GATE 2026 Production and Industrial Engineering Question Paper with Solutions

ZOLLEGE

General Instructions

(i) This booklet contains 65 questions, each provided with a complete, step-by-step solution.

(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 each question on your own before reviewing the given solution.

(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

Correct Answer: (A) object

SOLUTION:

Step 1: Break the sentence into parts.

The sentence is 'The shopkeeper sells lemons.'

It has three main parts: a subject, a verb, and an object.

Step 2: Use the question test to find each part.

Ask "who sells?" The answer is "the shopkeeper", so that is the subject.

Ask "sells what?" The answer is "lemons", so that word answers the "what" question after the verb.

Step 3: Match this to the grammar rule.

A word that answers "what" or "whom" after the verb is called the object of the verb.

Since 'lemons' answers "sells what?", it takes the object position in the sentence.

Step 4: Rule out the other labels.

'Lemons' is not doing the selling, so it is not the subject.

It is not an action word like 'sells', so it is not the verb, and it is only one word, not the full phrase 'sells lemons', so it is not the predicate.

Final Answer:

The word 'lemons' completes the action started by the verb, so it is the object.

$$\boxed{\text{object}}$$

Quick Tip: Find the verb first, then ask "sells what?" The word that answers this is the object.

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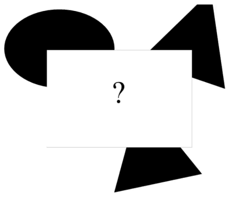
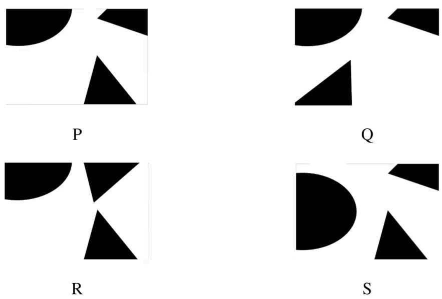
2. The figure below is supposed to show three non-overlapping shapes, one oval and two triangles. Which one of the following figures P, Q, R, or S fits the missing portion indicated by '?' and completes the oval and the two triangles?





(A) P

(B) Q

(C) R

(D) S

Correct Answer: (A) P

SOLUTION:

Step 1: Split the puzzle into three separate shapes.
Instead of looking at the whole picture together, look at the oval, the first triangle, and the second triangle one at a time.
Each candidate piece must complete all three shapes together, so checking them one by one narrows down the choice fast.

Step 2: Trace the oval alone.
Cover everything except the oval's visible edge and the curved patch in each option.
Only a patch with a small, gentle curve of the right size keeps the oval looking like a smooth, closed oval, not a circle or a flat shape, and this already rules out S, since its curved patch is far too large.

Step 3: Trace the first triangle alone.
Look only at the cut corner of the triangle at the top of the main figure.
The missing piece needs a small triangular corner tilted at the same angle to close this triangle without a kink, and Q's triangle corner tilts the wrong way, so Q is ruled out at this step.

Step 4: Trace the second triangle alone.
Now look only at the triangle shown just below the box in the main figure.
The missing piece needs a lower triangle with a matching slant to close this second triangle, and R's lower triangle has a different slant, so R is ruled out here.

Step 5: Confirm the surviving option.
After removing S, Q, and R for failing one shape each, only P is left.
P's curve, its top triangle corner, and its lower triangle all match the three shapes in the main figure at the same time.

Final Answer:
Checking the oval and both triangles one at a time leaves only P as the piece that fits.

$\boxed{P}$

Quick Tip: Check the oval's curve and both triangles' corners separately, the right piece must complete all three shapes without any overlap.

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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

Correct Answer: (A) 0

SOLUTION:

Step 1: Look at each curve as a parabola.
The curve $y = x^2$ opens upward with its lowest point at the origin $(0, 0)$.
The curve $y = -x^2 - 2x - 1$ opens downward, since the coefficient of x^2 is negative.

Step 2: Find the vertex of the second parabola.
Rewrite $y = -x^2 - 2x - 1$ by factoring out the negative sign:

$$y = -(x^2 + 2x + 1) = -(x + 1)^2$$

This is a perfect square, so the vertex sits at $x = -1, y = 0$, and this is the highest point the curve ever reaches.

Step 3: Compare the highest and lowest values.
For the downward parabola $y = -(x+1)^2$, the value of y is always less than or equal to 0, since a square is never negative.
For the upward parabola $y = x^2$, the value of y is always greater than or equal to 0, so the two curves can only share a point where both equal 0 at the same time.

Step 4: Check where each curve equals zero.
$y = x^2 = 0$ only at $x = 0$.
$y = -(x+1)^2 = 0$ only at $x = -1$.
These two zero points happen at different x values, so the curves never touch $y = 0$ together.

Final Answer:
Since the curves cannot meet even at their shared boundary value $y = 0$, they never cross in the real plane.

$$\boxed{0}$$

Quick Tip: Set both equations equal, form a quadratic in x, and check its discriminant.

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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.

Correct Answer: (C) The current captain is older than Anish.

SOLUTION:

Step 1: Break the passage into a condition and a result.
The passage gives an "if...then" statement: if Anish scores a hundred runs, then he becomes captain, and he becomes the youngest captain in the team's history.
The passage then tells us the condition did not happen, since Anish got out for zero runs.

Step 2: Apply the rule for a false condition.
When the condition of an "if...then" statement is false, the result described does not happen either.
So Anish does not become captain, and he does not become the youngest captain in history, because neither event was triggered.

Step 3: Work out what "would have been the youngest" really means.
Saying Anish "would have become the youngest captain in his team's

history" tells us that, had he taken over, his age would have been lower than every captain the team has ever had, including whoever is captain right now.
This is a fact about ages, and it does not depend on whether the hundred runs actually happened.

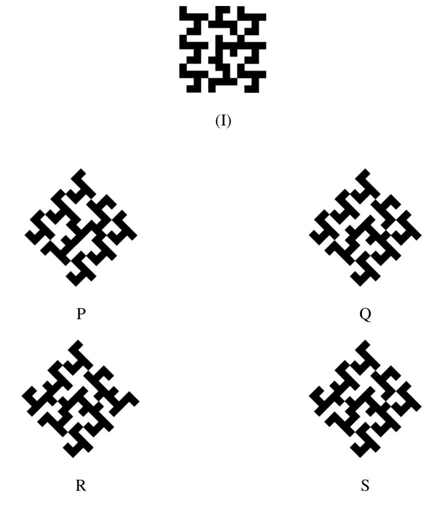
Step 4: Use this to test each option quickly.
Option (A) needs the condition to be true, but we are told it is false, so (A) fails.
Option (B) needs Anish to already be captain, but the passage treats becoming captain as a new, unfulfilled event, so (B) fails, and option (D) talks about the youngest player, but the passage only compares Anish to captains, so (D) is not guaranteed.
Option (C) follows directly from the age comparison in Step 3, since the real captain must be older than the hypothetical "youngest ever" Anish would have been.

Final Answer:
The age comparison built into the passage shows the current captain is older than Anish.

$$\boxed{\text{The current captain is older than Anish.}}$$

Quick Tip: Focus on what "youngest captain in history" tells you about the current captain's age compared to Anish.

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

Correct Answer: (B) Q

SOLUTION:

Step 1: Turn the problem into tracking a single corner.
A full rotation moves every part of a shape by the same angle, so it is enough to track just one sharp corner or arm tip of figure (I) and see where it should end up.
This is faster than trying to compare the whole complicated pattern piece by piece.

Step 2: Recall how a clockwise turn moves a point.
On a clock face, the hands move clockwise, so a point near the "12 o'clock" position of a shape moves toward "1:30" after a 45° clockwise turn, since 45° is one eighth of a full circle.

We use this clock idea to guess the new position of our chosen corner.

Step 3: Apply this to figure (I).

Pick the arm tip nearest the top of the square in figure (I) and treat it like the "12 o'clock" mark.

After a 45° clockwise turn, this tip should move to sit near the upper right corner of the new diamond shape, one eighth of a turn away from where it started.

Step 4: Test each option against this prediction.

In S, the tip moves to the upper left instead of the upper right, which matches a counter-clockwise turn, not clockwise, so S is wrong.

In R, the tip goes almost to the right side of the diamond, which is closer to a 90° turn, too far for 45°, so R is wrong.

In P, the tip lands close to the right spot, but the arm's bend faces the opposite way, showing the figure was flipped, not purely rotated, so P is wrong.

In Q, the tip lands at the predicted upper right spot and the bend direction of the arm still matches figure (I), so Q passes both checks.

Final Answer:

Tracking one corner through a clockwise 45° turn shows Q is the only option that lands and bends correctly.

$$\boxed{Q}$$

Quick Tip: Track one distinct hook or corner of figure (I) and see where a 45-degree clockwise turn should place it, then match handedness too.

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)

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

SOLUTION:

Step 1: Pick the easiest word first:
Lethal clearly means deadly or fatal, so we can be sure (iv) matches with (r) Deadly.
This single sure pair lets us throw out any option that does not send (iv) to (r).

Step 2: Eliminate using this pair.
Option (B) sends (iv) to (p) and option (D) sends (iv) to (q), so we drop both right away.
Only options (A) and (C) keep (iv)-(r), so the answer must be one of these two.

Step 3: Break the tie between (A) and (C).
Option (A) has (i)-(q), meaning Lonely is matched to Solitary.

Option (C) has (i)-(s), meaning Lonely is matched to Terrible.
Lonely means being alone, which is the sense of Solitary, not Terrible, so option (A) fits better here.

Step 4: Confirm with the remaining two words.
In option (A), Literal goes to Verbatim (p), which fits since both mean word for word, and Lousy goes to Terrible (s), which fits since both mean very bad.
Every pair in option (A) checks out, while option (C) fails on Lonely.

Final Answer:
The full match is Lonely-Solitary, Literal-Verbatim, Lousy-Terrible, Lethal-Deadly, which is option (A).

$$\boxed{\text{(A) (i)-(q); (ii)-(p); (iii)-(s); (iv)-(r)}}$$

Quick Tip: Match each word to its closest meaning: Lonely = alone, Literal = exact wording, Lousy = bad, Lethal = deadly.
Find the option where all four pairs agree with these meanings.

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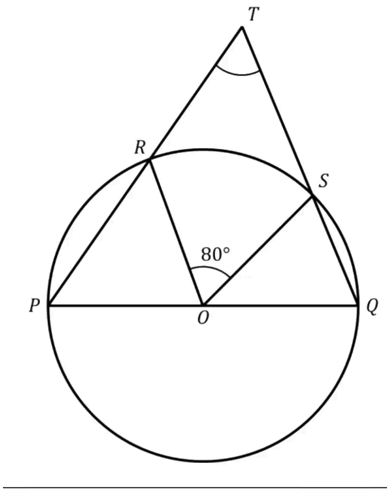
7. In the given figure, $\overline{PQ}$ is the diameter of a circle with center O. Two points R and S are chosen on the circle such that $\angle ROS = 80°$. When $\overline{PR}$ and $\overline{QS}$ are extended, they meet at T.



The value of $\angle RTS$ is _______

(A) 40°

(B) 50°

(C) 60°

(D) 80°

Correct Answer: (B) 50°

SOLUTION:

Step 1: Set up the secant angle rule:

When two secants are drawn from an outside point, the angle between them equals half the difference between the far arc and the near arc they cut off.

Here the near arc is arc RS and the far arc is arc PQ on the side away from R and S.

Step 2: Find the near arc.

The near arc RS is given directly by the central angle, so arc RS $= 80°$.

Step 3: Find the far arc.

Since PQ is a diameter, it splits the circle into two arcs of $180°$ each, so the far arc PQ on the side away from R and S is one full semicircle, $180°$.

Step 4: Apply the formula.

$$\angle RTS = \frac{\text{far arc} - \text{near arc}}{2} = \frac{180° - 80°}{2} = 50°$$

Step 5: Check option (A) 40 degrees.

40 degrees would come from taking half the near arc alone, $80°/2$, without subtracting from the far arc, so it is wrong.

Step 6: Check option (B) 50 degrees.

This is exactly what the secant formula gives in Step 4, so it is the right option.

Step 7: Check option (C) 60 degrees.

60 degrees does not fit the formula for any reasonable pairing of the arcs here, so it is wrong.

Step 8: Check option (D) 80 degrees.

80 degrees is just the near arc value copied over without applying the formula, so it is wrong.

Final Answer:

Using the exterior angle formula for two secants also gives 50 degrees.

$$\boxed{\angle RTS = 50^\circ}$$

Quick Tip: Use the rule that an inscribed angle is half the central angle to find angle RQS first.
Then use the right angle in the semicircle and the angle sum of triangle TRQ.

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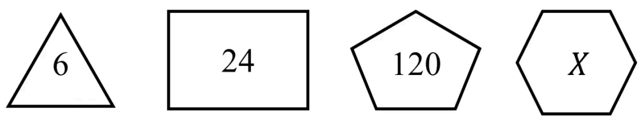
8. Based on the relationship between each polygon and the number inside it, the value of 'X' is ________



(A) 720

(B) 596

(C) 24

(D) 240

Correct Answer: (A) 720

SOLUTION:

Step 1: Look at how each number grows from the one before it:
Instead of jumping straight to a formula, we check what number we multiply by to go from one shape's number to the next shape's number.

Step 2: Find the first multiplier.

Going from the triangle's 6 to the rectangle's 24 gives $24/6 = 4$. Notice 4 is the number of sides of the rectangle itself.

Step 3: Find the second multiplier.
Going from the rectangle's 24 to the pentagon's 120 gives $120/24 = 5$. Again 5 is the number of sides of the pentagon itself.

Step 4: Spot the pattern and use it.
Each new number is the old number multiplied by the side count of the new shape. The hexagon has 6 sides, so we multiply the pentagon's 120 by 6.

$$X = 120 \times 6 = 720$$

Step 5: Check option (A) 720.
This matches the value from Step 4, so this option is correct.

Step 6: Check option (B) 596.
596 is not 6 times 120 and breaks the multiplier pattern found in Steps 2 and 3, so this option is wrong.

Step 7: Check option (C) 24.
24 belongs to the earlier rectangle shape and does not come from multiplying 120 by 6, so this option is wrong.

Step 8: Check option (D) 240.
240 is only 120 multiplied by 2, not by 6, so it does not follow the pattern and is wrong.

Final Answer:
Multiplying step by step through the side counts also gives 720.

$$\boxed{X = 720}$$

Quick Tip: Count the sides of each shape and compare with the number inside it.
Check if the number equals the factorial of the side count.

