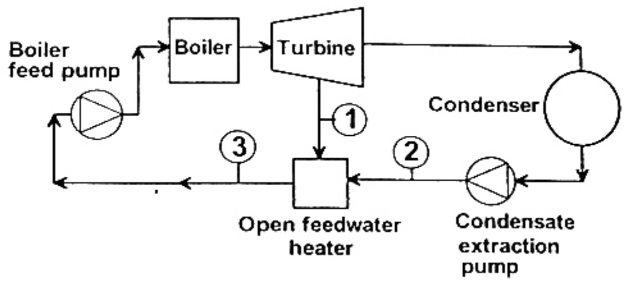
52. A thermal power plant operates on a regenerative cycle with a single open feedwater heater, as shown in the figure. For the state points shown, the specific enthalpies are: $h_1 = 2800$ kJ/kg and $h_2 = 200$ kJ/kg. The bleed to the feedwater heater is 20% of the boiler steam generation rate. The specific enthalpy at state 3 is



(*a*) 720 kJ/kg

(*b*) 2280 kJ/kg

(*c*) 1500 kJ/kg

(*d*) 3000 kJ/kg

53. Moist air at a pressure of 100 kPa is compressed to 500 kPa and then cooled to 35°C in an aftercooler. The air at the entry to the aftercooler is unsaturated and becomes just saturated at the exit of the aftercooler. The saturation pressure of water at 35°C is 5.628 kPa. The partial pressure of water vapour (in kPa) in the moist air entering the compressor is closest to

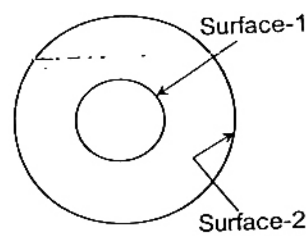
(*a*) 0.57

(*b*) 1.13

(*c*) 2.26

(*d*) 4.52

54. A hollow enclosure is formed between two infinitely long concentric cylinders of radii 1 m and 2 m, respectively. Radiative heat exchange takes place between the inner surface of the larger cylinder (surface-2) and the outer surface of the smaller cylinder (surface-1). The radiating surfaces are diffuse and the medium in the enclosure is non-participating. The fraction of the thermal radiation leaving the larger surface and striking itself is



(*a*) 0.25

(*b*) 0.5

(*c*) 0.75

(*d*) 1

55. Air (at atmospheric pressure) at a dry bulb temperature of 40°C and wet bulb temperature of 20°C is humidified in an air washer operating with continuous water recirculation. The wet bulb depression (i.e. the difference between the dry and wet bulb temperatures) at the exit is 25% of that at the inlet. The dry bulb temperature at the exit of the air washer is closest to

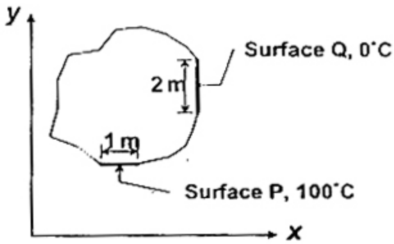
(*a*) 10°C

(*b*) 20°C

(*c*) 25°C

(*d*) 30°C

56. Steady two-dimensional heat conduction takes place in the body shown in the figure below. The normal temperature gradients over surfaces P and Q can be considered to be uniform. The temperature gradient $\frac{\partial T}{\partial x}$ at surface Q is equal to 10 K/m. Surfaces P and Q are maintained at constant temperatures as shown in the figure, while the remaining part of the boundary is insulated. The body has a constant thermal conductivity of 0.1 W/m.K. The values of $\frac{\partial T}{\partial x}$ and $\frac{\partial T}{\partial y}$ at surface P are



(*a*) $\frac{\partial T}{\partial x} = 20$ K/m, $\frac{\partial T}{\partial y} = 0$ K/m

(*b*) $\frac{\partial T}{\partial x} = 0$ K/m, $\frac{\partial T}{\partial y} = 10$ K/m

(*c*) $\frac{\partial T}{\partial x} = 10$ K/m, $\frac{\partial T}{\partial y} = 10$ K/m

(*d*) $\frac{\partial T}{\partial x} = 0$ K/m, $\frac{\partial T}{\partial y} = 20$ K/m

