 75 kPa, $h_f = 384.39$ kJ/kg, $v_f = 0.001037$ m^3/kg, s_f = 1.213 kJ/kg-K
At 75 kPa, h_{fg} = 2278.6 kJ/kg, s_{fg} = 6.2434 kJ/kg-K
At P = 3 MPa and T = 350 °C (superheated steam), $h = 3115.3$ kJ/kg, $s = 6.7428$ kJ/kg-K

Q.48 A hypothetical engineering stress-strain curve shown in the figure has three straight lines PQ, QR, RS with coordinates P(0,0), Q(0.2,100), R(0.6,140) and S(0.8,130). 'Q' is the yield point, 'R' is the UTS point and 'S' the fracture point.



The toughness of the material (in MJ/m^3) is __________

Q.49 Heat is removed from a molten metal of mass 2 kg at a constant rate of 10 kW till it is completely solidified. The cooling curve is shown in the figure.



Assuming uniform temperature throughout the volume of the metal during solidification, the latent heat of fusion of the metal (in kJ/kg) is __________

Q.50 The tool life equation for HSS tool is $VT^{0.14}f^{0.7}d^{0.4}$ = Constant. The tool life (T) of 30 min is obtained using the following cutting conditions:

V = 45 m/min, f = 0.35 mm, d = 2.0 mm

If speed (V), feed (f) and depth of cut (d) are increased individually by 25%, the tool life (in min) is

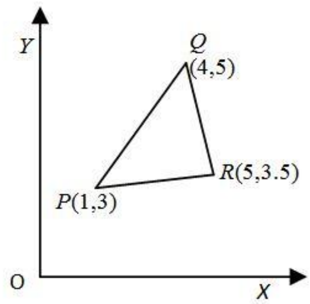
(A) 0.15 (B) 1.06 (C) 22. 50 (D) 30.0

Q.51 A cylindrical job with diameter of 200 mm and height of 100 mm is to be cast using modulus method of riser design. Assume that the bottom surface of cylindrical riser does not contribute as cooling surface. If the diameter of the riser is equal to its height, then the height of the riser (in mm) is

(A) 150 (B) 200 (C) 100 (D) 125

Q.52 A 300 mm thick slab is being cold rolled using roll of 600 mm diameter. If the coefficient of friction is 0.08, the maximum possible reduction (in mm) is __________

Q.53 The figure below represents a triangle PQR with initial coordinates of the vertices as $P(1,3)$, $Q(4,5)$ and $R(5,3.5)$. The triangle is rotated in the X-Y plane about the vertex P by angle θ in clockwise direction. If $\sin\theta = 0.6$ and $\cos\theta = 0.8$, the new coordinates of the vertex Q are



(A) (4.6, 2.8) (B) (3.2, 4.6) (C) (7.9, 5.5) (D) (5.5, 7.9)

Q.54 The annual demand for an item is 10,000 units. The unit cost is Rs. 100 and inventory carrying charges are 14.4% of the unit cost per annum. The cost of one procurement is Rs. 2000. The time between two consecutive orders to meet the above demand is _______ month(s).

Q.55 Maximize $Z = 15X_1 + 20X_2$

subject to

$12X_1 + 4X_2 \geq 36$

$12X_1 - 6X_2 \leq 24$

$X_1, X_2 \geq 0$

The above linear programming problem has

(A) infeasible solution (B) unbounded solution
(C) alternative optimum solutions (D) degenerate solution

END OF THE QUESTION PAPER

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.

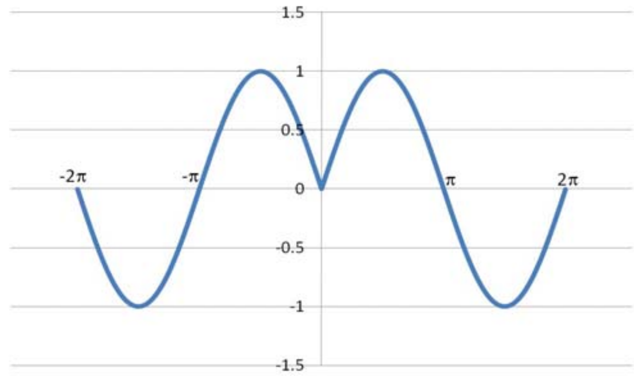
B, FH, LNP, _ _ _ _.

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

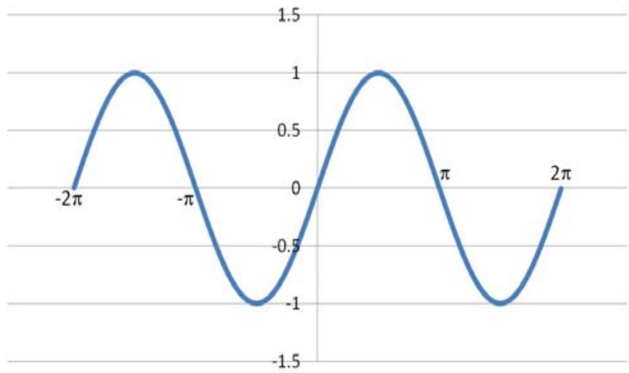
Q.9 The binary operation □ is defined as $a \square b = ab+(a+b)$, where a and b are any two real numbers. The value of the identity element of this operation, defined as the number x such that $a \square x = a$, for any a, is _____.

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

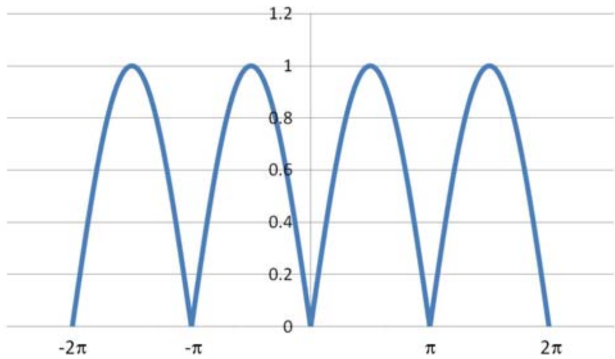
Q.10 Which of the following curves represents the function $y = \ln(|e^{[|\sin(|x|)|]}|)$ for $|x| < 2\pi$? Here, x represents the abscissa and y represents the ordinate.