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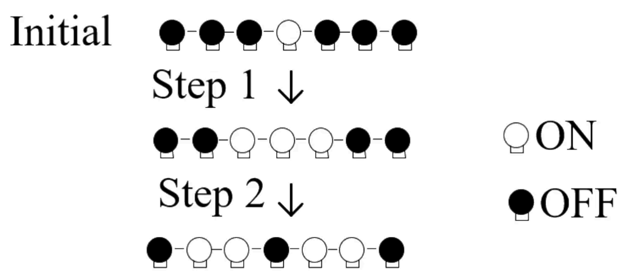
9. Consider a linear arrangement of seven bulbs, each of which can be in the ON or OFF state. The initial configuration of the bulbs is shown in the figure. In every Step, the states of the bulbs are changed based on the following rules:
Any OFF bulb with exactly one ON neighbor at the end of the previous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

Correct Answer: (B) 4

SOLUTION:

Step 1: Track the pattern using a table instead of writing each row in words:

We list bulbs 1 to 7 across the top and fill in a 1 for ON and a 0 for OFF at each step.

Step	B1	B2	B3	B4	B5	B6	B7
0	0	0	0	1	0	0	0
1	0	0	1	1	1	0	0
2	0	1	1	0	1	1	0
3	1	1	1	0	1	1	1
4	1	0	1	0	1	0	1
5	1	0	1	0	1	0	1

Step 2: Notice the table stops changing after Step 4.

Row 5 is identical to row 4, so applying the rules again cannot change anything from here on, meaning every step from Step 4 onward, including Step 8, is 1 0 1 0 1 0 1.

Step 3: Count the ON bulbs in the fixed row.

Bulbs 1, 3, 5, and 7 hold a 1, which are four bulbs, and bulbs 2, 4, and

6 hold a 0, which are three bulbs, and $4 + 3 = 7$ checks out against the total of seven bulbs.

Step 4: Check option (A) 5.
The table shows only four 1's in the fixed row, not five, so this option is wrong.

Step 5: Check option (B) 4.
The table gives exactly four 1's in the fixed row, so this option is correct.

Step 6: Check option (C) 3.
Three is the count of OFF bulbs in the fixed row, not the count of ON bulbs, so this option is wrong.

Step 7: Check option (D) 0.
The table never reaches an all OFF row, since the fixed row keeps four bulbs ON forever, so this option is wrong.

Final Answer:
Reading straight off the table, Step 8 has four bulbs ON.

$$\boxed{4}$$

Quick Tip: Write out the bulb states as a row of 0s and 1s and apply the two rules step by step.
Watch for the row where applying the rules again gives back the same row.

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

Correct Answer: (D) 42

SOLUTION:

Step 1: Try small values of Q directly:

Instead of factoring, we can test small positive integers for Q and see when $Q^2 + 13$ becomes a perfect square.

Step 2: Test values one by one.

For $Q = 1$: $1 + 13 = 14$, not a perfect square. For $Q = 2$: $4 + 13 = 17$, not a perfect square. For $Q = 3$: $9 + 13 = 22$, not a perfect square. For $Q = 4$: $16 + 13 = 29$, not a perfect square. For $Q = 5$: $25 + 13 = 38$, not a perfect square. For $Q = 6$: $36 + 13 = 49$, and $49 = 7^2$, which is a perfect square.

Step 3: Confirm this is the only small solution.

As Q grows larger, consecutive squares get further apart, so once Q passes 6 the gap between Q^2 and the next square becomes bigger than 13, and no new solution can appear, so $Q = 6$ and $P = 7$ is the only pair that fits.

Step 4: Compute the product.

$$P \times Q = 7 \times 6 = 42$$

Step 5: Check option (A) 13.
13 is just the fixed number given in the problem, not a product of the two integers we found, so this option is wrong.

Step 6: Check option (B) 26.
26 does not equal 7×6, so this option is wrong.

Step 7: Check option (C) 39.
39 also does not equal 7×6, so this option is wrong.

Step 8: Check option (D) 42.
This equals 7×6 from Step 4, so this option is correct.

Final Answer:
Testing small values directly also confirms the product is 42.

$$\boxed{P \times Q = 42}$$

Quick Tip: Rewrite the equation as a difference of squares, (P-Q)(P+Q) = 13.
Since 13 is prime, find the two factors and solve for P and Q.

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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

Correct Answer: (D) Development of a cost model of the product

SOLUTION:

Step 1: Recall the Pugh method for choosing concepts.
A common tool for concept selection is the Pugh matrix, where each concept is compared against a datum concept using a set of customer needs.
This tool needs only relative judgments (better, worse, same), not detailed cost numbers.

Step 2: Walk through the Pugh matrix stages.
Stage 1: Set up matrix with criteria and a reference concept
Stage 2: Score each concept against the reference
Stage 3: Rank the concepts by total score
Stage 4: Combine strong features into an improved concept
These four stages cover options (A), (B) and (C) directly.

Step 3: Test option (D) against this framework.
A cost model needs known geometry, materials and processes, none of which are locked in during concept selection since a concept is still just a sketch or idea at this point.
Cost modeling belongs to embodiment or detailed design work, once one concept has already won the selection round.

Step 4: Eliminate the other three options.

Since (A), (B) and (C) each map onto a real stage of the Pugh matrix, they get ruled out as the answer.
Only (D) sits outside the concept selection stage.

Final Answer:
The step that does not belong to concept selection is building a cost model.

$$\boxed{\text{Option (D)}}$$

Quick Tip: Concept selection uses a matrix to rate, rank and combine ideas. A detailed cost model needs a finalized design, so it comes later.

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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.

Correct Answer: (B) Wettability of the base metal by the filler material must be low.

SOLUTION:

Step 1: Set up the capillary flow condition.

Filler metal rises into the gap between two plates mainly through capillary action, and the height it can reach follows a simple physical rule.

$h = \frac{2\gamma \cos\theta}{\rho g r}$

Here γ is the surface tension of the molten filler, θ is the contact angle (wetting angle), ρ is density, and r is the gap width.

Step 2: Link this formula to wettability.

Good wetting means a small contact angle θ, which makes $\cos\theta$ large and pushes the capillary rise h higher.

So low wettability (large θ, small $\cos\theta$) would give poor or no capillary flow into the joint, which defeats the whole point of brazing.

Step 3: Match each option against known brazing needs.

Melting point of filler < melting point of base metal (needed, matches A)

Wettability should be HIGH, not low (contradicts B)

Low viscosity helps flow into thin gaps (matches C)

Low reactivity avoids brittle joints (matches D)

Step 4: Pick the false statement.

Since brazing needs high wettability for capillary flow to work, the statement claiming it must be low goes against the actual requirement.

That makes option (B) the false one, while (A), (C) and (D) all describe genuine filler metal needs.

Final Answer:

Wettability must be high, not low, so option (B) is the false statement.

$\boxed{\text{Option (B)}}$

Quick Tip: Brazing depends on capillary action, which needs HIGH wettability and low viscosity to pull filler into the joint gap.

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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

Correct Answer: (B) 20

SOLUTION:

Step 1: Write one combined formula for speed.
We can skip the middle step and connect welding speed directly to power, loss, area and specific energy in a single equation.
$P_{in} \times \eta = v \times A \times U$
This says the useful power equals the rate of energy used to melt metal moving at speed v over area A.

Step 2: Plug in the known numbers.
$P_{in} = 6000\ W, \eta = 0.5, A = 10\ mm^2, U = 15\ J/mm^3$
$6000 \times 0.5 = v \times 10 \times 15$

Step 3: Solve for the speed.

$3000 = 150v$

$v = \frac{3000}{150} = 20$

So the welding speed comes out to 20 mm/s using this single-equation route, matching the earlier stepwise method.

Step 4: Sanity check with rough numbers.

Half of 6 kW is 3 kW, and melting 1 mm^3 needs 15 J, so about 200 mm^3 gets melted every second.

Spread over a 10 mm^2 cross-section, that gives a speed close to 20 mm/s, confirming the answer holds up under a quick rough check too.

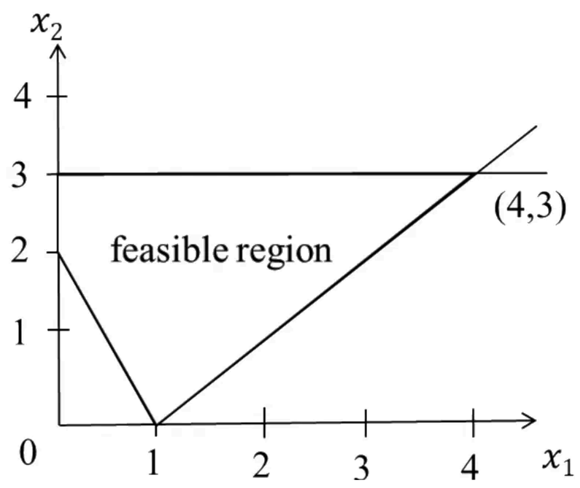
Final Answer:

Solving the combined power balance equation gives a welding speed of 20 mm/s.

$$\boxed{v = 20\ mm/s}$$

Quick Tip: Net power = input power x efficiency. Melt rate = net power / specific energy. Speed = melt rate / weld area.

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) $x_1 \geq 0; x_2 \geq 0; x_2 \leq 3; x_1 + x_2 \leq 1; x_1 + 0.5x_2 \geq 1$

Correct Answer: (B) $x_1 \geq 0; x_2 \geq 0; x_2 \leq 3; x_1 - x_2 \leq 1; x_1 + 0.5x_2 \geq 1$

SOLUTION:

Step 1: Pick a point clearly inside the shaded triangle.
Looking at the figure, a point like $(1, 1)$ sits well inside the shaded region, away from all three edges.
We can plug this point into each option and throw out any option that this point fails to satisfy.

Step 2: Test the top-boundary type of constraint.
$x_2 = 1$ at our test point, and the flat top of the triangle is at height 3, so a correct top constraint must allow $x_2 = 1$, meaning it should read $x_2 \leq 3$, not $x_2 \geq 3$.

This already removes option (A), since it uses $x_2 \geq 3$, which our test point fails.

Step 3: Test the diagonal constraints with the same point.

For option (D), check $x_1 + x_2 \leq 1$: at $(1, 1)$ this gives $1 + 1 = 2$, which is not ≤ 1, so option (D) fails this test too.

For options (B) and (C), check $x_1 - x_2 \leq 1$: at $(1, 1)$ this gives $1 - 1 = 0$ ≤ 1, which passes for both.

Step 4: Use the top-edge height to separate (B) and (C).

The only difference left between (B) and (C) is $x_2 \leq 3$ versus $x_2 \leq 4$. Since the figure clearly marks the flat top of the shaded region at height 3, right where the point $(4, 3)$ sits, the correct bound must be x_2 ≤ 3, not $x_2 \leq 4$.

Step 5: Confirm the remaining option.

This leaves option (B) as the only one consistent with both the test point and the marked height of the top edge in the figure.

$x_1 \geq 0, x_2 \geq 0, x_2 \leq 3, x_1 - x_2 \leq 1, x_1 + 0.5x_2 \geq 1$

Final Answer:

Testing a point inside the region and matching the marked top edge both confirm option (B).

$$\boxed{\text{Option (B)}}$$

Quick Tip: Find the line through each pair of boundary points, then check which side of each line the shaded triangle lies on.

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) $\frac{1+e}{2}$

Correct Answer: (C) $\frac{e+1}{2e}$

SOLUTION:

Step 1: Get a rough decimal value of the integral first.

The true value of $\int_0^1 e^{-x^2} dx$ is close to 0.7468, a well known constant tied to the error function.

We can use this rough number to test which option lands closest, without needing the exact trapezoidal formula first.

Step 2: Convert each option into a decimal.

Option A: $1 = 1.000$

Option B: $\frac{1}{e} \approx 0.368$

Option C: $\frac{e+1}{2e} \approx \frac{3.718}{5.437} \approx 0.684$

Option D: $\frac{1+e}{2} \approx \frac{3.718}{2} \approx 1.859$

Step 3: Compare each decimal to the true value 0.7468.

Option A is too high, option B is too low, option D is far too high, but option C at about 0.684 sits closest to the true value among all four choices.

Step 4: Confirm this using the trapezoidal shortcut.
For a curve that dips down like e^{-x^2}, the trapezoidal estimate using just the two end points, $f(0) = 1$ and $f(1) = 1/e$, gives exactly $\frac{1+1/e}{2}$ $= \frac{e+1}{2e}$.
This matches option C again, so both the decimal comparison and the formula route agree on the same choice.

Step 5: Note why this is only an approximation.
The trapezoidal rule with just one segment slightly overestimates the true area here, since it connects the two end points with a straight line while the real curve bends below that line.
Even so, among the four given options, it is still the closest match to the actual integral value.

Final Answer:
Comparing decimal values and using the trapezoidal rule both point to option C as the closest approximation.

$$\boxed{\frac{e+1}{2e}}$$

Quick Tip: e^-x^2 has no simple antiderivative. Use the trapezoidal rule with f(0)=1 and f(1)=1/e over the single interval [0,1].

• • •

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 $-i$

Correct Answer: (A) $+1$ or -1

SOLUTION:

Step 1: What the problem is asking:

We want $\frac{1}{i^n}$ for even positive n, using $i = \sqrt{-1}$.

A quick way to see the pattern is to just plug in small even values of n and watch what happens.

Step 2: Try small even values of n:

For n = 2: $i^2 = -1$, so $\frac{1}{i^2} = \frac{1}{-1} = -1$.

For n = 4: $i^4 = 1$, so $\frac{1}{i^4} = 1$.

For n = 6: $i^6 = (i^4)(i^2) = 1 \times (-1) = -1$, so $\frac{1}{i^6} = -1$.

For n = 8: $i^8 = (i^4)^2 = 1$, so $\frac{1}{i^8} = 1$.

$$n = 2, 6, 10, \ldots \Rightarrow \frac{1}{i^n} = -1, \qquad n = 4, 8, 12, \ldots \Rightarrow \frac{1}{i^n} = 1$$

Step 3: Spot the pattern:

The values alternate strictly between +1 and -1 as n runs through the even numbers, they never come out as +i, -i, or anything else.

So no single fixed value works for every even n, the answer has to allow both +1 and -1.

This rules out option (B) (that is for odd n), option (C) (fails at n = 2), and option (D) (never happens for even n).

Final Answer:

Testing even values confirms the result swings between +1 and -1, matching option (A).

$$\boxed{+1 \text{ or } -1}$$

Quick Tip: Powers of i repeat every 4 steps: i, -1, -i, 1. For even n, i^n is always +1 or -1.