57. In a steady state steady flow process taking place in a device with a single inlet and a single outlet, the work done per unit mass flow rate is given by $w = -\int_{inlet}^{outlet} v dp$, where v is the specific volume and p is the pressure. The expression for w given above

(*a*) is valid only if the process is both reversible and adiabatic

(*b*) is valid only if the process is both reversible and isothermal

(*c*) is valid for any reversible process

(*d*) is incorrect; it must be $w = \int_{inlet}^{outlet} p dv$

58. For the standard transportation linear programme with m sources and n destinations and total supply equaling total demand, an optimal solution (lowest cost) with the smallest number of non-zero x_{ij} values (amounts from source i to destination j) is desired. The best upper bound for this number is

(*a*) mn

(*b*) 2 (m + n)

(*c*) m + n

(*d*) m + n – 1

59. A moving average system is used for forecasting weekly demand. $F_1(t)$ and $F_2(t)$ are sequences of forecasts with parameters m_1 and m_2, respectively, where m_1 and m_2 ($m_1 > m_2$) denote the numbers of weeks over which the moving averages are taken. The actual demand shows a step increase from d_1 to d_2 at a certain time. Subsequently,

(*a*) neither $F_1(t)$ nor $F_2(t)$ will catch up with the value d_2

(*b*) both sequences $F_1(t)$ and $F_2(t)$ will reach d_2 in the same period

(*c*) $F_1(t)$ will attain the value d_2 before $F_2(t)$

(*d*) $F_2(t)$ will attain the value d_2 before $F_1(t)$

60. For the network below, the objective is to find the length of the shortest path from node P to node G. Let d_{ij} be the length of directed are from node i to node j.

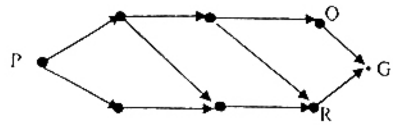
Let s_j be the length of the shortest path from P to node j. Which of the following equations can be used to find s_G?

(*a*) $s_G = \text{Min}\{s_Q, s_R\}$

(*b*) $s_G = \text{Min}\{s_Q - d_{QG}, s_R - d_{RG}\}$

(*c*) $s_G = \text{Min}\{s_Q + d_{QG}, s_R + d_{RG}\}$

(*d*) $s_G = \text{Min}\{d_{QG}, d_{RG}\}$

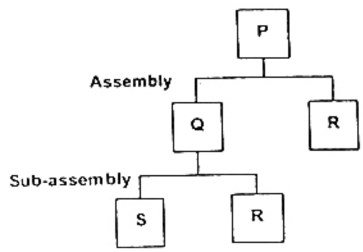


61. The product structure of an assembly P is shown in the figure.

Estimated demand for end product P is as follows

Week	1	2	3	4	5	6
Demand	1000	1000	1000	1000	1200	1200

ignore lead times for assembly and sub-assembly. Production capacity (per week) for component R is the bottleneck operation. Starting with zero inventory, the smallest capacity that will ensure a feasible production plan up to week 6 is



(*a*) 1000

(*b*) 1200

(*c*) 2200

(*d*) 2400

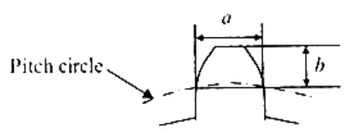
62. One tooth of a gear having 4 module and 32 teeth is shown in the figure. Assume that the gear tooth and the corresponding tooth space make equal intercepts on the pitch circumference. The dimensions 'a' and 'b', respectively, are closest to

(*a*) 6.08 mm, 4 mm

(*b*) 6.48 mm, 4.2 mm

(*c*) 6.28 mm, 4.3 mm

(*d*) 6.28 mm, 4.1 mm



63. While cooling, a cubical casting of side 40 mm undergoes 3%, 4% and 5% volume shrinkage during the liquid state, phase transition and solid state, respectively. The volume of metal compensated from the riser is

(*a*) 2%

(*b*) 7%

(*c*) 8%

(*d*) 9%

64. In a single point turning tool, the side rake angle and orthogonal rake angle are equal. φ is the principal cutting edge angle and its range is $0° \le \varphi \le 90°$. The chip flows in the orthogonal plane. The value of φ is closest to

