Q. 1 – Q. 5 carry one mark each.

Q.1 "Going by the _____ that many hands make light work, the school _____ involved all the students in the task."

The words that best fill the blanks in the above sentence are

(A) principle, principal
(B) principal, principle
(C) principle, principle
(D) principal, principal

Q.2 "Her _____ should not be confused with miserliness; she is ever willing to assist those in need."

The word that best fills the blank in the above sentence is

(A) cleanliness (B) punctuality (C) frugality (D) greatness

Q.3 Seven machines take 7 minutes to make 7 identical toys. At the same rate, how many minutes would it take for 100 machines to make 100 toys?

(A) 1 (B) 7 (C) 100 (D) 700

Q.4 A rectangle becomes a square when its length and breadth are reduced by 10 m and 5 m, respectively. During this process, the rectangle loses 650 m^2 of area. What is the area of the original rectangle in square meters?

(A) 1125 (B) 2250 (C) 2924 (D) 4500

Q.5 A number consists of two digits. The sum of the digits is 9. If 45 is subtracted from the number, its digits are interchanged. What is the number?

(A) 63 (B) 72 (C) 81 (D) 90

Q. 6 – Q. 10 carry two marks each.

Q.6 For integers a, b and c, what would be the minimum and maximum values respectively of $a + b + c$ if $\log|a| + \log|b| + \log|c| = 0$?

(A) -3 and 3 (B) -1 and 1 (C) -1 and 3 (D) 1 and 3

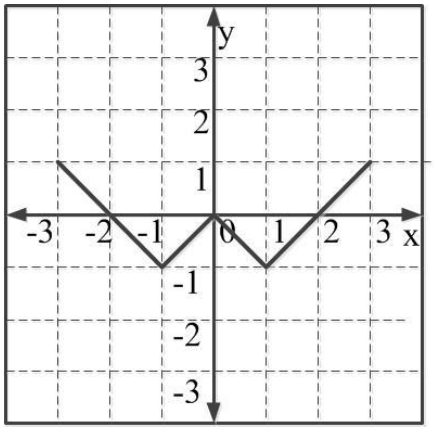
Q.7 Given that a and b are integers and $a + a^2\, b^3$ is odd, which one of the following statements is correct?

(A) a and b are both odd
(B) a and b are both even
(C) a is even and b is odd
(D) a is odd and b is even

Q.8 From the time the front of a train enters a platform, it takes 25 seconds for the back of the train to leave the platform, while travelling at a constant speed of 54 km/h. At the same speed, it takes 14 seconds to pass a man running at 9 km/h in the same direction as the train. What is the length of the train and that of the platform in meters, respectively?

(A) 210 and 140
(B) 162.5 and 187.5
(C) 245 and 130
(D) 175 and 200

Q.9 Which of the following functions describe the graph shown in the below figure?



(A) $y = \big||x| + 1\big| - 2$
(B) $y = \big||x| - 1\big| - 1$
(C) $y = \big||x| + 1\big| - 1$
(D) $y = \big||x - 1| - 1\big|$

Q.10 Consider the following three statements:
(i) Some roses are red.
(ii) All red flowers fade quickly.
(iii) Some roses fade quickly.

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

(A) If (i) is true and (ii) is false, then (iii) is false.
(B) If (i) is true and (ii) is false, then (iii) is true.
(C) If (i) and (ii) are true, then (iii) is true.
(D) If (i) and (ii) are false, then (iii) is false.

END OF THE QUESTION PAPER

Q. 1 – Q. 25 carry one mark each.

Q.1 Four red balls, four green balls and four blue balls are put in a box. Three balls are pulled out of the box at random one after another without replacement. The probability that all the three balls are red is

(A) 1/72 (B) 1/55 (C) 1/36 (D) 1/27

Q.2 The rank of the matrix $\begin{bmatrix} -4 & 1 & -1 \\ -1 & -1 & -1 \\ 7 & -3 & 1 \end{bmatrix}$ is

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

Q.3 According to the Mean Value Theorem, for a continuous function $f(x)$ in the interval $[a,b]$, there exists a value ξ in this interval such that $\int_a^b f(x)dx =$

(A) $f(\xi)(b-a)$ (B) $f(b)(\xi-a)$
(C) $f(a)(b-\xi)$ (D) 0

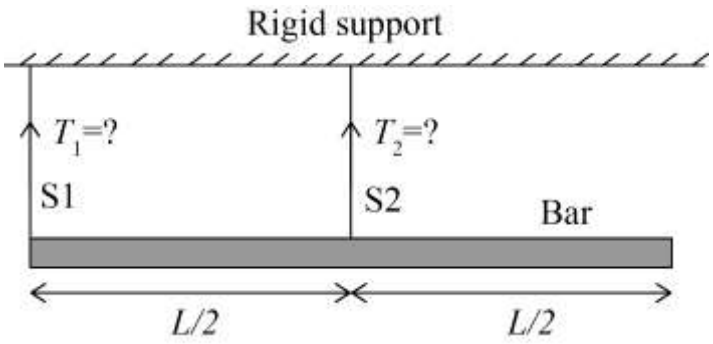
Q.4 $F(z)$ is a function of the complex variable $z = x+iy$ given by

$$F(z) = i\,z + k\,Re(z) + i\,Im(z).$$

For what value of k will $F(z)$ satisfy the Cauchy-Riemann equations?

(A) 0 (B) 1 (C) -1 (D) y

Q.5 A bar of uniform cross section and weighing 100 N is held horizontally using two massless and inextensible strings S1 and S2 as shown in the figure.



The tensions in the strings are

(A) T_1 = 100 N and T_2 = 0 N (B) T_1 = 0 N and T_2 = 100 N
(C) T_1 = 75 N and T_2 = 25 N (D) T_1 = 25 N and T_2 = 75 N

Q.6 If σ_1 and σ_3 are the algebraically largest and smallest principal stresses respectively, the value of the maximum shear stress is

(A) $\frac{\sigma_1+\sigma_3}{2}$ (B) $\frac{\sigma_1-\sigma_3}{2}$ (C) $\sqrt{\frac{\sigma_1+\sigma_3}{2}}$ (D) $\sqrt{\frac{\sigma_1-\sigma_3}{2}}$

Q.7 The equation of motion for a spring-mass system excited by a harmonic force is

$$M\ddot{x}+Kx=F\cos(\omega t),$$

where M is the mass, K is the spring stiffness, F is the force amplitude and ω is the angular frequency of excitation. Resonance occurs when ω is equal to

(A) $\sqrt{\frac{M}{K}}$ (B) $\frac{1}{2\pi}\sqrt{\frac{K}{M}}$ (C) $2\pi\sqrt{\frac{K}{M}}$ (D) $\sqrt{\frac{K}{M}}$

Q.8 For an Oldham coupling used between two shafts, which among the following statements are correct?

I. Torsional load is transferred along shaft axis.
II. A velocity ratio of 1:2 between shafts is obtained without using gears.
III. Bending load is transferred transverse to shaft axis.
IV. Rotation is transferred along shaft axis.

(A) I and III (B) I and IV (C) II and III (D) II and IV

Q.9 For a two-dimensional incompressible flow field given by $\vec{u}=A\left(x\,\hat{i}-y\,\hat{j}\right)$, where $A>0$, which one of the following statements is FALSE?

(A) It satisfies continuity equation.
(B) It is unidirectional when $x\to 0$ and $y\to\infty$.
(C) Its streamlines are given by $x=y$.
(D) It is irrotational.

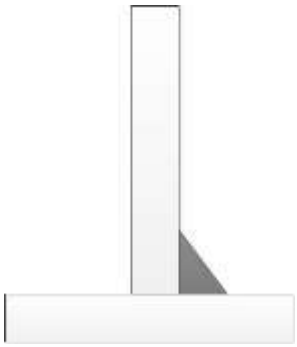
Q.10 Which one of the following statements is correct for a superheated vapour?

(A) Its pressure is less than the saturation pressure at a given temperature.
(B) Its temperature is less than the saturation temperature at a given pressure.
(C) Its volume is less than the volume of the saturated vapour at a given temperature.
(D) Its enthalpy is less than the enthalpy of the saturated vapour at a given pressure.