• • •

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

Correct Answer: (A) P-2; Q-1; R-4; S-3

SOLUTION:

Step 1: What we are checking:
We have to link P, Q, R, S (instruments) to 1, 2, 3, 4 (their applications), and four answer choices give different pairings.
Instead of matching all four from scratch, we can knock out wrong options one distinguishing fact at a time.

Step 2: Use one strong fact to eliminate options:
A sine bar is an angle-measuring tool, it works with slip gauges to set up precise angles, it has nothing to do with cuboid length or roughness.
So P must go with 2 (planar surface inclination), this alone kills options (B) and (C), since both give P a value other than 2.
We are left with options (A) and (D), both of which already agree on P-2 and Q-1.

Step 3: Break the tie between the remaining options:
Options (A) and (D) only differ on R and S.
Option (A) says R-4, S-3, meaning vernier calliper measures cuboid length and ring GO gauge checks shaft tolerance.
Option (D) says R-3, S-4, meaning vernier calliper checks shaft tolerance and ring GO gauge measures cuboid length.
A ring gauge is a fixed go/no-go tool, it can only tell pass or fail on a

shaft diameter, it cannot give a length reading for a cuboid, so S must be 3, not 4.
That makes option (D) wrong and confirms option (A).

Final Answer:
Eliminating with the sine bar fact and the ring gauge fact leaves only one consistent pairing.

$$\boxed{P\text{-}2;\ Q\text{-}1;\ R\text{-}4;\ S\text{-}3}$$

Quick Tip: Match each tool to its single most common shop-floor job: angle, roughness, length, or go/no-go check.

• • •

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

Correct Answer: (D) Austempering

SOLUTION:

Step 1: Set up a quick comparison in your head:
Four heat treatments are on offer, and each one has one signature product: normalizing gives fine pearlite, annealing gives coarse

pearlite, martempering gives martensite, austempering gives bainite. Since the question asks for ONLY bainite, we just need to match the product to the process.

Step 2: Think about the cooling path on a TTT diagram:

To get bainite, the cooling curve has to dodge the "nose" of the C-curve fast enough to avoid pearlite, then flatten out (isothermal hold) somewhere in the middle temperature band where bainite forms.

Normalizing and annealing both cool continuously without a hold, so they land in the pearlite region, not bainite.

Martempering also uses an isothermal hold, but that hold sits close to M_s (martensite start), so the steel forms martensite once air cooling resumes, not bainite.

Step 3: Locate austempering on the diagram:

Austempering's hold sits lower than the pearlite nose but above M_s, right inside the bainite bay of the TTT diagram, and the hold continues until the transformation is complete.

Because the steel never drops below M_s while austenite still remains, no martensite forms at all, the whole structure converts to bainite.

$$M_s < T_{hold} < T_{nose}, \quad \text{held until transformation is 100 percent complete}$$

Final Answer:

The isothermal hold placed inside the bainite bay is what makes austempering the right choice.

$$\boxed{\text{Austempering}}$$

Quick Tip: Compare the four heat treatments by where the isothermal hold sits on the TTT diagram.

• • •

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

Correct Answer: (C) Hypo-eutectoid steel

SOLUTION:

Step 1: Think in terms of carbon content instead of phase names:
Every steel type on the Fe-C diagram is really just defined by how much carbon it has compared to the eutectoid point at about 0.76 percent carbon.
So instead of memorizing definitions, we can work out which side of 0.76 percent this alloy must sit on.

Step 2: Use the phase that forms first as a clue:
If the steel had exactly 0.76 percent carbon, cooling through the eutectoid line would give a single-step change straight from austenite to 100 percent pearlite, with nothing forming early.
Since this alloy forms a solid phase (ferrite) before it even reaches the

eutectoid line, its carbon content has to be below 0.76 percent, because ferrite is the low-carbon phase (about 0.02 percent carbon or less) and the material rejects carbon into the remaining austenite as ferrite grows.
If the alloy had carbon above 0.76 percent, the excess carbon would instead push out pro-eutectoid cementite (a high-carbon phase), not ferrite.

$$\%C_{alloy} < 0.76\%, \quad \text{ferrite (low-C phase) precipitates first}$$

Step 3: Confirm the classification:
Carbon content below the eutectoid value, with ferrite forming first and pearlite forming at the eutectoid line, is the standard definition of hypo-eutectoid steel.
This also rules out hyper-eutectoid (needs cementite first), eutectoid (needs no pro-eutectoid phase), and hyper-eutectic (that term belongs to cast iron, above 4.3 percent carbon, not steel at all).

Final Answer:
Working backward from which phase forms first confirms low carbon content and a hypo-eutectoid classification.

$$\boxed{\text{Hypo-eutectoid steel}}$$

Quick Tip: Pro-eutectoid ferrite forms only when carbon content is below the eutectoid point.

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

Correct Answer: (D) Gib-head key

SOLUTION:

Step 1: Sort the four keys into two groups first:
Group by whether the key is sunk (cut into both shaft and hub) or not, and whether it is tapered or parallel in cross-section.
Saddle key: not sunk, sits on the shaft surface, held by friction only.
Woodruff key: sunk, half-disc shape, mainly used for self-alignment on tapered or small shafts.
Feather key: sunk, parallel (uniform) cross-section, made to allow sliding.
Gib-head key: sunk, tapered cross-section, made to be driven in tight.

Step 2: Apply the "sunk" filter:
The question says the key is a sunk key, so the saddle key is out right away since it is not a sunk key at all.
That leaves woodruff, feather, and gib-head keys still in the running.

Step 3: Apply the "tapered and locks axial motion" filter:
The feather key is deliberately parallel, its whole job is to let the hub move axially while still turning with the shaft, so it cannot be the

answer to a question that wants axial motion prevented.
The woodruff key is also not the tapered wedge type described here, it is chosen mainly for alignment on small or tapered shaft ends.
The gib-head key is the one built with a taper along its length, and once it is hammered in, the wedge action locks the hub axially in place, exactly matching "tapered" and "prevents relative axial motion."

$$\text{Sunk keys: Woodruff, Feather, Gib-head} \;\rightarrow\; \text{Tapered + locks axially: Gib-head only}$$

Final Answer:
Filtering step by step on sunk, then tapered, then axial-locking behavior isolates one key.

$$\boxed{\text{Gib-head key}}$$

Quick Tip: Sunk keys are cut into both shaft and hub; only the tapered ones resist axial sliding.

• • •

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

Correct Answer: (A) Bulk modulus

SOLUTION:

Step 1: Setting Up the Elastic Constants:

In solid mechanics there are four common elastic constants: Young's modulus E, shear modulus G, bulk modulus K, and Poisson's ratio ν. Each one is defined as a ratio of a particular type of stress to the matching type of strain, so the fastest way to answer this question is to line up all four definitions side by side.

Step 2: Comparing the Definitions:

E = longitudinal stress divided by longitudinal strain, this applies to simple tension or compression.

G = shear stress divided by shear strain, this applies to twisting or sliding action.

K = hydrostatic (volumetric) stress divided by volumetric strain, this applies to uniform squeezing from all sides.

ν = lateral strain divided by longitudinal strain, notice this is a ratio of two strains, not stress to strain at all.

Step 3: Matching to the Question:

The question specifically asks for hydrostatic stress divided by volumetric strain, and from the list above this description belongs only to the bulk modulus K.

Compressibility looks similar but is actually $1/K$, that is strain divided by stress, so it is the inverse quantity and not the one described here.

Final Answer:

Matching the ratio in the question to the standard elastic constant definitions gives the bulk modulus.

$$\boxed{K = \frac{\text{hydrostatic stress}}{\text{volumetric strain}} \Rightarrow \text{Bulk modulus}}$$

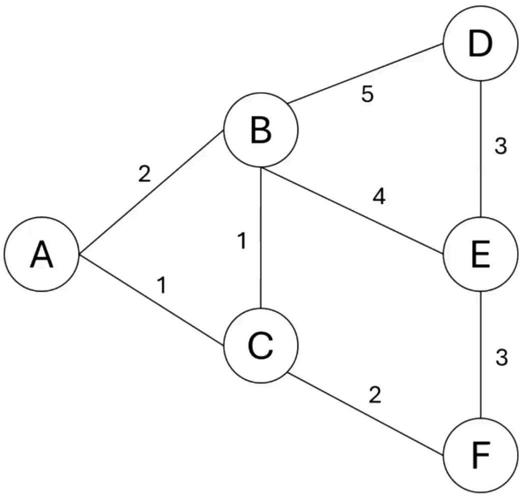
Quick Tip: Compare the ratio given in the question with the standard definitions of Young's modulus, bulk modulus, compressibility, and Poisson's ratio.

• • •

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

Correct Answer: (C) 2

SOLUTION:

Step 1: Labelling Nodes by Shortest Distance from A:

Start at A with a distance label of 0, then work outward, relaxing each edge to find the shortest known distance to every node.

Direct neighbours of A: B gets label 2 (via A-B), C gets label 1 (via A-C).

Step 2: Relaxing the Remaining Edges:

From C, going to B gives $1 + 1 = 2$, which ties the existing label on B, so B now has TWO equally short ways to reach it: directly from A, and via C.

From B (label 2), going to E gives $2 + 4 = 6$, so E gets a tentative label of 6.

From C, going to F gives $1 + 2 = 3$, so F gets label 3; then from F to E gives $3 + 3 = 6$, matching the label already on E.

From B, going to D gives $2 + 5 = 7$, then from D to E gives $7 + 3 = 10$, which is worse than 6, so this route is dropped.

Step 3: Counting Paths at the Shortest Label:

The final shortest label on E is $d = 6$.

Since B itself can be reached in two equally short ways (direct, and via C), both extend through edge B-E into two distinct shortest paths to E: A-B-E and A-C-B-E.

The route through F gives a third distinct shortest path: A-C-F-E.

So the count of shortest paths is $p = 3$.

Final Answer:

Dividing the shortest label by the number of shortest paths reaching it gives the required ratio.

$$\boxed{d/p = 6/3 = 2}$$

Quick Tip: List every possible route from A to E along the given edges, add up the weights, and find the minimum total distance and how many routes achieve it.

• • •

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.

Correct Answer: (C) Stockouts are permissible.

SOLUTION:

Step 1: Picture the EOQ Inventory Cycle:
In the standard EOQ model, stock level starts at Q units right when an order arrives, falls steadily as items are consumed at a constant known rate, and hits exactly zero at the moment the next order arrives.
This picture, a repeating sawtooth pattern that always touches zero and immediately jumps back up, is only possible if three things hold: demand is constant and known, replenishment is essentially instant (zero lead time), and the stock level never goes below zero.

Step 2: Reading Off the Assumptions from the Picture:
Constant known demand gives the straight downward sloping line in

the sawtooth, this matches option (A).
Instant replenishment gives the vertical jump back up to Q with no waiting gap, this matches option (B).
Average stock over a cycle is $Q/2$, and since holding cost equals $(Q/2)C_h$, cost rises directly with Q, this matches option (D).

Step 3: The Missing Piece, Shortages:
The sawtooth diagram never dips below the zero line, that is the whole point of the basic model, it deliberately avoids stockouts by reordering just in time.
If stockouts were allowed, the diagram would need an extra segment below zero representing backorders, and that situation belongs to a different, more advanced model called EOQ with planned shortages, not the basic EOQ model.

Final Answer:
Since the basic EOQ sawtooth diagram never permits negative stock, "stockouts are permissible" is not one of its assumptions.

$$\boxed{\text{Option (C) is NOT an assumption of the basic EOQ model}}$$

Quick Tip: Think about what the classic EOQ sawtooth inventory diagram looks like and whether it ever allows stock to run negative.

• • •

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.

Correct Answer: (D) The start of painting activity cannot be delayed without causing delay in completion of the construction project.

SOLUTION:

Step 1: Two Kinds of Float, and What Zero Means for Both:
Total float measures slack against the whole project's finish date, while free float measures slack only against the early start of the very next activity in the same chain.
When BOTH of these are zero at once for painting, it tells us there is no cushion anywhere, not against the immediate next activity and not against the far off project completion date either.

Step 2: Ruling Out the Dummy Activity Idea:
A dummy activity exists purely on paper to enforce a precedence link and always carries zero time, written as $duration = 0$.
Painting has a real duration of 6 days doing actual work, so by definition it cannot be a dummy activity, this removes option (A) right away.

Step 3: Using the Critical Path Test:
The standard test for whether an activity lies on the critical path is simply $TF = 0$.
Painting satisfies $TF = 0$, so it must lie on the critical path, meaning it

is critical, not non critical, this removes option (B).

Step 4: Testing the Delay Claim:

If an activity truly had spare time to shift its start, its total float would be a positive number, not zero.

Because painting shows $TF = 0$, there is exactly zero days of leeway, so pushing its start even by one day forces the project's completion date to move by that same one day.

This directly rules out option (C), which wrongly claims a delay is harmless, and confirms option (D), which correctly states a delay is not harmless.

Final Answer:

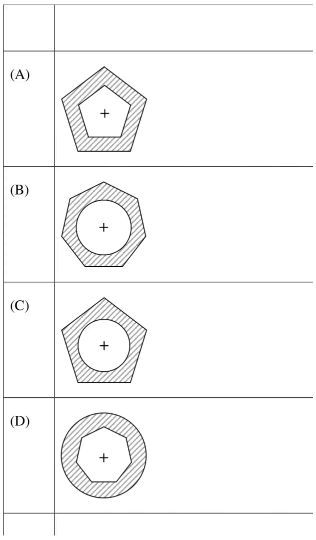
Zero float on both counts means painting sits on the critical path and any delay to its start delays the whole project.

$$\boxed{\text{The start of painting cannot be delayed without delaying the project}}$$

Quick Tip: Zero total float means an activity lies on the critical path, so recall what that implies about delaying its start.

• • •

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)

Correct Answer: (B) (Outer octagon, inner circle) ; (C) (Outer pentagon, inner circle)

SOLUTION:

Step 1: The One Rule That Decides Everything:
For true centrifugal casting there is a single governing rule to remember: the outer profile is controlled by the mold, but the inner profile is controlled purely by the spinning liquid itself.
Since a rotating liquid under centrifugal action always settles into a shape of constant radius, the inner bore of any true centrifugal casting must be a perfect circle.
No amount of clever mold design can force the free inner surface into

a square, pentagon, or any other polygon, because there is no core touching that surface.