(*a*) 0°

(*b*) 45°

(*c*) 60°

(*d*) 90°

65. A researcher conducts electrochemical machining (ECM) on a binary alloy (density 6000 kg/m^3) of iron (atomic weight 56, valency 2) and metal P (atomic weight 24, valency 4). Faraday's constant = 96500 coulomb/mole. Volumetric material removal rate of the alloy is 50 mm^3/s at a current of 2000 A. The percentage of the metal P in the alloy is closest to

(*a*) 40
(*b*) 25
(*c*) 15
(*d*) 79

66. In a single pass rolling operation, a 20 mm thick plate with plate width of 100 mm, is reduced to 18 mm. The roller radius is 250 mm and rotational speed is 10 rpm. The average flow stress for the plate material is 300 MPa. The power required for the rolling operation in kW is closest to

(*a*) 15.2
(*b*) 18.2
(*c*) 30.4
(*d*) 45.6

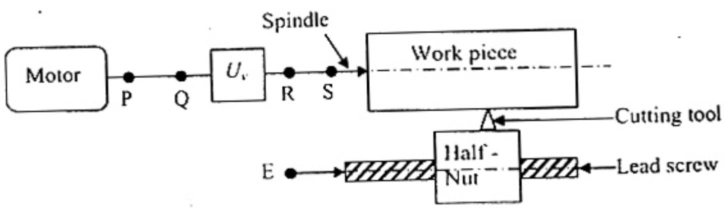
67. In arc welding of a butt joint, the welding speed is to be selected such that highest cooling rate is achieved. Melting efficiency and heat transfer efficiency are 0.5 and 0.7, respectively. The area of the weld cross section is 5 mm^2 and the unit energy required to melt the metal is 10 J/mm^3. If the welding power is 2 kW, the welding speed in mm/s is closest to

(*a*) 4
(*b*) 14
(*c*) 24
(*d*) 34

68. In the deep drawing of cups, blanks show a tendency to wrinkle up around the periphery (flange). The most likely cause and remedy of the phenomenon are, respectively,

(*a*) Buckling due to circumferential compression; Increase blank holder pressure
(*b*) High blank holder pressure and high friction; Reduce blank holder pressure and apply lubricant
(*c*) High temperature causing increase in circumferential length; Apply coolant to blank
(*d*) Buckling due to circumferential compression; decrease blank holder pressure

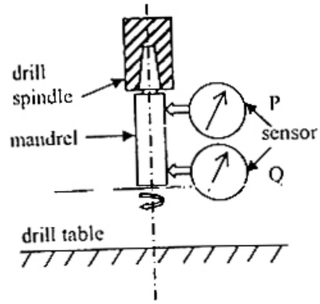
69. The figure shows an incomplete schematic of a conventional lathe to be used for cutting threads with different pitches. The speed gear box U_r is shown and the feed gear box U_s is to be placed. P, Q, R and S denote locations and have no other significance. Changes in U_r should NOT affect the pitch of the thread being cut and changes in U_s should NOT affect the cutting speed.



The correct connections and the correct placement of U_s are given by

(*a*) Q and E are connected. U_s is placed between P and Q.
(*b*) S and E are connected. U_s is placed between R and S.
(*c*) Q and E are connected. U_s is placed between Q and E.
(*d*) S and E are connected. U_s is placed between S and E.

70. A displacement sensor (a dial indicator) measures the lateral displacement of a mandrel mounted on the taper hole inside a drill spindle. The mandrel axis is an extension of the drill spindle taper hole axis and the protruding portion of the mandrel surface is perfectly cylindrical. measurements are taken with the sensor placed at two positions P and Q as shown in the figure. The readings are recorded as R_x = maximum deflection minus minimum deflection, corresponding to sensor position at X, over one rotation.



If $R_P = R_Q > 0$, which one of the following would be consistent with the observation?

