GATE 2024 Textile Engineering and Fibre Science Question Paper with Solutions

Total Time Allowed : 3 hours	Maximum Marks : 100	Total Questions : 65

General Instructions

Read the following instructions very carefully and strictly follow them:

This question paper is divided into three sections:
1. The total duration of the examination is 3 hours.
2. The total number of questions is **65**, carrying a maximum of **100 marks**.
3. The marking scheme is as follows:
(i) For 1-mark MCQs, $\frac{1}{3}$ mark will be deducted for every incorrect response.
(ii) For 2-mark MCQs, $\frac{2}{3}$ mark will be deducted for every incorrect response.
(iii) No negative marking for numerical answer type (NAT) questions.
4. No marks will be awarded for unanswered questions.
5. Follow the instructions provided during the exam for submitting your answers.

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1. If $\rightarrow$ denotes increasing order of intensity, then the meaning of the words [dry $\rightarrow$ arid $\rightarrow$ parched] is analogous to [diet $\rightarrow$ fast $\rightarrow$ ____]. Which one of the given options is appropriate to fill the blank?

(A) starve
(B) reject
(C) feast
(D) deny

Correct Answer: (A) starve

Solution:

Step 1: Understanding the Concept:
This question presents an analogy, which is a comparison between two things, typically for the purpose of explanation or clarification. The relationship between the first set of words must be mirrored in the second set.

Step 2: Detailed Explanation:
First, we need to analyze the relationship in the given example: [dry $\rightarrow$ arid $\rightarrow$ parched].

- **Dry:** Lacking moisture.
- **Arid:** Extremely dry, having little or no rain.
- **Parched:** Dried out with heat; extremely thirsty.

The sequence shows an increasing intensity of dryness.

Now, we apply the same logic to the second set of words: [diet $\rightarrow$ fast $\rightarrow$ ____].

- **Diet:** To restrict oneself to small amounts or special kinds of food in order to lose weight. This is a form of controlled eating.
- **Fast:** To abstain from all or some kinds of food or drink, especially as a religious observance. This is a higher intensity of food restriction than a diet.

We need a word that represents an even higher intensity of abstaining from food.

Let's evaluate the options:

- **(A) starve:** To suffer or die from hunger. This is the most extreme form of lacking food, fitting the pattern of increasing intensity.
- **(B) reject:** To refuse to accept. This does not fit the context of food consumption intensity.
- **(C) feast:** A large meal, typically a celebratory one. This is the opposite of the established pattern.
- **(D) deny:** To state that one refuses to admit the truth or existence of something. This is irrelevant to the context.

Therefore, 'starve' correctly completes the analogy.

Step 3: Final Answer:
The logical sequence of increasing intensity is diet $\rightarrow$ fast $\rightarrow$ starve. Thus, option (A) is the correct choice.

Quick Tip

For analogy questions, first identify the precise relationship between the words in the given pair (e.g., increasing intensity, cause and effect, part to whole). Then, apply that same relationship to find the missing word in the second pair.

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2. If two distinct non-zero real variables x and y are such that $(x+y)$ is proportional to $(x-y)$, then the value of $\frac{x}{y}$ is:

(A) depends on xy
(B) depends only on x and not on y
(C) depends only on y and not on x
(D) is a constant

Correct Answer: (D) is a constant

Solution:

Step 1: Understanding the Concept:
The term "proportional to" means that one quantity is a constant multiple of another. If A is proportional to B, we can write this relationship as $A \propto B$, which translates to the equation $A = k \cdot B$, where k is the constant of proportionality.

Step 2: Key Formula or Approach:
We are given that $(x+y)$ is proportional to $(x-y)$. We can write this as:

$$(x+y) = k(x-y)$$

where k is a non-zero constant. Our goal is to rearrange this equation to find an expression for the ratio $\frac{x}{y}$.

Step 3: Detailed Explanation:
Starting with the equation from Step 2:

$$x + y = k(x-y)$$

Distribute k on the right-hand side:

$$x + y = kx - ky$$

Now, we want to isolate terms with x on one side and terms with y on the other side.

$$y + ky = kx - x$$

Factor out y from the left side and x from the right side:

$$y(1+k) = x(k-1)$$

To find the ratio $\frac{x}{y}$, we can divide both sides by y and by $(k-1)$. Since x and y are distinct and non-zero, k cannot be 1 (which would imply $y = 0$) or -1 (which would imply $x = 0$).

$$\frac{x}{y} = \frac{1+k}{k-1}$$

Step 4: Final Answer:
The expression for $\frac{x}{y}$ is $\frac{1+k}{k-1}$. Since k is a constant of proportionality, the entire expression $\frac{1+k}{k-1}$ is also a constant. Therefore, the value of $\frac{x}{y}$ is a constant.

> Quick Tip
>
> Whenever you see the phrase "is proportional to," immediately translate it into an equation with a constant of proportionality (k). Then, use algebraic manipulation to solve for the desired variable or ratio.

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3. Consider the following sample of numbers: 9, 18, 11, 14, 15, 17, 10, 69, 11, 13. The median of the sample is

(A) 13.5
(B) 14
(C) 11
(D) 18.7

Correct Answer: (A) 13.5

Solution:

Step 1: Understanding the Concept:
The median is the middle value in a dataset that has been arranged in order of magnitude. If there is an even number of observations, the median is the average of the two middle values.

Step 2: Key Formula or Approach:
1. Arrange the data in ascending (or descending) order.
2. Count the number of observations, n.
3. If n is odd, the median is the $\left(\frac{n+1}{2}\right)^{th}$ value.
4. If n is even, the median is the average of the $\left(\frac{n}{2}\right)^{th}$ and $\left(\frac{n}{2}+1\right)^{th}$ values.

Step 3: Detailed Explanation:
First, let's list the given numbers: 9, 18, 11, 14, 15, 17, 10, 69, 11, 13.
The total number of observations is $n = 10$.

Next, we arrange the numbers in ascending order:

$$9, 10, 11, 11, 13, 14, 15, 17, 18, 69$$

Since $n = 10$ (an even number), the median will be the average of the two middle numbers. The middle positions are:

$$\text{Position 1} = \frac{n}{2} = \frac{10}{2} = 5^{th} \text{ position}$$

$$\text{Position 2} = \frac{n}{2} + 1 = \frac{10}{2} + 1 = 6^{th} \text{ position}$$

Let's find the values at these positions in our sorted list:

- The value at the 5th position is 13.
- The value at the 6th position is 14.

Now, we calculate the average of these two values to find the median:

$$\text{Median} = \frac{13 + 14}{2} = \frac{27}{2} = 13.5$$

Step 4: Final Answer:
The median of the sample is 13.5.

> Quick Tip
>
> The most common mistake when calculating the median is forgetting to sort the data first. Always arrange the numbers in order before finding the middle value. For an even number of data points, remember it's the average of the two central numbers.

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4. The number of coins of 1, 5, and 10 denominations that a person has are in the ratio 5:3:13. Of the total amount, the percentage of money in 5 coins is

(A) 21%
(B) 143%
(C) 10%
(D) 30%

Correct Answer: (C) 10%

Solution:

Step 1: Understanding the Concept:
This problem involves ratios and percentages. We are given the ratio of the *number* of coins, not their value. We need to calculate the total value of money and then find what percentage of that total value comes from the 5-denomination coins.

Step 2: Key Formula or Approach:
1. Let the number of coins of each denomination be represented by the ratio multiplied by a common factor, k.
2. Calculate the monetary value for each denomination by multiplying the number of coins by their respective denomination value.
3. Calculate the total monetary value.
4. Use the percentage formula: Percentage $= \left(\frac{\text{Value from 5-denomination coins}}{\text{Total Value}}\right) \times 100\%$.

Step 3: Detailed Explanation:
Let the common factor for the ratio be k.
The ratio of the number of coins (1:5:10) is 5:3:13.

- Number of 1-denomination coins $= 5k$
- Number of 5-denomination coins $= 3k$
- Number of 10-denomination coins $= 13k$

Now, let's calculate the value contributed by each type of coin:

- Value from 1-denomination coins $= 1 \times 5k = 5k$
- Value from 5-denomination coins $= 5 \times 3k = 15k$
- Value from 10-denomination coins $= 10 \times 13k = 130k$

The total amount of money is the sum of these values:

$$\text{Total Amount} = 5k + 15k + 130k = 150k$$

We need to find the percentage of the total amount that is in 5-denomination coins. The value from these coins is $15k$.

$$\text{Percentage} = \left(\frac{\text{Value from 5-denomination coins}}{\text{Total Amount}}\right) \times 100\%$$

$$\text{Percentage} = \left(\frac{15k}{150k}\right) \times 100\%$$

The k cancels out:

$$\text{Percentage} = \left(\frac{15}{150}\right) \times 100\% = \frac{1}{10} \times 100\% = 10\%$$

Step 4: Final Answer:
The percentage of money in 5-denomination coins is 10%.

Quick Tip

Be careful to distinguish between the ratio of the number of items and the ratio of their values. Always calculate the values first before finding the total amount and percentages.

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5. For positive non-zero real variables p and q, if $\log(p^2 + q^2) = \log p + \log q + 2\log 3$, then, the value of $\frac{p^2+q^2}{pq}$ is

(A) 79
(B) 81
(C) 9
(D) 83

Correct Answer: (C) 9

Solution:

Step 1: Understanding the Concept:
This problem requires the application of fundamental logarithm properties to simplify a given equation and solve for the value of a specific expression.

Step 2: Key Formula or Approach:
We will use the following logarithm rules:

- **Product Rule:** $\log a + \log b = \log(ab)$
- **Power Rule:** $c \log a = \log(a^c)$

The basic principle we will use is that if $\log(X) = \log(Y)$, then $X = Y$.

Step 3: Detailed Explanation:
We are given the equation:

$$\log(p^2 + q^2) = \log p + \log q + 2\log 3$$

Let's simplify the right-hand side (RHS) of the equation using the logarithm rules.
First, apply the power rule to the last term:

$$2\log 3 = \log(3^2) = \log 9$$

Now the RHS is:

$$\text{RHS} = \log p + \log q + \log 9$$

Next, apply the product rule to combine all terms on the RHS:

$$\text{RHS} = \log(p \cdot q \cdot 9) = \log(9pq)$$

So, our original equation becomes:

$$\log(p^2 + q^2) = \log(9pq)$$

Since the logarithms on both sides are equal (and have the same base), their arguments must be equal:

$$p^2 + q^2 = 9pq$$

The question asks for the value of the expression $\frac{p^2+q^2}{pq}$.
We can substitute the result we just found ($p^2 + q^2 = 9pq$) into this expression:

$$\frac{p^2 + q^2}{pq} = \frac{9pq}{pq}$$

The term pq cancels out from the numerator and the denominator.

$$\frac{9pq}{pq} = 9$$

Step 4: Final Answer:
The value of the expression $\frac{p^2+q^2}{pq}$ is 9.

> Quick Tip
>
> When you see an equation with multiple log terms, the first step is almost always to use the log rules to combine them into a single log term on each side of the equation. This allows you to eliminate the logs and work with a simpler algebraic expression.

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6. In the given text, the blanks are numbered (i)-(iv). Select the best match for all the blanks. Steve was advised to keep his head ..(i).. before heading ..(ii).. to bat; for, while he had a head ..(iii).. batting, he could only do so with a cool head ..(iv).. his shoulders.

(A) (i) down, (ii) down, (iii) on, (iv) for
(B) (i) on, (ii) down, (iii) for, (iv) on
(C) (i) down, (ii) out, (iii) for, (iv) on
(D) (i) on, (ii) out, (iii) on, (iv) for

Correct Answer: (C) (i) down, (ii) out, (iii) for, (iv) on

Solution:

Step 1: Understanding the Concept:
This question tests your knowledge of common English idioms and phrasal verbs, particularly those involving the word "head". We need to choose the set of prepositions that

correctly fits into all four blanks to make the sentence grammatically and idiomatically correct.

Step 2: Detailed Explanation:
Let's analyze each blank and the corresponding idiom:

- **Blank (i): "keep his head (i)..."**
  The idiom **"keep your head down"** means to remain calm and focused, or to avoid attracting attention. This fits the context of getting advice before a high-pressure activity like batting. So, (i) should be **down**.

- **Blank (ii): "heading (ii).. to bat"**
  The phrasal verb **"heading out"** means to leave a place to go somewhere else. "Heading out to bat" is a common phrase in sports like cricket or baseball. So, (ii) should be **out**.

- **Blank (iii): "he had a head (iii).. batting"**
  The idiom **"to have a head for something"** means to have a natural talent or aptitude for it. In this context, "a head for batting" means he is a naturally good batsman. So, (iii) should be **for**.

- **Blank (iv): "a cool head (iv).. his shoulders"**
  The idiom **"to have a cool head on one's shoulders"** means to be calm, sensible, and level-headed, especially in difficult situations. So, (iv) should be **on**.

Step 3: Final Answer:
Combining our findings, the correct words are: (i) down, (ii) out, (iii) for, (iv) on. This corresponds to option (C).

The complete sentence reads: "Steve was advised to keep his head **down** before heading **out** to bat; for, while he had a head **for** batting, he could only do so with a cool head **on** his shoulders."

Quick Tip
When tackling fill-in-the-blanks questions with multiple blanks, evaluate each blank individually based on common phrases and idioms. Then, check if your chosen words match one of the given options completely.

7. A rectangular paper sheet of dimensions 54 cm x 4 cm is taken. The two longer edges of the sheet are joined together to create a cylindrical tube. A cube whose surface area is equal to the area of the sheet is also taken. Then, the ratio of the volume of the cylindrical tube to the volume of the cube is:

(A) $\frac{1}{\pi}$
(B) $\frac{2}{\pi}$
(C) $\frac{3}{\pi}$
(D) $\frac{4}{\pi}$

Correct Answer: (A) $\frac{1}{\pi}$

Solution:

Step 1: Understanding the Concept:
The problem involves comparing the volumes of two different 3D shapes: a cylinder and a cube. The dimensions of these shapes are derived from a given rectangular sheet. We need to calculate the volume of each shape based on the information provided and then find their ratio.

Step 2: Key Formula or Approach:
We will use the following standard formulas from mensuration:

- Area of a rectangle: $A_{rect} = \text{length} \times \text{width}$
- For a cylinder with radius r and height h:
  - Circumference of the base: $C = 2\pi r$
  - Volume: $V_{cyl} = \pi r^2 h$
- For a cube with side length a:
  - Total Surface Area: $A_{cube} = 6a^2$
  - Volume: $V_{cube} = a^3$

Step 3: Detailed Explanation:
Part 1: Calculate the volume of the cylindrical tube.
The dimensions of the rectangular sheet are given as 54 cm $\times$ 4 cm.
The sheet is formed into a cylinder by joining the two longer edges. This means: - The height of the cylinder (h) will be the length of the longer edge, so $h = 54$ cm.
- The circumference of the base of the cylinder (C) will be the length of the shorter edge, so $C = 4$ cm.

