

General Instructions

- (i) This question paper contains 65 questions. All questions are compulsory.
- (ii) It comprises 33 single-correct multiple-choice questions, 12 multiple-correct questions and 20 numerical / integer-type questions.
- (iii) These questions follow the GATE examination pattern.
- (iv) Questions carry 1 or 2 marks. MCQs have negative marking ($1/3$ or $2/3$ of the marks); MSQ and numerical-answer (NAT) questions carry no negative marking.
- (v) GATE is a 3-hour paper of 65 questions (100 marks).
- (vi) A virtual scientific calculator is provided; physical calculators are not allowed.
- (vii) Attempt every question; detailed solutions are provided in the companion solutions booklet.
- (viii) For multiple-correct questions, all correct options must be selected to earn full marks.
- (ix) For numerical questions, report the answer rounded exactly as asked.

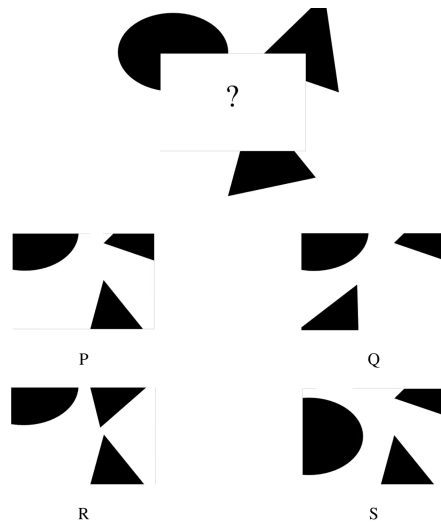
1. 'The shopkeeper sells lemons.'

In this sentence, the word 'lemons' is the _____.

- (A) object
- (B) subject
- (C) predicate
- (D) verb

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2. The figure below is supposed to show three non-overlapping shapes, one oval and two triangles. Which one of the following figures P, Q, R, or S fits the missing portion indicated by '?' and completes the oval and the two triangles?



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

...

3. At how many points will the curves $y = x^2$ and $y = -x^2 - 2x - 1$ intersect in the real (x, y) plane?

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

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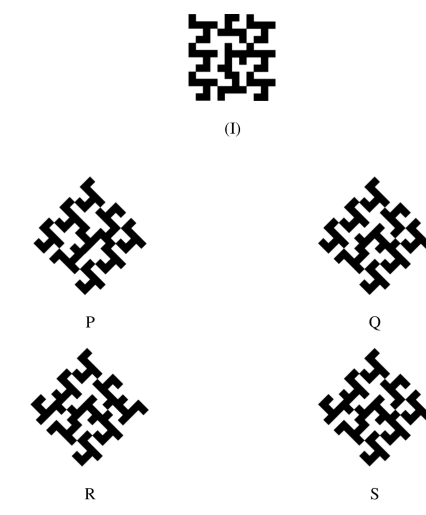
4. 'If Anish had scored hundred runs in today's match, he would have been made the captain of his team. He would have then become the youngest captain in his team's history. Unfortunately, he got out without scoring any runs. Hence, there won't be any change in the captaincy for now.'

Based on the paragraph above, which one of the following statements is true?

- (A) Anish made hundred runs but was denied captaincy.
- (B) Anish was the captain of his team before the game today.
- (C) The current captain is older than Anish.
- (D) Anish is the youngest player in his team.

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5. Which one of the following figures P, Q, R, or S, correctly shows the 45° clockwise-rotated version of figure (I)?



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

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6. Match the words in Column I with their synonyms in Column II.

Column I Column II

(i) Lonely (p) Verbatim

(ii) Literal (q) Solitary

(iii) Lousy (r) Deadly

(iv) Lethal (s) Terrible

(A) (i)-(q); (ii)-(p); (iii)-(s); (iv)-(r)

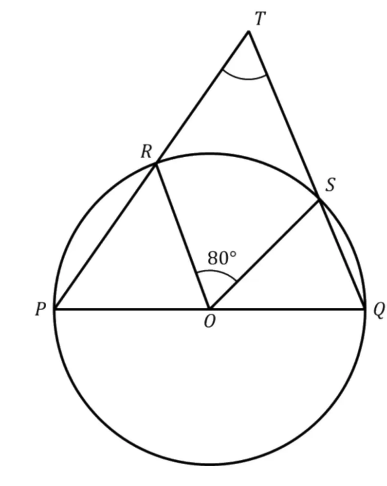
(B) (i)-(q); (ii)-(s); (iii)-(r); (iv)-(p)

(C) (i)-(s); (ii)-(p); (iii)-(q); (iv)-(r)

(D) (i)-(r); (ii)-(s); (iii)-(p); (iv)-(q)

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7. In the given figure, $\overline{PQ}$ is the diameter of a circle with center O . Two points R and S are chosen on the circle such that $\angle ROS = 80^\circ$. When $\overline{PR}$ and $\overline{QS}$ are extended, they meet at T .