(*a*) The drill spindle rotational axis is coincident with the drill spindle taper hole axis

(*b*) The drill spindle rotational axis intersects the drill spindle taper hole axis at point P

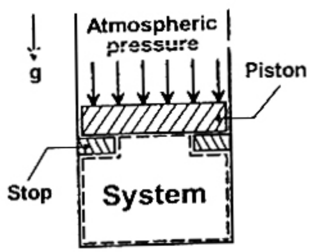
(c) The drill spindle rotational axis is parallel to the drill spindle taper hole axis

(*d*) The drill spindle rotational axis intersects the drill spindle taper hole axis at point Q

Common Data Questions

Common Data for Questions 71, 72 and 73:

In the figure shown, the system is a pure substance kept in a piston-cylinder arrangement. The system is initially a two-phase mixture containing 1 kg of liquid and 0.03 kg of vapour at a pressure of 100 kPa. Initially, the piston rests on a set of stops, as shown in the figure. A pressure of 200 kPa is required to exactly balance the weight of the piston and the outside atmospheric pressure. Heat transfer takes place into the system until its volume increases by 50%. Heat transfer to the system occurs in such a manner that the piston, when allowed to move, does so in a very slow (quasi-static / quasi-equilibrium) process. The thermal reservoir from which heat is transferred to the system has a temperature of 400°C. Average temperature of the system boundary can be taken as 175°C. The heat transfer to the system is 1 kJ, during which its entropy increases by 10 J/K.



Specific volume of liquid (v_f) and vapour (v_g) phases, as well as values of saturation temperatures, are given in the table below.

Pressure (kPa)	Saturation temperature, T_{sat} (°C)	v_f(m³/kg)	v_g(m$_3$/kg)
100	100	0.001	0.1
200	200	0.0015	0.002

71. At the end of the process, which one of the following situations will be true?

(a) superheated vapour will be left in the system

(b) no vapour will be left in the system

(c) a liquid + vapour mixture will be left in the system

(d) the mixture will exist at a dry saturate vapour state

72. The work done by the system during the process is

(a) 0.1 kJ (b) 0.2 kJ

(c) 0.3 kJ (d) 0.4 kJ

73. The net entropy generation (considering the system and the thermal reservoir together) during the process is closest to

(a) 7.5 J/K (b) 7.7 J/K

(c) 8.5 J/K (d) 10 J/K

Common Data for Questions 74 and 75:

Consider the Linear Programme (LP)

Max $4x + 6y$

subject to

$3x + 2y \leq 6$

$2x + 3y \leq 6$

$x, y \geq 0$

74. After introducing slack variables s and t, the initial basic feasible solution is represented by the table below (basic variables are s = 6 and t = 6, and the objective function value is 0).

	– 4	– 6	0	0	0
s	3	2	1	0	6
t	2	3	0	1	6
	x	y	s	t	RHS

After some simplex iterations, the following table is obtained

	0	0	0	2	12
s	5/3	0	1	–1/3	2
y	2/3	1	0	1/3	2
	x	y	s	t	RHS

From this, one can conclude that

(a) the LP has a unique optimal solution

(b) the LP has an optimal solution that is not unique

(c) the LP is infeasible

(d) the LP is unbounded

75. The dual for the LP in Q 74 is

(a) Min 6u + 6v
subject to
$3u + 2v \geq 4$
$2u + 3v \geq 6$
$u, v \geq 0$

(b) Max 6u + 6v
subject to
$3u + 2v \leq 4$
$2u + 3v \leq 6$
$u, v \geq 0$

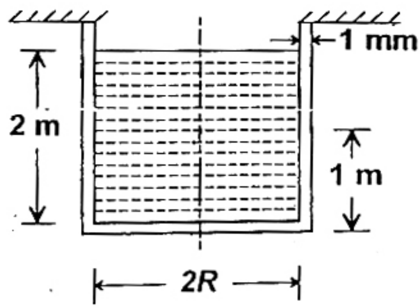
(c) Mix 4u + 6v
subject to
$3u + 2v \geq 6$
$2u + 3v \geq 6$
$u, v \geq 0$

(d) Min 4u + 6v
subject to
$3u + 2v \leq 6$
$2u + 3v \leq 6$
$u, v \geq 0$

Linked Answer Questions: Q.76 to Q.85 carry two marks each.

Statement for Linked Answer Questions 76 and 77:

A cylindrical container of radius R = 1 m, wall thickness 1 mm is filled with water up to a depth of 2 m and suspended along its upper rim. The density of water is 1000 kg/m³ and acceleration due to gravity is 10 m/s². The self-weight of the cylinder is negligible. The formula for hoop stress in a thin-walled cylinder can be used at all points along the height of the cylindrical container.