Step 2: Applying the Rule as a Filter:
Using this rule as a quick filter, we simply need to reject every option whose inner shape is not a circle and accept every option whose inner shape is a circle, regardless of what the outer shape looks like.

$$\text{Inner shape is a circle} \implies \text{achievable}, \quad \text{Inner shape is not a circle} \implies \text{not achievable}$$

Step 3: Sorting the Four Options:
Option (A) has a pentagon inner bore, this fails the filter immediately.
Option (B) has an octagon outer profile with a circular inner bore, this passes the filter since only the outer shape is a polygon.
Option (C) has a pentagon outer profile with a circular inner bore, this also passes since the inner bore is still circular.
Option (D) has a circular outer profile with a circular inner bore, the simplest and most standard case, this clearly passes.

Final Answer:
Filtering by the rule that the inner bore must be circular leaves options (B), (C), and (D) as the achievable cross-sections.

$$\boxed{\text{(B), (C), (D)}}$$

Quick Tip: Remember that in true centrifugal casting the outer shape is set by the mold but the inner bore is always a circle, since it forms from the free liquid surface.

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

Correct Answer: (A) P-3; Q-1; R-2; S-4 ; (D) P-3; Q-1; R-2; S-5

SOLUTION:

Step 1: List the four defects and think about where metal is stretched or pulled:

This is a matching type MSQ, so instead of matching one by one, group the processes by the kind of stress they put on the material.

Extrusion and wire drawing pull the metal through a die, creating tension at the core, that is what causes centerburst.

Deep drawing stretches a flat sheet into a cup shape, and this uneven stretching around the flange is what produces earing.

Rolling squeezes the strip between two rollers, and uneven elongation through the thickness produces zipper cracks.

Forging and casting both involve metal flowing and meeting itself, so cold shut can appear in either.

Step 2: Fix the three definite pairs first:
From the reasoning above, P (centerburst) always pairs with 3 (extrusion), Q (earing) always pairs with 1 (deep drawing), and R (zipper cracks) always pairs with 2 (rolling).
These three pairs, P-3, Q-1, R-2, appear in exactly the same form in options (A) and (D), so the answer must be one or both of these two options.

Step 3: Decide what S (cold shut) pairs with:
Cold shut is not tied to just one process. It happens whenever two flows of metal meet but do not fuse: in closed die forging (option A gives S-4) when the die closes before the flash fully joins, and in casting (option D gives S-5) when two streams of molten metal meet a fraction too late and freeze before bonding.
Since both situations genuinely produce a cold shut, both S-4 and S-5 are acceptable pairings.

Step 4: Reject the remaining options:
Option (B) breaks the fixed pairing by sending centerburst to casting and earing to rolling, so it is wrong.
Option (C) sends centerburst to deep drawing, which contradicts the definite pairing found in Step 2, so it is wrong too.

Final Answer:
Only the options that keep P-3, Q-1, R-2 fixed and use either S-4 or S-5 are correct.

$$\boxed{\text{(A) and (D)}}$$

Quick Tip: Match each defect to the process where it typically forms; remember cold shut can occur in both forging and casting.

• • •

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

Correct Answer: (A) IGES ; (B) STEP ; (D) STL

SOLUTION:

Step 1: Sort the four options by what kind of thing they actually are:
Before checking each one against a definition, it helps to ask a simple question: is this option even a file format, or is it something else entirely?
IGES, STEP and STL are all names you would see in a Save As or Export dialog box of a CAD software, which is a strong hint they are file formats.
NDC is not something you ever export a model as, it is a coordinate frame used inside rendering pipelines.

Step 2: Trace the history of neutral CAD formats:
IGES was introduced early on as the first widely adopted neutral

format so that a model built in one CAD system could be opened in another.
Later, STEP was developed as an improved, ISO standardised format that could also carry manufacturing and assembly information along with geometry.
Both of these formats exist purely to move CAD models between systems, which matches exactly what the question is asking about.

Step 3: Place STL in the picture:
STL takes a different approach: instead of exact curves and surfaces, it approximates the model as a set of flat triangles.
This makes it heavier in file size for curved parts, but it is universally accepted for rapid prototyping and 3D printing, so it still counts as an established data transfer format for geometry.

Step 4: Eliminate NDC on the basis of what it does:
NDC only describes how coordinates are normalised for display on a screen, for example scaling x and y between -1 and 1.
It never stores a model on disk and cannot be exchanged between CAD systems, so it fails the basic definition of a data transfer format.

Final Answer:
The formats built for CAD data exchange are IGES, STEP and STL, and NDC does not belong in this list.

$$\boxed{\text{(A), (B) and (D)}}$$

Quick Tip: Ask whether each option is something you can export a 3D model as; NDC is a screen coordinate concept, not a file format.

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

Correct Answer: (A) 0 ; (C) -0.9

SOLUTION:

Step 1: Think about where the formula for r comes from:

The correlation coefficient is built as the covariance of two variables divided by the product of their individual standard deviations.

$$r = \frac{Cov(X, Y)}{\sigma_X \sigma_Y}$$

This ratio is not arbitrary, it comes from a mathematical inequality, similar in spirit to the Cauchy-Schwarz inequality, which guarantees the numerator can never exceed the denominator in size.

Step 2: See why this forces a fixed boundary:

Because the covariance term can never be larger in magnitude than $\sigma_X \sigma_Y$, the ratio r can never cross beyond 1 on the positive side or below -1 on the negative side.

This is exactly why the bound $-1 \leq r \leq 1$ holds for every possible dataset, it is not a rule someone chose, it falls directly out of the formula.

Step 3: Use this boundary as a filter on the four numbers given:
0 sits comfortably inside the boundary, since $-1 \leq 0 \leq 1$ is true, so it can be a valid coefficient.
-0.9 also sits inside the boundary, since it is greater than -1 and less than 1, so it too can be valid.
10.3 and 2 both sit far outside the boundary on the positive side, well beyond what the formula allows, so neither can ever be produced by real data.

Step 4: Conclude which options survive the filter:
Only 0 and -0.9 pass this test, the other two numbers are mathematically impossible outputs of the correlation formula regardless of what dataset is used.

Final Answer:
The values a correlation coefficient can actually take are 0 and -0.9.

$$\boxed{0 \text{ and } -0.9}$$

Quick Tip: The correlation coefficient always lies between -1 and 1; check which options fall outside this range.

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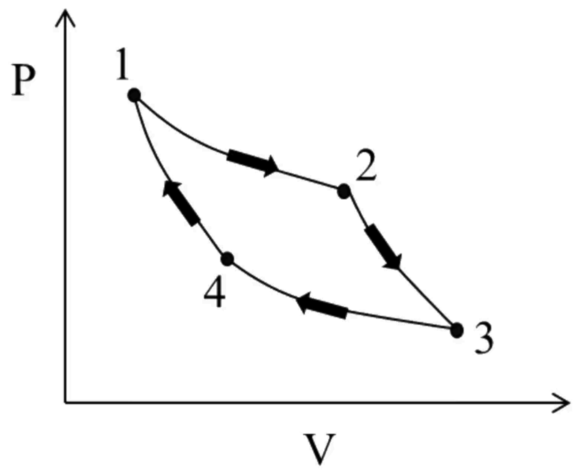
29.

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

Correct Answer: (B) 2-3 ; (D) 4-1

SOLUTION:

Step 1: Use the shape of the curves instead of memorising the cycle sequence:

On a P-V diagram, an easy way to tell an isothermal curve from an adiabatic curve is by how steep it looks near the same point.

For an ideal gas, an isothermal curve follows $PV = constant$, while an adiabatic curve follows $PV^{\gamma} = constant$, and since γ is always greater than 1, the adiabatic curve falls faster, so it looks steeper.

Step 2: Look at the four curves drawn between states 1, 2, 3 and 4:
Going around the loop from 1 to 2 to 3 to 4, two of the curves are flatter (these carry heat at a fixed temperature) and two are steeper (these carry no heat at all).
The curve from 1 to 2 and the curve from 3 to 4 are the flatter, constant temperature curves.
The curve from 2 to 3 and the curve from 4 to 1 are the steeper curves, where the gas changes temperature but exchanges no heat with the surroundings.

Step 3: Connect steepness to entropy behaviour:
A process with zero heat transfer, done reversibly, keeps entropy fixed, and that is exactly the definition of isentropic.
So the two steeper curves, 2-3 and 4-1, are the isentropic ones, while the two flatter curves, 1-2 and 3-4, involve heat transfer and therefore a change in entropy.

Step 4: Match this back to the given options:
(A) 1-2 and (C) 3-4 belong to the flatter, isothermal curves, so they are ruled out.
(B) 2-3 and (D) 4-1 belong to the steeper, adiabatic curves, so these are the correct picks.

Final Answer:
Reading the steepness of the curves confirms that 2-3 and 4-1 are the isentropic processes.

$$\boxed{\text{(B) and (D)}}$$

Quick Tip: Isothermal legs exchange heat; adiabatic legs (done reversibly) do not, and those are the isentropic ones.

• • •

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.

Correct Answer: 80

SOLUTION:

Step 1: Picture what "single step blanking" actually cuts through:
In a single stroke blanking operation, the punch shears through the sheet along the full outline of the square, all four edges at once, and nowhere is the cutting split into stages.
So the force needed depends only on the total shear area that gets separated in that one stroke.

Step 2: Build the shear area from the geometry:
Think of the cut as a thin rectangular strip running along each edge of the square, with a height equal to the sheet thickness.
Unrolling all four edges gives a total cutting length of $4 \times 50 = 200$ mm, and multiplying by the 2 mm thickness gives the shear area.

$$A_{shear} = 200 \times 2 = 400 \text{ mm}^2$$

Step 3: Apply the shear strength to this area:

Force equals stress times area, so multiplying the shear strength by the shear area gives the punch load needed to separate the blank in one go.

$$F = \tau \times A_{shear} = 200 \times 400 = 80000 \text{ N}$$

Step 4: Express the answer in the requested units:

Dividing by 10^3 converts the answer from newtons into the units the question asks for.

$$\frac{80000}{1000} = 80$$

Final Answer:

Whether the calculation is done edge by edge or by finding the total shear area first, the theoretical minimum blanking force comes out to 80, in units of 10^3 N.

$$\boxed{80}$$

Quick Tip: Blanking force equals shear strength times cutting perimeter times sheet thickness.

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).

Correct Answer: 0.15

SOLUTION:

Step 1: Understanding the Concept:
There are 15 inserts in the box, 5 coated and 10 uncoated, and 4 of them are picked together without noticing which is which.
This is a selection problem, so we use combinations rather than ordered probability.
We want the chance that the group of 4 chosen inserts is made up entirely of uncoated pieces.

Step 2: Key Formula or Approach:
When items are chosen "at once" (unordered, without replacement), the probability is the ratio of favourable combinations to total combinations.

$$P = \frac{^{10}C_4}{^{15}C_4}$$

Step 3: Detailed Explanation:
Total ways to choose any 4 inserts out of 15:

$$^{15}C_4 = \frac{15 \times 14 \times 13 \times 12}{4 \times 3 \times 2 \times 1} = 1365$$

Ways to choose 4 uncoated inserts out of the 10 available uncoated ones:

$$^{10}C_4 = \frac{10 \times 9 \times 8 \times 7}{4 \times 3 \times 2 \times 1} = 210$$

So the probability is:

$$P = \frac{210}{1365} = \frac{2}{13} = 0.1538$$

Final Answer:

Rounding this to two decimal places gives the required probability.

$$\boxed{0.15}$$

Quick Tip: Use the multiplication rule for drawing without replacement: $\frac{10}{15} \times \frac{9}{14} \times \frac{8}{13} \times \frac{7}{12}$, or equivalently the ratio of combinations $\frac{^{10}C_4}{^{15}C_4}$.

• • •

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).

Correct Answer: 28323

SOLUTION:

Step 1: Understanding the Concept:

NPV compares money received in the future with money paid today by bringing every cash flow back to its present day worth.

Here the customer invests INR 2,00,000 now and receives INR 1,00,000 at the end of year 1, year 2 and year 3.

We discount each of the three payouts separately at 15% per year and then subtract the initial outflow.

Step 2: Key Formula or Approach:

$$NPV = -C_0 + \sum_{t=1}^{n} \frac{C_t}{(1+r)^t}$$

where C_0 is the initial investment, C_t is the cash inflow in year t, and r is the discount rate.

Step 3: Detailed Explanation:

Year 1 present value: $\frac{1{,}00{,}000}{(1.15)^1} = 86,956.52$

Year 2 present value: $\frac{1{,}00{,}000}{(1.15)^2} = \frac{1{,}00{,}000}{1.3225} = 75,614.37$

Year 3 present value: $\frac{1{,}00{,}000}{(1.15)^3} = \frac{1{,}00{,}000}{1.520875} = 65,751.62$

Adding these three:

$$Total\ PV = 86,956.52 + 75,614.37 + 65,751.62 = 2,28,322.51$$

Now subtract the original investment:

$$NPV = 2,28,322.51 - 2,00,000 = 28,322.51$$

Final Answer:

Rounded to the nearest integer, the NPV of the investment is INR 28,323.

$$\boxed{28323}$$

Quick Tip: Discount each year's INR 1,00,000 payout back to present value at 15% (or use the annuity present value formula), sum them, then subtract the initial INR 2,00,000 investment.

• • •

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

$$VT^n f^m = constant$$

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).

Correct Answer: 2.25

SOLUTION:

Step 1: Understanding the Concept:

In the modified Taylor equation $VT^n f^m = constant$, the tool life stays the same in both cutting conditions given in the problem.

That means the T^n part is common to both sides and drops out of the comparison.

We are left with a direct relation between cutting speed and feed that we can solve for the feed ratio.

Step 2: Key Formula or Approach:

Equating the two conditions and cancelling T^n:

$$V_1 f_1^m = V_2 f_2^m$$

$$\left(\frac{f_1}{f_2}\right)^m = \frac{V_2}{V_1}$$

Step 3: Detailed Explanation:

We are given $m = 0.5$ and $V_1/V_2 = 2/3$, so $V_2/V_1 = 3/2 = 1.5$.

Substituting:

$$\left(\frac{f_1}{f_2}\right)^{0.5} = 1.5$$

Since the power on the left is 0.5 (a square root), we remove it by squaring both sides:

$$\frac{f_1}{f_2} = (1.5)^2 = 2.25$$

Final Answer:

Squaring both sides gives the feed ratio directly.

$$\boxed{2.25}$$

Quick Tip: Cancel the equal tool-life term T^n from both conditions, then solve $(f_1/f_2)^m = V_2/V_1$ for the feed ratio.

• • •

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).

Correct Answer: 1

SOLUTION:

Step 1: Understanding the Concept:

Instead of tracing the exact shape of the semicircle, it helps to first check whether the vector field behind this integral is conservative.