Now, we find the radius (r) of the cylinder's base using the circumference formula:

$$C = 2\pi r$$

$$4 = 2\pi r$$
$$r = \frac{4}{2\pi} = \frac{2}{\pi} \text{ cm}$$

Next, we calculate the volume of the cylinder (V_{cyl}):

$$V_{cyl} = \pi r^2 h$$

$$V_{cyl} = \pi \left(\frac{2}{\pi}\right)^2 (54)$$

$$V_{cyl} = \pi \left(\frac{4}{\pi^2}\right) (54)$$

$$V_{cyl} = \frac{4 \times 54}{\pi} = \frac{216}{\pi} \text{ cm}^3$$

Part 2: Calculate the volume of the cube.

The surface area of the cube (A_{cube}) is equal to the area of the rectangular sheet (A_{rect}). First, calculate the area of the sheet:

$$A_{rect} = 54 \text{ cm} \times 4 \text{ cm} = 216 \text{ cm}^2$$

So, the surface area of the cube is $A_{cube} = 216 \text{ cm}^2$.

Now, we find the side length (a) of the cube using the surface area formula:

$$A_{cube} = 6a^2$$

$$216 = 6a^2$$

$$a^2 = \frac{216}{6} = 36$$

$$a = \sqrt{36} = 6 \text{ cm}$$

Next, we calculate the volume of the cube (V_{cube}):

$$V_{cube} = a^3 = (6)^3 = 216 \text{ cm}^3$$

Part 3: Find the ratio of the volumes.

The required ratio is $\frac{\text{Volume of cylindrical tube}}{\text{Volume of the cube}}$.

$$\text{Ratio} = \frac{V_{cyl}}{V_{cube}} = \frac{216/\pi}{216}$$

$$\text{Ratio} = \frac{216}{\pi} \times \frac{1}{216} = \frac{1}{\pi}$$

Step 4: Final Answer:

The ratio of the volume of the cylindrical tube to the volume of the cube is $\frac{1}{\pi}$. This matches option (A).

💡 Quick Tip

When a rectangle is rolled to form a cylinder, it's crucial to identify which side becomes the height and which becomes the circumference. If the longer sides are joined, the longer side is the height, and the shorter side is the circumference. If the shorter sides were joined, the roles would be reversed. Read the problem carefully to avoid this common mistake.

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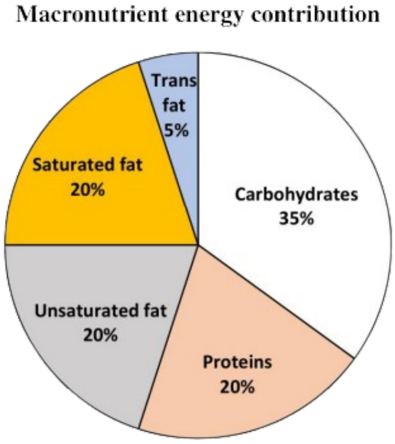
8. The pie chart presents the percentage contribution of different macronutrients to a typical 2,000 kcal diet of a person.



The typical energy density (kcal/g) of these macronutrients is given in the table. The total fat (all three types), in grams, this person consumes is

Macronutrient	Energy density (kcal/g)
Carbohydrates	4
Proteins	4
Unsaturated fat	9
Saturated fat	9
Trans fat	9

(A) 44.4
(B) 77.8
(C) 100
(D) 3,600

Correct Answer: (C) 100

Solution:

Step 1: Understanding the Concept:
This is a data interpretation question that requires combining information from a pie chart and a table. We need to first find the total energy (in kcal) contributed by fat and then convert this energy into mass (in grams) using the given energy density.

Step 2: Key Formula or Approach:
1. Find the total percentage of energy from all types of fat from the pie chart.
2. Calculate the total energy from fat in kcal: Total Energy (kcal) = (Total % from fat / 100) × Total diet kcal.
3. Use the energy density from the table to convert kcal to grams: Total Mass (g) = Total Energy from fat (kcal) / Energy Density (kcal/g).

Step 3: Detailed Explanation:
First, let's find the total percentage contribution from fat using the pie chart. The pie chart shows three types of fat:

- Saturated fat: 20%
- Unsaturated fat: 20%
- Trans fat: 5%

Total percentage from fat = 20% + 20% + 5% = 45%.

Next, let's calculate the total energy (in kcal) from fat based on a 2,000 kcal diet.

$$\text{Energy from fat} = 45\% \text{ of } 2000 \text{ kcal}$$

$$\text{Energy from fat} = \frac{45}{100} \times 2000 = 0.45 \times 2000 = 900 \text{ kcal}$$

Finally, we need to convert this energy into grams. The table provides the energy density for all types of fat as 9 kcal/g.

$$\text{Total fat in grams} = \frac{\text{Total energy from fat (kcal)}}{\text{Energy density of fat (kcal/g)}}$$

$$\text{Total fat in grams} = \frac{900 \text{ kcal}}{9 \text{ kcal/g}} = 100 \text{ g}$$

Step 4: Final Answer:
The total amount of fat consumed by the person is 100 grams.

Quick Tip
In data interpretation questions, carefully read the question to understand exactly what is being asked for. Pay close attention to the units (e.g., kcal vs. grams) and make sure your final answer is in the required unit.

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9. A rectangular paper of 20 cm x 8 cm is folded 3 times. Each fold is made along the line of symmetry, which is perpendicular to its long edge. The perimeter of the final folded sheet (in cm) is

(A) 18
(B) 24
(C) 20
(D) 21

Correct Answer: (A) 18

Solution:

Step 1: Understanding the Concept:
This is a spatial reasoning problem. We need to track the dimensions of a rectangular sheet of paper as it is folded sequentially. The key is to correctly identify the "long edge" at each step and fold perpendicular to it.

Step 2: Key Formula or Approach:
The perimeter of a rectangle is given by the formula $P = 2 \times (\text{length} + \text{width})$. We will apply this formula after determining the final dimensions of the paper after three folds.

Step 3: Detailed Explanation:
Let's trace the dimensions of the paper through each fold.

Initial State:

- Dimensions: 20 cm $\times$ 8 cm.
- The long edge is 20 cm.

Fold 1:

- The fold is along the line of symmetry perpendicular to the long edge (the 20 cm side). This means we fold the 20 cm side in half.
- New length = $20/2 = 10$ cm.
- The width remains unchanged.
- Dimensions after Fold 1: 10 cm $\times$ 8 cm.

Fold 2:

- We now consider the current sheet (10 cm $\times$ 8 cm). The long edge is now 10 cm.
- The fold is along the line of symmetry perpendicular to this new long edge. We fold the 10 cm side in half.

- New length $= 10/2 = 5$ cm.
- The width remains unchanged.
- Dimensions after Fold 2: 5 cm $\times$ 8 cm.

Fold 3:

- We now consider the current sheet (5 cm $\times$ 8 cm). The long edge is now 8 cm.
- The fold is along the line of symmetry perpendicular to this new long edge. We fold the 8 cm side in half.
- The 5 cm side remains unchanged.
- New width $= 8/2 = 4$ cm.
- Final Dimensions after Fold 3: 5 cm $\times$ 4 cm.

Final Perimeter Calculation: Now, we calculate the perimeter of the final 5 cm $\times$ 4 cm rectangle.

$$P = 2 \times (\text{length} + \text{width})$$
$$P = 2 \times (5 + 4)$$
$$P = 2 \times 9 = 18 \text{ cm}$$

Step 4: Final Answer:
The perimeter of the final folded sheet is 18 cm.

> Quick Tip
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> For geometry problems involving sequential actions like folding, it's very helpful to draw a small sketch for each step. This helps you visualize the changes in dimensions and orientation, reducing the chance of errors.

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10. The least number of squares to be added in the figure to make AB a line of symmetry is:

(A) 2
(B) 3
(C) 4
(D) 5

Correct Answer: (C) 4

Solution:

Step 1: Understanding the Concept:
The question asks for the minimum number of squares to add to a given figure to make it symmetrical about the line AB. A figure is symmetrical about a line if the part of the figure on one side of the line is a mirror image (reflection) of the part on the other side. The final figure must contain all the original squares.

Step 2: Detailed Explanation:
Let's analyze the given figure with respect to the line of symmetry AB. The final symmetric figure must contain the original figure and its reflection across the line AB. The number of squares to be added is the number of squares in the reflection that do not overlap with the original figure.

Let's denote the original figure as O. Let O_{above} be the part of the figure above the line AB and O_{below} be the part below the line AB.
- O_{above} consists of one square on the left side.
- O_{below} consists of a column of two squares on the left and an L-shape of three squares on the right. In total, there are 5 squares below the line.

To make the figure symmetric, the part above the line must be a mirror image of the part below it, and vice-versa. Let the final symmetric figure be S. The smallest such S is the union of the original figure O and its reflection O' across AB. So, $S = O \cup O'$.
The squares to be added are those in S but not in O, which is equivalent to finding the parts of the reflection O' that don't overlap with O.

1. **Reflecting the bottom part upwards:** The 5 squares of O_{below} are reflected to a new shape, let's call it R_{below}, above the line AB.
- The column of two squares on the left (below AB) reflects to a column of two squares above AB. The original figure already has the lower of these two squares (O_{above}). So, we need to add **1** new square on top.
- The L-shape of three squares on the right (below AB) reflects to an inverted L-shape of three squares above AB. There are no squares in the original figure at this position above the line. So, we need to add all **3** of these squares.
- Total squares to add above the line AB = 1 + 3 = 4.

2. **Reflecting the top part downwards:** The 1 square of O_{above} is reflected to a new shape, R_{above}, below the line AB.
- This reflected square corresponds to the top square of the two-square column already present on the left side below AB. Since this square already exists in O_{below}, no new squares need to be added below the line.

Combining these, the total number of squares to be added is 4, all of which are added above the line AB to complete the symmetry.

Step 3: Final Answer:

The least number of squares to be added to make the figure symmetric about line AB is 4.

💡 Quick Tip

For symmetry problems, imagine folding the paper along the line of symmetry. The shapes on both sides must overlap perfectly. Alternatively, for each square on one side, check if its mirror image exists on the other side. If not, you need to add it.

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11. The approximate value of the integral $\int_2^3 \frac{dx}{x}$ using Simpson's rule with $h = 0.5$ is:

(A) 0.12
(B) 0.19
(C) 0.41
(D) 0.58

Correct Answer: (C) 0.41

Solution:

Step 1: Understanding the Concept:
The problem requires us to find the approximate value of a definite integral using a numerical method called Simpson's 1/3 rule. This rule approximates the area under a curve by fitting parabolas to segments of the curve, which generally provides a more accurate result than methods like the Trapezoidal rule.

Step 2: Key Formula or Approach:
Simpson's 1/3 rule is given by the formula:

$$\int_a^b f(x)\,dx \approx \frac{h}{3}[y_0 + 4y_1 + 2y_2 + 4y_3 + \cdots + 4y_{n-1} + y_n]$$

where n is the number of subintervals (which must be even), $h = \frac{b-a}{n}$ is the step size, and $y_i = f(x_i)$.

Step 3: Detailed Explanation:
First, we identify the given parameters from the question: - The function to integrate is $f(x) = \frac{1}{x}$.
- The lower limit of integration is $a = 2$.
- The upper limit of integration is $b = 3$.
- The step size is $h = 0.5$.

Next, we calculate the number of subintervals, n:

$$n = \frac{b-a}{h} = \frac{3-2}{0.5} = \frac{1}{0.5} = 2$$

Since $n = 2$ is an even number, we can proceed with Simpson's rule. We need to evaluate the function at $n + 1 = 3$ points: x_0, x_1, x_2.

The points are calculated as: - $x_0 = a = 2$
- $x_1 = a + h = 2 + 0.5 = 2.5$
- $x_2 = a + 2h = 2 + 2(0.5) = 3$ (which is equal to b).

Now, we evaluate the function $f(x) = \frac{1}{x}$ at these points to find the corresponding y values: - $y_0 = f(x_0) = f(2) = \frac{1}{2} = 0.5$
- $y_1 = f(x_1) = f(2.5) = \frac{1}{2.5} = \frac{1}{5/2} = \frac{2}{5} = 0.4$
- $y_2 = f(x_2) = f(3) = \frac{1}{3}$

Now, we substitute these values into Simpson's rule formula for $n = 2$:

$$\int_2^3 \frac{dx}{x} \approx \frac{h}{3}[y_0 + 4y_1 + y_2]$$

Substituting the calculated values:

$$\approx \frac{0.5}{3}\left[0.5 + 4(0.4) + \frac{1}{3}\right]$$

To avoid rounding errors, it is best to work with fractions:

$$\approx \frac{1/2}{3}\left[\frac{1}{2} + 4\left(\frac{2}{5}\right) + \frac{1}{3}\right]$$

$$\approx \frac{1}{6}\left[\frac{1}{2} + \frac{8}{5} + \frac{1}{3}\right]$$

To add the fractions inside the bracket, we find a common denominator, which is 30:

$$\approx \frac{1}{6}\left[\frac{1 \times 15}{30} + \frac{8 \times 6}{30} + \frac{1 \times 10}{30}\right]$$

$$\approx \frac{1}{6}\left[\frac{15 + 48 + 10}{30}\right]$$

$$\approx \frac{1}{6}\left[\frac{73}{30}\right]$$

$$\approx \frac{73}{180}$$

Finally, we convert the fraction to a decimal to compare with the options:

$$\frac{73}{180} \approx 0.40555...$$

Step 4: Final Answer:
The calculated approximate value of the integral is 0.40555.... Comparing this with the given options: (A) 0.12
(B) 0.19
(C) 0.41
(D) 0.58
The value 0.40555... is closest to 0.41. Therefore, the correct option is (C).

Quick Tip

In Simpson's rule, remember the pattern of coefficients: it starts and ends with 1, and alternates between 4 and 2 for the terms in between. For $n = 2$, the simplest case, the pattern is just 1, 4, 1. Always double-check that the number of intervals, n, is even before applying the rule.

---

12. The differential equation $M(x, y)dx + N(x, y)dy = 0$ is exact if:

(A) $\frac{\partial M}{\partial y} = \frac{\partial N}{\partial x}$
(B) $\frac{\partial M}{\partial x} = \frac{\partial N}{\partial y}$
(C) $\frac{\partial M}{\partial y} + \frac{\partial N}{\partial x} = 0$
(D) $\frac{\partial M}{\partial x} + \frac{\partial N}{\partial y} = 0$

Correct Answer: (A) $\frac{\partial M}{\partial y} = \frac{\partial N}{\partial x}$

Solution:

Step 1: Understanding the Concept:
A first-order ordinary differential equation of the form $M(x, y)dx+N(x, y)dy = 0$ is called an **exact differential equation** if there exists a function $f(x, y)$, called the potential function, such that its total differential df is equal to the left-hand side of the equation. That is, $df = M(x, y)dx + N(x, y)dy$.