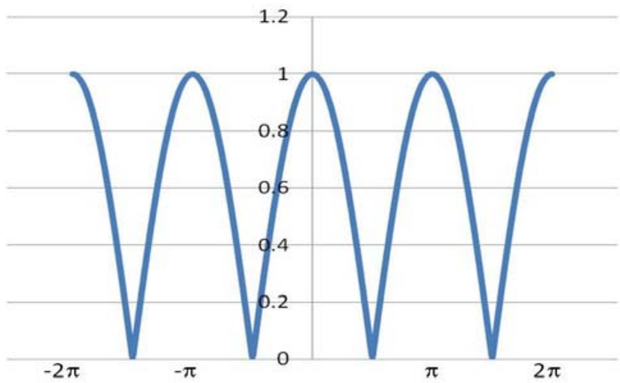
(A)



(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) $\dfrac{s}{s^2 + \omega^2}$

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

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

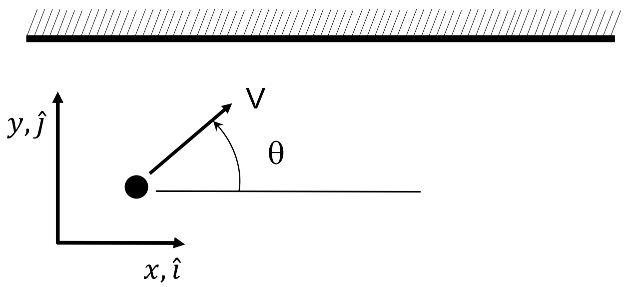
(D) $\dfrac{\omega}{s^2 - \omega^2}$

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) $-2MV \sin\theta\, \hat{j}$

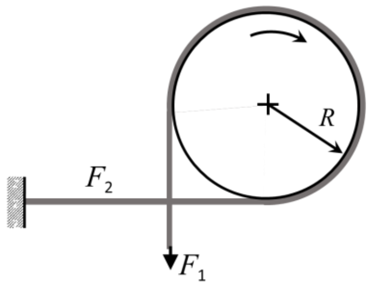
Q.7 A shaft with a circular cross-section is subjected to pure twisting moment. The ratio of the maximum shear stress to the largest principal stress is

(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

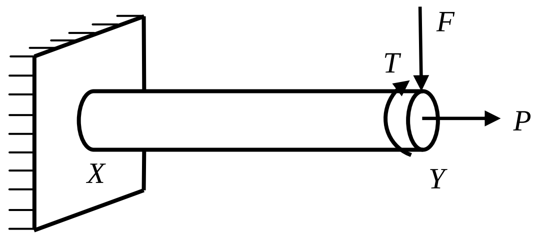
Q.9 The forces F_1 and F_2 in a brake band and the direction of rotation of the drum are as shown in the figure. The coefficient of friction is 0.25. The angle of wrap is $3\pi/2$ radians. It is given that R = 1 m and F_2 = 1 N. The torque (in N-m) exerted on the drum is _________



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

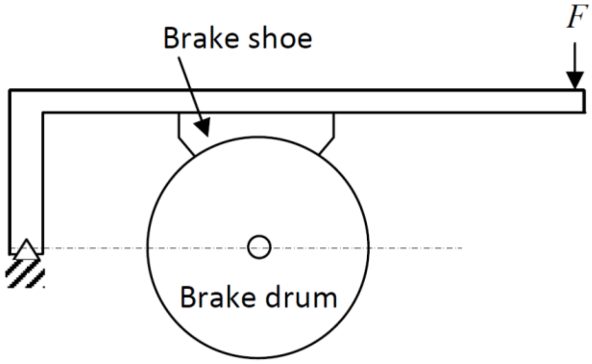
(A) $q = \sqrt{2\,k\,m}$ (B) $q = 2\sqrt{k\,m}$ (C) $q = \sqrt{\frac{2\,k}{m}}$ (D) $q = 2\sqrt{\frac{k}{m}}$

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) $1-\sqrt{\frac{R_\text{i}}{R_\text{o}}}$ (B) $\sqrt{1-\frac{R_\text{i}}{R_\text{o}}}$ (C) $1-\left(\frac{R_\text{i}}{R_\text{o}}\right)^{1/3}$ (D) $1-\frac{R_\text{i}}{R_\text{o}}$

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

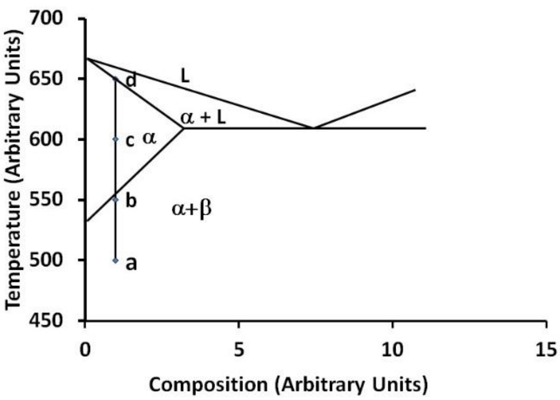
(A) temperature and pressure
(B) volume and pressure
(C) entropy and pressure
(D) temperature only

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: $\nabla\varphi = yz\hat{i} + xz\hat{j} + xy\hat{k}$. Consider the integral

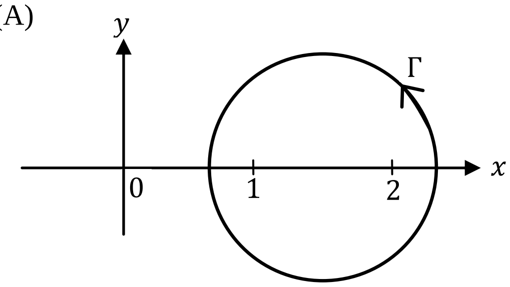
$\int_C \nabla\varphi . d\vec{r}$ on the curve $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$.

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

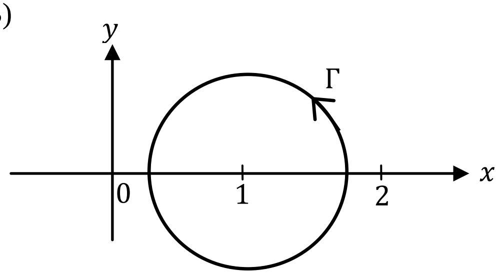
The value of the integral is ________

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

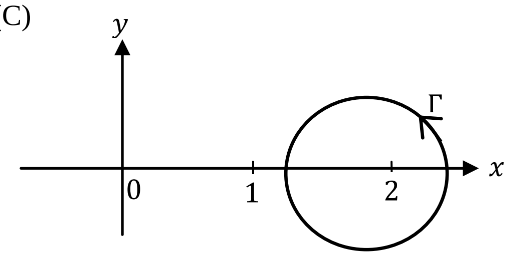
(A)



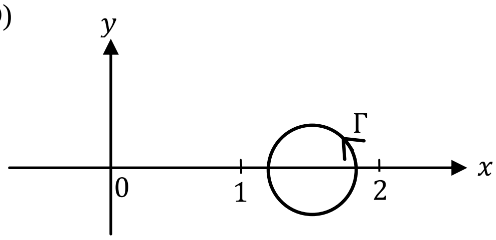
(B)



(C)



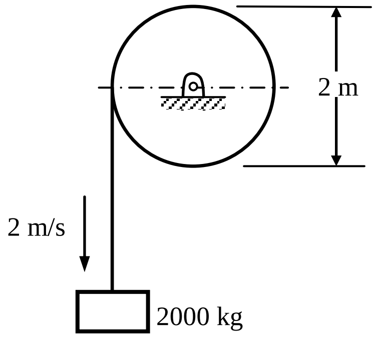
(D)



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 _________

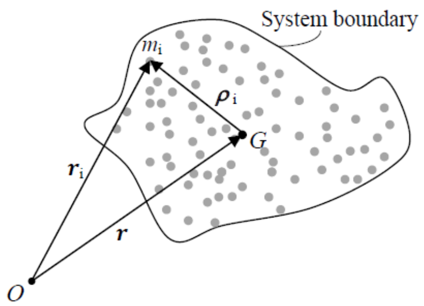
Q.29 The error in numerically computing the integral $\int_0^{\pi}(\sin x + \cos x)\,\mathrm{d}x$ using the trapezoidal rule with three intervals of equal length between 0 and π is ___________

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 $\boldsymbol{r}_i$. 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 $\boldsymbol{r}_i$).