76. The axial and circumferential stress (σ_d, σ_c) experienced by the cylinder wall at mid-depth (1 m as shown) are

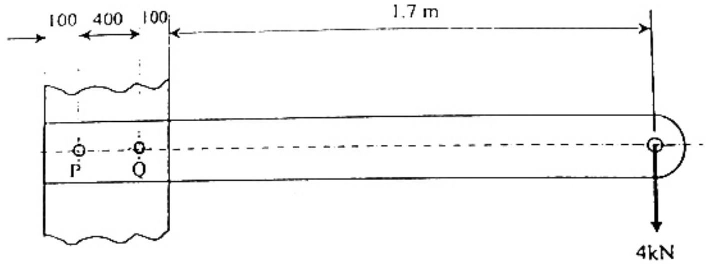
(a) (10, 10) MPa
(b) (5, 10) MPa
(c) (10, 5) MPa
(d) (5, 5) MPa

77. If the Young's modulus and Poisson's ratio of the container material are 100 GPa and 0.3, respectively, the axial strain in the cylinder wall at mid-depth is

(a) 2×10^{-5}
(b) 6×10^{-5}
(c) 7×10^{-5}
(d) 1.2×10^{-4}

Statement for Linked Answer Questions 78 and 79:

A steel bar of 10 × 50 mm is cantilevered with two M 12 bolts (P and Q) to support a static load of 4 kN as shown in the figure.



78. The primary and secondary shear loads on bolt P, respectively, are

(*a*) 2 kN, 20 kN (*b*) 20 kN, 2 kN

(*c*) 20 kN, 0 kN (*d*) 0 kN, 20 kN

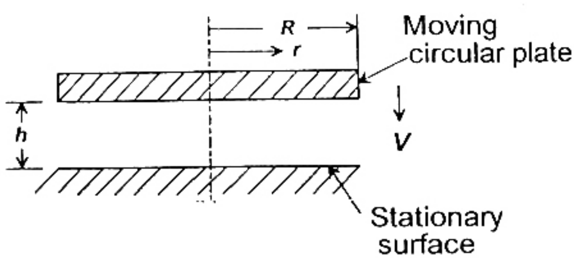
79. The resultant shear stress on bolt P is closest to

(*a*) 132 MPa (*b*) 159 MPa

(*c*) 178 MPa (*d*) 195 MPa

Statement for Linked Answer Questions 80 and 81:

The gap between a moving circular plate and a stationary surface is being continuously reduced, as the circular plate comes down at a uniform speed V towards the stationary bottom surface, as shown in the figure. In the process, the fluid contained between the two plates flows out radially. The fluid is assumed to be incompressible and inviscid.



80. The radial velocity v_r at any radius r, when the gap width is h, is

(*a*) $v_r = \frac{Vr}{2h}$ (*b*) $v_r = \frac{Vr}{h}$

(*c*) $v_r = \frac{2Vh}{r}$ (*d*) $v_r = \frac{Vh}{r}$

81. The radial component of the fluid acceleration at r = R is

(*a*) $\frac{3V^2R}{4h^2}$ (*b*) $\frac{V^2R}{4h^2}$

(*c*) $\frac{V^2R}{2h^2}$ (*d*) $\frac{V^2R}{4h^2}$

Statement for Linked Answer Questions 82 and 83:

Orthogonal turning is performed on a cylindrical workpiece with shear strength of 250 MPa. The following conditions are used: cutting velocity is 180 m/min, feed is 0.20 mm/rev, depth of cut is 3 mm, chip thickness ratio = 0.5. The orthogonal rake angle is 7°. Apply Merchant's theory for analysis.

82. The shear plane angle (in degrees) and the shear force respectively are

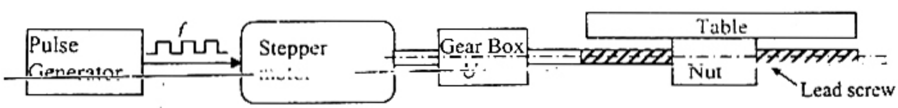
(*a*) 52 ; 320 N
(*b*) 52 ; 400 N
(*c*) 28 ; 400 N
(*d*) 28 ; 320 N