Step 2: Key Formula or Approach:
The total differential of a function $f(x, y)$ is defined as:

$$df = \frac{\partial f}{\partial x}dx + \frac{\partial f}{\partial y}dy$$

For the equation to be exact, we must have:

$$M(x, y) = \frac{\partial f}{\partial x} \quad \text{and} \quad N(x, y) = \frac{\partial f}{\partial y}$$

By Clairaut's theorem on the equality of mixed partial derivatives (assuming continuity), we have:

$$\frac{\partial^2 f}{\partial y \partial x} = \frac{\partial^2 f}{\partial x \partial y}$$

Substituting M and N gives us the condition for exactness.

Step 3: Detailed Explanation:
Taking the partial derivative of M with respect to y:

$$\frac{\partial M}{\partial y} = \frac{\partial}{\partial y}\left(\frac{\partial f}{\partial x}\right) = \frac{\partial^2 f}{\partial y \partial x}$$

Taking the partial derivative of N with respect to x:

$$\frac{\partial N}{\partial x} = \frac{\partial}{\partial x}\left(\frac{\partial f}{\partial y}\right) = \frac{\partial^2 f}{\partial x \partial y}$$

Since the mixed partial derivatives must be equal, it follows that:

$$\frac{\partial M}{\partial y} = \frac{\partial N}{\partial x}$$

This is the necessary and sufficient condition for the differential equation to be exact.

Step 4: Final Answer:
The differential equation $M(x, y)dx + N(x, y)dy = 0$ is exact if and only if $\frac{\partial M}{\partial y} = \frac{\partial N}{\partial x}$. This matches option (A).

Quick Tip

Memorize this fundamental condition for exactness: The partial derivative of the dx component (M) with respect to the *other* variable (y) must equal the partial derivative of the dy component (N) with respect to *its* other variable (x).

---

13. The value of the integral $\int_0^\infty \frac{dx}{e^x + e^{-x}}$ is:

(A) 0
(B) $\frac{\pi}{4}$
(C) $\frac{\pi}{2}$
(D) π

Correct Answer: (B) $\frac{\pi}{4}$

Solution:

Step 1: Understanding the Concept:
This question asks for the evaluation of an improper integral with an infinite upper limit. The integrand involves exponential functions. The key to solving this integral is to manipulate the integrand into a standard form that can be easily integrated, typically using a substitution.

Step 2: Key Formula or Approach:
The primary approach is to use the method of substitution. We will transform the integral into a standard form whose antiderivative is known. The relevant standard integral is:

$$\int \frac{du}{a^2+u^2} = \frac{1}{a}\tan^{-1}\left(\frac{u}{a}\right) + C$$

In our case, we will aim for the form where $a = 1$, which is $\int \frac{du}{1+u^2} = \tan^{-1}(u) + C$.

Step 3: Detailed Explanation:
Let the given integral be I.

$$I = \int_0^\infty \frac{dx}{e^x + e^{-x}}$$

First, we simplify the integrand. To eliminate the negative exponent, we can multiply the numerator and the denominator by e^x:

$$I = \int_0^\infty \frac{1}{e^x+e^{-x}} \cdot \frac{e^x}{e^x}\,dx$$

$$I = \int_0^\infty \frac{e^x}{e^x(e^x+e^{-x})}\,dx$$

$$I = \int_0^\infty \frac{e^x}{(e^x)^2 + e^x \cdot e^{-x}}\,dx$$

Since $e^x \cdot e^{-x} = e^{x-x} = e^0 = 1$, the integral becomes:

$$I = \int_0^\infty \frac{e^x}{(e^x)^2+1}\,dx$$

Now, this form suggests a substitution. Let's substitute $u = e^x$. Then, the differential du is:

$$\frac{du}{dx} = e^x \implies du = e^x\,dx$$

Next, we must change the limits of integration from x to u: - When $x = 0$ (lower limit), $u = e^0 = 1$.
- When $x \to \infty$ (upper limit), $u = e^x \to \infty$.

Substituting u and du and the new limits into the integral:

$$I = \int_1^\infty \frac{du}{u^2+1}$$

This is a standard integral. The antiderivative of $\frac{1}{u^2+1}$ is $\tan^{-1}(u)$.

$$I = \left[\tan^{-1}(u)\right]_1^{\infty}$$

Now, we evaluate this at the limits:

$$I = \lim_{b\to\infty} \left[\tan^{-1}(u)\right]_1^{b}$$

$$I = \lim_{b\to\infty} (\tan^{-1}(b)) - \tan^{-1}(1)$$

We know the values of the arctangent function at these points: - $\lim_{b\to\infty} \tan^{-1}(b) = \frac{\pi}{2}$ - $\tan^{-1}(1) = \frac{\pi}{4}$

Substituting these values back:

$$I = \frac{\pi}{2} - \frac{\pi}{4}$$

$$I = \frac{2\pi - \pi}{4} = \frac{\pi}{4}$$

Step 4: Final Answer:
The value of the integral is $\frac{\pi}{4}$. This corresponds to option (B).

> Quick Tip
>
> Whenever you see an integrand with the form $e^x + e^{-x}$ in the denominator, a useful first step is to multiply the numerator and denominator by e^x. This often converts the expression into a form suitable for a u-substitution with $u = e^x$. Also, recognizing that $e^x + e^{-x} = 2\cosh(x)$ can sometimes provide an alternative, quicker solution if you are familiar with hyperbolic functions.

---

14. Amongst the following polymers, the one with the lowest glass transition temperature is:

(A) Polyethylene
(B) Polypropylene
(C) Polystyrene
(D) Poly(ethylene terephthalate)

Correct Answer: (A) Polyethylene

Solution:

Step 1: Understanding the Concept:
The **glass transition temperature (Tg)** is a critical property of amorphous and semi-crystalline polymers. It is the temperature at which a polymer transitions from a hard, glassy, brittle state to a soft, rubbery, flexible state. This transition is reversible. The value of Tg depends on the polymer's chemical structure, particularly the flexibility of its molecular chains.

Step 2: Detailed Explanation:
Let's analyze the structures of the given polymers and their typical Tg values:

- **(A) Polyethylene (PE):** The chemical structure is $-[CH_2 - CH_2]_n-$. This is a very simple and flexible linear chain with no bulky side groups. This high flexibility allows for chain motion at very low temperatures. The Tg of Polyethylene is very low, typically around $-125°C$.

- **(B) Polypropylene (PP):** The structure is $-[CH_2 - CH(CH_3)]_n-$. The presence of the methyl ($-CH_3$) side group hinders the rotation of the polymer chain compared to PE. This reduces flexibility and increases the Tg. The Tg of Polypropylene is around $-20°C$.

- **(C) Polystyrene (PS):** The structure is $-[CH_2 - CH(C_6H_5)]_n-$. It has a large, bulky benzene ring as a side group. This significantly restricts chain mobility, leading to a much higher Tg. The Tg of Polystyrene is high, around $100°C$.

- **(D) Poly(ethylene terephthalate) (PET):** This is a polyester with rigid benzene rings directly in the polymer backbone. This inherent chain stiffness results in a relatively high Tg. The Tg of PET is around $70 - 80°C$.

Step 3: Final Answer:
Comparing the typical Tg values:

- PE: $\approx -125°C$
- PP: $\approx -20°C$
- PS: $\approx 100°C$
- PET: $\approx 75°C$

Clearly, Polyethylene has the lowest glass transition temperature due to its highly flexible molecular chains.

Quick Tip

As a general rule in polymer science, factors that decrease chain flexibility, such as bulky side groups (PS vs. PE), polar interactions, and rigid structures in the backbone (PET), will increase the glass transition temperature (Tg).

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15. Amongst the following fibre forming polymers, the one which is synthesised by chain growth polymerisation is:

(A) Poly(ethylene terephthalate)
(B) Nylon 6,6
(C) Polyacrylonitrile
(D) Poly(p-phenylene terephthalamide)

Correct Answer: (C) Polyacrylonitrile

Solution:

Step 1: Understanding the Concept:
There are two main types of polymerization reactions:

1. **Chain-growth (or Addition) Polymerization:** Monomers add one by one to the active center of a growing polymer chain. This process typically involves the breaking of a double or triple bond in the monomer. Examples include the polymerization of vinyl monomers like ethylene, propylene, and styrene.

2. **Step-growth (or Condensation) Polymerization:** Monomers (or oligomers) with reactive functional groups react with each other to form larger and larger molecules. Often, a small molecule like water (H_2O) or methanol (CH_3OH) is eliminated as a byproduct. Polyesters and polyamides are classic examples.

Step 2: Detailed Explanation:
Let's analyze the synthesis method for each of the given polymers:

- **(A) Poly(ethylene terephthalate) (PET):** This is a polyester. It is synthesized by the reaction between ethylene glycol and terephthalic acid. This is a condensation reaction where a molecule of water is eliminated for each ester linkage formed. Therefore, it is made by **step-growth polymerization**.

- **(B) Nylon 6,6:** This is a polyamide. It is synthesized from two monomers, hexamethylenediamine and adipic acid. This is also a condensation reaction that forms an amide linkage and eliminates a molecule of water. It is made by **step-growth polymerization**.

- **(C) Polyacrylonitrile (PAN):** This polymer is made from the acrylonitrile monomer ($CH_2 = CH - C \equiv N$). The polymerization proceeds by the opening of the carbon-carbon double bond, with monomers adding sequentially to a growing chain. This is a classic example of **chain-growth polymerization**.

- **(D) Poly(p-phenylene terephthalamide) (Kevlar):** This is an aromatic polyamide (aramid). It is formed from p-phenylenediamine and terephthaloyl chloride. It forms amide linkages through a condensation reaction, so it is made by **step-growth polymerization**.

Step 3: Final Answer:
Based on the analysis, only Polyacrylonitrile is synthesized by chain-growth polymerization. The other three are synthesized by step-growth polymerization.

> Quick Tip
>
> A quick way to identify the polymerization type is to look at the monomer structure. If the monomer has a C=C double bond that opens up to form the polymer backbone, it's almost always chain-growth. If the polymer is a polyester, polyamide, or polycarbonate, it's almost always step-growth.

---

16. The purpose of opening in blowroom is:

(A) Individualisation of fibres in tufts
(B) Parallelisation of fibres in tufts
(C) Separation of short fibres from tufts
(D) Creation of more voluminous tufts

Correct Answer: (A) Individualisation of fibres in tufts

Solution:

Step 1: Understanding the Concept:
The **blowroom** is the first department in a yarn spinning mill. Its primary purpose is to process the highly compressed bales of raw fiber (like cotton) that arrive at the mill. The overall goal of the blowroom is to open and clean the fiber to prepare it for the next stage, which is carding.

Step 2: Detailed Explanation:
Let's analyze the main functions of the blowroom and evaluate the given options:

- **Opening:** The main objective is to break down the large, compressed chunks of fiber from the bale into smaller and smaller tufts. This process is crucial for effective cleaning, as impurities are more easily removed from smaller tufts. The ultimate goal is to separate the fibers down to an individual state, a process known as fiber individualization.
- **Cleaning:** By opening the fiber mass, heavy impurities like dirt, dust, seeds, and leaf particles can be dislodged and removed through the use of beaters and air currents.
- **Mixing/Blending:** If different types of cotton or fibers are being used, the blowroom helps to mix them homogeneously.
- **Dust Removal:** A significant amount of microdust is removed.

Now let's look at the options in this context:

- **(A) Individualisation of fibres in tufts:** This accurately describes the primary "opening" function. The process starts by breaking bales into large clumps, then into small tufts, with the aim of eventually separating the tufts into individual fibers. This is the most correct description.
- **(B) Parallelisation of fibres in tufts:** Aligning fibers in a parallel manner is the primary function of the **carding** and **drawing** processes, which occur *after* the blowroom.
- **(C) Separation of short fibres from tufts:** Removing short fibers to improve yarn quality is the main purpose of the **combing** process, an optional stage that follows carding.
- **(D) Creation of more voluminous tufts:** The process breaks down large, dense tufts into smaller, fluffier ones. While the overall volume of the entire fiber mass increases as it's de-compressed, the individual tufts are made smaller, not more voluminous. Option (A) is a more precise and accurate description of the goal.

Step 3: Final Answer:
The core purpose of the opening action in a blowroom is the progressive reduction of tuft size, which is the first and most critical step towards the individualization of fibers.

Quick Tip

To answer questions about textile manufacturing processes, it's essential to know the sequence of operations and the main purpose of each stage: 1. **Blowroom:** Opening Cleaning 2. **Carding:** Individualization, Cleaning, Sliver Formation 3. **Drawing:** Parallelization Blending 4. **Combing (Optional):** Short Fiber Removal 5. **Roving:** Drafting Twisting 6. **Spinning:** Final Drafting Yarn Formation

17. Amongst the following, forward as well as reverse rotary motion in cotton combing is given to:

(A) Feed roller
(B) Cylinder comb
(C) Detaching rollers
(D) Drawing rollers in comber drawbox

Correct Answer: (C) Detaching rollers

Solution:

Step 1: Understanding the Concept:
The cotton combing process is a cyclic operation designed to remove short fibers, neps, and impurities, while also parallelizing the remaining long fibers. The key actions are feeding, nipping, combing, and detaching/piecing. The detaching rollers play a crucial role in pulling the combed fibers from the nipper and piecing them onto the previously combed web.

Step 2: Detailed Explanation:
Let's analyze the motion of each component:

- **(A) Feed roller:** The feed roller has an intermittent forward motion. It feeds a specific length of the lap (e.g., 4-6 mm) into the nippers during each cycle and then stops. It does not have a reverse motion.

- **(B) Cylinder comb (or Half-lap):** The cylinder comb rotates continuously in one direction (forward) to comb the leading fringe of fibers held by the nipper.

- **(C) Detaching rollers:** These rollers have a complex motion. They perform a **reverse rotation** to move the previously formed web backward slightly, presenting its tail end for the new tuft of combed fibers to be laid on top. Then, they perform a **forward rotation** to pull (detach) the new tuft through the top comb and piece it onto the web, moving the newly formed continuous web forward. This forward and reverse cycle is essential for the piecing operation.

- **(D) Drawing rollers in comber drawbox:** These rollers are located after the main combing section. They rotate continuously in one direction (forward) to draft the combined slivers from all the combing heads into a single, uniform comber sliver.

Step 3: Final Answer:
The detaching rollers are the only components in the list that exhibit both forward and

reverse rotary motion within a single combing cycle to perform the detaching and piecing-up action.

Quick Tip

To understand the combing cycle, visualize the "piecing-up" step. To join a new tuft to the old web, the old web must be moved back slightly (reverse motion) so the new tuft can overlap it. Then, both are pulled forward together (forward motion). This action is unique to the detaching rollers.

---

18. A circular weft knitting machine with 24 inch gauge and 20 inch diameter needle bed is used to make a tubular knitted fabric. If the fabric shrinks by 35% in course-wise direction upon withdrawal from the machine, the circumference (inch) of the shrunken tubular fabric is approximately:

(A) 40.9
(B) 56.2
(C) 68.6
(D) 72.2

Correct Answer: (A) 40.9

Solution:

Step 1: Understanding the Concept:
This problem involves calculating the initial circumference of a knitted fabric tube as it's produced on the machine and then applying a given shrinkage percentage to find the final circumference. The "gauge" of a knitting machine is irrelevant for calculating the circumference; only the diameter is needed. The course-wise direction in a weft-knitted fabric corresponds to the width or circumference of the tube.