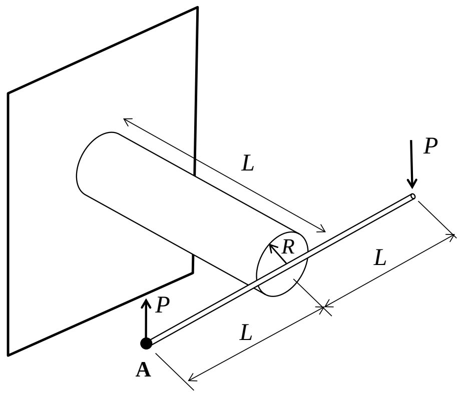
(A) $\sum_i \boldsymbol{r}_i \times m_i \ddot{\boldsymbol{\rho}}_i$

(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.



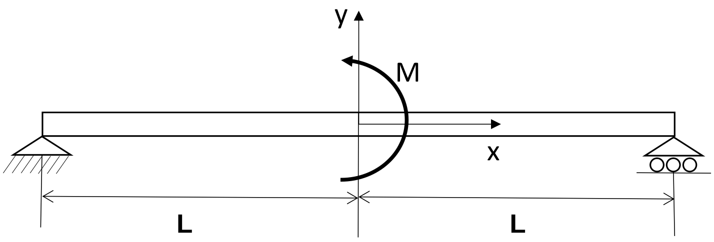
The vertical deflection at point **A** is

(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

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

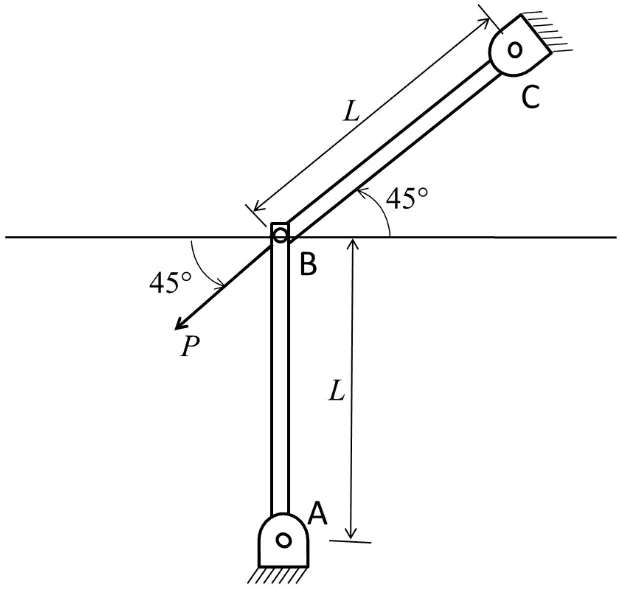
where E is the Young's modulus, I is the area moment of inertia and c is a constant (to be determined) .



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.

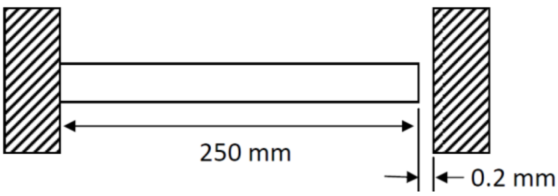


The stress (in Pa) in the link AB is ___________

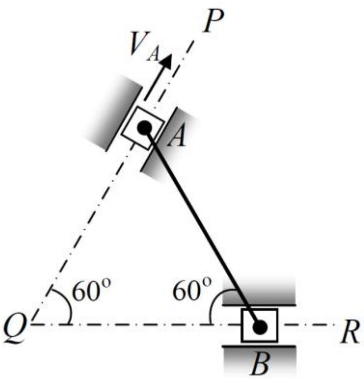
(Indicate compressive stress by a negative sign and tensile stress by a positive sign.)

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° C, the axial stress developed in the rod is __________ MPa.

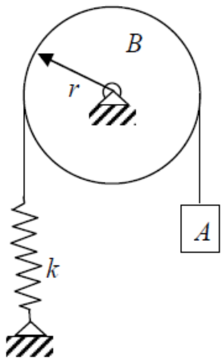
Young's modulus of the material of the rod is 200 GPa and the coefficient of thermal expansion is 10^{-5} per °C.



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.



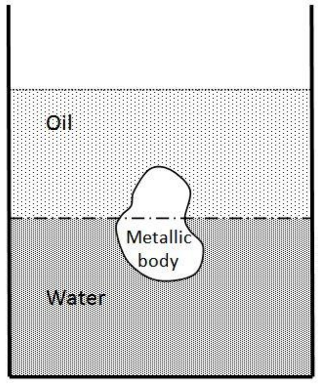
Q.38 In a structural member under fatigue loading, the minimum and maximum stresses developed at the critical point are 50 MPa and 150 MPa, respectively. The endurance, yield, and the ultimate strengths of the material are 200 MPa, 300 MPa and 400 MPa, respectively. The factor of safety using modified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

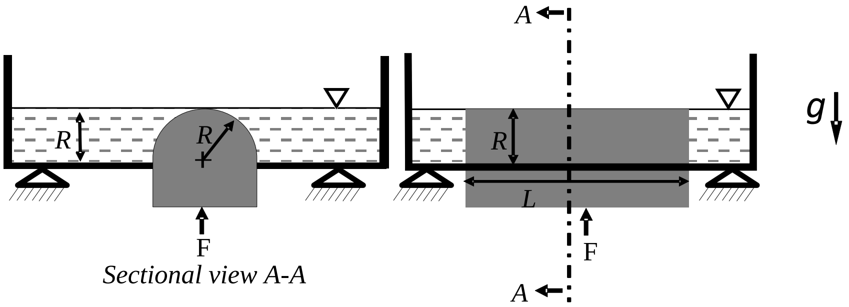
Acceleration due to gravity g = 10 m/s^2.



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 $A_\mathrm{c}/A_\mathrm{p}$ 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 $^\circ$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 (saturated vapour)
At $P = 0.8$ MPa, $h = 272.05$ kJ/kg, $s = 0.9322$ kJ/kg-K (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 _________

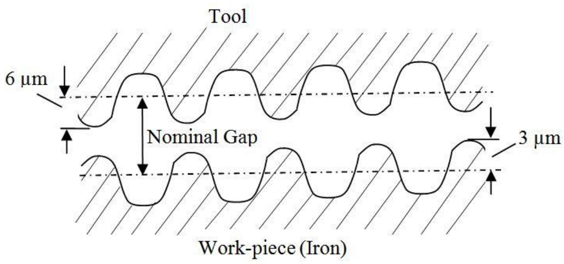
Q.50 The voltage-length characteristic of a direct current arc in an arc welding process is $V = (100 + 40l)$, where l is the length of the arc in mm and V is arc voltage in volts. During a welding operation, the arc length varies between 1 and 2 mm and the welding current is in the range 200-250 A.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

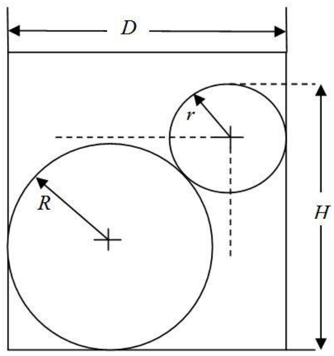
Q.52 The surface irregularities of electrodes used in an electrochemical machining (ECM) process are 3 μm and 6 μm as shown in the figure. If the work-piece is of pure iron and 12V DC is applied between the electrodes, the largest feed rate is ___________mm/min.