Q.11 In a linearly hardening plastic material, the true stress beyond initial yielding

(A) increases linearly with the true strain
(B) decreases linearly with the true strain
(C) first increases linearly and then decreases linearly with the true strain
(D) remains constant

Q.12 The type of weld represented by the shaded region in the figure is



(A) groove (B) spot (C) fillet (D) plug

Q.13 Using the Taylor's tool life equation with exponent $n = 0.5$, if the cutting speed is reduced by 50%, the ratio of new tool life to original tool life is

(A) 4 (B) 2 (C) 1 (D) 0.5

Q.14 A grinding ratio of 200 implies that the

(A) grinding wheel wears 200 times the volume of the material removed
(B) grinding wheel wears 0.005 times the volume of the material removed
(C) aspect ratio of abrasive particles used in the grinding wheel is 200
(D) ratio of volume of abrasive particle to that of grinding wheel is 200

Q.15 Interpolator in a CNC machine

(A) controls spindle speed
(B) coordinates axes movements
(C) operates tool changer
(D) commands canned cycle

Q.16 The time series forecasting method that gives equal weightage to each of the *m* most recent observations is

(A) Moving average method (B) Exponential smoothing with linear trend
(C) Triple Exponential smoothing (D) Kalman Filter

Q.17 The number of atoms per unit cell and the number of slip systems, respectively, for a face-centered cubic (FCC) crystal are

(A) 3, 3 (B) 3, 12 (C) 4, 12 (D) 4, 48

Q.18 A six-faced fair dice is rolled five times. The probability (in %) of obtaining "ONE" at least four times is

(A) 33.3 (B) 3.33 (C) 0.33 (D) 0.0033

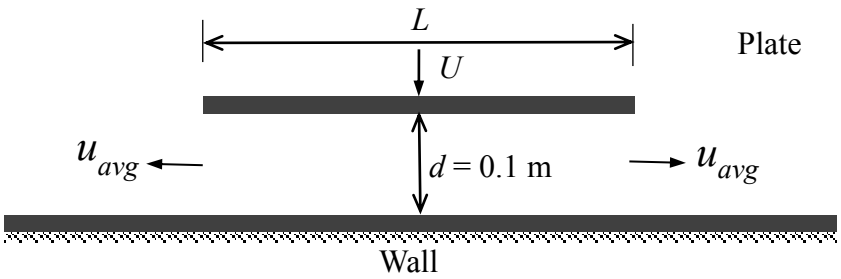
Q.19 A steel column of rectangular section (15 mm × 10 mm) and length 1.5 m is simply supported at both ends. Assuming modulus of elasticity, E = 200 GPa for steel, the critical axial load (in kN) is ____ (correct to two decimal places).

Q.20 A four bar mechanism is made up of links of length 100, 200, 300 and 350 mm. If the 350 mm link is fixed, the number of links that can rotate fully is _____.

Q.21 If the wire diameter of a compressive helical spring is increased by 2%, the change in spring stiffness (in %) is _____ (correct to two decimal places).

Q.22 A flat plate of width L = 1 m is pushed down with a velocity U = 0.01 m/s towards a wall resulting in the drainage of the fluid between the plate and the wall as shown in the figure. Assume two-dimensional incompressible flow and that the plate remains parallel to the wall.

The average velocity, u_{avg} of the fluid (in m/s) draining out at the instant shown in the figure is _____(correct to three decimal places).



Q.23 An ideal gas undergoes a process from state 1 (T_1 = 300 K, p_1 = 100 kPa) to state 2 (T_2 = 600 K, p_2 = 500 kPa). The specific heats of the ideal gas are : c_p = 1 kJ/kg-K and c_v = 0.7 kJ/kg-K. The change in specific entropy of the ideal gas from state 1 to state 2 (in kJ/kg-K) is _____(correct to two decimal places).

Q.24 For a Pelton wheel with a given water jet velocity, the maximum output power from the Pelton wheel is obtained when the ratio of the bucket speed to the water jet speed is _____ (correct to two decimal places).

Q.25 The height (in mm) for a 125 mm sine bar to measure a taper of $27^\circ 32'$ on a flat work piece is _____ (correct to three decimal places).

Q. 26 – Q. 55 carry two marks each.

Q.26 Let X_1, X_2 be two independent normal random variables with means μ_1, μ_2 and standard deviations σ_1, σ_2, respectively. Consider $Y = X_1 - X_2$; $\mu_1 = \mu_2 = 1$, $\sigma_1 = 1$, $\sigma_2 = 2$. Then,

(A) Y is normally distributed with mean 0 and variance 1
(B) Y is normally distributed with mean 0 and variance 5
(C) Y has mean 0 and variance 5, but is NOT normally distributed
(D) Y has mean 0 and variance 1, but is NOT normally distributed

Q.27 The value of the integral

$$\oiint_S \vec{r} \cdot \vec{n}\, dS$$

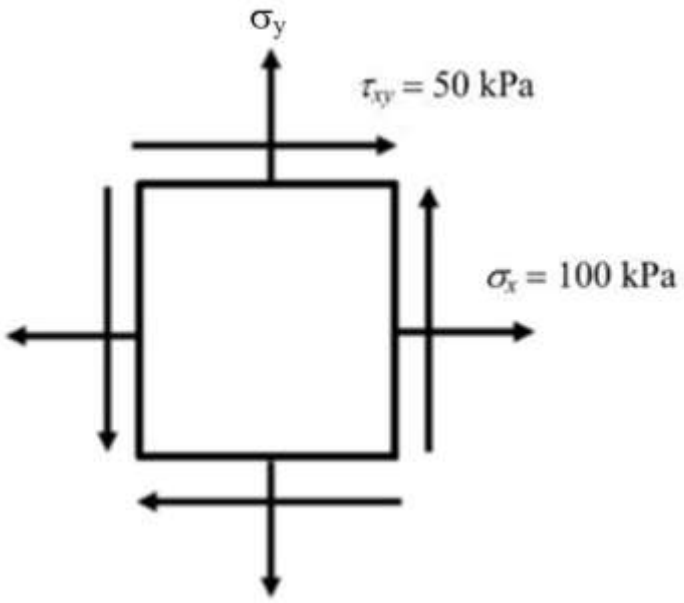
over the closed surface S bounding a volume V, where $\vec{r} = x\hat{\mathrm{i}} + y\hat{\mathrm{j}} + z\hat{\mathrm{k}}$ is the position vector and $\vec{n}$ is the normal to the surface S, is

(A) V (B) $2V$ (C) $3V$ (D) $4V$

Q.28 A point mass is shot vertically up from ground level with a velocity of 4 m/s at time, $t = 0$. It loses 20% of its impact velocity after each collision with the ground. Assuming that the acceleration due to gravity is 10 m/s^2 and that air resistance is negligible, the mass stops bouncing and comes to complete rest on the ground after a total time (in seconds) of

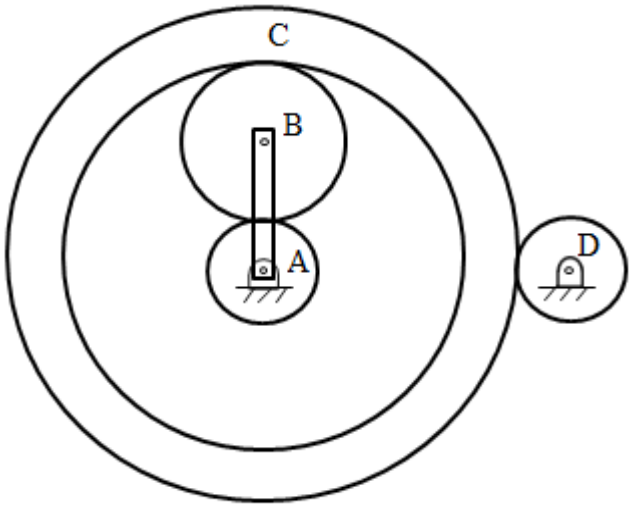
(A) 1 (B) 2 (C) 4 (D) ∞

Q.29 The state of stress at a point, for a body in plane stress, is shown in the figure below. If the minimum principal stress is 10 kPa, then the normal stress σ_y (in kPa) is



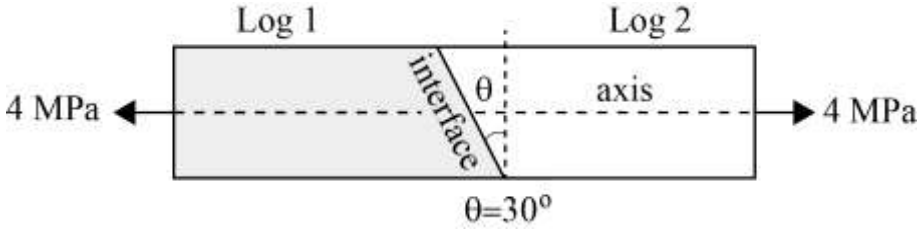
(A) 9.45 (B) 18.88 (C) 37.78 (D) 75.50

Q.30 An epicyclic gear train is shown in the figure below. The number of teeth on the gears A, B and D are 20, 30 and 20, respectively. Gear C has 80 teeth on the inner surface and 100 teeth on the outer surface. If the carrier arm AB is fixed and the sun gear A rotates at 300 rpm in the clockwise direction, then the rpm of D in the clockwise direction is



(A) 240 (B) –240 (C) 375 (D) –375

Q.31 A carpenter glues a pair of cylindrical wooden logs by bonding their end faces at an angle of $\theta = 30^{\circ}$ as shown in the figure.