83. The cutting and frictional forces, respectively, are

(*a*) 568 N ; 387 N
(*b*) 565 N ; 381 N
(*c*) 440 N ; 342 N
(*d*) 480 N ; 356 N

Statement for Linked Answer Questions 84 and 85:

In the feed drive of a Point–to–Point open loop CNC drive, a stepper motor rotating at 200 steps/rev drives a table through a gear box and lead screw-nut mechanism (pitch = 4 mm, number of starts = 1). The gear ratio = $\left(\dfrac{\text{Output rotational speed}}{\text{Input rotational speed}}\right)$ is given by U = $\frac{1}{4}$. The stepper motor (driven by voltage pulses from a pulse generator) executes 1 step/pulse of the pulse generator. The frequency of the pulse train from the pulse generator is f = 10,000 pulses per minute.



84. The basic Length Unit (BLU), i.e., the table movement corresponding to 1 pulse of the pulse generator, is

(*a*) 0.5 microns
(*b*) 5 microns
(*c*) 50 microns
(*d*) 500 microns

85. A customer insists on a modification to change the BLU of the CNC drive to 10 microns without changing the table speed. The modification can be accomplished by

(*a*) changing U to $\frac{1}{2}$ and reducing f to $\frac{f}{2}$

(*b*) changing U to $\frac{1}{8}$ and increasing f to 2f

(*c*) changing U to $\frac{1}{2}$ and keeping f unchanged

(*d*) keeping U unchanged and increasing f to 2f

ANSWERS

1. (c)	2. (b)	3. (b)	4. (a)	5. (c)	6. (d)	7. (d)	8. (d)	9. (b)	10. (d)
11. (b)	12. (d)	13. (b)	14. (*)	15. (d)	16. (b)	17. (c)	18. (a)	19. (*)	20. (c)
21. (a)	22. (b)	23. (d)	24. (d)	25. (*)	26. (d)	27. (b)	28. (c)	29. (a)	30. (*)
31. (d)	32. (b)	33. (a)	34. (b)	35. (b)	36. (c)	37. (*)	38. (*)	39. (d)	40. (*)
41. (b)	42. (c)	43. (a)	44. (*)	45. (*)	46. (b)	47. (a)	48. (c)	49. (*)	50. (d)
51. (d)	52. (a)	53. (b)	54. (b)	55. (*)	56. (d)	57. (c)	58. (d)	59. (*)	60. (c)
61. (c)	62. (d)	63. (b)	64. (*)	65. (*)	66. (*)	67. (b)	68. (*)	69. (d)	70. (c)
71. (*)	72. (*)	73. (*)	74. (b)	75. (a)	76. (b)	77. (a)	78. (a)	79. (b)	80. (*)
81. (*)	82. (d)	83. (*)	84. (b)	85. (a)					

EXPLANATIONS

1. Taylor series expansion of f(x) about a is given by

$$f(x) = f(a) + \frac{(x-a)}{1!} f'(a) + \frac{(x-a)^2}{2!} f''(a) + \text{-----}$$

Coefficient of $(x-a)^4$ is $\frac{f''''(a)}{4!}$

Now $f(x) = e^x$

$\Rightarrow$ $f''''(x) = e^x$

$\Rightarrow$ $f''''(a) = e^a$

Hence for a = 2, $\frac{f''''(a)}{4!} = \frac{e^2}{4!}$

2. $\ddot{x} + 3x = 0$

$\Rightarrow$ $(D^2 + 3)\, x = 0$

$$P.I. = \left(\frac{1}{D^2+3}\right)(0) = 0$$

Now C.F. is given by, $C_1 e^{m_1 t} + C_2 e^{m_2 t}$

$\therefore$ $m^2 + 3 = 0$

$\Rightarrow$ $m = \pm i\sqrt{3}$

Hence the solution is C.F. + P.I.

i.e. $C_1 e^{i\sqrt{3}t} + C_2 e^{-i\sqrt{3}t}$

But $x(0) = 1$ $\Rightarrow C_1 + C_2 = 1$

and $\dot{x}(0) = 0, \dot{x} = i\sqrt{3}\, C_1 e^{i\sqrt{3}t} - i\sqrt{3}\, C_2 e^{-i\sqrt{3}t}$

$\Rightarrow$ $\dot{x}(0) = 0$ $\Rightarrow C_1 = C_2 = \frac{1}{2}$