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



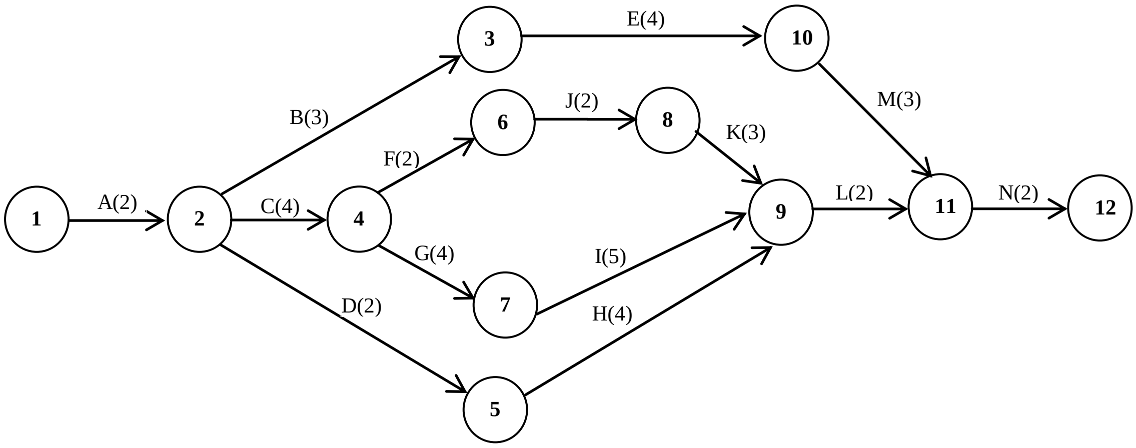
(A) $H = D + \sqrt{r^2 + R^2}$
(B) $H = (R + r) + (D + r)$
(C) $H = (R + r) + \sqrt{D^2 - R^2}$
(D) $H = (R + r) + \sqrt{2D(R + r) - D^2}$

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

Q. 1 – Q. 5 carry one mark each.

Q.1 Based on the given statements, select the appropriate option with respect to grammar and usage.

Statements
(i) The height of Mr. **X** is 6 feet.
(ii) The height of Mr. **Y** is 5 feet.

(A) Mr. **X** is longer than Mr. **Y**.

(B) Mr. **X** is more elongated than Mr. **Y**.

(C) Mr. **X** is taller than Mr. **Y**.

(D) Mr. **X** is lengthier than Mr. **Y**.

Q.2 The students ____________ the teacher on teachers' day for twenty years of dedicated teaching.

(A) facilitated (B) felicitated (C) fantasized (D) facillitated

Q.3 After India's cricket world cup victory in 1985, Shrotria who was playing both tennis and cricket till then, decided to concentrate only on cricket. And the rest is history.

What does the underlined phrase mean in this context?

(A) history will rest in peace (B) rest is recorded in history books

(C) rest is well known (D) rest is archaic

Q.4 Given $(9 \text{ inches})^{1/2} = (0.25 \text{ yards})^{1/2}$, which one of the following statements is **TRUE**?

(A) 3 inches = 0.5 yards (B) 9 inches = 1.5 yards

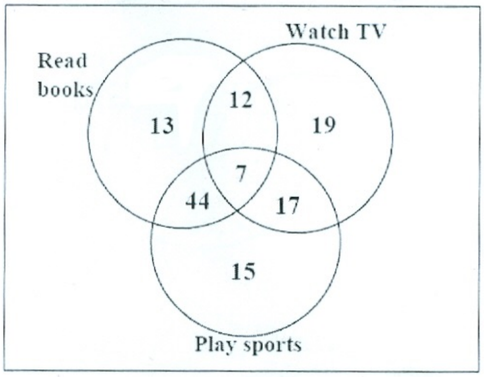
(C) 9 inches = 0.25 yards (D) 81 inches = 0.0625 yards

Q.5 ***S***, ***M***, ***E*** and ***F*** are working in shifts in a team to finish a project. ***M*** works with twice the efficiency of others but for half as many days as ***E*** worked. ***S*** and ***M*** have 6 hour shifts in a day, whereas ***E*** and ***F*** have 12 hours shifts. What is the ratio of contribution of ***M*** to contribution of ***E*** in the project?

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

Q. 6 – Q. 10 carry two marks each.

Q.6 The Venn diagram shows the preference of the student population for leisure activities.



From the data given, the number of students who like to read books or play sports is _____.

(A) 44 (B) 51 (C) 79 (D) 108

Q.7 Social science disciplines were in existence in an amorphous form until the colonial period when they were institutionalized. In varying degrees, they were intended to further the colonial interest. In the time of globalization and the economic rise of postcolonial countries like India, conventional ways of knowledge production have become obsolete.

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

(i) Social science disciplines have become obsolete.
(ii) Social science disciplines had a pre-colonial origin.
(iii) Social science disciplines always promote colonialism.
(iv) Social science must maintain disciplinary boundaries.

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

(C) (ii) and (iv) only (D) (iii) and (iv) only

Q.8 Two and a quarter hours back, when seen in a mirror, the reflection of a wall clock without number markings seemed to show 1:30. What is the actual current time shown by the clock?

(A) 8:15 (B) 11:15 (C) 12:15 (D) 12:45

Q.9 **M** and **N** start from the same location. **M** travels 10 km East and then 10 km North-East. **N** travels 5 km South and then 4 km South-East. What is the shortest distance (in km) between **M** and **N** at the end of their travel?