The glue used at the interface fails if

Criterion 1: the maximum normal stress exceeds 2.5 MPa.

Criterion 2: the maximum shear stress exceeds 1.5 MPa.

Assume that the interface fails before the logs fail. When a uniform tensile stress of 4 MPa is applied, the interface

(A) fails only because of criterion 1

(B) fails only because of criterion 2

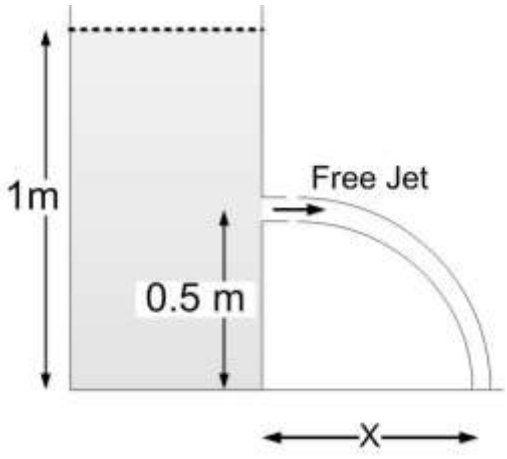
(C) fails because of both criteria 1 and 2

(D) does not fail

Q.32 A self-aligning ball bearing has a basic dynamic load rating (C_{10}, for 10^6 revolutions) of 35 kN. If the equivalent radial load on the bearing is 45 kN, the expected life (in 10^6 revolutions) is

(A) below 0.5 (B) 0.5 to 0.8 (C) 0.8 to 1.0 (D) above 1.0

Q.33 A tank open at the top with a water level of 1 m, as shown in the figure, has a hole at a height of 0.5 m. A free jet leaves horizontally from the smooth hole. The distance X (in m) where the jet strikes the floor is



(A) 0.5 (B) 1.0 (C) 2.0 (D) 4.0

Q.34 In a Lagrangian system, the position of a fluid particle in a flow is described as $x = x_o e^{-kt}$ and $y = y_o e^{kt}$ where t is the time while x_o, y_o, and k are constants. The flow is

(A) unsteady and one-dimensional
(B) steady and two-dimensional
(C) steady and one-dimensional
(D) unsteady and two-dimensional

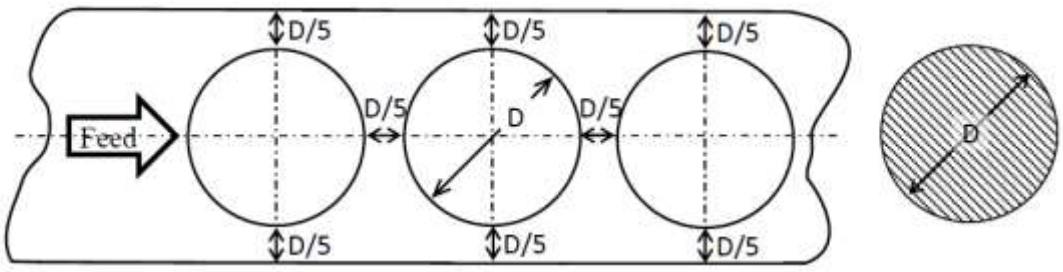
Q.35 The maximum reduction in cross-sectional area per pass (R) of a cold wire drawing process is

$$R = 1 - e^{-(n+1)},$$

where n represents the strain hardening coefficient. For the case of a perfectly plastic material, R is

(A) 0.865 (B) 0.826 (C) 0.777 (D) 0.632

Q.36 The percentage scrap in a sheet metal blanking operation of a continuous strip of sheet metal as shown in the figure is _____ (correct to two decimal places).



Q.37 An explicit forward Euler method is used to numerically integrate the differential equation

$$\frac{dy}{dt} = y$$

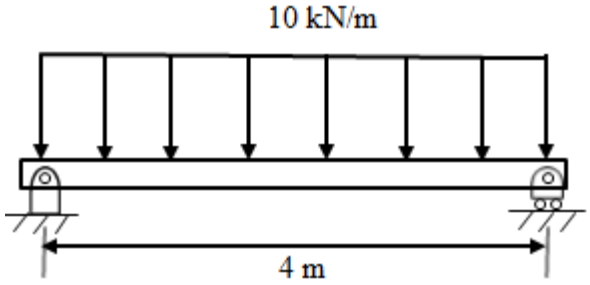
using a time step of 0.1. With the initial condition $y(0) = 1$, the value of $y(1)$ computed by this method is _____ (correct to two decimal places).

Q.38 $F(s)$ is the Laplace transform of the function

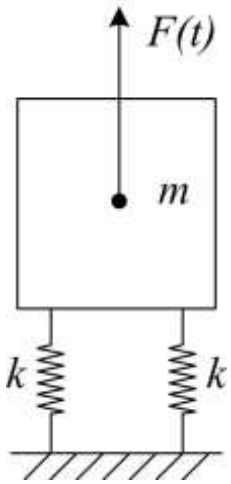
$$f(t) = 2t^2 e^{-t}$$

$F(1)$ is _____ (correct to two decimal places).

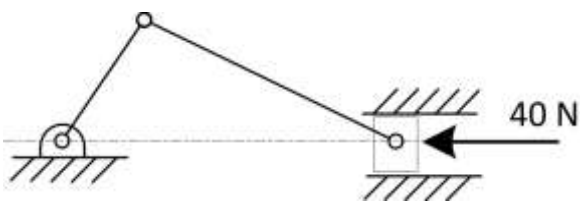
Q.39 A simply supported beam of width 100 mm, height 200 mm and length 4 m is carrying a uniformly distributed load of intensity 10 kN/m. The maximum bending stress (in MPa) in the beam is _____ (correct to one decimal place).



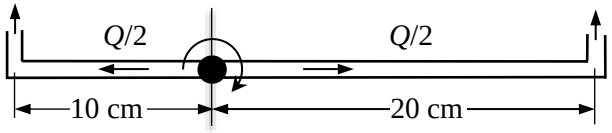
Q.40 A machine of mass $m = 200$ kg is supported on two mounts, each of stiffness $k = 10$ kN/m. The machine is subjected to an external force (in N) $F(t) = 50\cos 5t$. Assuming only vertical translatory motion, the magnitude of the dynamic force (in N) transmitted from each mount to the ground is _____ (correct to two decimal places).



Q.41 A slider crank mechanism is shown in the figure. At some instant, the crank angle is 45^o and a force of 40 N is acting towards the left on the slider. The length of the crank is 30 mm and the connecting rod is 70 mm. Ignoring the effect of gravity, friction and inertial forces, the magnitude of the crankshaft torque (in Nm) needed to keep the mechanism in equilibrium is _____ (correct to two decimal places).

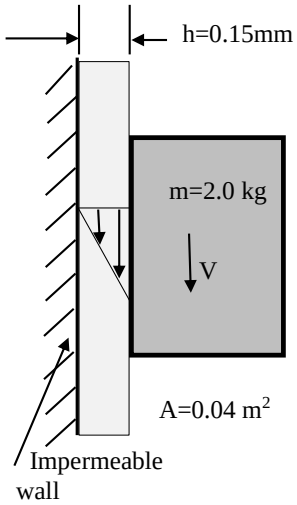


Q.42 A sprinkler shown in the figure rotates about its hinge point in a horizontal plane due to water flow discharged through its two exit nozzles.



The total flow rate Q through the sprinkler is 1 litre/sec and the cross-sectional area of each exit nozzle is 1 cm^2. Assuming equal flow rate through both arms and a frictionless hinge, the steady state angular speed of rotation (in rad/s) of the sprinkler is _____ (correct to two decimal places).

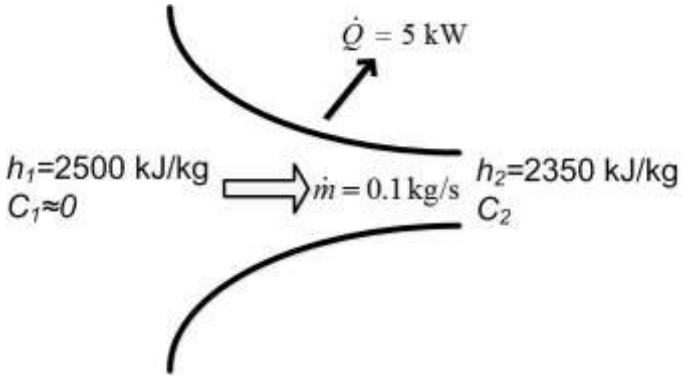
Q.43 A solid block of 2.0 kg mass slides steadily at a velocity V along a vertical wall as shown in the figure below. A thin oil film of thickness h = 0.15 mm provides lubrication between the block and the wall. The surface area of the face of the block in contact with the oil film is 0.04 m^2. The velocity distribution within the oil film gap is linear as shown in the figure. Take dynamic viscosity of oil as 7×10^{-3} Pa-s and acceleration due to gravity as 10 m/s^2. Neglect weight of the oil. The terminal velocity V (in m/s) of the block is _____ (correct to one decimal place).