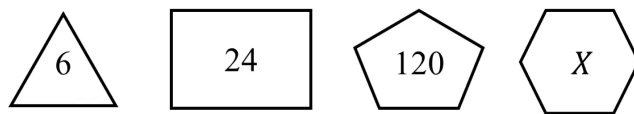


The value of $\angle RTS$ is _____

- (A) 40°
- (B) 50°
- (C) 60°
- (D) 80°

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8. Based on the relationship between each polygon and the number inside it, the value of 'X' is _____



- (A) 720
- (B) 596
- (C) 24
- (D) 240

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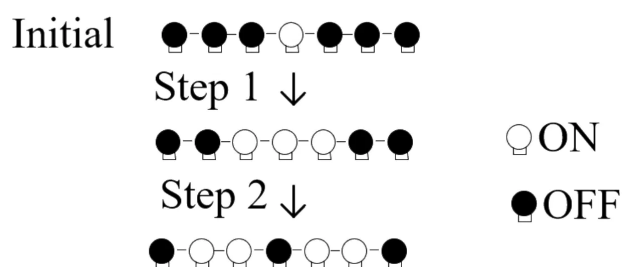
9. Consider a linear arrangement of seven bulbs, each of which can be in the ON or OFF state. The initial configuration of the bulbs is shown in the figure. In every Step, the states of the bulbs are changed based on the following rules:

Any OFF bulb with exactly one ON neighbor at the end of the previous Step is turned ON.

Any ON bulb with both neighbors ON at the end of the previous Step is turned OFF.

The state of any bulb not meeting the conditions above is left unchanged.

The state of bulbs at the end of Step 1 and Step 2 are also shown in the figure.



The number of bulbs which are ON at the end of Step 8 is _____

- (A) 5
- (B) 4
- (C) 3
- (D) 0

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10. P and Q are two positive integers such that $P^2 = Q^2 + 13$.

The product of the numbers P and Q is _____

- (A) 13
- (B) 26
- (C) 39
- (D) 42

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11. Which ONE of the following steps is NOT a part of product concept selection?

- (A) Preparation of the selection matrix
- (B) Ranking of the concepts
- (C) Combination and improvisation of the concept
- (D) Development of a cost model of the product

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12. Which ONE of the following is FALSE with respect to filler material used in brazing?

- (A) Melting temperature of the filler material must be less than the base metal.
- (B) Wettability of the base metal by the filler material must be low.
- (C) Viscosity of the filler material must be low for penetration into the interface.
- (D) Chemical reactivity between the filler material and the base metal must be low.

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13. An arc welding process is being carried out with a power source of 6 kW to weld two similar metals. The total energy loss is 50%, the area of cross-section of the weld is 10 mm^2 , and the specific energy needed to melt the metal is 15 J/mm^3 .

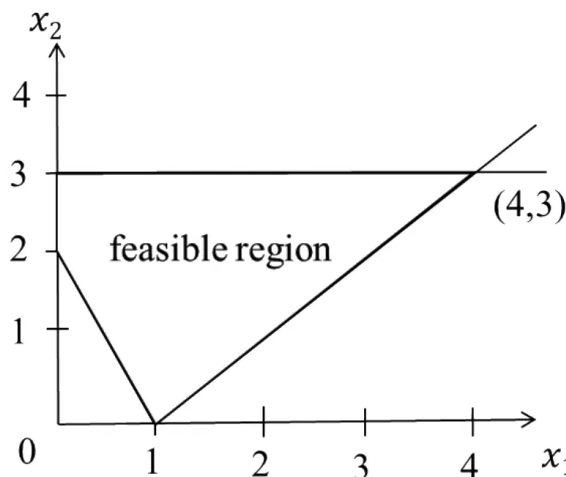
The speed of welding is _____ mm/s.

- (A) 10
- (B) 20
- (C) 30
- (D) 40

...

14. Which ONE of the following options represents correctly ALL the constraints resulting in the feasible region for the given linear programming problem as shown in the figure?

Note: Figure not to scale



- (A) $x_1 \geq 0; x_2 \geq 0; x_2 \geq 3; x_1 - x_2 \leq 1; x_1 - 0.5x_2 \geq 1$
- (B) $x_1 \geq 0; x_2 \geq 0; x_2 \leq 3; x_1 - x_2 \leq 1; x_1 + 0.5x_2 \geq 1$
- (C) $x_1 \geq 0; x_2 \geq 0; x_2 \leq 4; x_1 - x_2 \leq 1; x_1 + 0.5x_2 \geq 1$
- (D) $x_1 \geq 0; x_2 \geq 0; x_2 \leq 3; x_1 + x_2 \leq 1; x_1 + 0.5x_2 \geq 1$

...