Step 2: Key Formula or Approach:
1. Calculate the initial circumference of the fabric on the machine using the formula for the circumference of a circle: $C = \pi \times D$, where D is the diameter.
2. Calculate the final circumference after shrinkage. If the shrinkage is S%, the remaining fabric dimension is $(100 - S)$% of the original.
Final Circumference = Initial Circumference $\times(1 - \frac{\text{Shrinkage }\%}{100})$.

Step 3: Detailed Explanation:
Part 1: Calculate the initial circumference

The diameter of the needle bed is given as $D = 20$ inches.

$$\text{Initial Circumference} = \pi \times D$$

$$\text{Initial Circumference} = \pi \times 20 \approx 3.14159 \times 20 \approx 62.83 \text{ inches}$$

Part 2: Calculate the final circumference after shrinkage
The fabric shrinks by 35% in the course-wise (circumferential) direction. The shrinkage factor is $1 - \frac{35}{100} = 1 - 0.35 = 0.65$.

$$\text{Final Circumference} = \text{Initial Circumference} \times \text{Shrinkage Factor}$$

$$\text{Final Circumference} = 62.83 \text{ inches} \times 0.65$$

$$\text{Final Circumference} \approx 40.84 \text{ inches}$$

Step 4: Final Answer:
The calculated shrunken circumference is approximately 40.84 inches, which is closest to option (A) 40.9.

💡 Quick Tip
In knitting problems, be careful to distinguish between relevant and irrelevant information. Here, the machine gauge (needles per inch) is extra information not needed to solve for the circumference. Focus only on diameter and shrinkage.

---

19. A winder operates at 750 m/min with 93% efficiency. Time (min) taken for the winder to wind 1.2 kg of 20 tex yarn is approximately:

(A) 68
(B) 74
(C) 86
(D) 90

Correct Answer: (C) 86

Solution:

Step 1: Understanding the Concept:
This problem requires calculating the total time to wind a certain mass of yarn. We need to first determine the total length of the yarn from its mass and linear density (tex). Then, we calculate the actual (effective) winding speed by accounting for the machine's efficiency. Finally, we can find the time taken.

Step 2: Key Formula or Approach:
1. **Tex Definition:** Tex is the mass in grams of 1000 meters of yarn.
Tex $= \frac{\text{Mass (g)}}{\text{Length (km)}} = \frac{\text{Mass (g)}\times 1000}{\text{Length (m)}}$
Rearranging for length: Length (m) $= \frac{\text{Mass (g)}\times 1000}{\text{Tex}}$.
2. **Effective Speed:** Effective Speed = Operating Speed × Efficiency.
3. **Time Taken:** Time (min) $= \frac{\text{Total Length (m)}}{\text{Effective Speed (m/min)}}$.

Step 3: Detailed Explanation:
Part 1: Calculate the total length of the yarn

- Mass of yarn = 1.2 kg = 1200 g.
- Linear density = 20 tex.

$$\text{Total Length (m)} = \frac{1200 \text{ g} \times 1000}{20} = 60 \times 1000 = 60000 \text{ meters}$$

Part 2: Calculate the effective winding speed

- Operating speed = 750 m/min.
- Efficiency = 93% = 0.93.

$$\text{Effective Speed} = 750 \text{ m/min} \times 0.93 = 697.5 \text{ m/min}$$

Part 3: Calculate the time taken

$$\text{Time (min)} = \frac{\text{Total Length (m)}}{\text{Effective Speed (m/min)}}$$

$$\text{Time (min)} = \frac{60000 \text{ m}}{697.5 \text{ m/min}} \approx 86.02 \text{ min}$$

Step 4: Final Answer:
The time taken is approximately 86 minutes. This corresponds to option (C).

Quick Tip

Always ensure your units are consistent before performing calculations. Here, the mass was given in kg but the tex system uses grams, so the conversion was a necessary first step. Efficiency is always applied to the machine's operational rate (speed or production).

---

20. With reference to Shirley stiffness tester, the relationship between the fabric bending length (C) and the overhanging length (L) at the standard angle of deflection of 41.5° is approximately:

(A) C = 0.25L
(B) C = 0.5L
(C) C = L
(D) C = 2L

Correct Answer: (B) C = 0.5L

Solution:

Step 1: Understanding the Concept:
The Shirley stiffness tester is a standard instrument used to measure the stiffness of a fabric by quantifying its resistance to bending. It operates on the cantilever principle. A rectangular strip of fabric is slowly pushed over a horizontal platform. As it overhangs, it bends under its own weight. The length of the overhanging fabric (L) that causes the tip to deflect to a specific angle (41.5°) is measured.

Step 2: Key Formula or Approach:
The **bending length (C)** is a fundamental property of the fabric that represents its intrinsic stiffness. It is defined as the length of fabric that will bend under its own weight to a specific angle. For the standard deflection angle of $\theta = 41.5°$, the relationship between the bending length (C) and the overhanging length (L) is derived from the cantilever bending theory, which simplifies to a direct relationship.

Step 3: Detailed Explanation:
The underlying theory for the cantilever bending test, as developed by Peirce, provides a formula relating the bending length (C), the overhanging length (L), and the angle of deflection (θ):

$$C = L\left(\frac{\cos(\theta/2)}{8\tan\theta}\right)^{1/3}$$

This formula looks complex, but for the specific standard angle of $\theta = 41.5°$ used in the Shirley stiffness tester, the term in the parenthesis evaluates to a convenient value. Let's define a function $f(\theta) = \left(\frac{\cos(\theta/2)}{8\tan\theta}\right)^{1/3}$. At $\theta = 41.5°$:

$$f(41.5°) = \left(\frac{\cos(20.75°)}{8\tan(41.5°)}\right)^{1/3} = \left(\frac{0.935}{8 \times 0.885}\right)^{1/3} = \left(\frac{0.935}{7.08}\right)^{1/3} \approx (0.132)^{1/3} \approx 0.509$$

Therefore, at the standard angle of 41.5°, the relationship simplifies to:

$$C \approx 0.509 \times L$$

This is commonly approximated as:

$$C = 0.5L$$

This means that the bending length of the fabric is simply half of the overhanging length measured on the instrument's scale.

Step 4: Final Answer:
The relationship between bending length (C) and overhanging length (L) at the standard deflection angle of 41.5° is $C = 0.5L$.

> Quick Tip
>
> For textile testing questions, certain standard values and relationships are essential to memorize. The $C = L/2$ relationship for the Shirley stiffness tester at 41.5° is a fundamental concept in fabric mechanics and testing.

---

21. An evenness tester, working on capacitance principle, provides:

(A) Mass per unit length of yarn
(B) Standard deviation of mass per unit length of yarn
(C) Coefficient of variation of mass per unit length of yarn
(D) Coefficient of variation of diameter of yarn

Correct Answer: (C) Coefficient of variation of mass per unit length of yarn

Solution:

Step 1: Understanding the Concept:
A yarn evenness tester is a crucial instrument for quality control in spinning mills. Its purpose is to measure the variation in the linear density (mass per unit length) of a yarn along its length. The most common type works on the capacitance principle. The yarn is passed through a capacitor. Since the dielectric constant of the fiber material is much higher than that of air, changes in the amount of fiber (mass) between the capacitor plates cause changes in the capacitance. These changes are converted into an electrical signal representing the mass variation.

Step 2: Detailed Explanation:
Let's analyze what the instrument does and what it outputs:

- The instrument's primary measurement is the instantaneous **mass per unit length** of the yarn segment inside the sensor. So, option (A) is what is being measured, but not the final statistical value provided.

- The instrument continuously measures this mass variation along a significant length of yarn (e.g., hundreds of meters). It then processes this raw data statistically.

- It calculates the **average mass per unit length** and the **standard deviation (SD)** of this mass variation. So, option (B) is calculated internally.

- However, the standard deviation is an absolute measure and depends on the average yarn count. To get a normalized, comparable value for evenness across different yarns, the instrument calculates the **Coefficient of Variation (CV%)**. CV% is defined as (Standard Deviation / Mean) $\times$ 100%. This is the universally accepted metric for yarn evenness.

- Therefore, the primary output and the most important value provided by an evenness tester is the **Coefficient of variation of mass per unit length of yarn (CVm%)**.

- Option (D) is incorrect because capacitance testers are sensitive to mass, not diameter. Optical sensors are used to measure diameter variation.

Step 3: Final Answer:
While the tester measures mass per unit length and calculates its standard deviation, the key standardized output that it provides for assessing yarn quality is the Coefficient of Variation (CV%) of the mass per unit length.

Quick Tip

Remember that the standard output for "evenness" in the textile industry is almost always the CV% of mass. It allows for a fair comparison of the quality of different yarns, regardless of their average thickness (count). A lower CV% means a more even and higher quality yarn.

---

22. Amongst the following, the chemical used for bleaching of cotton fabric in acidic medium is:

(A) $NaClO_2$
(B) NaOCl
(C) $NaClO_3$
(D) $MgCl_2$

Correct Answer: (A) $NaClO_2$

Solution:

Step 1: Understanding the Concept:
Bleaching is a chemical treatment process in textile wet processing used to remove the natural coloring matter from fibers, resulting in a whiter fabric. Different bleaching agents are effective under different conditions (pH, temperature). Cotton is a cellulosic fiber.

Step 2: Detailed Explanation:
Let's analyze the chemicals and their typical application conditions for bleaching:

- **(A) $NaClO_2$ (Sodium Chlorite):** This is a powerful bleaching agent. When activated under acidic conditions (typically pH 3.5-4.5) and at high temperatures, it decomposes to form chlorine dioxide (ClO_2), which is the active bleaching species. Sodium chlorite is known for producing a very high degree of whiteness with minimal degradation of cellulose, making it excellent for cotton and synthetic blends. Its use in an **acidic medium** is its defining characteristic.

- **(B) NaOCl (Sodium Hypochlorite):** Commonly known as liquid bleach. It is an effective bleaching agent for cotton but must be used under **alkaline conditions** (pH 9-11). If used in an acidic medium, it releases toxic chlorine gas (Cl_2) and can severely damage the cotton fibers (oxycellulose formation).

- **(C) $NaClO_3$ (Sodium Chlorate):** This is a strong oxidizing agent but is not typically used as a primary bleaching agent in the textile industry. It is more commonly used in pulp and paper manufacturing and as an herbicide.

- **(D) $MgCl_2$ (Magnesium Chloride):** This is a salt, not a bleaching agent. It is sometimes used as a stabilizer in hydrogen peroxide bleaching baths but does not perform the bleaching action itself.

Step 3: Final Answer:
Sodium Chlorite ($NaClO_2$) is the chemical specifically used for bleaching cotton and other fibers in an acidic medium. The other options are either used in alkaline media or are not bleaching agents.

💡 Quick Tip

Associate the bleaching agent with its required pH condition:

- **Sodium Hypochlorite (NaOCl):** Alkaline
- **Hydrogen Peroxide (H_2O_2):** Alkaline
- **Sodium Chlorite ($NaClO_2$):** Acidic

This is a fundamental concept in textile wet processing.

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23. In a discharge printing process, two dyes of different colours, one with high dischargeability (HD) and another with low dischargeability (LD), are to be considered. The correct statement regarding the selection of dyes is:

(A) LD can be used only as illuminant colour but HD cannot be used either as ground or as illuminant colour
(B) HD can be used only as ground colour but LD cannot be used either as ground or as illuminant colour
(C) LD can be used only as ground colour and HD can be used only as illuminant colour
(D) HD can be used only as ground colour and LD can be used only as illuminant colour

Correct Answer: (D) HD can be used only as ground colour and LD can be used only as illuminant colour

Solution:

Step 1: Understanding the Concept:
Discharge printing is a textile printing technique with two main steps:

1. A piece of fabric is first dyed with a solid color, known as the **ground colour**.
2. A printing paste containing a chemical agent (discharging agent) is then printed onto the fabric in a specific pattern. This chemical destroys the ground colour dye molecules.

This can create a white pattern on a colored background. To create a colored pattern, a second dye, called the **illuminant colour**, is added to the discharge paste. This illuminant dye must be resistant to the discharging agent.

Step 2: Detailed Explanation:
Based on the process, we can deduce the required properties for each dye:

- **Ground Colour Dye:** This dye must be easily destroyed or de-colorized by the discharging agent. Therefore, it must have **High Dischargeability (HD)**.

- **Illuminant Colour Dye:** This dye is present in the discharge paste and is intended to create the new color in the printed areas. It must not be affected by the discharging agent. Therefore, it must have **Low Dischargeability (LD)** or be non-dischargeable.

Let's evaluate the options based on these rules:

- (A) This is incorrect. HD dyes are specifically chosen to be used as the ground colour.
- (B) This is incorrect. LD dyes are specifically chosen to be used as the illuminant colour.
- (C) This is the reverse of the correct selection. LD is for the illuminant, and HD is for the ground.
- (D) This statement correctly summarizes the rules. The dye that is easy to discharge (HD) is used for the background (ground colour), and the dye that resists discharge (LD) is used for the pattern (illuminant colour).

Step 3: Final Answer:
The correct selection criteria are that the ground colour must be an HD dye and the illuminant colour must be an LD dye. Option (D) correctly states this.

Quick Tip

To remember the roles in discharge printing, think of it like this: The ground dye has to be "discharged" (removed), so it needs to be easily dischargeable (High Dischargeability). The new pattern dye "illuminates" the discharged area and must resist the process, so it needs Low Dischargeability.

---

24. Amongst the following, the nitrogen containing fibre(s) is/are:

(A) Nylon 6
(B) Kevlar
(C) Acrylic
(D) Polyester

Correct Answer: (A) Nylon 6 (Note: B and C also contain nitrogen)

Solution:

Step 1: Understanding the Concept:
This question asks to identify which of the given polymer fibers has nitrogen atoms as

part of its chemical structure. This requires knowledge of the basic chemical composition of common synthetic fibers.

Step 2: Detailed Explanation:
Let's analyze the chemical makeup of each fiber:

- **(A) Nylon 6:** Nylon is a generic name for a family of synthetic polymers known as polyamides. The repeating unit of Nylon 6 contains the amide functional group **(-CONH-)**. This group clearly contains a nitrogen atom.

- **(B) Kevlar:** Kevlar is the brand name for an aromatic polyamide, or aramid. Its structure also consists of repeating units linked by amide bonds **(-CONH-)**. Therefore, Kevlar contains nitrogen.

- **(C) Acrylic:** Acrylic fiber is made from polyacrylonitrile. The monomer is acrylonitrile, which has the chemical formula $CH_2 = CHCN$. The polymer contains the nitrile group **(-CN)** as a side chain. This group contains a nitrogen atom.

- **(D) Polyester:** Polyester fibers, like Poly(ethylene terephthalate) (PET), are made of repeating units containing the ester functional group **(-COO-)**. This group is composed of carbon and oxygen atoms only. Polyesters do not contain nitrogen.