Q.44 A tank of volume 0.05 m^3 contains a mixture of saturated water and saturated steam at 200°C. The mass of the liquid present is 8 kg. The entropy (in kJ/kg K) of the mixture is _____ (correct to two decimal places).

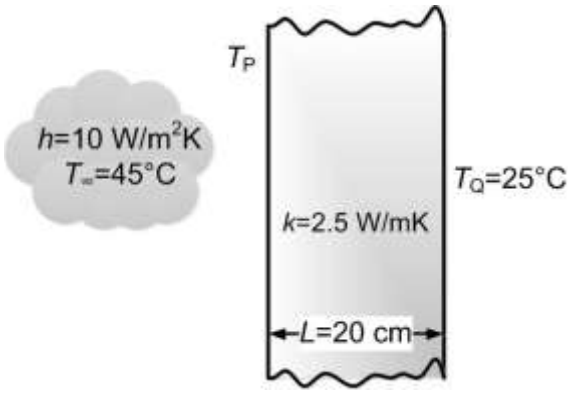
Property data for saturated steam and water are:
At 200°C, p_{sat} = 1.5538 MPa
v_f = 0.001157 m^3/kg, v_g = 0.12736 m^3/kg
$s_{fg} = 4.1014$ kJ/kg K, $s_f = 2.3309$ kJ/kg K

Q.45 Steam flows through a nozzle at a mass flow rate of $\dot{m} = 0.1\,\text{kg/s}$ with a heat loss of 5 kW. The enthalpies at inlet and exit are $2500\,\text{kJ/kg}$ and 2350 kJ/kg, respectively. Assuming negligible velocity at inlet ($C_1 \approx 0$), the velocity (C_2) of steam (in m/s) at the nozzle exit is _____ (correct to two decimal places).

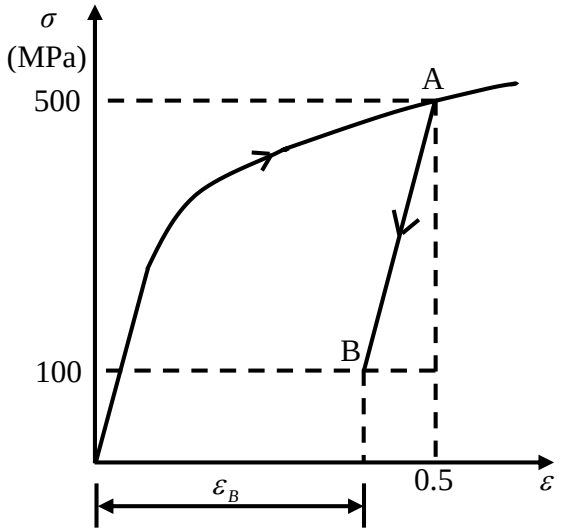


Q.46 An engine working on air standard Otto cycle is supplied with air at 0.1 MPa and 35°C. The compression ratio is 8. The heat supplied is 500 kJ/kg. Property data for air: c_p = 1.005 kJ/kg K, c_v = 0.718 kJ/kg K, R = 0.287 kJ/kg K. The maximum temperature (in K) of the cycle is _____ (correct to one decimal place).

Q.47 A plane slab of thickness L and thermal conductivity k is heated with a fluid on one side (P), and the other side (Q) is maintained at a constant temperature, T_Q of 25°C, as shown in the figure. The fluid is at 45°C and the surface heat transfer coefficient, h, is $10\,\text{W/m}^2\text{K}$. The steady state temperature, T_P, (in °C) of the side which is exposed to the fluid is _____ (correct to two decimal places).



Q.48 The true stress (σ) - true strain (ε) diagram of a strain hardening material is shown in figure. First, there is loading up to point A, i.e., up to stress of 500 MPa and strain of 0.5. Then from point A, there is unloading up to point B, i.e., to stress of 100 MPa. Given that the Young's modulus E = 200 GPa, the natural strain at point B (ε_B) is _____ (correct to three decimal places).



Q.49 An orthogonal cutting operation is being carried out in which uncut thickness is 0.010 mm, cutting speed is 130 m/min, rake angle is 15° and width of cut is 6 mm. It is observed that the chip thickness is 0.015 mm, the cutting force is 60 N and the thrust force is 25 N. The ratio of friction energy to total energy is _____ (correct to two decimal places).

Q.50 A bar is compressed to half of its original length. The magnitude of true strain produced in the deformed bar is _____ (correct to two decimal places).

Q.51 The minimum value of $3x + 5y$
such that:

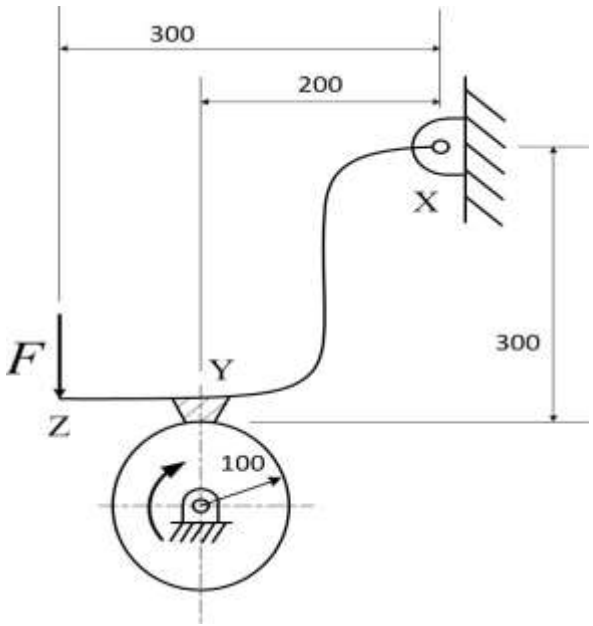
$$3x + 5y \leq 15$$
$$4x + 9y \leq 8$$
$$13x + 2y \leq 2$$
$$x \geq 0, y \geq 0$$

is _____.

Q.52 Processing times (including setup times) and due dates for six jobs waiting to be processed at a work centre are given in the table. The average tardiness (in days) using shortest processing time rule is _____ (correct to two decimal places).

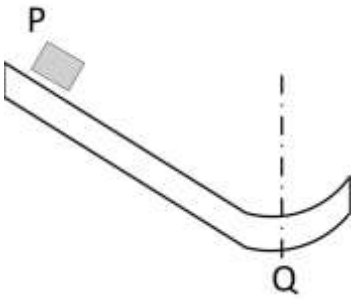
Job	Processing time (days)	Due date (days)
A	3	8
B	7	16
C	4	4
D	9	18
E	5	17
F	13	19

Q.53 The schematic of an external drum rotating clockwise engaging with a short shoe is shown in the figure. The shoe is mounted at point Y on a rigid lever XYZ hinged at point X. A force $F = 100\ N$ is applied at the free end of the lever as shown. Given that the coefficient of friction between the shoe and the drum is 0.3, the braking torque (in Nm) applied on the drum is _____ (correct to two decimal places).



(All dimensions are in mm)

Q.54 Block P of mass 2 kg slides down the surface and has a speed 20 m/s at the lowest point, Q, where the local radius of curvature is 2 m as shown in the figure. Assuming $g = 10\ m/s^2$, the normal force (in N) at Q is _____ (correct to two decimal places).



Q.55 An electrochemical machining (ECM) is to be used to cut a through hole into a 12 mm thick aluminum plate. The hole has a rectangular cross-section, 10 mm × 30 mm. The ECM operation will be accomplished in 2 minutes, with efficiency of 90%. Assuming specific removal rate for aluminum as $3.44 \times 10^{-2}\ mm^3/(A\ s)$, the current (in A) required is _____ (correct to two decimal places).

END OF THE QUESTION PAPER

Q. 1 – Q. 5 carry one mark each.

Q.1 "The dress _____ her so well that they all immediately _____ her on her appearance."

The words that best fill the blanks in the above sentence are

(A) complemented, complemented
(B) complimented, complemented
(C) complimented, complimented
(D) complemented, complimented

Q.2 "The judge's standing in the legal community, though shaken by false allegations of wrongdoing, remained _____."