(A) 18.60 (B) 22.50 (C) 20.61 (D) 25.00

Q.10 A wire of length 340 mm is to be cut into two parts. One of the parts is to be made into a square and the other into a rectangle where sides are in the ratio of 1:2. What is the length of the side of the square (in mm) such that the combined area of the square and the rectangle is a **MINIMUM?**

(A) 30 (B) 40 (C) 120 (D) 180

END OF THE QUESTION PAPER

Q. 1 – Q. 25 carry one mark each.

Q.1 A real square matrix A is called skew-symmetric if

(A) $A^T = A$
(B) $A^T = A^{-1}$
(C) $A^T = -A$
(D) $A^T = A + A^{-1}$

Q.2 $\underset{x \to 0}{\mathrm{Lt}} \dfrac{\log_e(1+4x)}{e^{3x}-1}$ is equal to

(A) 0 (B) $\frac{1}{12}$ (C) $\frac{4}{3}$ (D) 1

Q.3 Solutions of Laplace's equation having continuous second-order partial derivatives are called

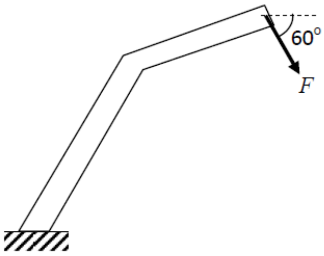
(A) biharmonic functions
(B) harmonic functions
(C) conjugate harmonic functions
(D) error functions

Q.4 The area (in percentage) under standard normal distribution curve of random variable Z within limits from −3 to +3 is __________

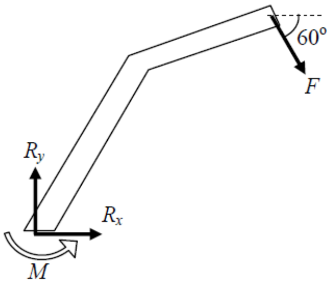
Q.5 The root of the function $f(x) = x^3 + x - 1$ obtained after first iteration on application of Newton-Raphson scheme using an initial guess of $x_0 = 1$ is

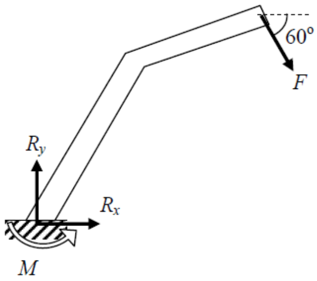
(A) 0.682 (B) 0.686 (C) 0.750 (D) 1.000

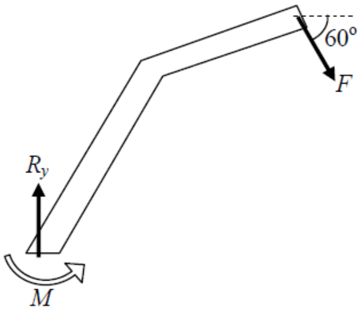
Q.6 A force F is acting on a bent bar which is clamped at one end as shown in the figure.

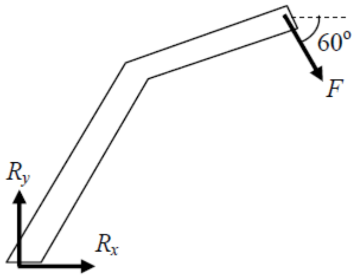


The CORRECT free body diagram is

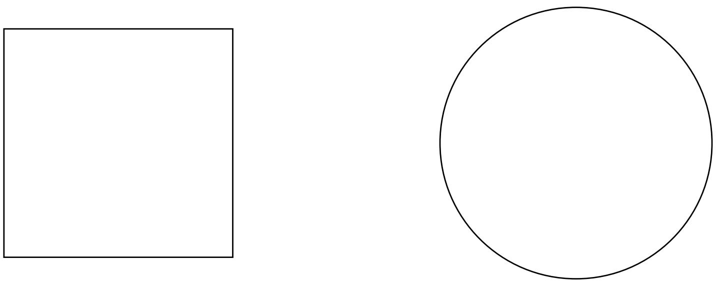
(A)


(B)


(C)


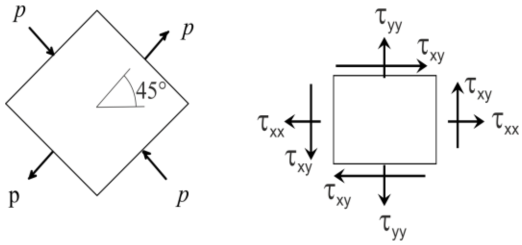
(D)


Q.7 The cross-sections of two solid bars made of the same material are shown in the figure. The square cross-section has flexural (bending) rigidity I_1, while the circular cross-section has flexural rigidity I_2. Both sections have the same cross-sectional area. The ratio I_1/I_2 is



(A) $1/\pi$ (B) $2/\pi$ (C) $\pi/3$ (D) $\pi/6$

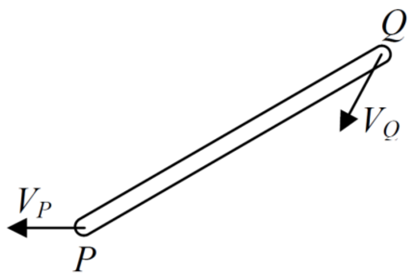
Q.8 The state of stress at a point on an element is shown in figure (a). The same state of stress is shown in another coordinate system in figure (b).



The components $(\tau_{xx}, \tau_{yy}, \tau_{xy})$ are given by

(A) $(p/\sqrt{2}, -p/\sqrt{2}, 0)$
(B) $(0, 0, p)$
(C) $(p, -p, p/\sqrt{2})$
(D) $(0, 0, p/\sqrt{2})$

Q.9 A rigid link PQ is undergoing plane motion as shown in the figure (V_P and V_Q are non-zero). V_{QP} is the relative velocity of point Q with respect to point P.



Which one of the following is TRUE?

(A) V_{QP} has components along and perpendicular to PQ
(B) V_{QP} has only one component directed from P to Q
(C) V_{QP} has only one component directed from Q to P
(D) V_{QP} has only one component perpendicular to PQ

Q.10 The number of degrees of freedom in a planar mechanism having n links and j simple hinge joints is

(A) $3(n-3) - 2j$
(B) $3(n-1) - 2j$
(C) $3n - 2j$
(D) $2j - 3n + 4$

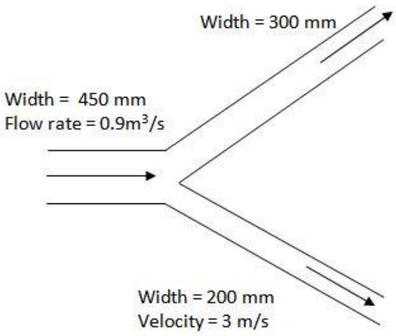
Q.11 The static deflection of a spring under gravity, when a mass of 1 kg is suspended from it, is 1 mm. Assume the acceleration due to gravity g =10 m/s^2. The natural frequency of this spring-mass system (in rad/s) is_____________

Q.12 Which of the bearings given below SHOULD NOT be subjected to a thrust load?

(A) Deep groove ball bearing
(B) Angular contact ball bearing
(C) Cylindrical (straight) roller bearing
(D) Single row tapered roller bearing

Q.13 A channel of width 450 mm branches into two sub-channels having width 300 mm and 200 mm as shown in figure. If the volumetric flow rate (taking unit depth) of an incompressible flow through the main channel is 0.9 m^3/s and the velocity in the sub-channel of width 200 mm is 3 m/s, the velocity in the sub-channel of width 300 mm is _____________ m/s.

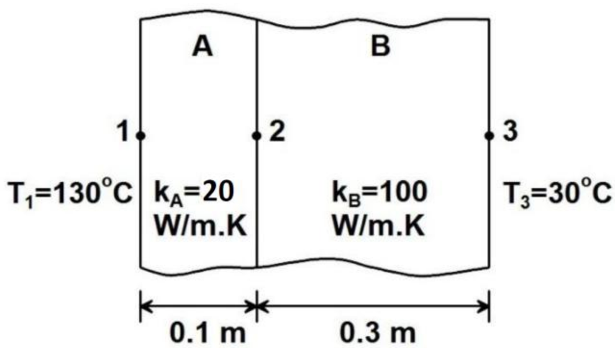
Assume both inlet and outlet to be at the same elevation.