If it is, the integral only depends on the start and end points, not on the actual path taken.

Here the field is $\mathbf{F} = 2x\mathbf{i} + 2y\mathbf{j} + 2z\mathbf{k}$.

Step 2: Key Formula or Approach:

A field is conservative if it can be written as the gradient of some scalar function ϕ, that is $\mathbf{F} = \nabla\phi$.

For such a field, the Fundamental Theorem of Line Integrals gives:

$$\int_C \mathbf{F}\cdot d\mathbf{r} = \phi(\text{end point}) - \phi(\text{start point})$$

Step 3: Detailed Explanation:

Try $\phi(x, y, z) = x^2 + y^2 + z^2$. Its partial derivatives are $\frac{\partial\phi}{\partial x} = 2x$, $\frac{\partial\phi}{\partial y} = 2y$ and $\frac{\partial\phi}{\partial z} = 2z$, which exactly match the field, so ϕ is a valid potential function and the field is conservative.

Since the path shape no longer matters, just evaluate ϕ at the two given endpoints, start $(0, 0, 0)$ and end $(1, 0, 0)$:

$$\int_C \mathbf{F}\cdot d\mathbf{r} = \phi(1, 0, 0) - \phi(0, 0, 0) = (1^2 + 0^2 + 0^2) - (0^2 + 0^2 + 0^2)$$

$$= 1 - 0 = 1$$

Final Answer:

Because the field is conservative, the integral equals the difference in potential between the endpoints.

$$\boxed{1}$$

Quick Tip: Check if the vector field is conservative by finding a potential function ϕ with $\nabla\phi = \mathbf{F}$; then the integral is just $\phi(\text{end}) - \phi(\text{start})$.

• • •

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).

Correct Answer: 0

SOLUTION:

Step 1: Understanding the Concept:
In aggregate planning, the stock left over at the end of a month becomes the opening stock for the next month.

So the ending inventory of October, 1500 units, is the beginning inventory for November.
We need to combine this opening stock with everything made or bought in November, and then compare the total against November's demand.

Step 2: Key Formula or Approach:

$$\text{Ending Inventory}_t = \text{Beginning Inventory}_t + \text{Production}_t + \text{Subcontracting}_t - \text{Demand}_t$$

Step 3: Detailed Explanation:
For November: beginning inventory = 1500 units, in-house production = 8000 units, subcontracted units = 1000 units (available the same month), and demand (from the table) = 10500 units.
Total supply available in November:

$$\text{Total Supply} = 1500 + 8000 + 1000 = 10500 \text{ units}$$

Comparing this with demand:

$$\text{Ending Inventory} = 10500 - 10500 = 0 \text{ units}$$

Final Answer:
Total supply exactly matches demand this month, so the closing inventory is nil.

$$\boxed{0}$$

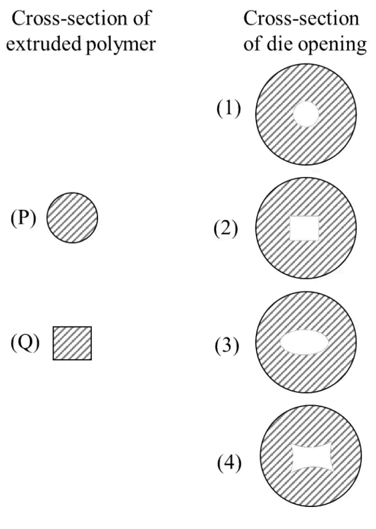
Quick Tip: Add opening stock, in-house production and subcontracted units for November, then subtract November's demand to get the closing stock.

• • •

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

Correct Answer: (A) P-1; Q-4

SOLUTION:

Step 1: Setting up a single rule for die swell:
Extruded polymers are viscoelastic, so they always swell after leaving the die, this is called die swell.
The amount of swell is bigger where the melt is less restrained, that means flat straight faces swell more than sharp corners.
We can use this one rule to test every option directly instead of first working out the shapes ourselves.

Step 2: Testing the options by elimination:
Take option (B), P-1 and Q-2. Die 2 is a plain square hole, so its flat sides would swell more than its corners and the extrudate would come out barrel shaped, not the clean square Q shown in the figure, so (B) fails.
Take option (C), P-3 and Q-2. Die 3 has an oval hole, and an oval swells into a bigger oval, never a perfect circle, so P cannot come from die 3, and (C) fails on the very first pair.
Take option (D), P-3 and Q-4. Again die 3 is oval and cannot give the round profile P, so (D) also fails.

Step 3: Confirming the surviving option:
Only option (A), P-1 and Q-4, is left standing.
Die 1 is a plain circular hole. A circle has the same restraint all around its edge, so it swells equally everywhere and simply grows into a larger circle, this matches profile P.
Die 4 has concave, pinched in sides, like a pin cushion. Because the middle of each side is pulled in, that region swells out the most when the melt exits, and this extra outward growth cancels the concave curve, leaving straight sides. The corners, which are less restrained by the geometry, swell least. The final result is a true flat sided square, which matches profile Q.

Final Answer:

Elimination and direct reasoning both point to the same pairing.

$$\boxed{P\text{–}1,\ Q\text{–}4}$$

Quick Tip: Think about die swell (the Barus effect): flat faces swell outward more than corners. A circular die stays circular; a square profile needs a pin-cushion shaped die to counteract uneven swelling.

• • •

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

Correct Answer: (A) 41.52

SOLUTION:

Step 1: Reframing the problem with a unit volume:

Imagine we tap-fill exactly 1 cm^3 of powder. Since the tap density is 3.26 g/cm^3, this 1 cm^3 of loosely packed powder contains a mass of 3.26 g of iron.

The apparent density value of 2.66 g/cm^3 describes the powder before tapping and does not enter this calculation, we only need the tap state and the fully solid state.

Step 2: Finding the true solid volume of that same mass:

If that 3.26 g of iron were melted and cast with zero porosity, its density would be the solid density $7.85\ g/cm^3$.

$$V_{solid} = \frac{mass}{\rho_{solid}} = \frac{3.26}{7.85} = 0.4153\ cm^3$$

So the same mass of iron that fills $1\ cm^3$ as tapped powder would occupy only $0.4153\ cm^3$ if it were fully dense with no pores at all.

Step 3: Converting the volume ratio into percent densification:

The degree of densification is the fraction of the tapped volume that is actually solid metal, expressed as a percentage.

$$\text{Densification} = \frac{V_{solid}}{V_{tapped}} \times 100 = \frac{0.4153}{1} \times 100 = 41.53\%$$

This is the same number as the direct density ratio, because V_{solid}/V_{tapped} and ρ_{tap}/ρ_{solid} are algebraically the same expression, just built up from a physical picture instead of a formula.

Final Answer:

Whether we compare densities directly or trace the volume of a fixed mass of powder, the iron powder is about 41.5 percent as dense as solid iron.

$$\boxed{41.52\%}$$

Quick Tip: Degree of densification = tap density divided by solid density, times 100. Apparent density is not needed for this ratio.

• • •

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

Correct Answer: (C) P-3; Q-4; R-1; S-2

SOLUTION:

Step 1: Picking the easiest checks first:

Instead of testing every matrix against every property in order, it is faster to spot the two easiest properties first: triangular and symmetric are visible just by looking at zero positions and mirrored entries.

Step 2: Spotting the triangular matrix:

$$S = \begin{bmatrix} 1 & 2 & 3 \\ 0 & 1 & 4 \\ 0 & 0 & 1 \end{bmatrix}$$

Every position below the main diagonal is already 0, nothing needs to be computed, this is an upper triangular matrix. So S matches property 2.

Step 3: Spotting the symmetric matrix:

$$P = \begin{bmatrix} -30 & 17 & 5 \\ 17 & 0 & -12 \\ 5 & -12 & 4 \end{bmatrix}$$

Reading across the diagonal, 17 appears twice, 5 appears twice, and -12 appears twice, in mirrored positions. A matrix with this mirror pattern equals its own transpose, so P is symmetric and matches property 3.

Step 4: Spotting the trace free matrix by adding the diagonal:

$$Q = \begin{bmatrix} 0 & 1 & 9 \\ 7 & 0 & 2 \\ 12 & 3 & 0 \end{bmatrix}$$

Adding the diagonal entries of Q gives $0 + 0 + 0 = 0$, so Q is trace free and matches property 4.

Step 5: Assigning the last matrix by elimination, then confirming with a shortcut:

Only R and property 1 (singular) are left, so by process of elimination R must be singular.

$$R = \begin{bmatrix} 2/3 & 1/3 & 2/3 \\ 0 & 2/3 & -1/3 \\ 0 & 4/3 & -2/3 \end{bmatrix}$$

As a quick check, row 3 is $(0, 4/3, -2/3)$, which is exactly row 2, $(0, 2/3, -1/3)$, multiplied by 2.

Since row 3 is a scalar multiple of row 2, the rows are linearly dependent, and a matrix with dependent rows always has a zero determinant, so R is confirmed singular.

Final Answer:

Working from the easiest pattern to the hardest gives the same match: P-3, Q-4, R-1, S-2.

$$\boxed{\text{Option (C)}}$$

Quick Tip: Check the easy properties first: look for zero entries below the diagonal (triangular), mirrored entries (symmetric), and a diagonal sum of zero (trace free). What is left over must be singular.

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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

Correct Answer: (A) 150

SOLUTION:

Step 1: Deciding to test each option directly:
Instead of solving the inequalities in general first, we can simply plug each candidate blank diameter into both feasibility formulas and see which one passes.
Reduction ratio is $(D_b - 100)/D_b$ and it must stay under 0.5. Thickness to diameter ratio is $2/D_b$ and it must stay above 0.01.

Step 2: Testing option (A), $D_b = 150$ mm:
Reduction ratio $= (150 - 100)/150 = 50/150 = 0.333$, which is less than 0.5, so this condition passes.
Thickness ratio $= 2/150 = 0.0133$, which is greater than 0.01, so this condition also passes. Both conditions hold, so 150 mm works.

Step 3: Testing option (B), $D_b = 250$ mm:
Reduction ratio $= (250 - 100)/250 = 150/250 = 0.6$, which is greater than 0.5, so this already fails the first condition, no need to check further.

Step 4: Testing option (C), $D_b = 350$ mm:
Reduction ratio $= (350 - 100)/350 = 250/350 = 0.714$, which is well above 0.5, so this fails too.

Step 5: Testing option (D), $D_b = 450$ mm:

Reduction ratio $= (450 - 100)/450 = 350/450 = 0.778$, again far above 0.5, so this also fails.

Final Answer:

Direct substitution confirms that only $D_b = 150$ mm keeps both the reduction ratio and the thickness to diameter ratio within the feasible range.

$$\boxed{D_b = 150\ mm}$$

Quick Tip: Convert both feasibility conditions into inequalities for D_b using t = 2 mm and d_p = 100 mm, then check which option satisfies both.

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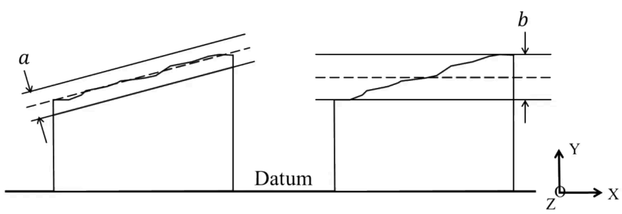
40. A student is trying to determine the flatness and parallelism of the top surface of a part whose cross-section, assumed uniform in the Z direction, is shown in the figure.

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.

Correct Answer: (A) a is flatness while b is parallelism.

SOLUTION:

Step 1: Using one decisive test instead of definitions:

There is one quick test that separates every form tolerance from every orientation tolerance: does the tolerance zone need a Datum to be defined, or not?

Form tolerances like flatness never need a Datum. Orientation tolerances like parallelism always need one. We can answer the whole question just by applying this single test to zones a and b.

Step 2: Applying the test to zone a:

Looking at the figure, the band for a is tilted at an angle that matches the slope of the actual top surface, and it has no fixed relationship to the bottom Datum line.

Since this zone can be defined using only the surface itself, with zero reference to the Datum, it fails the needs a Datum test, which means it must be the form tolerance, flatness.

Step 3: Applying the test to zone b:

The band for b is drawn as two lines running exactly parallel to the bottom Datum surface, at a constant vertical offset from it.

This zone cannot even be drawn without first knowing where the Datum is, so it passes the needs a Datum test, which means it must be the orientation tolerance, parallelism.

Step 4: Ruling out the combined-quantity options:

Options (C) and (D) propose that $a + b$ or $b - a$ represent these tolerances, but flatness and parallelism are each single, independently defined tolerance zones read directly off the drawing, not sums or differences of two zone widths, so these options do not fit how GD&T zones are actually defined.

Final Answer:

The Datum reference test confirms a is flatness and b is parallelism.

$$\boxed{\text{Option (A)}}$$

Quick Tip: Ask which tolerance zone needs the Datum to be drawn. Flatness never references a datum; parallelism always does.

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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) $1 - (a \times b \times t^{b-1} \times e^{-at^b})$

Correct Answer: (B) $a \times b \times t^{b-1}$

SOLUTION:

Step 1: Recognize the distribution:

The CDF $F(t) = 1 - e^{-at^b}$ is the standard form of the Weibull distribution, with a acting as a scale-related constant and b as the shape parameter.

This distribution is used heavily in reliability analysis because its hazard rate can increase, decrease, or stay constant depending on b.

Step 2: Apply the hazard rate definition:

By definition the hazard function is the density divided by the survival probability.

$$r(t) = \frac{f(t)}{1 - F(t)}$$

Here $f(t) = F'(t)$, so before substituting we need the derivative of $F(t)$ with respect to t.

Step 3: Work out $f(t)$ and $1 - F(t)$ separately:

Differentiating $F(t) = 1 - e^{-at^b}$ with respect to t:

$$f(t) = abt^{b-1}e^{-at^b}$$

And directly from the given CDF:

$$1 - F(t) = e^{-at^b}$$

Dividing the two:

$$r(t) = \frac{abt^{b-1}e^{-at^b}}{e^{-at^b}} = abt^{b-1}$$

Step 4: Confirm with the Weibull property:

A known fact about the Weibull distribution is that its hazard function always reduces to a pure power of t, scaled by shape and scale constants, never carrying the exponential term.

This matches what we derived, and rules out options (A), (C), and (D), each of which either keeps the exponential or introduces an unjustified subtraction from 1.

Final Answer:

The hazard rate simplifies neatly once the exponential terms cancel.

$$\boxed{r(t) = abt^{b-1}}$$

Quick Tip: Differentiate $F(t)$ to get $f(t)$, then divide by $1 - F(t)$; the exponential terms cancel.