Based on this analysis, Nylon 6, Kevlar, and Acrylic fibers all contain nitrogen. In a single-choice question format, this question is ambiguous. However, Nylon is the most common and classic example of a nitrogen-containing fiber class (polyamides) taught in introductory courses. All three options A, B, and C are technically correct answers. We select (A) as a representative correct answer.

Step 3: Final Answer:
Nylon 6 (a polyamide), Kevlar (an aramid/polyamide), and Acrylic (a polyacrylonitrile) all contain nitrogen atoms in their polymer structures. Polyester does not.

Quick Tip

Memorize the basic chemical groups for major fiber types:

- **Polyamides** (Nylon, Kevlar): Amide group **(-CONH-)** → Contains Nitrogen.
- **Polyesters** (PET): Ester group **(-COO-)** → No Nitrogen.
- **Acrylics**: Nitrile group **(-CN)** → Contains Nitrogen.
- **Polyolefins** (Polyethylene, Polypropylene): Only Carbon and Hydrogen → No Nitrogen.

---

25. As the package builds up in a roving frame, the component(s) whose speed DOES NOT remain constant, amongst the following, is/are:

(A) Spindle
(B) Bobbin
(C) Bobbin rail
(D) Drafting rollers

Correct Answer: (B) Bobbin (Note: C also has non-constant speed)

Solution:

Step 1: Understanding the Concept:
A roving frame has two primary functions: drafting the sliver to make it thinner (now called roving) and inserting a small amount of twist to give it strength. It then winds this roving onto a bobbin. To achieve a uniform package, two conditions must be met:

1. The rate at which roving is delivered by the drafting rollers must equal the rate at which it is wound onto the bobbin's surface.
2. A constant amount of twist must be inserted per unit length of roving.

This requires precise control and variation of certain component speeds as the bobbin diameter increases.

Step 2: Detailed Explanation:
Let's analyze the speed of each component:

- **(D) Drafting rollers:** These rollers deliver roving at a constant linear speed to ensure the final roving has a consistent thickness (hank). **Their speed is constant**.

- **(A) Spindle (Flyer):** The flyer rotates around the bobbin to insert twist. Since the delivery speed from the drafting rollers is constant, the flyer must rotate at a constant speed to insert a constant number of twists per unit length. **Its speed is constant**.

- **(B) Bobbin:** The bobbin winds the roving delivered by the flyer. The delivery speed is constant. As the roving is wound onto the bobbin, the package diameter increases. To wind a constant length of roving per minute onto an increasing diameter, the surface speed of the package must remain constant. Since surface speed is a product of rotational speed and diameter ($V = \omega \times r$), if the diameter (r) increases, the rotational speed (ω) of the bobbin must decrease. Therefore, the **bobbin's speed is NOT constant**.

- **(C) Bobbin rail:** The bobbin rail moves the bobbin up and down to distribute the roving evenly along the package height. Its linear speed is constantly changing as it reverses direction at the top and bottom of its traverse. Therefore, the **bobbin rail's speed is NOT constant**.

Both the bobbin and the bobbin rail have non-constant speeds. However, the fundamental principle of winding on a roving frame is the precise, continuous reduction of the bobbin's rotational speed. This is the primary speed variation being tested.

Step 3: Final Answer:
The bobbin's rotational speed must continuously decrease as the package diameter builds up. Therefore, its speed does not remain constant.

> Quick Tip
>
> Think about the core requirement: constant winding speed. Winding speed = $\pi \times$ diameter $\times$ rotational speed. If the diameter is increasing, the rotational speed must decrease to keep the product constant. This is a key principle in many winding processes in textiles.

---

26. Amongst the following, the correct condition(s) that will reduce bumping during weaving is/are:

(A) Higher warp tension
(B) Reduction in sweep of the sley
(C) Higher pick density
(D) Reduction of shed height

Correct Answer: (B) Reduction in sweep of the sley

Solution:

Step 1: Understanding the Concept:
"Bumping," more formally known as "beat-up," is the action in weaving where the reed, mounted on the sley, pushes the newly inserted weft yarn (pick) to the edge of the already formed fabric (the fell). The question asks which condition will "reduce bumping," which can be interpreted as reducing the force or severity of the beat-up action. A very forceful beat-up can damage yarns or create weaving defects.

Step 2: Detailed Explanation:
Let's analyze how each condition affects the beat-up force:

- **(A) Higher warp tension:** When the warp yarns are under higher tension, they form a more rigid sheet. It becomes more difficult for the reed to push the new weft yarn into the fabric structure, thus requiring a *higher* beat-up force. This would increase, not reduce, the severity of bumping.

- **(B) Reduction in sweep of the sley:** The sweep of the sley is the distance it travels during its forward motion towards the fell. The force of the beat-up is related to the mass and acceleration of the sley. A shorter sweep or travel distance generally implies a lower velocity and momentum at the point of impact, resulting in a gentler or *reduced* beat-up force.

- **(C) Higher pick density:** Pick density is the number of weft yarns per unit length of fabric. To pack more yarns into the same space, a *higher* beat-up force is required to overcome the increased resistance from the yarns already in the cloth. This would increase, not reduce, bumping.

- **(D) Reduction of shed height:** A smaller shed (the opening between upper and lower warp sheets) increases the friction between the warp yarns, the shuttle/weft carrier, and the reed. This can increase the overall strain on the system and often requires a more forceful beat-up to position the pick correctly against the fell.

Step 3: Final Answer:
Among the given options, reducing the sweep (or stroke) of the sley is the most direct way to reduce the kinetic energy of the beat-up motion, thereby reducing the bumping force.

Quick Tip

To analyze weaving parameters, consider the forces involved. Packing more threads (higher density) or weaving on a tighter foundation (higher tension) will almost always require more force. Reducing the motion (sweep of the sley) will reduce the force.

---

27. With reference to the principles of yarn hairiness measurement, the correct statement(s), amongst the following, is/are:

(A) Light scattering principle is used to measure length of hairs
(B) Light scattering principle is used to measure number of hairs
(C) Photocells are used to measure length of hairs
(D) Photocells are used to measure number of hairs

Correct Answer: (D) Photocells are used to measure number of hairs

Solution:

Step 1: Understanding the Concept:
Yarn hairiness refers to the fibers that protrude from the main body of the yarn. Measuring hairiness is important for predicting fabric appearance, pilling tendency, and performance in subsequent processes. The most common instruments for this measurement work on an optical principle.

Step 2: Detailed Explanation:
The dominant principle used in commercial yarn hairiness testers (like the Uster Zweigle Hairiness Tester) is the **photoelectric or light interruption method**.

- **How it works:** The yarn is passed through a beam of parallel light (often a laser) that is aimed at a photocell or photodetector.
- The main body of the yarn continuously blocks a portion of the light.
- When a protruding hair enters the light beam, it blocks additional light, causing a change in the electrical signal from the photocell.
- The instrument registers this change as a "count" of one hair.
- By setting up measurement zones at different, precise distances from the yarn core, the instrument can specifically count the number of hairs that are long enough to reach that zone. For example, it can count all hairs longer than 3mm, 4mm, etc.

Let's evaluate the options based on this principle:

- (A) & (B) Light scattering is a different principle, used more for assessing overall surface roughness rather than counting individual hairs for standard hairiness indices.
- (C) Photocells do not directly measure the length of an individual hair. They are used in a system that is set to *count* hairs that exceed a certain pre-defined length.
- (D) This is the most accurate statement. The fundamental job of the photocell in this setup is to detect the presence of a hair, allowing the instrument to count the **number of hairs**.

Step 3: Final Answer:
The principle of widely-used hairiness testers involves using photocells to count the number of times protruding fibers interrupt a light beam. Therefore, photocells are used to measure the number of hairs.

💡 Quick Tip

For hairiness testing, remember the key output is a count, not a measurement of individual lengths. The most famous value is the "S3 value," which is the total count of hairs longer than 3 mm, plus hairs between 1 and 2 mm, plus those between 2 and 3 mm. It's all about counting.

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28. A fluorocarbon-based soil release finish consists of alternating hydrophobic blocks and hydrophilic blocks arranged side by side on fabric surface. The correct statement(s) amongst the following is/are:

(A) In dry state, the hydrophobic blocks shield the hydrophilic blocks to repel soil
(B) During washing, the hydrophilic blocks swell and facilitate release of soil
(C) In dry state, the hydrophilic blocks shield the hydrophobic blocks to repel soil
(D) During washing, the hydrophobic blocks swell and facilitate release of soil

Correct Answer: (Note: Both A and B are correct descriptions of the finish's function in different environments)

Solution:

Step 1: Understanding the Concept:
Soil-release finishes are dual-action finishes. They aim to provide soil repellency during wear (dry state) and easy removal of soil during laundering (wet state). This is achieved by using polymers that have both hydrophobic (water/oil-hating) and hydrophilic (water-loving) parts. Fluorocarbons are excellent hydrophobic agents.

Step 2: Detailed Explanation:
Let's analyze the behavior of this dual-component finish in different environments:

- **In the dry state (in air):** The system arranges itself to minimize its surface energy. The low-energy hydrophobic fluorocarbon blocks orient themselves outwards, facing the air. They effectively cover or "shield" the higher-energy hydrophilic blocks. This hydrophobic surface repels water and oily soils, preventing them from penetrating the fabric. Statement **(A) In dry state, the hydrophobic blocks shield the hydrophilic blocks to repel soil** correctly describes this mechanism. Statement (C) is incorrect because hydrophilic blocks would attract dirt and moisture.
- **During washing (in water):** When the fabric is immersed in water, the environment changes. The hydrophilic blocks have a strong affinity for water. They re-orient themselves to face the water, swelling as they absorb moisture. This creates a layer of water between the fabric surface and the soil, lifting the soil away and allowing the detergent to wash it off. This is the "release" mechanism. Statement

(B) During washing, the hydrophilic blocks swell and facilitate release of soil correctly describes this process. Statement (D) is incorrect because hydrophobic blocks repel water and will not swell to facilitate soil release.

Both statements (A) and (B) describe correct and essential parts of how the finish works. Statement (A) describes the soil repellency aspect, and statement (B) describes the soil release aspect. Given the options, both are factually correct. In a single-choice context, there might be an emphasis on the "release" part of the "soil release finish," making (B) a strong candidate. However, both describe the working principle.

Step 3: Final Answer:
The finish has a dual mechanism. In the dry state, the hydrophobic blocks provide repellency (Statement A). In the wet state (washing), the hydrophilic blocks provide the release action (Statement B). Both A and B are correct descriptions of the finish's function.

> Quick Tip
>
> For dual-function finishes, think about how the polymer chains would orient themselves in different environments (air vs. water) to achieve the lowest energy state. In air, low-energy hydrophobic parts face out. In water, water-loving hydrophilic parts face out.

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29. If $g(x)$ is a continuous function such that $\int_a^b g(x)dx = \beta$, then the correct statement(s), amongst the following, is/are:

(A) $\int_{a-1}^{b-1} g(x-1)dx = \beta$
(B) $\int_{(1-b)/2}^{(1-a)/2} 2g(1-2x)dx = \beta$
(C) $\int_{a-c}^{b-c} g(x+c)dx = \beta$
(D) $\int_a^b g(a-x)dx = \beta$

Correct Answer: (B) $\int_{(1-b)/2}^{(1-a)/2} 2g(1-2x)dx = \beta$ and (C) $\int_{a-c}^{b-c} g(x+c)dx = \beta$

Solution:

Step 1: Understanding the Concept:
This question tests the properties of definite integrals, specifically the technique of substitution (u-substitution) to transform an integral into a known form. The goal is to see which of the given integrals can be transformed back to the original integral $\int_a^b g(x)dx = \beta$.

Step 2: Key Formula or Approach:
We will use the method of substitution. For an integral $\int_{x_1}^{x_2} f(u(x))u'(x)dx$, we can substitute $u = u(x)$, which gives $du = u'(x)dx$. The limits of integration also change from x_1, x_2 to $u(x_1), u(x_2)$.

Step 3: Detailed Explanation:
Let's check each option:

- **(A)** $\int_{a-1}^{b-1} g(x-1)dx$**:** This option has a typo in the question; it likely intended $g(x+1)$ or different limits. As written, let's substitute $u = x - 1$. Then $du = dx$.
When $x = a - 1$, $u = a - 1 - 1 = a - 2$.
When $x = b - 1$, $u = b - 1 - 1 = b - 2$.
The integral becomes $\int_{a-2}^{b-2} g(u)du$. This is not equal to β. Let's assume the question meant $\int_{a+1}^{b+1} g(x-1)dx$. With substitution $u = x - 1$, the integral becomes $\int_a^b g(u)du = \beta$. Let's check option C which is a generalization of this.

- **(B)** $\int_{(1-b)/2}^{(1-a)/2} 2g(1-2x)dx$**:** Let $u = 1 - 2x$. Then $du = -2dx$, which means $2dx = -du$.
Now, let's change the limits:
When $x = (1-b)/2$, $u = 1 - 2\left(\frac{1-b}{2}\right) = 1 - (1-b) = b$.
When $x = (1-a)/2$, $u = 1 - 2\left(\frac{1-a}{2}\right) = 1 - (1-a) = a$.
The integral becomes $\int_b^a g(u)(-du) = -\int_b^a g(u)du$. Using the property $\int_b^a f(x)dx = -\int_a^b f(x)dx$, we get:
$-(-\int_a^b g(u)du) = \int_a^b g(u)du = \beta$. This statement is correct.

- **(C)** $\int_{a-c}^{b-c} g(x+c)dx$**:** Let $u = x + c$. Then $du = dx$.
Now, let's change the limits:
When $x = a - c$, $u = (a - c) + c = a$.
When $x = b - c$, $u = (b - c) + c = b$.
The integral becomes $\int_a^b g(u)du = \beta$. This statement is correct.

- **(D)** $\int_a^b g(a-x)dx$**:** Let $u = a - x$. Then $du = -dx$.
Now, let's change the limits:
When $x = a$, $u = a - a = 0$.
When $x = b$, $u = a - b$.
The integral becomes $\int_0^{a-b} g(u)(-du) = \int_{a-b}^0 g(u)du$. This is not equal to β.

Step 4: Final Answer:
By applying the substitution method, we find that statements (B) and (C) correctly evaluate to β.

Quick Tip

When using substitution for definite integrals, always remember to transform the limits of integration according to the substitution. This is a common source of errors. A simple linear substitution like $u = x + c$ just shifts the integration interval.

---

31. Poly(ethylene terephthalate) has a number average molecular weight of 25000. The degree of polymerisation (rounded off to the nearest integer) is:

Correct Answer: 130

Solution:

Step 1: Understanding the Concept:
The degree of polymerisation (DP) represents the average number of repeating units, or monomers, in a polymer chain. It is a fundamental property that relates the microscopic structure (monomer size) to the macroscopic property (total molecular weight) of a polymer.