15. Which ONE of the following options is the closest approximation to the value of the given definite integral?

$$\int_0^1 e^{-x^2} dx$$

Note: Use numerical integration

- (A) 1
- (B) $\frac{1}{e}$
- (C) $\frac{e+1}{2e}$
- (D) $\frac{1+e}{2}$

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16. Which ONE of the following is the value of $\frac{1}{i^n}$?

where $i = \sqrt{-1}$, and n is an even positive integer.

- (A) +1 or -1
- (B) + i or - i
- (C) only +1
- (D) only - i

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17. Which ONE of the following CORRECTLY matches the metrology instruments and their respective most common applications?

Metrology Instrument		Application	
P	Sine bar	1	Surface roughness of milled planar surface
Q	Profilometer	2	Planar surface inclination of a part
R	Vernier calliper	3	Checking shaft diameter tolerance without direct measurement
S	Ring GO gauge	4	Length of any side of a cuboid

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

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18. A plain carbon steel sample of eutectoid composition is heat treated from austenizing temperature to achieve a microstructure consisting of ONLY bainite.

Which ONE of the following is the corresponding heat treatment method?

- (A) Normalizing
- (B) Annealing
- (C) Martempering
- (D) Austempering

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19. An Iron-Carbon alloy at room temperature has pro-eutectoid ferrite as a constituent in the microstructure, that formed above the eutectoid temperature. The alloy also has pearlite as another constituent that has formed below eutectoid temperature.

Which ONE of the following best describes this Iron-Carbon alloy?

- (A) Hyper-eutectic steel
- (B) Hyper-eutectoid steel
- (C) Hypo-eutectoid steel
- (D) Eutectoid steel

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20. An engineering student is fabricating a setup and needs a key for connecting a shaft to the hub of a rotating machine element. The student uses a sunk key which is tapered and prevents relative axial motion.

Which ONE of the following keys did the student most likely use?

- (A) Saddle key
- (B) Woodruff key
- (C) Feather key
- (D) Gib-head key

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21. The ratio of hydrostatic stress to volumetric strain is known as _____.

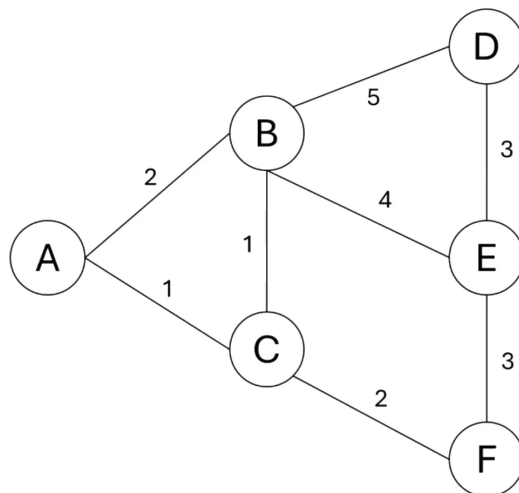
- (A) Bulk modulus
- (B) Compressibility
- (C) Poisson's ratio
- (D) Young's modulus

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22. In the given weighted graph, the weights represent distance between the corresponding vertices. The shortest distance between vertex A and vertex E is d .

The number of paths with distance d is p .

The value of d/p is _____.



- (A) 5
- (B) 3
- (C) 2
- (D) 8

...

23. Which ONE of the following is NOT an assumption of the economic order quantity (EOQ) model?

- (A) Demand is known and deterministic.
- (B) Lead time is zero.
- (C) Stockouts are permissible.
- (D) Holding cost for the quantity in stock is linearly increasing with the order quantity.

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24. Painting is one of the activities in a construction project. For the painting activity that takes 6 days, both the total float and the free float are zero.

Which ONE of the following is TRUE for the painting activity?

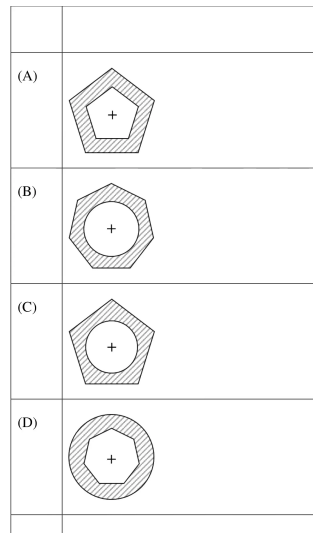
- (A) Painting is a dummy activity.
- (B) Painting is a non-critical activity.
- (C) The start of painting activity can be delayed without causing delay in completion of the construction project.
- (D) The start of painting activity cannot be delayed without causing delay in completion of the construction project.