The word that best fills the blank in the above sentence is

(A) undiminished (B) damaged (C) illegal (D) uncertain

Q.3 Find the missing group of letters in the following series:
BC, FGH, LMNO, _____

(A) UVWXY (B) TUVWX (C) STUVW (D) RSTUV

Q.4 The perimeters of a circle, a square and an equilateral triangle are equal. Which one of the following statements is true?

(A) The circle has the largest area.
(B) The square has the largest area.
(C) The equilateral triangle has the largest area.
(D) All the three shapes have the same area.

Q.5 The value of the expression $\frac{1}{1+\log_u vw} + \frac{1}{1+\log_v wu} + \frac{1}{1+\log_w uv}$ is _____.

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

Q. 6 – Q. 10 carry two marks each.

Q.6 Forty students watched films A, B and C over a week. Each student watched either only one film or all three. Thirteen students watched film A, sixteen students watched film B and nineteen students watched film C. How many students watched all three films?

(A) 0 (B) 2 (C) 4 (D) 8

Q.7 A wire would enclose an area of 1936 m^2, if it is bent into a square. The wire is cut into two pieces. The longer piece is thrice as long as the shorter piece. The long and the short pieces are bent into a square and a circle, respectively. Which of the following choices is closest to the sum of the areas enclosed by the two pieces in square meters?

(A) 1096 (B) 1111 (C) 1243 (D) 2486

Q.8 A contract is to be completed in 52 days and 125 identical robots were employed, each operational for 7 hours a day. After 39 days, five-seventh of the work was completed. How many additional robots would be required to complete the work on time, if each robot is now operational for 8 hours a day?

(A) 50 (B) 89 (C) 146 (D) 175

Q.9 A house has a number which needs to be identified. The following three statements are given that can help in identifying the house number.

i. If the house number is a multiple of 3, then it is a number from 50 to 59.
ii. If the house number is NOT a multiple of 4, then it is a number from 60 to 69.
iii. If the house number is NOT a multiple of 6, then it is a number from 70 to 79.

What is the house number?

(A) 54 (B) 65 (C) 66 (D) 76

Q.10 An unbiased coin is tossed six times in a row and four different such trials are conducted. One trial implies six tosses of the coin. If H stands for head and T stands for tail, the following are the observations from the four trials:
(1) HTHTHT (2) TTHHHT (3) HTTHHT (4) HHHT__ __.

Which statement describing the last two coin tosses of the fourth trial has the highest probability of being correct?

(A) Two T will occur.
(B) One H and one T will occur.
(C) Two H will occur.
(D) One H will be followed by one T.

END OF THE QUESTION PAPER

Q. 1 – Q. 25 carry one mark each.

Q.1 The Fourier cosine series for an even function $f(x)$ is given by

$$f(x) = a_0 + \sum_{n=1}^{\infty} a_n \cos(nx).$$

The value of the coefficient a_2 for the function $f(x) = \cos^2(x)$ in [0, π] is

(A) –0.5 (B) 0.0 (C) 0.5 (D) 1.0

Q.2 The divergence of the vector field $\vec{u} = e^x\left(\cos y\,\hat{i} + \sin y\,\hat{j}\right)$ is

(A) 0
(B) $e^x \cos y + e^x \sin y$
(C) $2e^x \cos y$
(D) $2e^x \sin y$

Q.3 Consider a function u which depends on position *x* and time *t*. The partial differential equation

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2}$$

is known as the

(A) Wave equation
(B) Heat equation
(C) Laplace's equation
(D) Elasticity equation

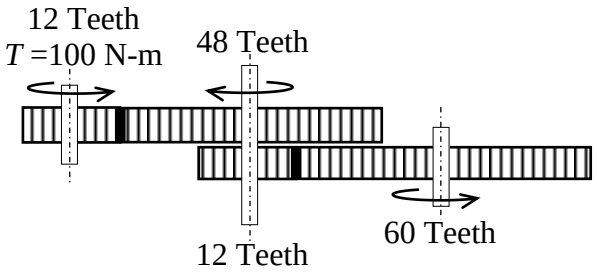
Q.4 If *y* is the solution of the differential equation $y^3 \frac{dy}{dx} + x^3 = 0$, $y(0) = 1$, the value of $y(-1)$ is

(A) −2 (B) −1 (C) 0 (D) 1

Q.5 The minimum axial compressive load, *P*, required to initiate buckling for a pinned-pinned slender column with bending stiffness *EI* and length *L* is

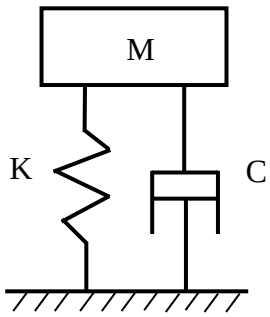
(A) $P = \frac{\pi^2 EI}{4L^2}$ (B) $P = \frac{\pi^2 EI}{L^2}$ (C) $P = \frac{3\pi^2 EI}{4L^2}$ (D) $P = \frac{4\pi^2 EI}{L^2}$

Q.6 A frictionless gear train is shown in the figure. The leftmost 12-teeth gear is given a torque of 100 N-m. The output torque from the 60-teeth gear on the right in N-m is



(A) 5 (B) 20 (C) 500 (D) 2000

Q.7 In a single degree of freedom underdamped spring-mass-damper system as shown in the figure, an additional damper is added in parallel such that the system still remains underdamped. Which one of the following statements is ALWAYS true?



(A) Transmissibility will increase.
(B) Transmissibility will decrease.
(C) Time period of free oscillations will increase.
(D) Time period of free oscillations will decrease.

Q.8 Pre-tensioning of a bolted joint is used to

(A) strain harden the bolt head
(B) decrease stiffness of the bolted joint
(C) increase stiffness of the bolted joint
(D) prevent yielding of the thread root

Q.9 The peak wavelength of radiation emitted by a black body at a temperature of 2000 K is 1.45 μm. If the peak wavelength of emitted radiation changes to 2.90 μm, then the temperature (in K) of the black body is

(A) 500 (B) 1000 (C) 4000 (D) 8000

Q.10 For an ideal gas with constant properties undergoing a quasi-static process, which one of the following represents the change of entropy (Δs) from state 1 to 2?

(A) $\Delta s = C_p \ln\left(\frac{T_2}{T_1}\right) - R\ln\left(\frac{P_2}{P_1}\right)$

(B) $\Delta s = C_V \ln\left(\frac{T_2}{T_1}\right) - C_p \ln\left(\frac{V_2}{V_1}\right)$

(C) $\Delta s = C_P \ln\left(\frac{T_2}{T_1}\right) - C_V \ln\left(\frac{P_2}{P_1}\right)$

(D) $\Delta s = C_V \ln\left(\frac{T_2}{T_1}\right) + R\ln\left(\frac{V_1}{V_2}\right)$

Q.11 Select the correct statement for 50% reaction stage in a steam turbine.

(A) The rotor blade is symmetric.
(B) The stator blade is symmetric.
(C) The absolute inlet flow angle is equal to absolute exit flow angle.
(D) The absolute exit flow angle is equal to inlet angle of rotor blade.

Q.12 Denoting *L* as liquid and *M* as solid in a phase-diagram with the subscripts representing different phases, a *eutectoid* reaction is described by

(A) $M_1 \rightarrow M_2 + M_3$

(B) $L_1 \rightarrow M_1 + M_2$

(C) $L_1 + M_1 \rightarrow M_2$

(D) $M_1 + M_2 \rightarrow M_3$

Q.13 During solidification of a pure molten metal, the grains in the casting near the mould wall are

(A) coarse and randomly oriented
(B) fine and randomly oriented
(C) fine and ordered
(D) coarse and ordered

Q.14 Match the following products with the suitable manufacturing process

Product		**Manufacturing Process**	
P	Toothpaste tube	1	Centrifugal casting
Q	Metallic pipes	2	Blow moulding
R	Plastic bottles	3	Rolling
S	Threaded bolts	4	Impact extrusion

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

Q.15 Feed rate in slab milling operation is equal to

(A) rotation per minute (rpm)
(B) product of rpm and number of teeth in the cutter
(C) product of rpm, feed per tooth and number of teeth in the cutter
(D) product of rpm, feed per tooth and number of teeth in contact

Q.16 Metal removal in electric discharge machining takes place through

(A) ion displacement
(B) melting and vaporization
(C) corrosive reaction
(D) plastic shear

Q.17 The preferred option for holding an odd-shaped workpiece in a centre lathe is

(A) live and dead centres
(B) three jaw chuck
(C) lathe dog
(D) four jaw chuck

Q.18 A local tyre distributor expects to sell approximately 9600 steel belted radial tyres next year. Annual carrying cost is Rs. 16 per tyre and ordering cost is Rs. 75. The economic order quantity of the tyres is

(A) 64 (B) 212 (C) 300 (D) 1200

Q.19 If $A = \begin{bmatrix} 1 & 2 & 3 \\ 0 & 4 & 5 \\ 0 & 0 & 1 \end{bmatrix}$ then $\det(A^{-1})$ is _____ (correct to two decimal places).