Step 2: Key Formula or Approach:
The degree of polymerisation (DP) is calculated by dividing the number average molecular weight of the polymer (M_n) by the molecular weight of the repeating monomer unit (M_0).

$$\text{DP} = \frac{M_n}{M_0}$$

Step 3: Detailed Explanation:
1. Identify the Polymer and its Repeating Unit:
The polymer is Poly(ethylene terephthalate), commonly known as PET. Its repeating unit is formed from ethylene glycol and terephthalic acid.
The chemical formula of the repeating unit is $C_{10}H_8O_4$.

2. Calculate the Molecular Weight of the Repeating Unit (M_0):
We need to sum the atomic weights of all atoms in the repeating unit. The standard atomic weights are approximately:

- Carbon (C): 12.01 g/mol
- Hydrogen (H): 1.008 g/mol
- Oxygen (O): 16.00 g/mol

Using these values:

$$M_0 = (10 \times 12.01) + (8 \times 1.008) + (4 \times 16.00)$$

$$M_0 = 120.1 + 8.064 + 64.00$$
$$M_0 = 192.164 \text{ g/mol}$$

For most competitive exams, using integer atomic weights (C=12, H=1, O=16) is sufficient and quicker:

$$M_0 = (10 \times 12) + (8 \times 1) + (4 \times 16) = 120 + 8 + 64 = 192 \text{ g/mol}$$

We will use $M_0 = 192$ g/mol.

3. Calculate the Degree of Polymerisation (DP):
The given number average molecular weight of the polymer is $M_n = 25000$ g/mol.
Using the formula:

$$\text{DP} = \frac{M_n}{M_0} = \frac{25000}{192}$$
$$\text{DP} \approx 130.2083$$

4. Round to the Nearest Integer:
The question asks to round the result to the nearest integer.

$$\text{DP} \approx 130$$

Step 4: Final Answer:
The degree of polymerisation, rounded to the nearest integer, is 130.

Quick Tip

For polymer chemistry problems, it's highly beneficial to memorize the structure and molecular weight of the repeating units for common polymers like PET, Nylon, PVC, and Polyethylene. This can save valuable time during calculations. For PET, a quick calculation of M_0 as 192 is a key step.

---

32. A cotton yarn of 20 tex count is replaced by a polyester yarn such that both the yarns have the same diameter and same packing density. Assuming densities of cotton and polyester fibers as 1.52 g/cm^3 and 1.38 g/cm^3, respectively, the count (tex) of the polyester yarn (rounded off to 2 decimal places) is:

Correct Answer: 18.16

Solution:

Step 1: Understanding the Concept:
The 'tex' count of a yarn is a measure of its linear density, specifically the mass in grams

per 1000 meters of yarn. The linear density is determined by the yarn's cross-sectional area, the density of the fiber material, and how tightly the fibers are packed (packing density). The problem states that a cotton yarn is replaced by a polyester yarn of the same diameter and packing density, and asks for the new tex count based on the difference in fiber densities.

Step 2: Key Formula or Approach:
The linear density (or tex count, T) of a yarn is directly proportional to its cross-sectional area (A), its fiber density (ρ_{fiber}), and its packing density (ϕ).

$$T \propto A \cdot \rho_{\text{fiber}} \cdot \phi$$

When comparing two yarns (cotton 'c' and polyester 'p'), we can form a ratio:

$$\frac{T_p}{T_c} = \frac{A_p \cdot \rho_p \cdot \phi_p}{A_c \cdot \rho_c \cdot \phi_c}$$

Given the conditions in the problem, we can simplify this relationship to find the unknown tex count.

Step 3: Detailed Explanation:
1. List the Given Information:
- Cotton yarn count, $T_c = 20$ tex.
- Cotton fiber density, $\rho_c = 1.52$ g/cm^3.
- Polyester fiber density, $\rho_p = 1.38$ g/cm^3.

2. Apply the Conditions:
- **Same diameter:** This implies that the cross-sectional areas of the two yarns are equal. So, $A_c = A_p$.
- **Same packing density:** This means $\phi_c = \phi_p$.

3. Simplify the Ratio Formula:
Using the formula from Step 2 and substituting the conditions:

$$\frac{T_p}{T_c} = \frac{A_p \cdot \rho_p \cdot \phi_p}{A_c \cdot \rho_c \cdot \phi_c}$$

Since $A_p = A_c$ and $\phi_p = \phi_c$, these terms cancel out:

$$\frac{T_p}{T_c} = \frac{\rho_p}{\rho_c}$$

This simplified formula shows that for yarns of the same diameter and packing, the tex count is directly proportional to the fiber density.

4. Calculate the Polyester Yarn Count (T_p):
Rearrange the formula to solve for T_p:

$$T_p = T_c \times \frac{\rho_p}{\rho_c}$$

Substitute the given values:

$$T_p = 20 \times \frac{1.38}{1.52}$$
$$T_p = 20 \times 0.9078947...$$
$$T_p \approx 18.15789...$$

5. Round to 2 Decimal Places:
The question requires the answer to be rounded to two decimal places.

$$T_p \approx 18.16 \text{ tex}$$

Step 4: Final Answer:
The count (tex) of the polyester yarn is 18.16.

> **Quick Tip**
>
> For problems comparing yarn counts under constant diameter and packing, remember this direct relationship: the ratio of the counts is equal to the ratio of the fiber densities. This shortcut, $T_2/T_1 = \rho_2/\rho_1$, can save significant time. Notice that since polyester is less dense than cotton, the resulting yarn has a lower tex count for the same volume.

---

32. A cotton yarn of 20 tex count is replaced by a polyester yarn such that both the yarns have the same diameter and same packing density. Assuming densities of cotton and polyester fibers as 1.52 g/cm^3 and 1.38 g/cm^3, respectively, the count (tex) of the polyester yarn (rounded off to 2 decimal places) is:

Correct Answer: 18.16

Solution:

Step 1: Understanding the Concept:
The question relates the linear density (tex count) of a yarn to its diameter, the packing density of fibers within the yarn, and the density of the fiber material itself. The key information is that the yarn diameter and the packing density are constant for both the cotton and polyester yarns.

Step 2: Key Formula or Approach:
The tex count (T) is the mass of the yarn per unit length. This mass depends on the yarn's volume and the density of the material within that volume. The mass of a yarn of length L and diameter D is given by:

$$\text{Mass} = \text{Volume} \times \text{Packing Density} \times \text{Fiber Density}$$

$$\text{Mass} = \left(\frac{\pi D^2}{4} L\right) \times \phi \times \rho$$

where ϕ is the packing density and ρ is the fiber density. The linear density (Tex is mass in g per 1000 m or 1 km) is $\frac{\text{Mass}}{L}$.

$$T \propto \left(\frac{\pi D^2}{4}\right) \times \phi \times \rho$$

Since diameter (D) and packing density (ϕ) are the same for both yarns, the Tex count is directly proportional to the fiber density (ρ).

$$\frac{T_{\text{polyester}}}{T_{\text{cotton}}} = \frac{\rho_{\text{polyester}}}{\rho_{\text{cotton}}}$$

Step 3: Detailed Explanation:
We are given:

- $T_{\text{cotton}} = 20$ tex
- $\rho_{\text{cotton}} = 1.52$ g/cm^3
- $\rho_{\text{polyester}} = 1.38$ g/cm^3

Using the proportionality relationship from Step 2:

$$T_{\text{polyester}} = T_{\text{cotton}} \times \frac{\rho_{\text{polyester}}}{\rho_{\text{cotton}}}$$

Substituting the given values:

$$T_{\text{polyester}} = 20 \times \frac{1.38}{1.52}$$
$$T_{\text{polyester}} = 20 \times 0.90789...$$
$$T_{\text{polyester}} \approx 18.1578...$$

Step 4: Final Answer:
Rounding the result to two decimal places, the count of the polyester yarn is 18.16 tex.

> Quick Tip
>
> For problems comparing yarns with constant diameter and packing, remember this simple rule: the yarn count (in a direct system like tex) is directly proportional to the fiber density. A less dense fiber will result in a finer (lower tex) yarn for the same diameter.

---

33. A knitted fabric is prepared from a yarn of 15 tex count. The fabric has 16 courses/cm, 17 wales/cm and 2.6 mm loop length. The areal density

(g/m^2) of the fabric (rounded off to the nearest integer) is:

Correct Answer: 106

Solution:

Step 1: Understanding the Concept:
Areal density of a fabric is its mass per unit area (e.g., grams per square meter). For a knitted fabric, this can be calculated from its structural parameters: the number of loops per unit area and the mass of the yarn in each loop.

Step 2: Key Formula or Approach:
1. Calculate the number of loops per unit area. Loops per cm^2 = (courses/cm) × (wales/cm) 2. Calculate the total length of yarn in that unit area. Yarn length per cm^2 = (Loops per cm^2) × (Loop length) 3. Calculate the mass of that length of yarn using its tex count. Mass (in grams) = Yarn length (in km) × Tex 4. Convert the calculated mass per cm^2 to mass per m^2 to get the areal density. (1 m^2 = 10,000 cm^2).
Areal Density (g/m^2) = (Courses/cm) × (Wales/cm) × (Loop Length in cm) × (Tex / 100)

Step 3: Detailed Explanation:
Given parameters:

- Yarn count = 15 tex (which is 15 g / 1000 m, or 15 g / 100,000 cm)
- Courses per cm (cpc) = 16
- Wales per cm (wpc) = 17
- Loop length (l) = 2.6 mm = 0.26 cm

Part 1: Loops per unit area

$$\text{Loops per cm}^2 = \text{cpc} \times \text{wpc} = 16 \times 17 = 272 \text{ loops/cm}^2$$

Part 2: Total yarn length per unit area

$$\text{Yarn length per cm}^2 = (\text{Loops per cm}^2) \times l = 272 \times 0.26 \text{ cm} = 70.72 \text{ cm of yarn per cm}^2 \text{ of fabric}$$

Part 3: Mass per unit area The yarn count is 15 tex, meaning 100,000 cm of yarn has a mass of 15 g. Mass per cm of yarn = $15/100,000$ g/cm.

$$\text{Mass per cm}^2 \text{ of fabric} = (\text{Yarn length per cm}^2) \times (\text{Mass per cm of yarn})$$

$$\text{Mass per cm}^2 = 70.72 \times \frac{15}{100000} \text{ g} = 0.010608 \text{ g/cm}^2$$

Part 4: Convert to g/m^2

$$\text{Areal Density (g/m}^2) = (\text{Mass per cm}^2) \times (10000 \text{ cm}^2/\text{m}^2)$$

$$\text{Areal Density} = 0.010608 \times 10000 = 106.08 \text{ g/m}^2$$

Step 4: Final Answer:
Rounding the result to the nearest integer, the areal density of the fabric is 106 g/m^2.

Quick Tip

A useful combined formula for knitted fabric areal density is: Areal Density (g/m^2) = (cpc × wpc × l [in mm] × Tex) / 100. Using this: (16 × 17 × 2.6 × 15) / 100 = 106.08 g/m^2. Memorizing this can save time.

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34. A 59.05 Ne cotton yarn, a 20 tex polyester/cotton blended yarn and a 90 denier polyester filament are twisted together to obtain a 3-ply yarn. Assuming there is no twist contraction, the resultant count (Ne) of the 3-ply yarn (rounded off to 2 decimal places) is:

Correct Answer: 14.76

Solution:

Step 1: Understanding the Concept:
This problem involves calculating the resultant yarn count of a 3-ply yarn, where each ply has a different count given in a different yarn numbering system (Ne, tex, denier). Yarn count systems are either direct (mass per unit length, like tex and denier) or indirect (length per unit mass, like Ne). To find the resultant count of a plied yarn, it's easiest to first convert all component counts into a single **direct** system (like tex), because their linear densities (mass per unit length) are additive. After summing them, the resultant direct count can be converted back to the desired indirect system (Ne).

Step 2: Key Formula or Approach:
The key is to use the standard conversion formulas between yarn count systems. The most common constant used is 590.5.

1. **Ne to Tex:** $\text{Tex} = \frac{590.5}{\text{Ne}}$
2. **Denier to Tex:** $\text{Tex} = \frac{\text{Denier}}{9}$
3. **Resultant Tex Count (T_R):** For a ply yarn, the resultant linear density is the sum of the linear densities of its components (assuming no twist contraction).

$$T_R = T_1 + T_2 + T_3$$

4. **Resultant Tex to Ne:** $\text{Ne}_{\text{Resultant}} = \frac{590.5}{T_R}$

Step 3: Detailed Explanation:
The process is to convert each of the three yarn counts to the tex system, sum them up, and then convert the final tex value back to Ne.

1. Convert Yarn 1 (Ne to Tex):
The first yarn is a 59.05 Ne cotton yarn.

$$T_1 = \frac{590.5}{\text{Ne}_1} = \frac{590.5}{59.05} = 10 \text{ tex}$$

2. Yarn 2 (already in Tex):
The second yarn is a 20 tex polyester/cotton blended yarn.

$$T_2 = 20 \text{ tex}$$

3. Convert Yarn 3 (Denier to Tex):
The third yarn is a 90 denier polyester filament.

$$T_3 = \frac{\text{Denier}_3}{9} = \frac{90}{9} = 10 \text{ tex}$$

4. Calculate the Resultant Tex Count (T_R):
Now, we add the tex values of the three components to get the resultant tex count of the 3-ply yarn.

$$T_R = T_1 + T_2 + T_3 = 10 + 20 + 10 = 40 \text{ tex}$$

5. Convert Resultant Tex to Ne:
Finally, we convert the resultant tex count back to the Ne system as requested by the question.

$$\text{Ne}_{\text{Resultant}} = \frac{590.5}{T_R} = \frac{590.5}{40}$$

$$\text{Ne}_{\text{Resultant}} = 14.7625$$

6. Round to 2 Decimal Places:
The question asks to round the final answer to 2 decimal places.

$$\text{Ne}_{\text{Resultant}} \approx 14.76$$

Step 4: Final Answer:
The resultant count (Ne) of the 3-ply yarn is 14.76.

Quick Tip

When dealing with ply yarns composed of different counts, especially from mixed direct and indirect systems, the most reliable method is to convert everything to a single direct system first (tex is the standard). Linear densities in direct systems are additive. Once you have the total linear density, convert it to the final required count system. This avoids confusion with the reciprocal addition formula used for indirect systems ($1/N_R = 1/N_1 + 1/N_2 + \ldots$).

35. One kg bone-dry cotton fabric is padded with water to obtain 80% wet pick up. The temperature of the wet fabric after padding is 30°C. Assume the specific heat of water to be 1 cal/(g·°C), the latent heat of evaporation of water to be 540 cal/g, and the specific heat of cotton to be 0.3 cal/(g·°C). The energy (kcal) required to dry the fabric completely (in integer) is:

Correct Answer: 509

Solution:

Step 1: Understanding the Concept:
The problem asks for the total energy required to completely dry a wet cotton fabric. This process involves two distinct stages of heat transfer:

1. **Sensible Heat:** The energy needed to raise the temperature of both the cotton and the water it contains from their initial temperature (30°C) to the boiling point of water (100°C).
2. **Latent Heat:** The energy needed to convert the water into steam (evaporation) at a constant temperature of 100°C.