Q.14 For a certain two-dimensional incompressible flow, velocity field is given by $2xy\,\hat{\imath} - y^2\hat{\jmath}$. The streamlines for this flow are given by the family of curves

(A) $x^2y^2 =$ constant
(B) $xy^2 =$ constant
(C) $2xy - y^2 =$ constant
(D) $xy =$ constant

Q.15 Steady one-dimensional heat conduction takes place across the faces 1 and 3 of a composite slab consisting of slabs A and B in perfect contact as shown in the figure, where k_A, k_B denote the respective thermal conductivities. Using the data as given in the figure, the interface temperature T_2 (in °C) is __________



Q.16 Grashof number signifies the ratio of

(A) inertia force to viscous force
(B) buoyancy force to viscous force
(C) buoyancy force to inertia force
(D) inertia force to surface tension force

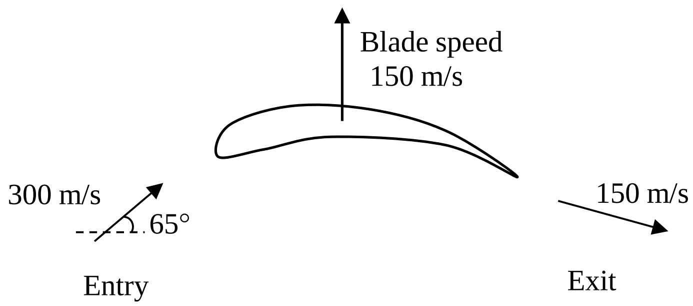
Q.17 The INCORRECT statement about the characteristics of critical point of a pure substance is that

(A) there is no constant temperature vaporization process
(B) it has point of inflection with zero slope
(C) the ice directly converts from solid phase to vapor phase
(D) saturated liquid and saturated vapor states are identical

Q.18 For a heat exchanger, ΔT_{max} is the maximum temperature difference and ΔT_{min} is the minimum temperature difference between the two fluids. $LMTD$ is the log mean temperature difference. C_{min} and C_{max} are the minimum and the maximum heat capacity rates. The maximum possible heat transfer (Q_{max}) between the two fluids is

(A) $C_{min}\ LMTD$ (B) $C_{min}\ \Delta T_{max}$ (C) $C_{max}\ \Delta T_{max}$ (D) $C_{max}\ \Delta T_{min}$

Q.19 The blade and fluid velocities for an axial turbine are as shown in the figure.



The magnitude of absolute velocity at entry is 300 m/s at an angle of 65° to the axial direction, while the magnitude of the absolute velocity at exit is 150 m/s. The exit velocity vector has a component in the downward direction. Given that the axial (horizontal) velocity is the same at entry and exit, the specific work (in kJ/kg) is__________

Q.20 Engineering strain of a mild steel sample is recorded as 0.100%. The true strain is

(A) 0.010% (B) 0.055% (C) 0.099% (D) 0.101%

Q.21 Equal amounts of a liquid metal at the same temperature are poured into three moulds made of steel, copper and aluminum. The shape of the cavity is a cylinder with 15 mm diameter. The size of the moulds are such that the outside temperature of the moulds do not increase appreciably beyond the atmospheric temperature during solidification. The sequence of solidification in the mould from the fastest to slowest is

(Thermal conductivities of steel, copper and aluminum are 60.5, 401 and 237 W/m-K, respectively.
Specific heats of steel, copper and aluminum are 434, 385 and 903 J/kg-K, respectively.
Densities of steel, copper and aluminum are 7854, 8933 and 2700 kg/m^3, respectively.)

(A) Copper - Steel - Aluminum
(B) Aluminum - Steel - Copper
(C) Copper - Aluminum - Steel
(D) Steel - Copper - Aluminum

Q.22 In a wire-cut EDM process the necessary conditions that have to be met for making a successful cut are that

(A) wire and sample are electrically non-conducting
(B) wire and sample are electrically conducting
(C) wire is electrically conducting and sample is electrically non-conducting
(D) sample is electrically conducting and wire is electrically non-conducting

Q.23 Internal gears are manufactured by

(A) hobbing
(B) shaping with pinion cutter
(C) shaping with rack cutter
(D) milling

Q.24 Match the following part programming codes with their respective functions

Part Programming Codes	Functions
P. G01	I. Spindle stop
Q. G03	II. Spindle rotation, clockwise
R. M03	III. Circular interpolation, anticlockwise
S. M05	IV. Linear interpolation

(A) P – II, Q – I, R – IV, S – III
(B) P – IV, Q – II, R – III, S – I
(C) P – IV, Q – III, R – II, S – I
(D) P – III, Q – IV, R – II, S – I

Q.25 In PERT chart, the activity time distribution is

(A) Normal (B) Binomial (C) Poisson (D) Beta

Q. 26 – Q. 55 carry two marks each.

Q.26 The number of linearly independent eigenvectors of matrix $A = \begin{bmatrix} 2 & 1 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 3 \end{bmatrix}$ is __________

Q.27 The value of the line integral $\oint_C \bar{F} \cdot \bar{r}' \, ds$, where C is a circle of radius $\frac{4}{\sqrt{\pi}}$ units is _________

Here, $\bar{F}(x, y) = y\,\hat{\imath} + 2x\,\hat{\jmath}$ and $\bar{r}'$ is the **UNIT** tangent vector on the curve C at an arc length s from a reference point on the curve. $\hat{\imath}$ and $\hat{\jmath}$ are the basis vectors in the *x*-*y* Cartesian reference. In evaluating the line integral, the curve has to be traversed in the counter-clockwise direction.

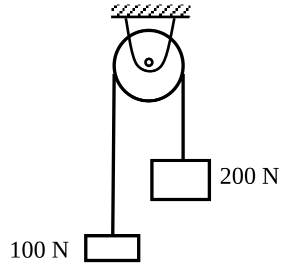
Q.28 $\lim_{x\to\infty} \sqrt{x^2+x-1} - x$ is

(A) 0 (B) ∞ (C) 1/2 (D) $-\infty$

Q.29 Three cards were drawn from a pack of 52 cards. The probability that they are a king, a queen, and a jack is

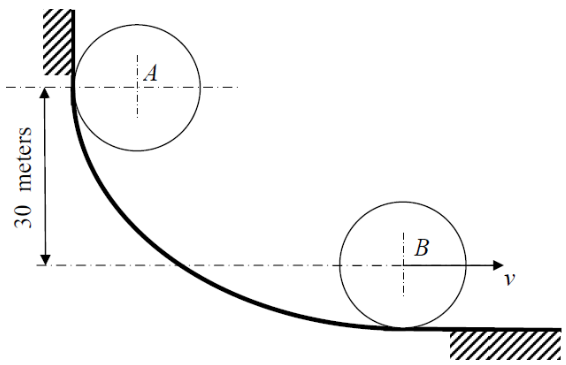
(A) $\frac{16}{5525}$ (B) $\frac{64}{2197}$ (C) $\frac{3}{13}$ (D) $\frac{8}{16575}$