• • •

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

Correct Answer: (B) P-3; Q-1; R-2; S-4

SOLUTION:

Step 1: Group the mechanisms by category first:
Instead of going process by process, it helps to first sort the four removal mechanisms into two families: thermal (melting/vaporization) and mechanical (impact, sputtering, shearing). This narrows down the matching before we even look at the specific process names.

Step 2: Identify the one purely thermal process:
Among P, Q, R, S only Laser beam machining (P) works by concentrated heat energy, so it must pair with the thermal mechanism Melting and vaporization (3).
That immediately fixes P-3 and rules out P being paired with 1, 2, or 4.

Step 3: Separate the two mechanical-erosive processes:
Abrasive waterjet machining (Q) and Ion beam machining (R) both remove material mechanically but at very different scales.
AWJM works at the macro/particle scale, so its abrasive grains chip material away by direct Impact based erosion (1): Q-1.
IBM works at the atomic scale in vacuum, knocking off individual atoms through Sputtering (2): R-2.

Step 4: Assign the leftover pair by elimination:

Mechanical milling (S) is the only conventional process in the list, and its cutter removes material as continuous chips through plastic deformation, which is Shearing (4).
With 3, 1 and 2 already used, 4 is the only mechanism left for S, confirming S-4 both by reasoning and by elimination.

Final Answer:
Grouping by thermal versus mechanical mechanism confirms the same pairing found directly.

$$\boxed{P\text{-}3;\ Q\text{-}1;\ R\text{-}2;\ S\text{-}4}$$

Quick Tip: Laser beam machining melts/vaporizes, abrasive waterjet erodes by impact, ion beam machining sputters, and milling shears chips.

• • •

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

Correct Answer: (C) 16

SOLUTION:

Step 1: Set up the force balance directly:
Rather than quoting the capillary rise formula from memory, we can derive it by balancing forces on the liquid column that rises in the tube.
The upward force comes from surface tension acting along the wetted circumference, and the downward force is the weight of the liquid column that has been lifted.

Step 2: Write the two forces in terms of diameter d:
The circumference of the tube is πd, so the vertical component of the surface tension force (with contact angle zero, so the full tension acts vertically) is:

$$F_{up} = \sigma \times \pi d$$

The weight of the raised column of height h and cross-section area $\frac{\pi d^2}{4}$ is:

$$F_{down} = \rho g \times \frac{\pi d^2}{4} \times h$$

Step 3: Equate the forces and solve for h:

$$\sigma \pi d = \rho g \frac{\pi d^2}{4} h$$

Cancelling πd from both sides:

$$\sigma = \rho g \frac{d}{4} h \implies h = \frac{4\sigma}{\rho g d}$$

This is the same relation used before, but now built from scratch using a force balance instead of recalling it.

Step 4: Plug in the numbers:

$\sigma = 0.1$, $d = 0.0025$ m, $\rho = 1000$, $g = 10$.

$$h = \frac{4 \times 0.1}{1000 \times 10 \times 0.0025} = \frac{0.4}{25} = 0.016\, m = 16\, mm$$

Final Answer:

The force balance approach confirms the same 16 mm answer independently.

$$\boxed{h = 16\, mm}$$

Quick Tip: Use $h = \dfrac{4\sigma \cos\theta}{\rho g d}$ with d in metres.

• • •

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) $3/n$

Correct Answer: (B) $n/3$

SOLUTION:

Step 1: Recall the general M/M/1 relations:

For any M/M/1 queue, the average number in the system is $L = \dfrac{\rho}{1-\rho}$ where $\rho = \lambda/\mu$ is the server utilization, and the average time in the system is $W = \dfrac{1}{\mu - \lambda}$.

These two expressions are not independent, they are connected through the arrival rate λ.

Step 2: Connect L and W through λ:

Dividing the expression for W by the expression for L:

$$\frac{W}{L} = \frac{1/(\mu-\lambda)}{\rho/(1-\rho)}$$

Since $\rho = \lambda/\mu$, we have $1 - \rho = (\mu - \lambda)/\mu$, so $\dfrac{\rho}{1-\rho} = \dfrac{\lambda}{\mu-\lambda}$.

Substituting this back:

$$\frac{W}{L} = \frac{1/(\mu-\lambda)}{\lambda/(\mu-\lambda)} = \frac{1}{\lambda}$$

Step 3: Interpret the result:

This shows $W = L/\lambda$ for any M/M/1 queue, which is exactly Little's Law recovered from the individual formulas rather than quoted directly.

So regardless of what μ actually is, as long as the queue is stable (ρ < 1, which is given), this ratio holds.

Step 4: Apply it to the given data:

We are told $L = n$ and $\lambda = 3$ per minute, so:

$$W = \frac{L}{\lambda} = \frac{n}{3}$$

This confirms option (B) without needing to know the actual service rate μ.

Final Answer:

Deriving from the underlying M/M/1 formulas gives the same relation as Little's Law.

$$\boxed{W = \frac{n}{3} \text{ minutes}}$$

Quick Tip: Apply Little's Law, $L = \lambda W$, with $L = n$ and $\lambda = 3$.

• • •

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

Correct Answer: (C) 15 ; (D) 20

SOLUTION:

Step 1: State the riser design rule in modulus-ratio form:

A commonly used practical guideline (based on Chvorinov's Rule) is that the riser modulus should be at least equal to the casting modulus, often written as a ratio:

$$\frac{M_{riser}}{M_{casting}} \geq 1$$

If this ratio is 1 or greater, the riser solidifies at the same time or later than the casting, so it can keep feeding liquid metal right up until the casting is fully solid.

Step 2: Find the casting modulus numerically:

The steel cube has side $a = 10$ cm, giving volume $V_c = 1000\ cm^3$ and surface area $A_c = 600\ cm^2$ (all six faces exposed).

$$M_c = \frac{1000}{600} = 1.667\ cm$$

Step 3: Test each candidate diameter directly instead of solving an inequality first:

For a cylinder with $h = d$ and no shared surface, general formulas give

$V_r = \frac{\pi}{4}d^3$ and $A_r = \frac{3\pi}{2}d^2$, so $M_r = d/6$.
Now plug in each option:
For $d = 5$: $M_r = 5/6 = 0.833$ cm, ratio $= 0.833/1.667 = 0.5$, less than 1, riser freezes too soon. Fails.
For $d = 8$: $M_r = 8/6 = 1.333$ cm, ratio $= 1.333/1.667 = 0.8$, still less than 1. Fails.
For $d = 15$: $M_r = 15/6 = 2.5$ cm, ratio $= 2.5/1.667 = 1.5$, greater than 1. Works.
For $d = 20$: $M_r = 20/6 = 3.333$ cm, ratio $= 3.333/1.667 = 2.0$, greater than 1. Works.

Step 4: Collect the passing values:
Only $d = 15$ cm and $d = 20$ cm give a modulus ratio of 1 or more, so only these two riser sizes are large enough to remain liquid until after the casting solidifies.

Final Answer:
Testing each option against the modulus ratio confirms the same two valid diameters.

$$\boxed{d = 15\ cm \text{ and } d = 20\ cm}$$

Quick Tip: Use Chvorinov's Rule: the riser's modulus $d/6$ must be at least the cube's modulus $10/6$, so $d \geq 10\ cm$.

• • •

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

Correct Answer: (C) R ; (D) S

SOLUTION:

Step 1: What the Problem Wants:
We are told the strip must reduce from 23 mm to 20 mm in one pass on rolls of diameter 200 mm, and we are given four possible friction values.
Instead of finding the least friction needed first, this approach directly computes how much reduction each lubricant CAN produce, and compares that with the 3 mm reduction that is actually needed.

Step 2: Formula for Maximum Draft:
The largest thickness drop that a given friction coefficient can support is

$$\Delta h_{max} = \mu^2 R$$

with $R = 100$ mm (half of the 200 mm roll diameter).
A lubricant works only if its Δh_{max} is at least the needed 3 mm.

Step 3: Testing Each Lubricant One at a Time:
For P, $\mu = 0.05$, so $\Delta h_{max} = (0.05)^2(100) = 0.25$ mm. This is much smaller than 3 mm, so P cannot roll the strip down to 20 mm.
For Q, $\mu = 0.10$, so $\Delta h_{max} = (0.10)^2(100) = 1.0$ mm. Still less than 3 mm, so Q also fails.
For R, $\mu = 0.20$, so $\Delta h_{max} = (0.20)^2(100) = 4.0$ mm. Since 4.0 mm is more than the 3 mm required, R is capable of the pass.
For S, $\mu = 0.25$, so $\Delta h_{max} = (0.25)^2(100) = 6.25$ mm. This comfortably covers the 3 mm requirement, so S also works.

Final Answer:
Comparing the maximum possible draft of each lubricant with the 3 mm actually needed shows that only R (4.0 mm capacity) and S (6.25 mm capacity) are sufficient.

$$\boxed{\Delta h_{max}(R) = 4 \text{ mm}, \ \Delta h_{max}(S) = 6.25 \text{ mm}, \ \text{both} \geq 3 \text{ mm}}$$

Quick Tip: Use the rolling condition $\Delta h \leq \mu^2 R$ to find the minimum friction needed, then check which lubricants meet it.

• • •

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.

Correct Answer: (A) C is constant 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.

SOLUTION:

Step 1: What This Question Is Really Testing:

This problem is about two competing assumptions Merchant used for the shear stress on the shear plane, and how each assumption changes the constant C in the shear angle formula.

Rather than describing both theories first, this solution goes through the four statements one by one and checks each against the underlying physics.

Step 2: The Underlying Physics to Use:

If the shear stress τ_s on the shear plane does NOT depend on the normal stress σ_n, minimizing the cutting energy always gives the same angle relation, $\phi = 45° - \beta/2 + \alpha/2$, so $C = 45°$ is a universal number, true for every material.

If instead τ_s increases linearly with σ_n through a material constant k (that is, $\tau_s = \tau_0 + k\sigma_n$), the minimization instead gives $C = \cot^{-1}(k)/2$, which changes from one material to another because k does.

Step 3: Checking Each Statement:

Statement (A) says C is constant when τ_s is independent of σ_n. That matches the first case above exactly ($C = 45°$ always), so (A) is TRUE.

Statement (B) says C is constant when τ_s depends on σ_n. But we just saw that in this case $C = \cot^{-1}(k)/2$ changes with the material constant k, so C is NOT constant here, making (B) FALSE.

Statement (C) says C depends on material properties when τ_s is independent of σ_n. This is the opposite of what happens in the first case, where C stays fixed at 45° regardless of material, so (C) is FALSE.

Statement (D) says C depends on material properties when τ_s is linearly dependent on σ_n. This is exactly the second case, where $C = \cot^{-1}(k)/2$ varies with the material constant k, so (D) is TRUE.

Final Answer:

Going through all four statements individually confirms that only (A) and (D) hold.

$$\boxed{\text{Correct statements: A, D}}$$

Quick Tip: Recall Merchant's two theories: constant shear stress gives a fixed C = 45 degrees, shear stress dependent on normal stress gives a material-dependent C.

• • •

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)

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

Correct Answer: (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)

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

SOLUTION:

Step 1: A Different Way to Test Each Matrix:

Instead of memorizing the standard rotation matrix pattern, we can test each option by seeing what it does to the three basis directions $\hat{\imath} = (1, 0, 0)$, $\hat{\jmath} = (0, 1, 0)$, and $\hat{k} = (0, 0, 1)$.

A rotation about the Y-axis is the only kind of rotation that leaves the Y-direction, $\hat{\jmath}$, completely unmoved, while both $\hat{\imath}$ and $\hat{k}$ get mixed together by $\cos\theta$ and $\sin\theta$ terms.

Step 2: Applying the Test to Each Option:

In option (A), multiplying the rotation block by $\hat{\jmath} = (0, 1, 0)$ gives $(-\sin\theta, \cos\theta, 0)$, which is not equal to $\hat{\jmath}$ unless $\theta = 0$, so $\hat{\jmath}$ moves, this rules out a Y-axis rotation here (it is in fact a Z rotation, since $\hat{k} = (0, 0, 1)$ stays fixed instead).

In option (B), multiplying by $\hat{\imath} = (1, 0, 0)$ leaves it unchanged, meaning the X-direction is the one that stays fixed, so this is an X-axis rotation, not Y.

In option (C), multiplying the rotation block by $\hat{\jmath} = (0, 1, 0)$ gives exactly $(0, 1, 0)$ back, unchanged, while $\hat{\imath}$ and $\hat{k}$ pick up $\cos\theta, \sin\theta$

terms. This confirms option (C) is a pure rotation about Y, with no shift since the translation entries are all zero.
In option (D), the rotation part is identical to (C), so $\hat{j}$ again stays fixed under the rotation block, the extra column $(3, 4, 2)$ only shifts the origin and does not change which axis the rotation happens about. So (D) also involves a Y-axis rotation, combined with a translation.

Final Answer:
Testing which basis vector stays fixed under each rotation block shows that $\hat{j}$ (the Y-direction) is preserved only in options (C) and (D).

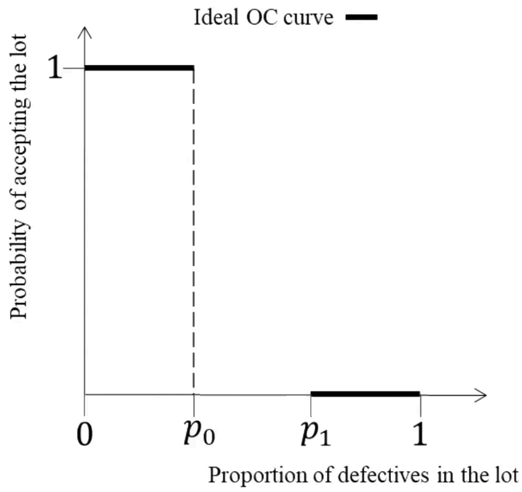
$$\boxed{\text{C and D are the Y-axis rotations}}$$

Quick Tip: A pure Y-axis rotation matrix keeps the middle row and column as 0, 1, 0; a translation column does not change which axis the rotation happens about.

• • •

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.

Correct Answer: (C) Producer's risk is zero. ; (D) Consumer's risk is zero.

SOLUTION:

Step 1: Recall What an OC Curve Tells Us:

An OC curve plots the probability that a sampling plan accepts a lot, P_a, against the true fraction defective p in that lot.

A real sampling plan gives an S-shaped curve because a sample can never perfectly represent the whole lot, but the 'ideal' curve in this figure represents a hypothetical plan with zero sampling error, a straight vertical drop instead of a smooth S-curve.