The total energy required is the sum of the sensible heat and the latent heat.

Step 2: Key Formula or Approach:

- Mass of water (m_{water}): Calculated from the wet pick up percentage.

$$m_{water} = \frac{\text{Wet Pick Up\%}}{100} \times m_{fabric}$$

- Sensible Heat ($Q_{sensible}$): $Q = m \cdot c \cdot \Delta T$, where m is mass, c is specific heat, and ΔT is the change in temperature.
- Latent Heat of Evaporation (Q_{latent}): $Q = m \cdot L$, where m is the mass of water and L is the latent heat of evaporation.
- Total Energy (Q_{total}): $Q_{total} = Q_{sensible,water} + Q_{sensible,cotton} + Q_{latent,water}$

Step 3: Detailed Explanation:
1. Calculate the Mass of Water and Fabric in Grams:
- Mass of bone-dry cotton fabric, $m_{cotton} = 1$ kg $= 1000$ g.
- Wet pick up is 80%. This means the mass of water absorbed is 80% of the dry fabric's mass.

$$m_{water} = \frac{80}{100} \times 1000 \text{ g} = 800 \text{ g}$$

2. Calculate the Total Sensible Heat ($Q_{sensible}$):
The temperature needs to be raised from $T_{initial} = 30°C$ to the boiling point of water, $T_{final} = 100°C$. - Change in temperature, $\Delta T = T_{final} - T_{initial} = 100 - 30 = 70°C$.
- Sensible heat for water:

$$Q_{sensible,water} = m_{water} \cdot c_{water} \cdot \Delta T = 800 \text{ g} \times 1 \frac{\text{cal}}{\text{g} \cdot° \text{C}} \times 70°\text{C} = 56000 \text{ cal}$$

- Sensible heat for cotton:

$$Q_{sensible,cotton} = m_{cotton} \cdot c_{cotton} \cdot \Delta T = 1000 \text{ g} \times 0.3 \frac{\text{cal}}{\text{g} \cdot° \text{C}} \times 70°\text{C} = 21000 \text{ cal}$$

- Total sensible heat:

$$Q_{sensible} = Q_{sensible,water} + Q_{sensible,cotton} = 56000 + 21000 = 77000 \text{ cal}$$

3. Calculate the Latent Heat of Evaporation (Q_{latent}):
This is the energy needed to evaporate the 800 g of water at 100°C.

$$Q_{latent} = m_{water} \cdot L_{water} = 800 \text{ g} \times 540 \frac{\text{cal}}{\text{g}} = 432000 \text{ cal}$$

4. Calculate the Total Energy (Q_{total}) and Convert to kcal:
- Total energy in calories:

$$Q_{total} = Q_{sensible} + Q_{latent} = 77000 \text{ cal} + 432000 \text{ cal} = 509000 \text{ cal}$$

- The question asks for the answer in kilocalories (kcal). Since 1 kcal = 1000 cal:

$$Q_{total}(\text{kcal}) = \frac{509000}{1000} = 509 \text{ kcal}$$

Step 4: Final Answer:
The energy required to dry the fabric completely is 509 kcal. Since the question asks for an integer value, the answer is 509.

Quick Tip

In thermodynamics problems related to drying, always remember to account for both the sensible heat (heating the material and water) and the latent heat (phase change of water). A common mistake is to forget to heat the base material (the fabric itself). Also, pay close attention to units (g vs. kg, cal vs. kcal) and perform conversions accurately at the final step.

---

36. The three eigenvalues of the matrix $A = \begin{pmatrix} -2 & x & -3 \\ 2 & 1 & -6 \\ -1 & -2 & z \end{pmatrix}$ are $\lambda_1 = 5$ and $\lambda_2 = \lambda_3 = -3$. The value of z is:

Correct Answer: 0

Solution:

Step 1: Understanding the Concept:
This problem uses a fundamental property of matrices in linear algebra. One of the key properties of eigenvalues is that the sum of the eigenvalues of a matrix is equal to the trace of that matrix. The trace of a square matrix is the sum of the elements on its main diagonal.

Step 2: Key Formula or Approach:
For any square matrix A,

$$\sum_{i=1}^{n} \lambda_i = \text{tr}(A)$$

where λ_i are the eigenvalues and $\text{tr}(A)$ is the trace of the matrix. The trace is calculated as:

$$\text{tr}(A) = \sum_{i=1}^{n} A_{ii}$$

Step 3: Detailed Explanation:
First, let's find the sum of the given eigenvalues:

$$\sum \lambda_i = \lambda_1 + \lambda_2 + \lambda_3$$

$$\sum \lambda_i = 5 + (-3) + (-3) = 5 - 6 = -1$$

Next, let's find the trace of the given matrix A:

$$A = \begin{pmatrix} -2 & x & -3 \\ 2 & 1 & -6 \\ -1 & -2 & z \end{pmatrix}$$

The elements on the main diagonal are -2, 1, and z.

$$\text{tr}(A) = -2 + 1 + z = -1 + z$$

Now, we equate the sum of the eigenvalues with the trace of the matrix:

$$\sum \lambda_i = \text{tr}(A)$$

$$-1 = -1 + z$$

Solving for z:

$$z = -1 + 1$$

$$z = 0$$

Step 4: Final Answer:
The value of z is 0. Note that the value of x is not needed to solve this problem.

💡 Quick Tip

For matrix problems involving eigenvalues, always check if you can use the trace or determinant properties. The sum of eigenvalues equals the trace, and the product of eigenvalues equals the determinant. These properties often provide a much faster solution than trying to solve the characteristic equation.

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37. A scientist wants to find the root of the equation

$$2x^3 + x^2 - 1 = 0$$

lying in (0,1). He applies the Secant method only once by taking two initial guesses 0.5 and 0.7. The value of the root is approximately:

(A) 0.17
(B) 0.52
(C) 0.65
(D) 0.75

Correct Answer: (C) 0.65

Solution:

Step 1: Understanding the Concept:
The Secant method is a numerical, iterative technique used to find the root of a function $f(x)$. It works by approximating the function with a secant line (a line passing through two points on the function's curve) and finding the x-intercept of this line. This x-intercept then becomes the next approximation for the root. The method requires two initial guesses to start the process.

Step 2: Key Formula or Approach:
The iterative formula for the Secant method is given by:

$$x_{n+1} = x_n - f(x_n)\frac{x_n - x_{n-1}}{f(x_n) - f(x_{n-1})}$$

Here, we are asked to apply the method only once. We are given the initial guesses $x_0 = 0.5$ and $x_1 = 0.7$. We need to find the next approximation, x_2. Setting $n = 1$ in the formula gives:

$$x_2 = x_1 - f(x_1)\frac{x_1 - x_0}{f(x_1) - f(x_0)}$$

Step 3: Detailed Explanation:
1. Define the Function and Initial Guesses:
The function is $f(x) = 2x^3 + x^2 - 1$.

The initial guesses are $x_0 = 0.5$ and $x_1 = 0.7$.

2. Evaluate the Function at the Initial Guesses:
First, we calculate $f(x_0)$:

$$f(x_0) = f(0.5) = 2(0.5)^3 + (0.5)^2 - 1$$

$$f(0.5) = 2(0.125) + 0.25 - 1$$

$$f(0.5) = 0.25 + 0.25 - 1 = -0.5$$

Next, we calculate $f(x_1)$:

$$f(x_1) = f(0.7) = 2(0.7)^3 + (0.7)^2 - 1$$

$$f(0.7) = 2(0.343) + 0.49 - 1$$

$$f(0.7) = 0.686 + 0.49 - 1 = 1.176 - 1 = 0.176$$

3. Apply the Secant Method Formula:
Now we substitute all the values into the formula for x_2:

$$x_2 = 0.7 - (0.176)\frac{0.7 - 0.5}{0.176 - (-0.5)}$$

$$x_2 = 0.7 - (0.176)\frac{0.2}{0.176 + 0.5}$$

$$x_2 = 0.7 - (0.176)\frac{0.2}{0.676}$$

$$x_2 = 0.7 - \frac{0.0352}{0.676}$$

Now, calculate the value of the fraction:

$$\frac{0.0352}{0.676} \approx 0.052071$$

Finally, calculate x_2:

$$x_2 \approx 0.7 - 0.052071$$

$$x_2 \approx 0.647929$$

Step 4: Final Answer:
The calculated value of the root after one iteration is approximately 0.6479. Rounding this to two decimal places gives 0.65. Comparing this to the given options, the closest value is 0.65.
Therefore, the correct option is (C).

Quick Tip

The Secant method is essentially a simplified version of Newton's method where the derivative is approximated by the slope of the line connecting the two previous points. This avoids the need to calculate the analytical derivative, which can be complex or computationally expensive. Make sure to perform calculations carefully, as small errors in evaluating the function can lead to a significantly different result.

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38. Determine the correctness or otherwise of the following Assertion [a] and Reason [r]:
[a]: Nylon 6 should be thoroughly dried before melt spinning.
[r]: The glass transition temperature of Nylon 6 decreases in presence of moisture.

(A) Both [a] and [r] are true and [r] is the correct reason for [a]
(B) Both [a] and [r] are true and [r] is not the correct reason for [a]
(C) Both [a] and [r] are false
(D) [a] is true but [r] is false

Correct Answer: (B) Both [a] and [r] are true and [r] is not the correct reason for [a]

Solution:

Step 1: Understanding the Concept:
This question assesses knowledge of polymer processing, specifically the melt spinning of Nylon 6, and the effect of moisture on its properties. We need to evaluate the truth of both the assertion and the reason, and then determine if the reason logically explains the assertion.

Step 2: Detailed Explanation:
Analyze the Assertion [a]:

a : Nylon 6 should be thoroughly dried before melt spinning.

- Nylon 6 is a polyamide, containing amide (-CONH-) linkages. Melt spinning occurs at high temperatures (above the melting point, $\sim 220°C$). At these high temperatures, any moisture (water) present will cause hydrolytic degradation of the polymer chains. The water molecules attack the amide bonds, breaking them and reducing the molecular weight of the polymer. This leads to a drastic loss in mechanical properties (like strength and toughness) of the resulting fiber. Therefore, it is absolutely essential to dry Nylon 6 chips thoroughly before melt spinning. **Assertion [a] is true.**

Analyze the Reason [r]:

r : The glass transition temperature of Nylon 6 decreases in presence of moisture.

- Moisture acts as a plasticizer for Nylon 6. Water molecules can penetrate the amorphous regions of the polymer and disrupt the strong intermolecular hydrogen bonds between the polyamide chains. This increases chain mobility, allowing the polymer to transition from a glassy to a rubbery state at a lower temperature. Thus, the glass transition temperature (Tg) is significantly lowered by the presence of moisture. **Reason [r] is true.**

Analyze the link between [a] and [r]:

- Does the decrease in Tg explain why Nylon needs to be dried?
- The primary reason for drying Nylon before melt spinning is to prevent **hydrolytic degradation at high temperatures**, which lowers molecular weight and ruins fiber properties. The effect on Tg is a separate phenomenon that is important for the properties of the final solid fiber at room temperature, but it is not the critical reason for drying before the melting stage. The melting temperature itself is also slightly depressed, but the main issue is the chemical breakdown (hydrolysis).
- Therefore, while both statements are individually true, the reason given ([r]) is not the correct or primary explanation for the assertion ([a]).

Step 3: Final Answer:
Both assertion [a] and reason [r] are true statements. However, the reason [r] does not correctly explain the assertion [a]. The correct reason for [a] is the prevention of hydrolytic degradation. Thus, option (B) is the correct choice.

> Quick Tip
>
> For Assertion-Reason questions, use a two-step process. First, verify if each statement is true or false independently. Second, if both are true, ask ”Is [a] true *because* of [r]?” The connection must be direct and causal. Be aware of common polymer science facts, like water acting as a plasticizer for nylons (lowering Tg) and causing hydrolysis at high temperatures.

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39. Determine the correctness or otherwise of the following Assertion [a] and Reason [r]:
[a]: Cotton does not exhibit melting behaviour when exposed to flame.
[r]: Cotton is not crystalline enough to exhibit melting behaviour.

(A) Both [a] and [r] are true and [r] is the correct reason for [a]
(B) Both [a] and [r] are true and [r] is not the correct reason for [a]

(C) Both [a] and [r] are false
(D) [a] is true but [r] is false

Correct Answer: (D) [a] is true but [r] is false

Solution:

Step 1: Understanding the Concept:
This question deals with the thermal properties of cotton fiber. We need to assess its behavior when heated (specifically, if it melts) and relate this behavior to its molecular structure (crystallinity).

Step 2: Detailed Explanation:
Analyze the Assertion [a]:

a : Cotton does not exhibit melting behaviour when exposed to flame.

- Cotton is a natural cellulosic fiber. When subjected to high heat, like a flame, it does not melt into a liquid state. Instead, it undergoes thermal decomposition (pyrolysis). It chars, glows, and burns, often leaving a fine grey ash. This is characteristic of cellulosic materials. Therefore, **Assertion [a] is true**.

Analyze the Reason [r]:

r : Cotton is not crystalline enough to exhibit melting behaviour.

- Melting is the process of transitioning from an ordered crystalline solid to a disordered liquid state. This statement suggests that a lack of crystallinity is why cotton doesn't melt. However, this is incorrect. Cotton is a semi-crystalline polymer with a relatively high degree of crystallinity (typically 65-70%). The actual reason cotton does not melt is that its decomposition temperature (around 350°C) is lower than its theoretical melting point. The strong intermolecular hydrogen bonds within its crystalline structure require a very high amount of energy to break; before this energy level is reached, the chemical bonds within the cellulose molecules themselves break down. Therefore, the reason given is factually incorrect. **Reason [r] is false**.

Step 3: Final Answer:
The assertion [a] is a correct statement, but the reason [r] provides a false explanation. Thus, option (D) is the correct choice.

💡 Quick Tip

A simple way to remember the thermal behavior of fibers is to classify them as thermoplastic or non-thermoplastic.

- **Thermoplastics** (e.g., Polyester, Nylon, Polypropylene) melt and often shrink from a flame.
- **Non-thermoplastics** (e.g., Cotton, Rayon, Wool) do not melt; they char and burn.

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40. Amongst the different zones in a carding machine, if
$P =$ **draft between feed roller and taker-in**
$Q =$ **draft between taker-in and cylinder**
$R =$ **draft between cylinder and doffer**
then the drafts follow the order:

(A) $Q < R < P$
(B) $Q < P < R$
(C) $R < Q < P$
(D) $R < P < Q$

Correct Answer: (D) $R < P < Q$

Solution:

Step 1: Understanding the Concept:
In a carding machine, "draft" refers to the attenuation or drawing out of the fiber mass, achieved by passing the material between pairs of rollers rotating at different surface speeds. Draft is calculated as the ratio of the surface speed of the faster (delivery) roller to the surface speed of the slower (feed) roller. The magnitude of the draft in each zone is related to the specific function of that zone.