Q.30 An inextensible massless string goes over a frictionless pulley. Two weights of 100 N and 200 N are attached to the two ends of the string. The weights are released from rest, and start moving due to gravity. The tension in the string (in N) is __________

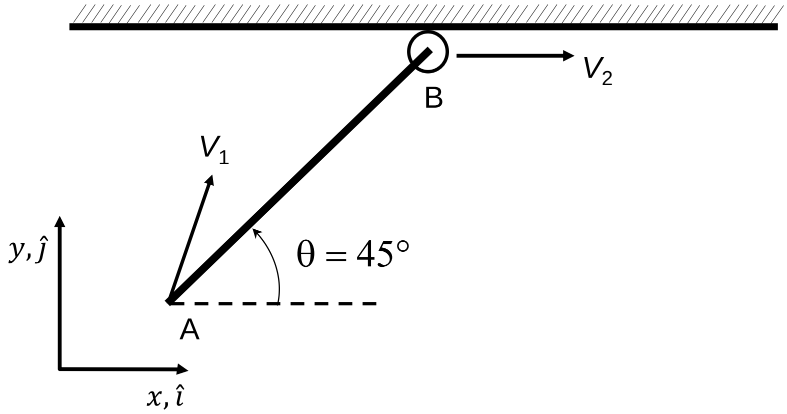


Q.31 A circular disc of radius 100 mm and mass 1 kg, initially at rest at position *A*, rolls without slipping down a curved path as shown in figure. The speed *v* of the disc when it reaches position *B* is _________ m/s.

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

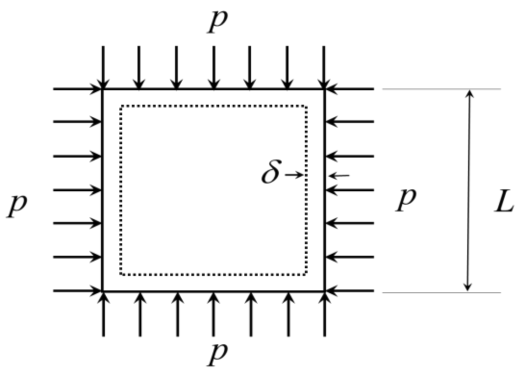


Q.32 A rigid rod (AB) of length $L = \sqrt{2}$ m is undergoing translational as well as rotational motion in the *x*-*y* plane (see the figure). The point A has the velocity $V_1 = \hat{\imath} + 2\hat{\jmath}$ m/s. The end B is constrained to move only along the *x* direction.



The magnitude of the velocity V_2 (in m/s) at the end B is __________

Q.33 A square plate of dimension $L \times L$ is subjected to a uniform pressure load p = 250 MPa on its edges as shown in the figure. Assume plane stress conditions. The Young's modulus E = 200 GPa.

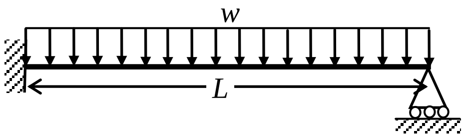


The deformed shape is a square of dimension $L - 2\,\delta$. If $L = 2$ m and $\delta = 0.001$ m, the Poisson's ratio of the plate material is __________

Q.34 Two circular shafts made of same material, one solid (S) and one hollow (H), have the same length and polar moment of inertia. Both are subjected to same torque. Here, θ_S is the twist and τ_S is the maximum shear stress in the solid shaft, whereas θ_H is the twist and τ_H is the maximum shear stress in the hollow shaft. Which one of the following is TRUE?

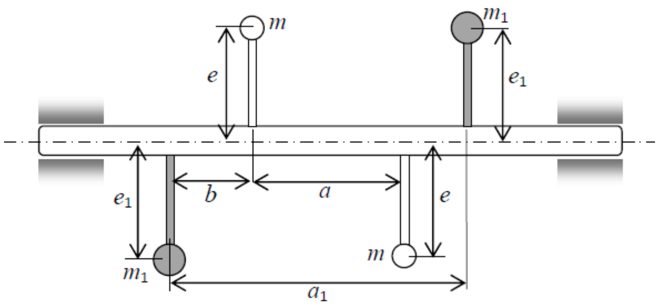
(A) $\theta_S = \theta_H$ and $\tau_S = \tau_H$
(B) $\theta_S > \theta_H$ and $\tau_S > \tau_H$
(C) $\theta_S < \theta_H$ and $\tau_S < \tau_H$
(D) $\theta_S = \theta_H$ and $\tau_S < \tau_H$

Q.35 A beam of length L is carrying a uniformly distributed load w per unit length. The flexural rigidity of the beam is EI. The reaction at the simple support at the right end is

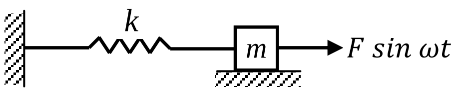


(A) $\frac{wL}{2}$ (B) $\frac{3wL}{8}$ (C) $\frac{wL}{4}$ (D) $\frac{wL}{8}$

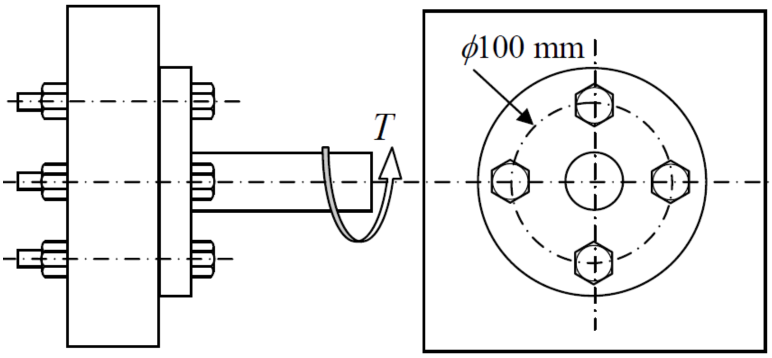
Q.36 Two masses m are attached to opposite sides of a rigid rotating shaft in the vertical plane. Another pair of equal masses m_1 is attached to the opposite sides of the shaft in the vertical plane as shown in figure. Consider m = 1 kg, e = 50 mm, e_1 = 20 mm, b = 0.3 m, a = 2 m and a_1 = 2.5 m. For the system to be dynamically balanced, m_1 should be ________ kg.



Q.37 A single degree of freedom spring-mass system is subjected to a harmonic force of constant amplitude. For an excitation frequency of $\sqrt{\frac{3k}{m}}$, the ratio of the amplitude of steady state response to the static deflection of the spring is __________



Q.38 A bolted joint has four bolts arranged as shown in figure. The cross sectional area of each bolt is 25 mm^2. A torque T = 200 N-m is acting on the joint. Neglecting friction due to clamping force, maximum shear stress in a bolt is ______ MPa.