Q.20 A hollow circular shaft of inner radius 10 mm, outer radius 20 mm and length 1 m is to be used as a torsional spring. If the shear modulus of the material of the shaft is 150 GPa, the torsional stiffness of the shaft (in kN-m/rad) is _____ (correct to two decimal places).

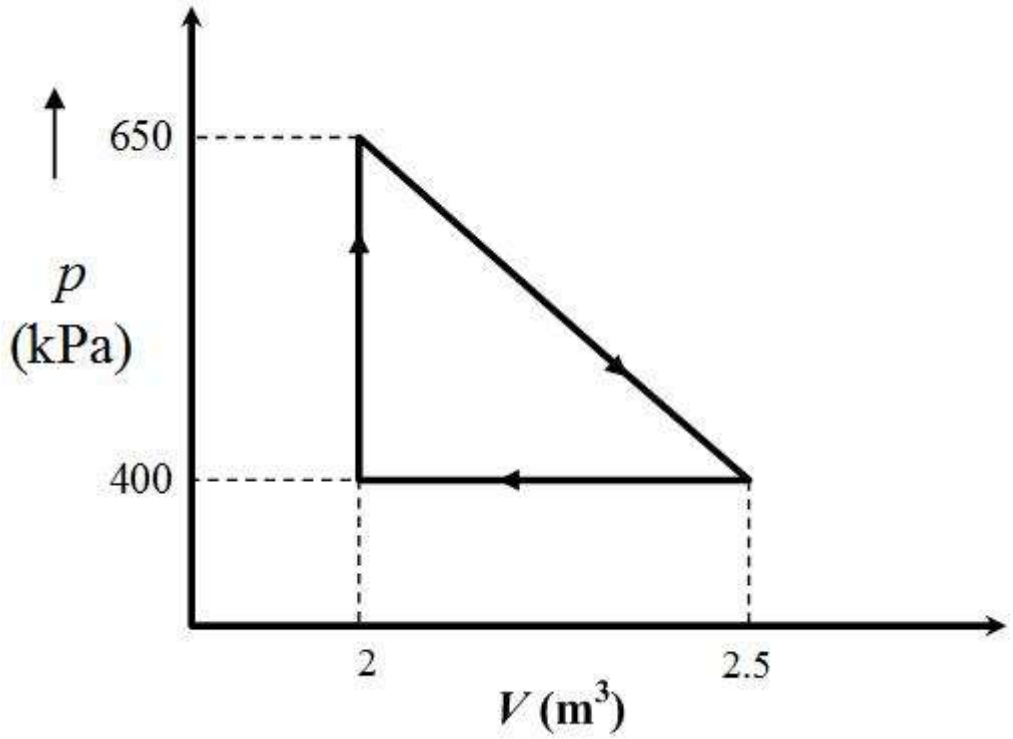
Q.21 Fatigue life of a material for a fully reversed loading condition is estimated from

$$\sigma_a = 1100 N^{-0.15},$$

where σ_a is the stress amplitude in MPa and N is the failure life in cycles. The maximum allowable stress amplitude (in MPa) for a life of 1×10^5 cycles under the same loading condition is _____ (correct to two decimal places).

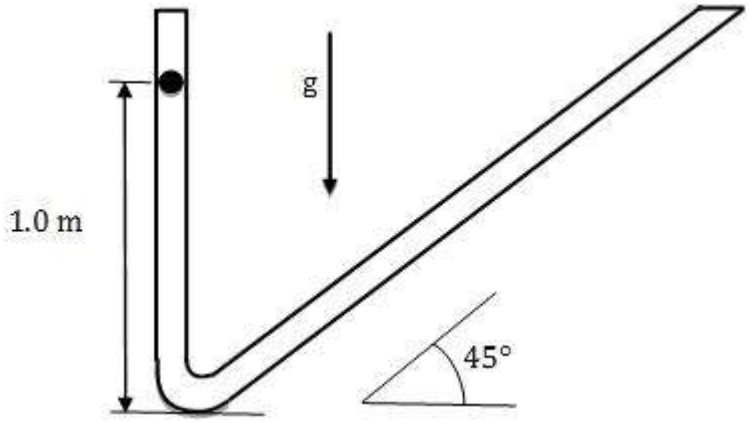
Q.22 The viscous laminar flow of air over a flat plate results in the formation of a boundary layer. The boundary layer thickness at the end of the plate of length L is δ_L. When the plate length is increased to twice its original length, the percentage change in laminar boundary layer thickness at the end of the plate (with respect to δ_L) is _____ (correct to two decimal places).

Q.23 An engine operates on the reversible cycle as shown in the figure. The work output from the engine (in kJ/cycle) is _____ (correct to two decimal places).



Q.24 The arrival of customers over fixed time intervals in a bank follow a Poisson distribution with an average of 30 customers/hour. The probability that the time between successive customer arrival is between 1 and 3 minutes is _____ (correct to two decimal places).

Q.25 A ball is dropped from rest from a height of 1 m in a frictionless tube as shown in the figure. If the tube profile is approximated by two straight lines (ignoring the curved portion), the total distance travelled (in m) by the ball is _____ (correct to two decimal places).



Q. 26 – Q. 55 carry two marks each.

Q.26 Let z be a complex variable. For a counter-clockwise integration around a unit circle C, centred at origin,

$$\oint_C \frac{1}{5z-4}\, dz = A\pi i \,,$$

the value of A is

(A) 2/5 (B) 1/2 (C) 2 (D) 4/5

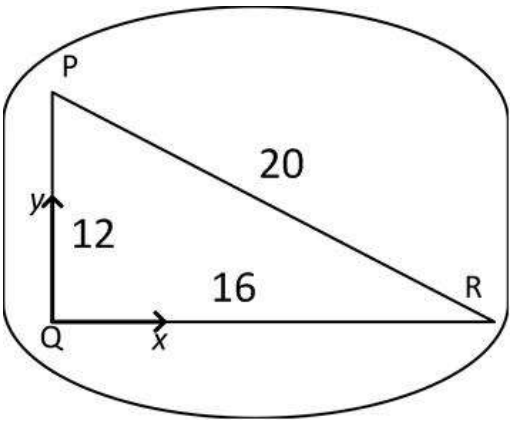
Q.27 Let X_1 and X_2 be two independent exponentially distributed random variables with means 0.5 and 0.25, respectively. Then $Y = \min(X_1, X_2)$ is

(A) exponentially distributed with mean $1/6$
(B) exponentially distributed with mean 2
(C) normally distributed with mean $3/4$
(D) normally distributed with mean $1/6$

Q.28 For a position vector $\vec{r} = x\,\hat{\mathrm{i}} + y\,\hat{\mathrm{j}} + z\,\mathrm{k}$ the norm of the vector can be defined as $|\vec{r}| = \sqrt{x^2 + y^2 + z^2}$. Given a function $\phi = \ln|\vec{r}|$, its gradient $\nabla\phi$ is

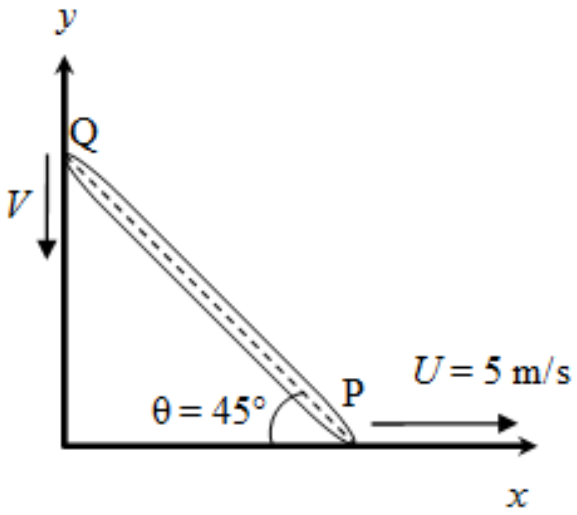
(A) $\vec{r}$ (B) $\dfrac{\vec{r}}{|\vec{r}|}$ (C) $\dfrac{\vec{r}}{\vec{r}\cdot\vec{r}}$ (D) $\dfrac{\vec{r}}{|\vec{r}|^3}$

Q.29 In a rigid body in plane motion, the point R is accelerating with respect to point P at $10\angle 180°$ m/s^2. If the instantaneous acceleration of point Q is zero, the acceleration (in m/s^2) of point R is