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25. Which ONE or MORE among the following tube cross-sections shown can be produced by true centrifugal casting method?

Note: The cross-sections shown are perpendicular to the axis of rotation.

Figures are not to scale.



(A) (Outer pentagon, inner pentagon)

(B) (Outer octagon, inner circle)

(C) (Outer pentagon, inner circle)

(D) (Outer circle, inner circle)

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26.

Which ONE or MORE among the following options CORRECTLY match(es) the type of defects with the corresponding metal working processes in which they are likely to occur?

Defect Code	Defect	Process Code	Process
P	Centerburst	1	Deep drawing
Q	Earing	2	Rolling
R	Zipper cracks	3	Extrusion
S	Cold shut	4	Closed die forging
		5	Casting

- (A) P-3; Q-1; R-2; S-4
- (B) P-5; Q-2; R-3; S-4
- (C) P-1; Q-2; R-4; S-5
- (D) P-3; Q-1; R-2; S-5

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27.

Which ONE or MORE among the options given is/are well established format(s) of data transfer used in geometrical modelling related to computer aided design (CAD)?

- (A) IGES
- (B) STEP
- (C) NDC
- (D) STL

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28.

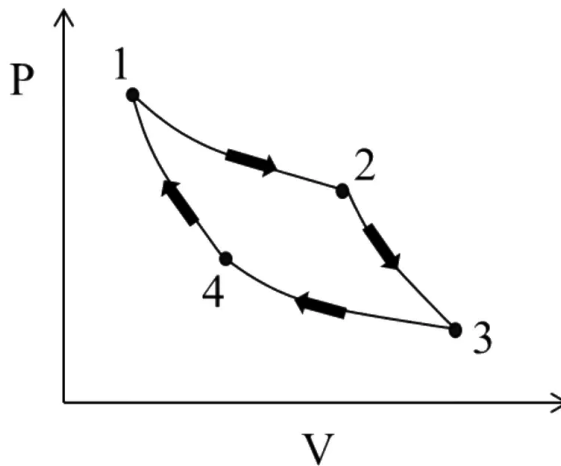
In statistical analysis of numerical data, which ONE or MORE among the options is/are possible value(s) of correlation coefficient?

- (A) 0
- (B) 10.3
- (C) -0.9
- (D) 2

...

29.

Which ONE or MORE among the following processes of the Carnot cycle is/are isentropic?



Note: Figure is not to scale

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

...

30.

A square of side length 50 mm is to be blanked from a strip of 2 mm thickness. The sheet metal has a shear strength of 200 MPa.

To enable a single step blanking operation, the theoretical minimum blanking force required is _____ $\times 10^3$ N (in integer).

Note: Neglect the effect of clearances and friction.

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31. A box in a machine shop consists of 5 coated and 10 uncoated cutting inserts which are of otherwise similar characteristics. The inserts got mixed up randomly in the box. An operator has taken 4 of them at once without noticing the differences to mount on a 4-tooth face milling cutter that uses inserts.

The probability of the milling cutter having all uncoated inserts is _____ (rounded off to two decimal places).

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32. A customer has made a lumpsum investment of INR 2,00,000 with a bank. The discount rate is 15% per year. The investment enables the customer to receive a payout of INR 1,00,000 yearly for next three consecutive years.

The net present value (NPV) of his/her investment is INR _____ (rounded off to the nearest integer).

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33. A modified Taylor tool life equation is given as follows:

$$VT^n f^m = \text{constant}$$

where V is the cutting speed (m/s), T is the tool life in minutes and f is the feed in mm/rev, $n = 0.25$ and $m = 0.5$. Under two different cutting conditions (V_1, f_1) and (V_2, f_2) the tool life (T_1, T_2) was found to be the same.

If the ratio of the cutting speeds (V_1/V_2) used is $2/3$, then the ratio of corresponding feeds (f_1/f_2) must be _____ (rounded off to two decimal places).

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34. Consider the line integral

$$\int_C (2x \, dx + 2y \, dy + 2z \, dz)$$

where C is a semi-circle in the $z = 0$ plane with start point at $(0, 0, 0)$ and end point at $(1, 0, 0)$.

The value of the line integral is _____ (in integer).

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35. Consider the aggregate planning problem for a toy car manufacturing organization whose demand at a plant is as follows:

Month	September	October	November	December
Demand (in units)	8000	6500	10500	9500

The organization has ONLY the following options available for aggregate planning to meet the demand: (1) in-house production, (2) subcontracting, and (3) inventory holding. Assume that the quantity subcontracted in a given month is available in the same month.