Step 2: Working with Probability of Rejection Instead:

Since $P_a + P_{reject} = 1$ at every value of p, we can find the rejection probability just as easily as the acceptance probability from the graph.

Below p_0: the graph shows $P_a = 1$, so $P_{reject} = 1 - 1 = 0$. Since producer's risk is the chance of a good lot ($p \leq p_0$) being rejected, and $P_{reject} = 0$ throughout this whole region, the producer's risk is 0, not 100 percent. This confirms (C) is correct and rules out (A).

Above p_1: the graph shows $P_a = 0$ directly. Since consumer's risk is the chance of a bad lot ($p \geq p_1$) being accepted, and $P_a = 0$ throughout this whole region, the consumer's risk is 0, not 100 percent. This confirms (D) is correct and rules out (B).

Step 3: Why This Makes Sense:

The word 'ideal' here means the sampling plan behaves like a perfect 100 percent inspection: every lot at or below the AQL passes, every lot at or above the LTPD fails, with nothing in between except the theoretical jump from p_0 to p_1.

Real plans cannot achieve this because a sample never tells you the lot's true defect rate with certainty, which is exactly why real OC curves are smooth S-curves with nonzero risks on both sides.

Final Answer:

Working from $P_{reject} = 1 - P_a$ at both ends of the curve confirms both risks are zero for the ideal case.

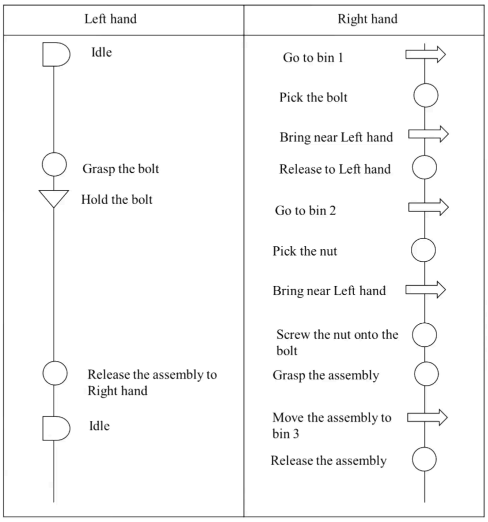
$$\boxed{\alpha = 0,\ \beta = 0 \implies \text{options C and D}}$$

Quick Tip: On the ideal OC curve, acceptance probability is 1 below p0 and 0 above p1, leaving no room for wrongly rejecting good lots or wrongly accepting bad ones.

• • •

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.

Correct Answer: (A) The work distribution between the two hands is not balanced. ; (B) The two hands do not follow opposite motions.

SOLUTION:

Step 1: The Principles We Are Checking Against:

Two rules from motion economy apply directly to a two-hand process chart: first, both hands should carry a roughly equal share of the work, and second, the hands should move together in a balanced, mirror-image pattern rather than one hand sitting still.

This solution checks the four given statements against the chart one at a time, rather than describing the whole chart first.

Step 2: Testing Statement (A), Balance of Work:

Counting the symbols in each column, the right hand has roughly ten active steps (travel, grasp, release, assemble, screw) while the left hand has essentially only one meaningful step, holding the bolt in place, sandwiched between two Idle periods.

Ten-plus active steps against effectively one is a heavily lopsided split, so statement (A), 'work distribution is not balanced,' matches the chart, TRUE.

Step 3: Testing Statement (C), the Opposite Claim:

Statement (C) claims the opposite of (A), that the work is well distributed. Since we already established the split is roughly ten tasks to one, this statement contradicts the chart, so (C) is FALSE.

Step 4: Testing Statement (B), Opposite Motions:

'Opposite motions' would mean, for instance, the left hand reaches to a bin at the same time the right hand returns, in a mirrored rhythm. Here the left hand does not reach anywhere at all after grasping the bolt, it just holds position, while the right hand does all the reaching to bin 1, bin 2, and bin 3 by itself.

Since one hand is static while the other moves alone, there is no opposite or mirrored motion happening, so statement (B) is TRUE.

Step 5: Testing Statement (D), Dominant Hand Usage:
The operator is left-handed, so the left hand is the dominant one.
Statement (D) claims the dominant hand does most of the work.
But we already found the right hand, the non-dominant hand here, performs almost every task, including the precise screwing action, while the dominant left hand only holds the bolt still.
This is the reverse of what (D) claims, so (D) is FALSE.

Final Answer:
Checking each statement individually against the chart confirms only (A) and (B) hold true.

$$\boxed{\text{Correct options: A, B}}$$

Quick Tip: Compare how many active tasks each hand performs and whether their motions mirror each other, then check which hand is actually the dominant one.

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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

Correct Answer: (A) Mild steel ; (B) Stainless steel

SOLUTION:

Step 1: Rule to remember:

Diamond tools are made of carbon, and carbon dissolves readily into iron at machining temperatures.

So any material that contains iron will chemically attack a diamond tool and is normally kept away from diamond machining.

Step 2: Sorting the four materials by chemistry:

Ferrous group (contains iron): mild steel and stainless steel both belong here, since stainless steel is just steel with chromium and nickel added.

Non ferrous group (no iron): silicon and aluminium alloy belong here.

Step 3: Matching with real practice:

Silicon wafers in the electronics industry are diced and ground using diamond tools all the time, because silicon is hard, brittle, and has zero iron content.

Aluminium alloys are also commonly turned and milled with polycrystalline diamond (PCD) inserts, since aluminium gives excellent finish with diamond and does not react with carbon.

Mild steel and stainless steel, being iron rich, cause rapid graphitisation of the diamond edge, so shops switch to carbide or CBN tools for these instead.

Final Answer:

The materials not commonly machined with diamond tools are mild steel and stainless steel, options (A) and (B).

$\boxed{\text{(A) and (B)}}$

Quick Tip: Diamond tools react chemically with iron. Materials without iron (silicon, aluminium) are diamond friendly; ferrous metals are not.

• • •

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.

Correct Answer: 9

SOLUTION:

Step 1: A shortcut using the velocity ratio:
Because the commanded path is a straight 45 degree line, the X and Y feed components are equal in the ideal case, both being $\frac{150}{\sqrt{2}}$ mm/min. The X component is not disturbed by the error, only Y is reduced by 5 percent.

Step 2: Linking X travel and Y travel through time:
At any instant, the distances covered along X and along Y are both proportional to the same elapsed time t, so:

$$\frac{Y_{actual}}{X_{actual}} = \frac{V_{y,actual}}{V_{x,actual}} = \frac{0.95 \times V_y}{V_x}$$

Since $V_x = V_y$ for the 45 degree path, this ratio simplifies directly to 0.95, so the actual mm/min speeds do not even need to be calculated.

Step 3: Applying this ratio at X = 180 mm:

$$Y_{actual} = 0.95 \times X_{actual} = 0.95 \times 180 = 171 \text{ mm}$$

On the intended 45 degree path, when X = 180 mm, Y should also be 180 mm.
So the error is:

$$Error = 180 - 171 = 9 \text{ mm}$$

Final Answer:
The Y-axis positional error works out to the same 9 mm with this shortcut, confirming the answer.

$$\boxed{9 \text{ mm}}$$

Quick Tip: Split the feed into X and Y components; X stays unaffected by the error so use it to find time, then find the actual Y distance travelled in that time.

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 cm^2 s^{-1}; assume π = 3.14.

Correct Answer: 32.1

SOLUTION:

Step 1: Working through the beam radius instead of diameter:
Absorbed power: $P_{abs} = 0.10 \times 1000\ \text{W} = 100\ \text{W}$.
Beam radius: $r = 0.05\ \text{mm} = 0.005\ \text{cm}$.

Step 2: Heat flux from the radius:

Using area as πr^2 instead of $\frac{\pi}{4}d^2$, which gives the same value through a different route:

$$A = \pi r^2 = 3.14 \times (0.005)^2 = 3.14 \times 2.5 \times 10^{-5} = 7.85 \times 10^{-5}\ \text{cm}^2$$

$$H = \frac{100}{7.85 \times 10^{-5}} = 1.274 \times 10^6\ \text{W/cm}^2$$

This matches the diameter based route exactly, confirming the area calculation.

Step 3: Building the bracket term step by step:

Temperature difference: $\Delta\theta = 3400 - 32 = 3368°\text{C}$.

$$\frac{\Delta\theta \cdot k}{2H} = \frac{3368 \times 2.15}{2 \times 1.274 \times 10^6} = \frac{7241.2}{2.548 \times 10^6} = 2.842 \times 10^{-3}$$

Squaring this ratio:

$$\left(2.842 \times 10^{-3}\right)^2 = 8.077 \times 10^{-6}$$

$$\frac{\pi}{\alpha} = \frac{3.14}{0.79} = 3.975$$

$$t_m = 3.975 \times 8.077 \times 10^{-6} = 3.211 \times 10^{-5}\ \text{s} = 32.11\ \mu s$$

Final Answer:

Rounding to one decimal place, $t_m = 32.1\ \mu s$, matching the diameter based calculation.

$$\boxed{32.1\ \mu s}$$

Quick Tip: Convert all lengths to cm to match the given thermal conductivity and diffusivity units, then substitute directly into the given formula.

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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).

Correct Answer: 1.00

SOLUTION:

Step 1: An alternate route through the graph length:
Instead of applying both magnifications together in one shot, let us first work out how long the trace is on paper, then how tall it is on average, and only then scale down to the real surface.

Step 2: Length of the trace on the graph paper:

The real sampling length is 0.8 mm, and it was stretched by the horizontal magnification of 100:

$$L_{graph} = 0.8 \times 100 = 80 \text{ mm}$$

Step 3: Average height on the graph, then scale down:

Total enclosed area on the graph, above and below the line together:

$$\sum A = (140 + 60 + 150 + 50) + (70 + 50 + 120 + 160) = 400 + 400 = 800 \text{ mm}^2$$

Average height on the graph is area divided by graph length:

$$h_{graph} = \frac{800}{80} = 10 \text{ mm}$$

This 10 mm is the roughness height as blown up by the vertical magnification alone, so it must be divided back down:

$$R_a = \frac{h_{graph}}{V_{mag}} = \frac{10}{10000} = 0.001 \text{ mm}$$

Final Answer:

0.001 mm equals 1.00 μm, matching the direct formula method.

$$\boxed{1.00\ \mu m}$$

Quick Tip: Add all the areas above and below the datum line, then divide by the true length times both magnifications to get Ra directly in mm.

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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 $\pi = 3.14$.

Correct Answer: 0.25

SOLUTION:

Step 1: Combining everything into a single formula first:

Instead of calculating stress and then strain in separate stages, let us combine the definitions into one expression before touching numbers:

$$\nu = \frac{\epsilon_{lateral}}{\epsilon_{axial}} = \frac{\Delta D/D}{F/(AE)} = \frac{\Delta D \cdot A \cdot E}{D \cdot F}$$

Step 2: Filling in the geometry term:

$$A = \frac{\pi}{4}D^2 = \frac{3.14}{4}(10)^2 = 78.5\ \text{mm}^2$$

$D = 10\ \text{mm}$, $\Delta D = 3 \times 10^{-3}\ \text{mm}$, $E = 150{,}000\ \text{MPa}$, $F = 14{,}000\ \text{N}$.

Step 3: Substituting all values into the combined formula at once:

$$\nu = \frac{(3 \times 10^{-3}) \times 78.5 \times 150000}{10 \times 14000}$$

Working out the numerator: $3 \times 10^{-3} \times 78.5 = 0.2355$, then $0.2355 \times 150000 = 35325$.
Working out the denominator: $10 \times 14000 = 140000$.

$$\nu = \frac{35325}{140000} = 0.2523$$

Final Answer:
Rounded to two decimal places, the Poisson's ratio is 0.25, the same result as computing stress and strain in separate steps.

$$\boxed{\nu = 0.25}$$

Quick Tip: Find axial stress from force and area, divide by E to get axial strain, then compare it with the diametral strain (change in diameter over diameter).

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.

Correct Answer: 2.5

SOLUTION:

Step 1: Understanding the Concept:
We are asked to size a pinion module using the Lewis bending-strength equation for gear teeth.
The face width is fixed as a multiple of the module ($b = 10m$), so the unknowns reduce to a single variable, the module itself.

Step 2: Key Formula or Approach:
Instead of substituting numbers step by step, first combine the torque relation and the Lewis equation into a single design formula.
From torque: $T = F_t \cdot \frac{d}{2} = F_t \cdot \frac{zm}{2}$, so $F_t = \frac{2T}{zm}$.
From the Lewis equation: $F_t = \sigma(cm)Ym = \sigma Y c\, m^2$, where $b = cm$ and here $c = 10$.
Equating the two gives a single closed-form design equation:

$$m^3 = \frac{2T}{\sigma Y c z}$$

Step 3: Detailed Explanation:

Substitute the known values directly into this single formula: T = 95000 N-mm, $\sigma = 180$ N/mm^2, $Y = 0.342$, $c = 10$, $z = 20$.

$$m^3 = \frac{2 \times 95000}{180 \times 0.342 \times 10 \times 20}$$

$$m^3 = \frac{190000}{12312}$$

$$m^3 = 15.432$$

Taking the cube root gives $m = 2.4897$ mm, which rounds to 2.5 mm.

Final Answer:

The pinion needs a module of 2.5 mm to safely carry the specified torque.

$$\boxed{m = 2.5 \text{ mm}}$$

Quick Tip: Use the Lewis equation $F_t = \sigma b Y m$ with $b = 10m$, and relate the tangential force to torque through $F_t = 2T/d$ where $d = zm$.

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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).

Correct Answer: 2667

SOLUTION:

Step 1: Understanding the Concept:
We need the Break-Even Point (BEP) in units. Since the selling price is not stated directly, we first find it from the profit condition given in the problem.

Step 2: Key Formula or Approach:
Total Cost, $TC = FC + v \times Q$.
Total Revenue, $TR = P \times Q$.
Profit $= TR - TC$, and break-even quantity $= \dfrac{FC}{P - v}$.

Step 3: Detailed Explanation:
First compute the total cost at the given sales volume of 5000 units:

$$TC = 300000 + (150 \times 5000) = 300000 + 750000 = 1050000$$

Since profit is 20% of revenue, the cost portion is the remaining 80% of revenue:

$$0.8 \times TR = TC = 1050000$$

$$TR = \frac{1050000}{0.8} = 1312500$$

The selling price per unit is then:

$$P = \frac{TR}{Q} = \frac{1312500}{5000} = 262.5$$

Now the break-even quantity:

$$Q_{BEP} = \frac{300000}{262.5 - 150} = \frac{300000}{112.5} = 2666.67$$

Final Answer:

Rounding off to the nearest integer, the break-even quantity is 2667 units.

$$\boxed{Q_{BEP} = 2667 \text{ units}}$$

Quick Tip: First find the selling price per unit using the given profit percentage of revenue, then apply the break-even formula: Fixed Cost divided by (Selling Price minus Variable Cost).