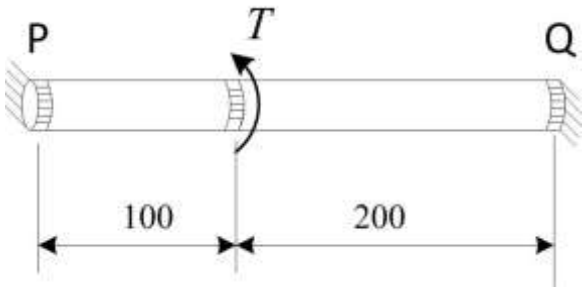
(A) $8\angle 233°$ (B) $10\angle 225°$ (C) $10\angle 217°$ (D) $8\angle 217°$

Q.30 A rigid rod of length 1 m is resting at an angle $\theta = 45^o$ as shown in the figure. The end P is dragged with a velocity of $U = 5$ m/s to the right. At the instant shown, the magnitude of the velocity V (in m/s) of point Q as it moves along the wall without losing contact is



(A) 5 (B) 6 (C) 8 (D) 10

Q.31 A bar of circular cross section is clamped at ends P and Q as shown in the figure. A torsional moment $T = 150$ Nm is applied at a distance of 100 mm from end P. The torsional reactions (T_P, T_Q) in Nm at the ends P and Q respectively are



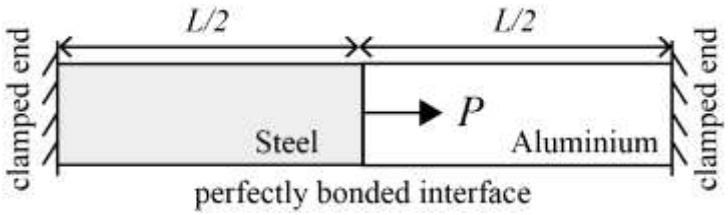
(All dimensions are in mm)

(A) $(50, 100)$ (B) $(75, 75)$ (C) $(100, 50)$ (D) $(120, 30)$

Q.32 In a cam-follower, the follower rises by h as the cam rotates by δ (radians) at constant angular velocity ω (radians/s). The follower is uniformly accelerating during the first half of the rise period and it is uniformly decelerating in the latter half of the rise period. Assuming that the magnitudes of the acceleration and deceleration are same, the maximum velocity of the follower is

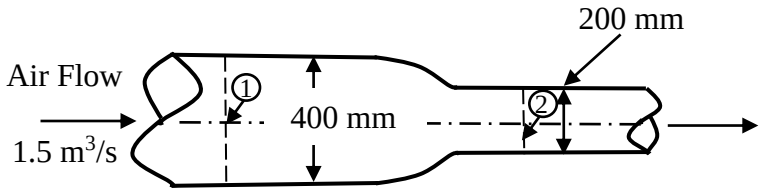
(A) $\frac{4h\omega}{\delta}$ (B) $h\omega$ (C) $\frac{2h\omega}{\delta}$ (D) $2h\omega$

Q.33 A bimetallic cylindrical bar of cross sectional area 1 m^2 is made by bonding Steel (Young's modulus = 210 GPa) and Aluminium (Young's modulus = 70 GPa) as shown in the figure. To maintain tensile axial strain of magnitude 10^{-6} in Steel bar and compressive axial strain of magnitude 10^{-6} in Aluminum bar, the magnitude of the required force P (in kN) along the indicated direction is



(A) 70 (B) 140 (C) 210 (D) 280

Q.34 Air flows at the rate of 1.5 m^3/s through a horizontal pipe with a gradually reducing cross-section as shown in the figure. The two cross-sections of the pipe have diameters of 400 mm and 200 mm. Take the air density as 1.2 kg/m^3 and assume inviscid incompressible flow. The change in pressure $(p_2 - p_1)$ (in kPa) between sections 1 and 2 is



(A) –1.28 (B) 2.56 (C) –2.13 (D) 1.28

Q.35 The problem of maximizing $z = x_1 - x_2$ subject to constraints $x_1 + x_2 \le 10,\ x_1 \ge 0,\ x_2 \ge 0$ and $x_2 \le 5$ has

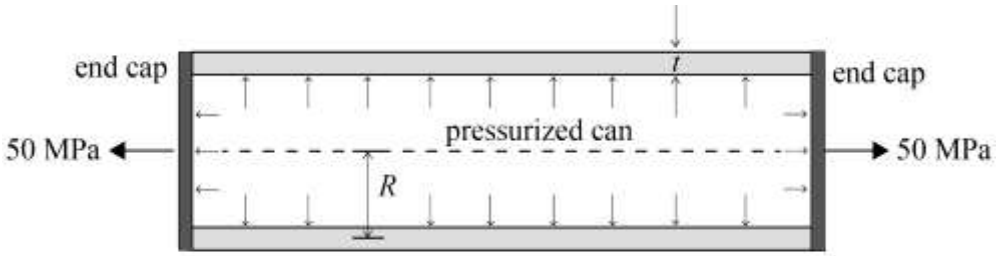
(A) no solution
(B) one solution
(C) two solutions
(D) more than two solutions

Q.36 Given the ordinary differential equation

$$\frac{d^2y}{dx^2} + \frac{dy}{dx} - 6y = 0$$

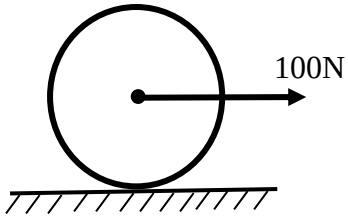
with $y(0) = 0$ and $\frac{dy}{dx}(0) = 1$, the value of $y(1)$ is _____ (correct to two decimal places).

Q.37 A thin-walled cylindrical can with rigid end caps has a mean radius $R = 100$ mm and a wall thickness of $t = 5$ mm. The can is pressurized and an additional tensile stress of 50 MPa is imposed along the axial direction as shown in the figure. Assume that the state of stress in the wall is uniform along its length. If the magnitudes of axial and circumferential components of stress in the can are equal, the pressure (in MPa) inside the can is _____ (correct to two decimal places).

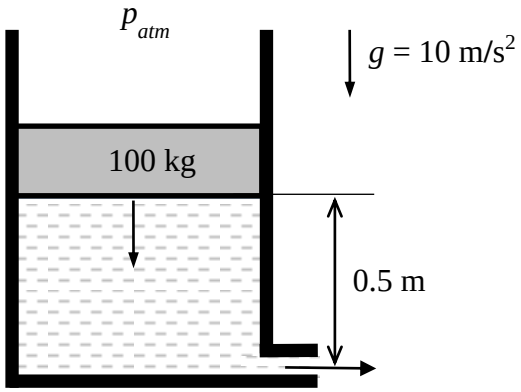


Q.38 A bar is subjected to a combination of a steady load of 60 kN and a load fluctuating between −10 kN and 90 kN. The corrected endurance limit of the bar is 150 MPa, the yield strength of the material is 480 MPa and the ultimate strength of the material is 600 MPa. The bar cross-section is square with side *a*. If the factor of safety is 2, the value of *a* (in mm), according to the modified Goodman's criterion, is _____ (correct to two decimal places).

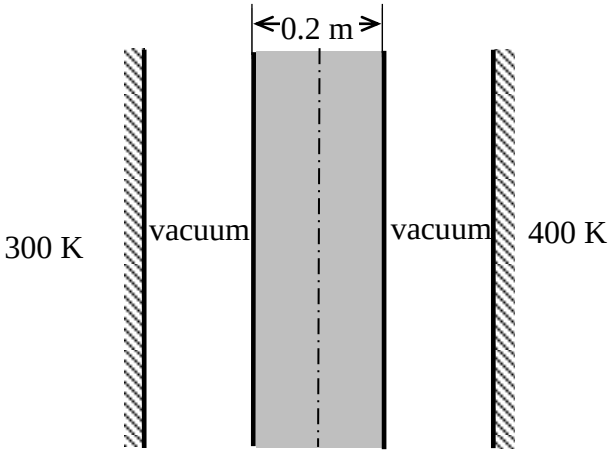
Q.39 A force of 100 N is applied to the centre of a circular disc, of mass 10 kg and radius 1 m, resting on a floor as shown in the figure. If the disc rolls without slipping on the floor, the linear acceleration (in m/s^2) of the centre of the disc is _____ (correct to two decimal places).