A part of their optimal solution is as follows:

Inventory at the end of October = 1500 units

Units produced in-house in November = 8000 units

Units subcontracted in November = 1000 units

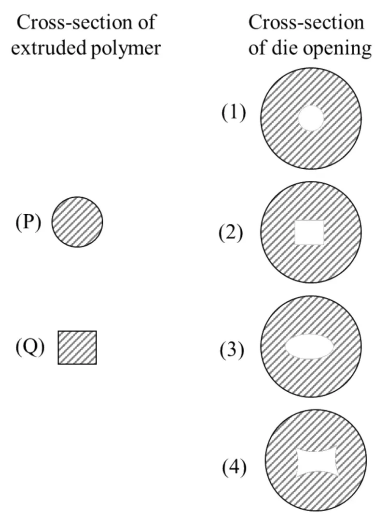
The inventory at the end of November is _____ units (in integer).

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36. In a polymer extrusion process, some cross-sectional shapes of the extruded polymers are shown. Cross-sections of available dies are also shown.

Which ONE of the following options CORRECTLY matches the extruded cross section with the die opening that most likely generated it?

Note: The cross-sections are in a plane orthogonal to the extrusion direction. Figures are not to scale.



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

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37. Iron powder produced by gas atomization has a tap density and an apparent density of 3.26 g/cm^3 and 2.66 g/cm^3 , respectively. The density of solid iron is 7.85 g/cm^3 .

Which ONE of the following options is the closest approximation to the degree of densification (in percentage) of this iron powder?

- (A) 41.52
- (B) 81.59
- (C) 33.89
- (D) 75.41

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38. Which ONE of the following options CORRECTLY matches the matrices to their properties?

Matrix	Property
$P = \begin{bmatrix} -30 & 17 & 5 \\ 17 & 0 & -12 \\ 5 & -12 & 4 \end{bmatrix}$	1: Singular
$Q = \begin{bmatrix} 0 & 1 & 9 \\ 7 & 0 & 2 \\ 12 & 3 & 0 \end{bmatrix}$	2: Triangular
$R = \begin{bmatrix} 2/3 & 1/3 & 2/3 \\ 0 & 2/3 & -1/3 \\ 0 & 4/3 & -2/3 \end{bmatrix}$	3: Symmetric
$S = \begin{bmatrix} 1 & 2 & 3 \\ 0 & 1 & 4 \\ 0 & 0 & 1 \end{bmatrix}$	4: Trace free

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

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39. A sheet metal drawing is considered feasible if the following conditions are met:

- Reduction ratio < 0.5
- Thickness to diameter ratio $> 1\%$

A sheet metal drawing process is being planned on a sheet metal with a thickness of 2 mm with a punch of diameter 100 mm with various blanks of diameter D_b .

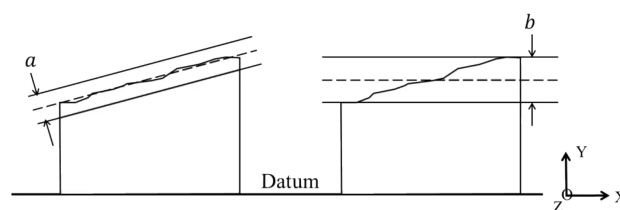
Which ONE of the following blank diameters D_b (in mm) will result in feasible drawing?

- (A) 150
- (B) 250
- (C) 350
- (D) 450

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40. A student is trying to determine the flatness and parallelism of the top surface of a part whose cross-section, assumed uniform in the Z direction, is shown in the figure.

Which ONE of the following options is CORRECT?



- (A) a is flatness while b is parallelism.
- (B) a is parallelism while b is flatness.
- (C) $a + b$ is parallelism while $b - a$ is flatness.
- (D) $a + b$ is flatness while $b - a$ is parallelism.

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41. The function, $r(t)$, signifies the likelihood that a component has survived up to time t and fails in the next instant of time.

$$r(t) = f(t)/(1 - F(t))$$

where $f(t)$ denotes the probability density function for time to failure with corresponding cumulative distribution function given by,

$$F(t) = 1 - e^{-at^b}, \quad a > 0, b > 0$$

Which ONE of the following represents $r(t)$?

- (A) $a \times b \times t^{b-1} \times e^{-at^b}$
- (B) $a \times b \times t^{b-1}$
- (C) $1 - (a \times b \times t^{b-1})$
- (D) $1 - (a \times b \times t^{b-1} \times e^{-at^b})$

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42. Which ONE of the following options CORRECTLY matches the machining process and associated predominant material removal mechanism?