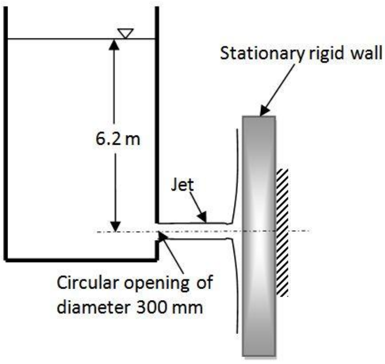


Q.39 Consider a fully developed steady laminar flow of an incompressible fluid with viscosity μ through a circular pipe of radius R. Given that the velocity at a radial location of $R/2$ from the centerline of the pipe is U_1, the shear stress at the wall is $K\mu U_1/R$, where K is __________

Q.40 The water jet exiting from a stationary tank through a circular opening of diameter 300 mm impinges on a rigid wall as shown in the figure. Neglect all minor losses and assume the water level in the tank to remain constant. The net horizontal force experienced by the wall is ___________ kN.

Density of water is 1000 kg/m^3.

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



Q.41 For a two-dimensional flow, the velocity field is $\vec{u} = \frac{x}{x^2+y^2}\hat{i} + \frac{y}{x^2+y^2}\hat{j}$, where $\hat{i}$ and $\hat{j}$ are the basis vectors in the *x*-*y* Cartesian coordinate system. Identify the **CORRECT** statements from below.

(1) The flow is incompressible.
(2) The flow is unsteady.
(3) *y*-component of acceleration, $a_y = \frac{-y}{(x^2+y^2)^2}$
(4) *x*-component of acceleration, $a_x = \frac{-(x+y)}{(x^2+y^2)^2}$

(A) (2) and (3) (B) (1) and (3) (C) (1) and (2) (D) (3) and (4)

Q.42 Two large parallel plates having a gap of 10 mm in between them are maintained at temperatures T_1 = 1000 K and T_2 = 400 K. Given emissivity values, $\varepsilon_1 = 0.5$, $\varepsilon_2 = 0.25$ and Stefan-Boltzmann constant $\sigma = 5.67 \times 10^{-8}$ W/m^2-K^4, the heat transfer between the plates (in kW/m^2) is ____________________

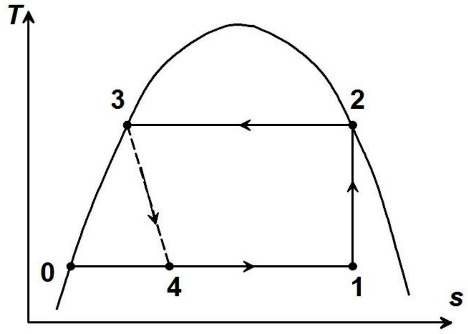
Q.43 A cylindrical steel rod, 0.01 m in diameter and 0.2 m in length is first heated to 750 ^{o}C and then immersed in a water bath at 100 ^{o}C. The heat transfer coefficient is 250 W/m^2-K. The density, specific heat and thermal conductivity of steel are ρ = 7801 kg/m^3, c = 473 J/kg-K, and k = 43 W/m-K, respectively. The time required for the rod to reach 300 ^{o}C is ________ seconds.

Q.44 Steam at an initial enthalpy of 100 kJ/kg and inlet velocity of 100 m/s, enters an insulated horizontal nozzle. It leaves the nozzle at 200 m/s. The exit enthalpy (in kJ/kg) is __________

Q.45 In a mixture of dry air and water vapor at a total pressure of 750 mm of Hg, the partial pressure of water vapor is 20 mm of Hg. The humidity ratio of the air in grams of water vapor per kg of dry air (g_w/kg_{da}) is __________

Q.46 In a 3-stage air compressor, the inlet pressure is p_1, discharge pressure is p_4 and the intermediate pressures are p_2 and p_3 ($p_2 < p_3$). The total pressure ratio of the compressor is 10 and the pressure ratios of the stages are equal. If p_1 = 100 kPa, the value of the pressure p_3 (in kPa) is __________

Q.47 In the vapour compression cycle shown in the figure, the evaporating and condensing temperatures are 260 K and 310 K, respectively. The compressor takes in liquid-vapour mixture (state 1) and isentropically compresses it to a dry saturated vapour condition (state 2). The specific heat of the liquid refrigerant is 4.8 kJ/kg-K and may be treated as constant. The enthalpy of evaporation for the refrigerant at 310 K is 1054 kJ/kg.



The difference between the enthalpies at state points 1 and 0 (in kJ/kg) is ____________

Q.48 Spot welding of two steel sheets each 2 mm thick is carried out successfully by passing 4 kA of current for 0.2 seconds through the electrodes. The resulting weld nugget formed between the sheets is 5 mm in diameter. Assuming cylindrical shape for the nugget, the thickness of the nugget is________mm.

Latent heat of fusion for steel	1400 kJ/kg
Effective resistance of the weld joint	200 $\mu\Omega$
Density of steel	8000 kg/m^3

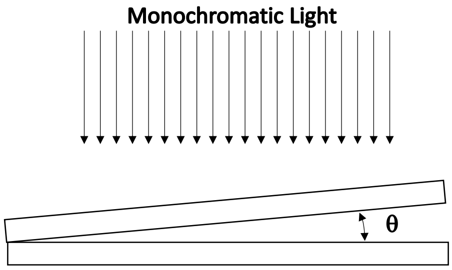
Q.49 For an orthogonal cutting operation, tool material is HSS, rake angle is 22°, chip thickness is 0.8 mm, speed is 48 m/min and feed is 0.4 mm/rev. The shear plane angle (in degrees) is

(A) 19.24 (B) 29.70 (C) 56.00 (D) 68.75

Q.50 In a sheet metal of 2 mm thickness a hole of 10 mm diameter needs to be punched. The yield strength in tension of the sheet material is 100 MPa and its ultimate shear strength is 80 MPa. The force required to punch the hole (in kN) is __________

Q.51 In a single point turning operation with cemented carbide tool and steel work piece, it is found that the Taylor's exponent is 0.25. If the cutting speed is reduced by 50% then the tool life changes by ______ times.

Q.52 Two optically flat plates of glass are kept at a small angle θ as shown in the figure. Monochromatic light is incident vertically.



If the wavelength of light used to get a fringe spacing of 1 mm is 450 nm, the wavelength of light (in nm) to get a fringe spacing of 1.5 mm is _________

Q.53 A point P (1, 3, −5) is translated by $2\hat{\imath} + 3\hat{\jmath} - 4\hat{k}$ and then rotated counter clockwise by 90° about the z-axis. The new position of the point is

(A) (−6, 3, −9) (B) (−6, −3, −9) (C) (6, 3, −9) (D) (6, 3, 9)

Q.54 The demand for a two-wheeler was 900 units and 1030 units in April 2015 and May 2015, respectively. The forecast for the month of April 2015 was 850 units. Considering a smoothing constant of 0.6, the forecast for the month of June 2015 is

(A) 850 units (B) 927 units (C) 965 units (D) 970 units

Q.55 A firm uses a turning center, a milling center and a grinding machine to produce two parts. The table below provides the machining time required for each part and the maximum machining time available on each machine. The profit per unit on parts I and II are Rs. 40 and Rs. 100, respectively. The maximum profit per week of the firm is Rs._________

Type of machine	Machining time required for the machine part (minutes)		Maximum machining time available per week (minutes)
	I	II	
Turning Center	12	6	6000
Milling Center	4	10	4000
Grinding Machine	2	3	1800

END OF THE QUESTION PAPER