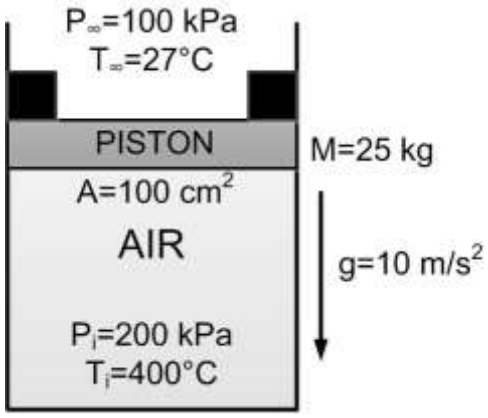
Q.40 A frictionless circular piston of area 10^{-2} m^2 and mass 100 kg sinks into a cylindrical container of the same area filled with water of density 1000 kg/m^3 as shown in the figure. The container has a hole of area 10^{-3} m^2 at the bottom that is open to the atmosphere. Assuming there is no leakage from the edges of the piston and considering water to be incompressible, the magnitude of the piston velocity (in m/s) at the instant shown is _____ (correct to three decimal places).



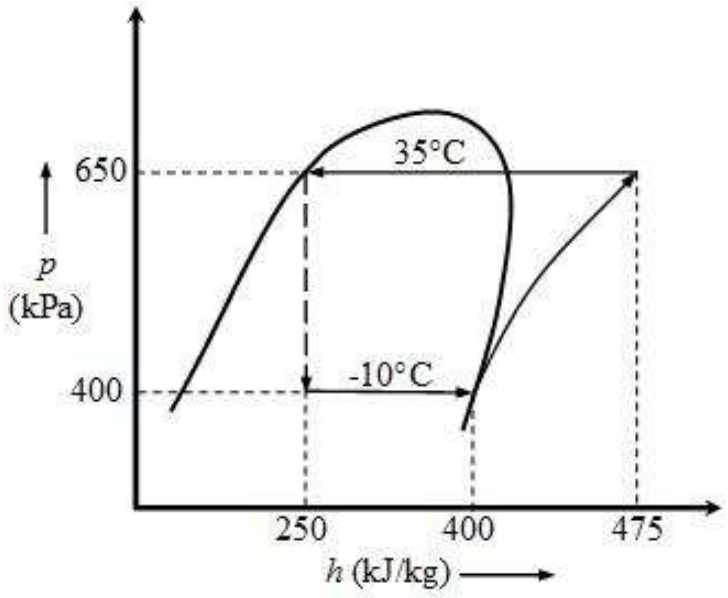
Q.41 A 0.2 m thick infinite black plate having a thermal conductivity of 3.96 W/m-K is exposed to two infinite black surfaces at 300 K and 400 K as shown in the figure. At steady state, the surface temperature of the plate facing the cold side is 350 K. The value of Stefan-Boltzmann constant, σ, is 5.67×10^{-8} W/m^2 K^4. Assuming 1-D heat conduction, the magnitude of heat flux through the plate (in W/m^2) is _____ (correct to two decimal places).



Q.42 Air is held inside a non-insulated cylinder using a piston (mass M=25 kg and area A=100 cm^2) and stoppers (of negligible area), as shown in the figure. The initial pressure P_i and temperature T_i of air inside the cylinder are 200 kPa and 400°C, respectively. The ambient pressure P_∞ and temperature T_∞ are 100 kPa and 27°C, respectively. The temperature of the air inside the cylinder (°C) at which the piston will begin to move is _____ (correct to two decimal places).



Q.43 A standard vapor compression refrigeration cycle operating with a condensing temperature of $35^{\circ}C$ and an evaporating temperature of $-10^{\circ}C$ develops 15 kW of cooling. The *p-h* diagram shows the enthalpies at various states. If the isentropic efficiency of the compressor is 0.75, the magnitude of compressor power (in kW) is _____ (correct to two decimal places).



Q.44 Ambient air is at a pressure of 100 kPa, dry bulb temperature of $30^{\circ}C$ and 60% relative humidity. The saturation pressure of water at $30^{\circ}C$ is 4.24 kPa. The specific humidity of air (in g/kg of dry air) is _____ (correct to two decimal places).

Q.45 A test is conducted on a one-fifth scale model of a Francis turbine under a head of 2 m and volumetric flow rate of 1 m^3/s at 450 rpm. Take the water density and the acceleration due to gravity as 10^3 kg/m^3 and 10 m/s^2, respectively. Assume no losses both in model and prototype turbines. The power (in MW) of a full sized turbine while working under a head of 30 m is _____ (correct to two decimal places).

Q.46 The true stress (in MPa) versus true strain relationship for a metal is given by

$$\sigma = 1020\,\varepsilon^{0.4}.$$

The cross-sectional area at the start of a test (when the stress and strain values are equal to zero) is 100 mm^2. The cross-sectional area at the time of necking (in mm^2) is _____ (correct to two decimal places)

Q.47 A steel wire is drawn from an initial diameter (d_i) of 10 mm to a final diameter (d_f) of 7.5 mm. The half cone angle (α) of the die is 5° and the coefficient of friction (μ) between the die and the wire is 0.1. The average of the initial and final yield stress $[(\sigma_Y)_{avg}]$ is 350 MPa. The equation for drawing stress σ_f, (in MPa) is given as:

$$\sigma_f = (\sigma_Y)_{avg}\left\{1 + \frac{1}{\mu \cot \alpha}\right\}\left[1 - \left(\frac{d_f}{d_i}\right)^{2\mu \cot\alpha}\right]$$

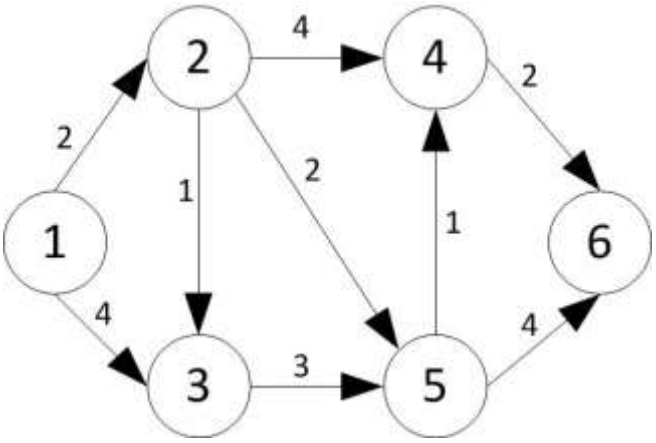
The drawing stress (in MPa) required to carry out this operation is _____ (correct to two decimal places).

Q.48 Following data correspond to an orthogonal turning of a 100 mm diameter rod on a lathe.
Rake angle: $+15^o$; Uncut chip thickness: 0.5 mm; nominal chip thickness after the cut: 1.25 mm. The shear angle (in degrees) for this process is _____ (correct to two decimal places).

Q.49 Taylor's tool life equation is used to estimate the life of a batch of identical HSS twist drills by drilling through holes at constant feed in 20 mm thick mild steel plates. In test 1, a drill lasted 300 holes at 150 rpm while in test 2, another drill lasted 200 holes at 300 rpm. The maximum number of holes that can be made by another drill from the above batch at 200 rpm is _____ (correct to two decimal places).

Q.50 For sand-casting a steel rectangular plate with dimensions 80 mm × 120 mm × 20 mm, a cylindrical riser has to be designed. The height of the riser is equal to its diameter. The total solidification time for the casting is 2 minutes. In Chvorinov's law for the estimation of the total solidification time, exponent is to be taken as 2. For a solidification time of 3 minutes in the riser, the diameter (in mm) of the riser is _____ (correct to two decimal places).

Q.51 The arc lengths of a directed graph of a project are as shown in the figure. The shortest path length from node 1 to node 6 is _____.



Q.52 A circular hole of 25 mm diameter and depth of 20 mm is machined by EDM process. The material removal rate (in mm^3/min) is expressed as

$$4\times10^4 IT^{-1.23},$$

where $I = 300$ A and the melting point of the material, $T = 1600^{\circ}C$. The time (in minutes) for machining this hole is _____ (correct to two decimal places)

Q.53 A welding operation is being performed with voltage = 30 V and current = 100 A. The cross-sectional area of the weld bead is 20 mm^2. The work-piece and filler are of titanium for which the specific energy of melting is 14 J/mm^3. Assuming a thermal efficiency of the welding process 70%, the welding speed (in mm/s) is _____ (correct to two decimal places).

Q.54 Steam in the condenser of a thermal power plant is to be condensed at a temperature of 30°C with cooling water which enters the tubes of the condenser at 14°C and exits at 22°C. The total surface area of the tubes is 50 m^2, and the overall heat transfer coefficient is 2000 W/m^2 K. The heat transfer (in MW) to the condenser is _____ (correct to two decimal places).

Q.55 A vehicle powered by a spark ignition engine follows air standard Otto cycle (γ=1.4). The engine generates 70 kW while consuming 10.3 kg/hr of fuel. The calorific value of fuel is 44,000 kJ/kg. The compression ratio is _____ (correct to two decimal places).

END OF THE QUESTION PAPER