Advanced machining process	Predominant material removal mechanism
P Laser beam machining	1 Impact based erosion
Q Abrasive waterjet machining	2 Sputtering
R Ion beam machining	3 Melting and vaporization
S Mechanical milling	4 Shearing

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

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43. A glass tube of 2.5 mm diameter is immersed vertically in a fluid. Assume contact angle is zero. The surface tension of the fluid is 0.1 N/m, density of the fluid is 1000 kg/m^3 and acceleration due to gravity is 10 m/s^2 .

The approximate capillary rise is _____ mm.

- (A) 2
- (B) 8
- (C) 16
- (D) 32

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44. In an M/M/1 queuing system, the customers arrive at a rate of 3 per minute, and the average number of customers in the system is n at steady state. Assume that the server utilization is less than 1.

Which ONE of the following is the average time a customer spends in the system (in minutes) at steady state?

- (A) $3n$
- (B) $n/3$
- (C) $n/6$
- (D) $3/n$

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45. A steel cube of side 10 cm is made by the sand-casting process. A cylindrical side-riser with diameter, d , and height, h , needs to be used.

Assume:

- No surface sharing between the riser and casting.
- $d = h$.
- The connecting link between the riser and casting does not freeze before the casting.
- All the surfaces of the riser and casting are subjected to identical cooling conditions.

In this situation, which ONE or MORE among the following values of d (in cm) can theoretically fully compensate for shrinkage during casting?

- (A) 5
- (B) 8
- (C) 15
- (D) 20

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46. In a rolling operation, a 200 mm wide strip of 23 mm thickness needs to be reduced to 20 mm in a single pass. The roll diameter is 200 mm. Four lubricants P, Q, R, and S with coefficient of friction 0.05, 0.1, 0.2, and 0.25, respectively, are available for use at the roll-strip interface. Assume that the strip width remains constant throughout the process.

Which ONE or MORE among the following lubricants will enable the rolling process to achieve the desired final thickness of the strip in a single pass?

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

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47. In the theory of orthogonal machining, assuming that the shear plane will take up an angle that minimizes energy, the shear angle can be shown to be

$$\phi = C - \frac{\beta}{2} + \frac{\alpha}{2}$$

where ϕ is the shear angle, α the rake angle, and β the friction angle.

Which ONE or MORE among the following is/are TRUE?

- (A) C is constant if the shear stress on the shear plane is independent of the normal stress.
- (B) C is constant if the shear stress on the shear plane is dependent on the normal stress.
- (C) C depends on material properties if the shear stress on the shear plane is independent of the normal stress.
- (D) C depends on material properties if the shear stress on the shear plane is linearly dependent on the normal stress.

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48. Which ONE or MORE among the following homogeneous representations in robotics involve(s) rotation about Y-axis by an angle θ ?

(A)

$$\begin{pmatrix} \cos \theta & -\sin \theta & 0 & 0 \\ \sin \theta & \cos \theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

(B)

$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos \theta & -\sin \theta & 0 \\ 0 & \sin \theta & \cos \theta & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

(C)

$$\begin{pmatrix} \cos \theta & 0 & \sin \theta & 0 \\ 0 & 1 & 0 & 0 \\ -\sin \theta & 0 & \cos \theta & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

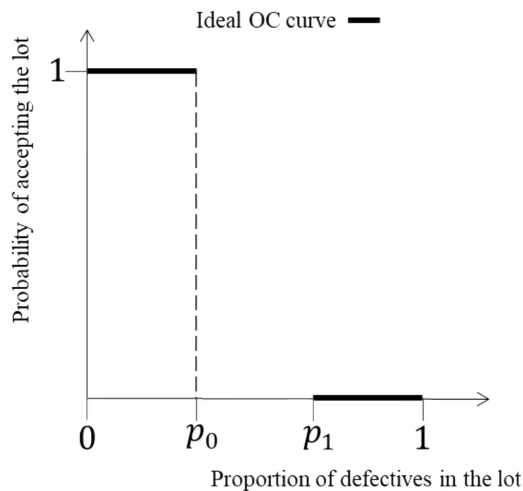
(D)

$$\begin{pmatrix} \cos \theta & 0 & \sin \theta & 3 \\ 0 & 1 & 0 & 4 \\ -\sin \theta & 0 & \cos \theta & 2 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

...

49. Which ONE or MORE among the following options is/are TRUE for the ideal operating characteristics (OC) curve given in the figure?

Note: p_0 represents the acceptable quality level (AQL) and p_1 represents the lot tolerance percent defective (LTPD).