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:

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).

Correct Answer: 0

SOLUTION:

Step 1: Understanding the Concept:

Before running any optimization, always check whether the constraints actually describe the problem the way you would expect.

Here the intern's model looks like a transportation problem, but a small sign error changes its meaning completely.

Step 2: Key Formula or Approach:
In a proper transportation problem the demand side must be written as an equality or a "greater than or equal to" constraint, $\sum_i X_{ij} \geq D_j$ or $= D_j$, to force the markets to actually receive their oil.
The intern instead wrote $\sum_i X_{ij} \leq D_j$, an upper limit.
Since the objective is Minimize $Z = \sum C_{ij}X_{ij}$ with all $C_{ij} > 0$ and $X_{ij} \geq 0$, the smallest possible value any variable can take is zero, and zero never violates a "less than or equal to" bound.

Step 3: Detailed Explanation:
Because every cost is positive, Z is a non-negative combination of the decision variables, so $Z \geq 0$ for any feasible point, meaning zero is a lower bound on the objective.
This lower bound is actually reachable, because setting all four variables to zero, $X_{11} = X_{12} = X_{21} = X_{22} = 0$, does not violate any constraint: the capacities 500 and 600 are not exceeded, the demand upper bounds 300 and 400 are not exceeded, and non-negativity holds trivially.
Since the lower bound $Z \geq 0$ is attained by a feasible point, it must be the optimal value:

$$Z^* = \min\left(250X_{11} + 280X_{12} + 150X_{21} + 180X_{22}\right) = 0$$

Final Answer:
Because the demand constraint only caps supply instead of requiring it, the true optimum of the flawed model is 0.

$$\boxed{Z^* = 0}$$

Quick Tip: Check the direction of the demand constraint carefully. A "less than or equal to" sign on demand does not force any oil to actually be delivered.

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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.

Correct Answer: 2

SOLUTION:

Step 1: Understanding the Concept:

We need to build the actual clock-time schedule that results from the SPT rule and then compare each program's finish time with its promised due date.

Step 2: Key Formula or Approach:

SPT rule: sort programs in increasing order of processing time.

Processing times: Program 2 (40) < Program 1 (60) < Program 3 (90) < Program 4 (100).

So the run sequence is: 2, then 1, then 3, then 4.

A program is tardy only if its actual completion clock time is later than its promised due date.

Step 3: Detailed Explanation:

The server starts at 10:00 am and runs one program after another with no gaps.

Program 2 runs first: starts 10:00 am, takes 40 minutes, finishes at 10:40 am. Due date is 11:30 am, so it is on time.

Program 1 runs next: starts 10:40 am, takes 60 minutes, finishes at 11:40 am. Due date is 12:00 noon, so it is on time.

Program 3 runs next: starts 11:40 am, takes 90 minutes, finishes at 1:10 pm. Due date is 1:00 pm, so it is 10 minutes late, tardy.

Program 4 runs last: starts 1:10 pm, takes 100 minutes, finishes at 2:50 pm. Due date is 1:30 pm, so it is 1 hour 20 minutes late, tardy.

Final Answer:

Two programs, numbers 3 and 4, finish after their promised times.

$$\boxed{\text{Number of tardy jobs} = 2}$$

Quick Tip: Arrange the programs in increasing order of processing time, compute each program's completion time by adding processing times cumulatively from 10:00 am, and compare each with its due date.

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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).

Correct Answer: 14.78

SOLUTION:

Step 1: Understanding the Concept:

We need to solve a first order ordinary differential equation from scratch using the initial condition given, rather than quoting a memorized formula.

Step 2: Key Formula or Approach:

The equation $\frac{dy}{dt} = 2y$ can be solved by the method of separation of variables, moving all the y terms to one side and all the t terms to the other.

Step 3: Detailed Explanation:

Separate the variables:

$$\frac{dy}{y} = 2\,dt$$

Integrate both sides:

$$\int \frac{1}{y}\,dy = \int 2\,dt$$

$$\ln(y) = 2t + C$$

Apply the initial condition $y = 2$ at $t = 0$ to find C:

$$\ln(2) = 2(0) + C \implies C = \ln(2)$$

So the particular solution is:

$$\ln(y) = 2t + \ln(2)$$

Exponentiate both sides:

$$y = e^{2t+\ln 2} = e^{2t} \cdot e^{\ln 2} = 2e^{2t}$$

Now evaluate at $t = 1$:

$$y(1) = 2e^2 = 2 \times 7.389056 = 14.778112$$

Final Answer:

Rounded off to two decimal places, the value is 14.78.

$$\boxed{y(1) = 14.78}$$

Quick Tip: An equation of the form $dy/dt = ky$ always has the solution $y(t) = y_0 e^{kt}$, where y_0 is the initial value.

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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).

Correct Answer: 0.80

SOLUTION:

Step 1: Understanding the Concept:
We need to calculate the probability of finding 2 or more defects ($X \geq 2$) in a device, given that the distribution is Poisson with an average rate (λ) of 3.

Step 2: Key Formula or Approach:
Instead of summing infinite probabilities from 2 to infinity, we use the complementary probability rule:

$$P(X \geq 2) = 1 - P(X < 2) = 1 - [P(X = 0) + P(X = 1)]$$

Step 3: Detailed Explanation:
Given $\lambda = 3$.
Calculate the probability of exactly 0 defects:

$$P(X = 0) = \frac{e^{-3} \cdot 3^0}{0!} = e^{-3} \approx 0.049787$$

Calculate the probability of exactly 1 defect:

$$P(X = 1) = \frac{e^{-3} \cdot 3^1}{1!} = 3e^{-3} \approx 0.149361$$

Sum these probabilities to find $P(X < 2)$:

$$P(X < 2) = 0.049787 + 0.149361 = 0.199148$$

Finally, find the probability of at least two defects:

$$P(X \geq 2) = 1 - 0.199148 = 0.800852$$

Final Answer:
Rounded off to two decimal places, the probability comes out to be 0.80. Whenever a question asks for "at least" in a Poisson distribution, calculating the complement is usually the fastest and most practical method.

$$\boxed{P(X \geq 2) \approx 0.80}$$

Quick Tip: Use the complement rule: P(X≥2) = 1 - P(0) - P(1) for a Poisson distribution with mean 3.

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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).

Correct Answer: 76

SOLUTION:

Step 1: Understanding the Concept:
We need to calculate the standard time to complete one full job (comprising elements A and B) and then determine how many jobs (units) the worker can produce in exactly one hour.

Step 2: Key Formula or Approach:
Average Observed Time (OT) = Sum of times divided by number of observations.
Normal Time (NT) = OT $\times$ Rating Factor.
Standard Time (ST) = Total NT $\times(1 +$ Allowance Factor$)$.
Output per hour = 3600 seconds divided by ST in seconds.

Step 3: Detailed Explanation:
Element A:
Average OT = $\frac{20+25+21}{3} = \frac{66}{3} = 22$ seconds.

Normal Time (NT_A) = $22 \times 1.05 = 23.1$ seconds.

Element B:

Average OT = $\frac{19+17+18}{3} = \frac{54}{3} = 18$ seconds.

Normal Time (NT_B) = $18 \times 0.90 = 16.2$ seconds.

Total Job:

Total Normal Time = $23.1 + 16.2 = 39.3$ seconds.

Adding 20% allowance to the total Normal Time gives the Standard Time:

$$ST = 39.3 \times (1 + 0.20) = 39.3 \times 1.2 = 47.16 \text{ seconds/unit}$$

Production Output:

Total time available in an hour = 3600 seconds.

$$\text{Units per hour} = \frac{3600}{47.16} = 76.335 \text{ units}$$

Final Answer:

Since we require the integer value, the output is 76 units per hour. Apply the rating factor to the average observed time for each individual element before adding them up, applying an average rating factor to the total time would give an incorrect result.

$$\boxed{76 \text{ units per hour}}$$

Quick Tip: Find normal time for each element, add allowance, then convert standard time per unit into units produced per hour.

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).

Correct Answer: 0.006

SOLUTION:

Step 1: Understanding the Concept:

We need to calculate the clearance between a specific mating condition of a hole and a shaft. Clearance is the empty space between them, given by (Hole size minus Shaft size).

Step 2: Key Definitions:

Minimum Material Condition (LMC) is the size limit that contains the least amount of material. For a shaft, this is its smallest allowed diameter.

Maximum Material Condition (MMC) is the size limit that contains the most amount of material. For a hole, this is its smallest allowed diameter, since adding more material shrinks the hole.

Step 3: Detailed Explanation:

Identify the limits for the shaft:

Maximum Shaft = $22 + 0.075 = 22.075$ mm.

Minimum Shaft = $22 + 0.004 = 22.004$ mm.

The Shaft at LMC (least material) is its smallest size, 22.004 mm.

Identify the limits for the hole:

Maximum Hole = $22 + 0.018 = 22.018$ mm.

Minimum Hole = $22 + 0.010 = 22.010$ mm.
The Hole at MMC (most material) is its smallest size, 22.010 mm.
Calculate the specific clearance under these conditions:

$$\text{Clearance} = \text{Hole Size (MMC)} - \text{Shaft Size (LMC)}$$

$$\text{Clearance} = 22.010 - 22.004 = 0.006 \text{ mm}$$

Final Answer:
The magnitude of the clearance is 0.006 mm. For a hole, MMC is the minimum diameter and LMC is the maximum diameter, while for a shaft it is the opposite: MMC is the maximum diameter and LMC is the minimum diameter.

$$\boxed{\text{Clearance} = 0.006 \text{ mm}}$$

Quick Tip: MMC hole is the smallest hole size; LMC shaft is the smallest shaft size. Clearance is the difference between them.

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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.

Correct Answer: 9

SOLUTION:

Step 1: Understanding the Concept:
We have a three-station sequential assembly line operating with dedicated workers. We need to determine the total production output over a 6 hour period running in a steady state.

Step 2: Key Formula or Approach:
In a sequential assembly line, the overall pace of production is entirely dictated by the slowest activity. This slowest step is known as the bottleneck.
The cycle time (C) of the entire line equals the activity time of the bottleneck.

$$\text{Throughput} = \frac{\text{Total Available Time}}{\text{Cycle Time}}$$

Step 3: Detailed Explanation:

Identify the bottleneck activity:

Cutting = 30 mins.

Welding = 40 mins.

Polishing = 25 mins.

The longest activity is Welding (40 minutes). Therefore, the cycle time of the entire assembly line is 40 minutes per item. This means in steady state, a completed item drops off the end of the line exactly every 40 minutes.

Calculate the total available time:

$$6 \text{ hours} = 6 \times 60 = 360 \text{ minutes}$$

Calculate total production:

$$\text{Total Items} = \frac{360 \text{ minutes}}{40 \text{ minutes/item}} = 9 \text{ items}$$

Final Answer:

The total number of items coming out of the assembly line is 9. The phrase "running in steady state" means you do not need to account for the initial transient fill up time of the empty assembly line, you simply divide the total time by the bottleneck time.

$$\boxed{9 \text{ items}}$$

Quick Tip: The slowest activity (largest time per item) sets the pace of the whole assembly line.

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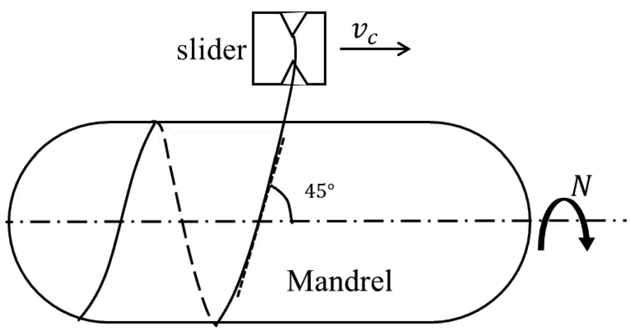
65. In the composite filament winding process as shown in the figure, the mandrel diameter is 700 mm and is rotating at a speed, $N = 6$ rev/min. If a 45° helical winding angle is needed, the axial velocity, v_c, of the slider should be ________ m/s (rounded off to two decimal places).
Assume $\pi =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



Note: Figure is not to scale

Note: Figure is not to scale.

Correct Answer: 0.22

SOLUTION:

Step 1: Understanding the Question:

In a filament winding process, a continuous fibre is wound onto a rotating mandrel. The angle of the fibre (helical angle) results from the combined vector velocities of the rotating mandrel surface and the linearly translating slider feeding the fibre.

Step 2: Key Formula or Approach:

If the helical winding angle relative to the axis of rotation is α, the relationship is:

$$\tan(\alpha) = \frac{\text{Surface velocity of mandrel}}{\text{Axial velocity of slider}} = \frac{V_m}{v_c}$$

Surface velocity $V_m = \pi DN$.

Step 3: Detailed Explanation:

Given data:

Mandrel diameter $D = 700 \text{ mm} = 0.7 \text{ m}$.

Rotational speed $N = 6 \text{ rev/min}$.

Helical angle $\alpha = 45^\circ$.

$\pi = \frac{22}{7}$.

First, calculate the circumferential surface velocity of the mandrel:

$$V_m = \pi DN = \left(\frac{22}{7}\right) \times 0.7 \times 6$$

$$V_m = 22 \times 0.1 \times 6 = 13.2 \text{ m/min}$$

Now, apply the velocity vector relationship to find v_c:

$$\tan(45^\circ) = \frac{13.2}{v_c}$$

Since $\tan(45^\circ) = 1$:

$$1 = \frac{13.2}{v_c} \implies v_c = 13.2 \text{ m/min}$$

The question requires the velocity in m/s. Convert the units:

$$v_c = \frac{13.2 \text{ m}}{60 \text{ s}} = 0.22 \text{ m/s}$$

Final Answer:

The required axial velocity is 0.22 m/s. Be careful with the definition of the winding angle in the diagram, sometimes it is defined relative to the transverse plane instead of the axial plane. Here at 45 degrees the tangent is 1 regardless, making it foolproof, but for other angles like 30 or 60 degrees, verify which axis the angle is drawn against.

$$\boxed{v_c = 0.22 \text{ m/s}}$$

Quick Tip: Surface velocity of the mandrel equals πDN; relate it to slider speed using tan of the winding angle.