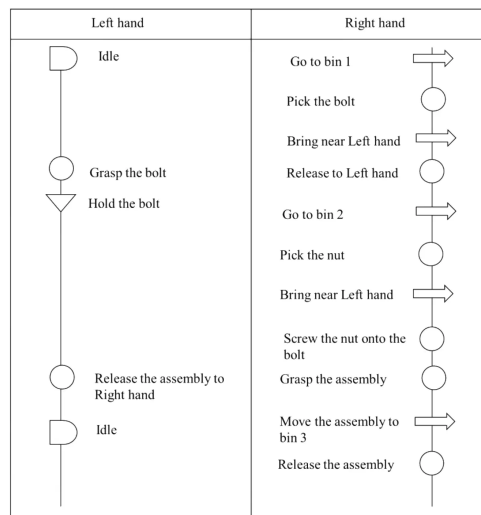


- (A) Producer's risk is 100%.
- (B) Consumer's risk is 100%.
- (C) Producer's risk is zero.
- (D) Consumer's risk is zero.

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50. The operation chart of a method of assembling nuts and bolts for a left-handed operator has been illustrated in the figure.

Which ONE or MORE among the following options is/are CORRECT?



- (A) The work distribution between the two hands is not balanced.
- (B) The two hands do not follow opposite motions.
- (C) The work is well distributed between the two hands.
- (D) The dominant hand of the operator performs majority of the tasks.

• • •

51. Which ONE or MORE among the following work materials is/are NOT commonly machined using diamond cutting tools?

- (A) Mild steel
- (B) Stainless steel
- (C) Silicon
- (D) Aluminium alloy

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52. A linear slot is to be milled in a single pass from the point (0, 0) to (180, 180) on XY plane by a CNC machine. The actual velocity along the Y-axis is 5% less than the intended value. The programmed feed rate along the intended slot is 150 mm/min.

The magnitude of the positional error along the Y-axis when the X-coordinate reaches 180 mm, is _____ mm (in integer).

Note: All coordinates are in mm.

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53. In laser beam machining, the time (t_m) required for the material to attain the melting temperature from a room temperature (θ_0) of 32°C is expressed by the following expression:

$$t_m = \frac{\pi}{\alpha} \left(\frac{(\theta_m - \theta_0)k}{2H} \right)^2$$

where α is thermal diffusivity, θ_m is melting temperature, k is thermal conductivity, H is heat flux.

If a uniformly distributed 1 kW power laser beam with a beam diameter of 0.1 mm is used for machining tungsten carbide, and 10% of beam absorption is assumed, the time t_m is _____ μs (rounded off to one decimal place).

Note: Thermal properties of tungsten carbide: melting temperature = 3400°C; thermal conductivity = 2.15 W/cm-°C; diffusivity = 0.79 cm² s⁻¹; assume $\pi = 3.14$.

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54. In the measurement of surface roughness using a 2D stylus profilometer, a surface profile measured over a length of 0.8 mm was recorded on a graph paper. During recording, vertical magnification of 10,000 and horizontal magnification of 100 were used. The areas in the as-recorded graph above and below the datum line are as follows:

Above (mm^2): 140, 60, 150, 50

Below (mm^2): 70, 50, 120, 160

The average surface roughness (R_a) of the surface is _____ μm (rounded off to two decimal places).

• • •

55. A cylindrical metal component of 10 mm diameter is subjected to uniform uniaxial tension during operation. It was observed that a force of 14 kN produces a uniform reduction of 3×10^{-3} mm in diameter. Assume that material behaviour is homogeneous, isotropic, and linear elastic.

If its Young's modulus is 150 GPa, the Poisson's ratio of the material is _____ (rounded off to two decimal places).

Note: Assume $\pi = 3.14$.

• • •

56.

A custom pinion, with a width equal to 10 times the module, has 20 full depth teeth and a pressure angle of 20 degrees is being designed. It should transmit a torque of 95 N-m to a corresponding spur gear.

Considering the safe bending stress to be 180 MPa and form factor to be 0.342, the module of the pinion is _____ mm (rounded off to one decimal place).

Note: The Lewis equation gives the tangential force as $F_t = \sigma b Y m$, where σ is the safe bending stress, b is the width, Y is the form factor, and m is the module.

• • •

57.

A company has a fixed cost of INR 3,00,000 and a variable cost of INR 150 per unit for manufacturing of a product. The company sells 5,000 units of that product making a profit equivalent to 20% of the total sales revenue.

The break-even quantity for that product is _____ units (rounded off to the nearest integer).

• • •

58.

A company must allocate oil produced from their two plants to meet all the demands of two markets. The cost per litre of allocation from plant $i \in \{1, 2\}$ to market $j \in \{1, 2\}$ is denoted by C_{ij} . The market demand D_j , plant production capacity K_i and C_{ij} values are given in the table.

	Market 1 (j = 1)	Market 2 (j = 2)	Capacity K_i (litres)
Plant 1 (i = 1)	$C_{11} = 250$	$C_{12} = 280$	$K_1 = 500$
Plant 2 (i = 2)	$C_{21} = 150$	$C_{22} = 180$	$K_2 = 600$
Demand D_j (litres)	$D_1 = 300$	$D_2 = 400$	

The company hired an intern to formulate an optimization model to decide on the quantity (X_{ij}) to be allocated from plant i to market j , and the formulation is given below:

$$\text{Minimize } Z = \sum_{i=1}^2 \sum_{j=1}^2 C_{ij} X_{ij}$$

Subject to:

$$\sum_{j=1}^2 X_{ij} \leq K_i \quad \forall i \in \{1, 2\}$$

$$\sum_{i=1}^2 X_{ij} \leq D_j \quad \forall j \in \{1, 2\}$$

$$X_{ij} \geq 0$$

The optimal value of the objective function of the linear programming problem formulated by the intern is _____ (in integer).

• • •

59.

The computer centre (CC) in an institute manages the central server for which researchers queue to run their computer programs. CC processes programs only one at a time. Four computer programs are available at 10:00 am on a given day. The time required to run each program on the central server and their respective promised time of completion (i.e., due date) on that same day are given in the table.

Program	1	2	3	4
Processing time (in minutes)	60	40	90	100
Promised time (i.e., due date)	12 noon	11:30 am	1:00 pm	1:30 pm

If the CC follows shortest processing time (SPT) rule to sequence the computer programs, then number of tardy jobs is _____.

Note: Ignore program change-over times.

• • •

60.

If $\frac{dy}{dt} = 2y$, and the value of y at $t = 0$ is 2, then the value of y at $t = 1$ is _____ (rounded off to two decimal places).

• • •

61. The number of soldering defects that occur in a semiconductor device follows a discrete Poisson distribution with a probability mass function

$$p(x) = \frac{e^{-\lambda} \lambda^x}{x!}$$

The average number of soldering defects per semiconductor device is 3. The probability that a randomly selected semiconductor device will have at least two soldering defects is _____ (rounded off to two decimal places).

• • •

62. A time study was carried out for a job broken into two elements. For each element, three iterations of task were observed, and observed time was recorded. The observed times (in seconds) and the rating factor for each element are given in the table.

Work element Observed time (seconds) Rating factor

A	20; 25; 21	105%
B	19; 17; 18	90%

If a further 20% needs to be added for allowances, then the standard output of the worker is _____ units per hour (in integer).

• • •

63. In a hole-shaft assembly, the following are the dimensions and tolerances (all in mm) provided for the hole and shaft:

Hole: $22^{+0.018}_{+0.010}$

Shaft: $22^{+0.075}_{+0.004}$

The magnitude of the clearance when the shaft is at the minimum material condition and hole is at the maximum material condition is _____ mm (to three decimal places).

• • •

64. Consider an assembly line producing an item through a process involving three activities in the following order: cutting, welding, and polishing. There are three workers available: one is assigned only for cutting, one is assigned only for welding, and one is assigned only for polishing.

The activity time per item is given in the table.

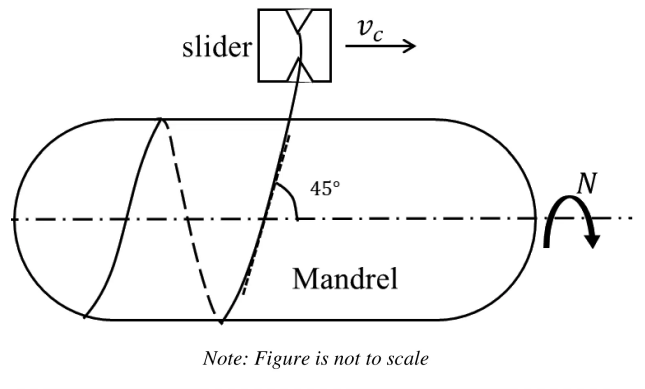
Activity name	Cutting	Welding	Polishing
Activity time/item (in minutes)	30	40	25

Assuming that the process is running in steady state, the total number of items coming out of the assembly line in six hours is _____ (in integer).

Note: Assume that workers, items, and machines/tools are available as and when needed.

• • •

65. In the composite filament winding process as shown in the figure, the mandrel diameter is 700 mm and is rotating at a speed, $N = 6$ rev/min. If a 45° helical winding angle is needed, the axial velocity, v_c , of the slider should be _____ m/s (rounded off to two decimal places). Assume $\pi = 22/7$. Ignore the thickness of the composite layers already wound on the mandrel.



Note: Figure is not to scale.