Step 2: Detailed Explanation:
Let's analyze the function and relative speeds in each zone:

- **R = draft between cylinder and doffer:** The doffer rotates significantly slower than the main cylinder. This is necessary to allow the individualized fibers on the cylinder to be transferred and condensed into a coherent web on the doffer's surface. While the ratio $V_{\text{cylinder}}/V_{\text{doffer}}$ is high (often called the condensing ratio, typically 15-30), this zone has the lowest drafting action compared to the others. So, **R has the smallest value**.
- **P = draft between feed roller and taker-in:** The feed roller transports the compressed lap at a very slow speed. The taker-in rotates at a high speed, striking

the lap to break it down into small tufts. This is the initial opening stage, and the speed difference is very large, resulting in a high draft. So, **P has a high value**.

- **Q = draft between taker-in and cylinder:** The main cylinder rotates at a surface speed significantly higher than the taker-in. This is the primary carding zone where the small tufts from the taker-in are opened up into individual fibers through the carding action between the cylinder and the flats. This process of final individualization involves the highest degree of attenuation. Therefore, this zone has the highest speed differential and the **highest draft (Q)**.

Step 3: Final Answer:
Based on the function of each zone, the main carding draft (Q) is the highest. The initial opening draft (P) is also high but generally less than Q. The condensing action at the doffer (R) represents the lowest draft value. Therefore, the drafts follow the order $R < P < Q$.

Quick Tip

Relate the draft magnitude to the primary action in that zone:

- **Highest Draft (Q):** Main individualization of fibers (Taker-in to Cylinder).
- **Medium Draft (P):** Initial opening of lap into tufts (Feed to Taker-in).
- **Lowest Draft (R):** Condensing of fibers into a web (Cylinder to Doffer).

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41. Group I lists yarn manufacturing technologies and Group II contains typical structural features of the yarns. Match the manufacturing technology with the structural features of the yarn.

Group I
P. Rotor spinning
Q. Air-jet spinning
R. Wrap spinning
S. Bobtex spinning

Group II
1. Twistless parallel fibres in core and helically arranged filament on surface
2. Helically twisted core and distinct wrappers on surface
3. Multifilament core covered by staple fibres stuck to molten polymer
4. Twistless core wrapped regularly and helically by thin fibre ribbons

Table 1: Match the technologies in Group I with their corresponding descriptions in Group II

(A) P $\rightarrow$ 1, Q $\rightarrow$ 2, R $\rightarrow$ 3, S $\rightarrow$ 4
(B) P $\rightarrow$ 2, Q $\rightarrow$ 1, R $\rightarrow$ 4, S $\rightarrow$ 3
(C) P $\rightarrow$ 2, Q $\rightarrow$ 1, R $\rightarrow$ 3, S $\rightarrow$ 4
(D) P $\rightarrow$ 3, Q $\rightarrow$ 4, R $\rightarrow$ 2, S $\rightarrow$ 1

Correct Answer: (B) P $\rightarrow$ 2, Q $\rightarrow$ 1, R $\rightarrow$ 4, S $\rightarrow$ 3

Solution:

Step 1: Understanding the Concept:
This question requires knowledge of different yarn manufacturing technologies and the unique structural characteristics of the yarns they produce. We need to correctly associate each spinning method with its resulting yarn structure.

Step 2: Detailed Explanation:
Let's analyze each technology in Group I and match it with the descriptions in Group II.

- **P. Rotor spinning (Open-End spinning):** In this process, fibres are collected on the inner surface of a high-speed rotor and are continuously peeled off and twisted to form the yarn. This results in a yarn structure with a core that is helically twisted and distinct wrapper fibres on the surface that are wound in the opposite direction. This matches description **2**.

- **Q. Air-jet spinning (e.g., Murata Jet Spinner):** This method uses a vortex of compressed air to wrap some of the outer fibres around a core of parallel, untwisted staple fibres. This creates a yarn with a twistless parallel core and wrapper fibres on the surface. While the description mentions "helically arranged filament", air-jet spinning uses staple fibers for wrapping. However, among the choices, the description of a twistless core with helical wrapping is most representative. The term "filament" might be used loosely or could refer to a specific variant. A closer look at description **1** "Twistless parallel fibres in core and helically arranged filament on surface" is a better match for Air-jet than other options. Note: Wrap spinning is a more literal fit for this description if the wrapper is a filament, but let's evaluate all options. The core of an air-jet yarn is indeed twistless and parallel. The wrappers are staple fibres, not a continuous filament. Let's re-evaluate after checking the other pairs.
- **R. Wrap spinning:** In this technology, a core of staple fibres is wrapped with a continuous filament yarn or a fine tape/ribbon. The core fibres themselves remain parallel and untwisted. This perfectly matches description **4**: "Twistless core wrapped regularly and helically by thin fibre ribbons".
- **S. Bobtex spinning:** This is a less common adhesive spinning process. A core of multifilament yarn is passed through a system where it is coated with a molten

polymer (adhesive). Staple fibres are then applied to this sticky core, adhering to it to form the final yarn. This matches description **3**: "Multifilament core covered by staple fibres stuck to molten polymer".

Let's re-evaluate Q. Air-jet spinning. - P $\rightarrow$ 2 - R $\rightarrow$ 4 - S $\rightarrow$ 3 Looking at the available options, if P $\rightarrow$ 2, R $\rightarrow$ 4, and S $\rightarrow$ 3, the only remaining match for Q is 1. Air-jet spinning produces a yarn with a core of parallel fibers (twistless core) and wrapper fibers. Description 1 is "Twistless parallel fibres in core and helically arranged filament on surface". The key discrepancy is "filament" vs "staple wrapper fibers". However, compared to other descriptions, it is the closest structural analogue. Therefore, the combination P$\rightarrow$2, Q$\rightarrow$1, R$\rightarrow$4, S$\rightarrow$3 is the most logical fit.

Step 3: Final Answer:
Based on the analysis:

- P (Rotor spinning) matches 2 (Helically twisted core and distinct wrappers).
- Q (Air-jet spinning) matches 1 (Twistless parallel fibres in core, helically arranged wrappers).
- R (Wrap spinning) matches 4 (Twistless core wrapped by ribbons/filaments).
- S (Bobtex spinning) matches 3 (Multifilament core with staple fibres stuck on).

This corresponds to the combination given in option (B).

Quick Tip

For yarn technology matching questions, focus on the fundamental principle of twist insertion or yarn formation for each method. Ring spinning = true twist. Rotor spinning = false twist + true twist + wrappers. Air-jet/Vortex = twistless core + wrappers. Wrap spinning = twistless core + filament wrap.

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42. Group I lists weaving machine-related parameters, and Group II contains the shortcomings of these parameters. Match the machine-related parameter with its shortcoming.

Group I
P. Variable heald staggering
Q. High eccentricity ratio
R. Fixed heald staggering
S. Late shedding

Group II
1. Not favourable for heavy fabric

2. Reduction in shed height
3. Reduction of sley dwell
4. Higher vibration in weaving machine

(A) P $\rightarrow$ 1, Q $\rightarrow$ 3, R $\rightarrow$ 2, S $\rightarrow$ 4
(B) P $\rightarrow$ 1, Q $\rightarrow$ 3, R $\rightarrow$ 4, S $\rightarrow$ 2
(C) P $\rightarrow$ 3, Q $\rightarrow$ 4, R $\rightarrow$ 2, S $\rightarrow$ 1
(D) P $\rightarrow$ 3, Q $\rightarrow$ 4, R $\rightarrow$ 1, S $\rightarrow$ 2

Correct Answer: (D) P $\rightarrow$ 3, Q $\rightarrow$ 4, R $\rightarrow$ 1, S $\rightarrow$ 2

Solution:

Step 1: Understanding the Concept:
This question tests the understanding of weaving machine kinematics and settings. Each parameter in Group I affects the weaving process and has specific advantages and disadvantages. We need to match the setting with its corresponding negative consequence (shortcoming).

Step 2: Detailed Explanation:
Let's analyze each parameter in Group I:

- **P. Variable heald staggering:** This refers to an asymmetric heald crossing profile, often used to create a longer dwell time for the healds at the top or bottom of the shed. This can be beneficial, but a common type of asymmetric motion can lead to a shorter sley dwell (the time the sley is at its rearmost position, crucial for shuttle/projectile passage). Therefore, P matches with **3. Reduction of sley dwell**.

- **Q. High eccentricity ratio (in the sley drive mechanism):** Eccentricity in the crank-connecting rod system for the sley affects its motion. A high eccentricity ratio (ratio of crank radius to connecting rod length) leads to more non-uniform motion, which causes higher acceleration and deceleration. This results in increased inertial forces and thus **4. Higher vibration in the weaving machine**.

- **R. Fixed heald staggering:** This refers to a standard, symmetric heald crossing. While simple and common, it may not provide enough time for weft insertion, especially for very wide looms or dense/heavy fabrics which require more time for beat-up and warp relaxation. Hence, it is **1. Not favourable for heavy fabric** compared to optimized staggering.

- **S. Late shedding:** Shedding timing refers to when the healds cross (shed closes) relative to the beat-up position of the crank. In late shedding, the healds cross after the crank has passed the front center. This timing generally leads to a smaller effective shed height at the moment of weft insertion and beat-up, which can cause issues with yarn abrasion and shuttle passage. This corresponds to **2. Reduction in shed height**.

Step 3: Final Answer:
Based on the analysis, the correct pairings are:

- P $\rightarrow$ 3 (Variable heald staggering $\rightarrow$ Reduction of sley dwell)
- Q $\rightarrow$ 4 (High eccentricity ratio $\rightarrow$ Higher vibration in weaving machine)
- R $\rightarrow$ 1 (Fixed heald staggering $\rightarrow$ Not favourable for heavy fabric)
- S $\rightarrow$ 2 (Late shedding $\rightarrow$ Reduction in shed height)

This combination matches option (D).

Quick Tip

To remember weaving timings, think about a clock face. Early shedding is when the shed closes before the crank reaches front-center (12 o'clock). Late shedding is when it closes after. The timing affects the 'beat-up line' and the overall geometry of the shed, impacting fabric quality and machine stress. High eccentricity always suggests more aggressive motion and thus more vibration.

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43. Determine the correctness or otherwise of the following Assertion [a] and Reason [r]:
[a]: The variability of fibre diameter in melt-blown nonwoven fabric is remarkably higher than that in spunbond nonwoven fabric.
[r]: Hot air attenuation in the melt-blown process is responsible for high variation in fibre diameter.

(A) Both [a] and [r] are true and [r] is the correct reason for [a]
(B) Both [a] and [r] are true and [r] is not the correct reason for [a]
(C) Both [a] and [r] are false
(D) [a] is true but [r] is false

Correct Answer: (A) Both [a] and [r] are true and [r] is the correct reason for [a]

Solution:

Step 1: Understanding the Concept:
This question compares two nonwoven manufacturing processes, melt-blowing and spunbonding, in terms of the resulting fiber diameter uniformity. It requires knowledge of how fibers are formed and attenuated (drawn) in each process.

Step 2: Detailed Explanation:
Analysis of Assertion [a]:
The assertion states that melt-blown fabrics have a much higher fiber diameter variability compared to spunbond fabrics.

- **Melt-blowing:** Produces very fine microfibers, typically 1-5 micrometers in diameter. The process uses high-velocity hot air to attenuate the molten polymer filaments. This process is turbulent and less controlled, leading to a wide distribution of fiber diameters.
- **Spunbonding:** Produces fibers that are generally thicker, typically 15-35 micrometers. The attenuation is primarily mechanical (e.g., using godet rolls) or aerodynamic in a more controlled manner. This leads to more uniform fiber diameters.

Therefore, the assertion [a] is **true**. The variability is indeed significantly higher in melt-blown products.

Analysis of Reason [r]:
The reason states that the hot air attenuation in the melt-blown process is responsible for this high variation.

- In melt-blowing, molten polymer is extruded through fine nozzles directly into a stream of high-velocity, hot air. This hot air simultaneously heats the polymer to keep it malleable and applies a strong drag force that stretches and attenuates the fibers. The turbulent nature of this high-speed air flow causes instabilities in the drawing process. Different filaments experience slightly different air velocities and temperatures, leading to non-uniform stretching and thus a high variation in the final fiber diameter.

Therefore, the reason [r] is also **true**.

Connecting Reason [r] to Assertion [a]:
The reason directly explains the assertion. The specific mechanism used in melt-blowing—turbulent hot air attenuation—is precisely why the resulting fibers have a much wider diameter distribution than those from the more mechanically controlled spunbond process. The reason correctly identifies the cause of the phenomenon described in the assertion.

Step 3: Final Answer:
Both the assertion [a] and the reason [r] are true statements, and the reason [r] provides the correct scientific explanation for the assertion [a]. This corresponds to option (A).

Quick Tip

Remember the key difference: Spunbond = more controlled, mechanical/aerodynamic drawing, thicker and more uniform fibers. Melt-blown = turbulent hot air drawing, very fine but highly variable fibers. The process defines the product properties.

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44. A print paste for pigment printing of cotton fabric is prepared by using a synthetic thickener. The suitable chemical, amongst the following, to build the viscosity of the print paste is:

(A) HCOOH (Formic Acid)
(B) NH_4OH (Ammonium Hydroxide)
(C) CH_3COOH (Acetic Acid)
(D) $MgCl_2$ (Magnesium Chloride)

Correct Answer: (B) NH_4OH (Ammonium Hydroxide)

Solution:

Step 1: Understanding the Concept:
The question is about the chemistry of print pastes used in textile printing, specifically with synthetic thickeners. Synthetic thickeners, often based on acrylic acid copolymers, are supplied in an acidic state where their polymer chains are coiled up, resulting in low viscosity. To become effective thickeners, these chains must uncoil and swell. This process is triggered by a change in pH.

Step 2: Detailed Explanation:

- **Synthetic Thickeners:** These are high molecular weight polymers containing carboxyl (-COOH) groups. In their supplied form, the paste is acidic, and these groups are not ionized. The polymer chains are tightly coiled.
- **Viscosity Building Mechanism:** To increase the viscosity, the pH of the paste must be raised by adding an alkali. The alkali neutralizes the acidic carboxyl groups, converting them to carboxylate ions ($-COO^-$). The negative charges on these ions repel each other, causing the coiled polymer chains to uncoil and stretch out. This uncoiling and the associated hydration of the polymer chains dramatically increase the viscosity of the paste, making it suitable for printing.
- **Analyzing the Options:** We need to identify the alkali among the given choices.
  - (A) HCOOH (Formic Acid) is an acid.

– (B) NH_4OH (Ammonium Hydroxide) is a weak base (alkali). It is commonly used for this purpose because it is volatile and evaporates during the drying and curing stage, leaving the fabric with a neutral pH.
– (C) CH_3COOH (Acetic Acid) is an acid.
– (D) $MgCl_2$ (Magnesium Chloride) is a salt. It acts as a catalyst in some printing systems but does not build viscosity by neutralizing the thickener.

Step 3: Final Answer:
Ammonium hydroxide (NH_4OH) is the suitable chemical (alkali) to neutralize the synthetic thickener, causing the polymer chains to uncoil and thus build the required viscosity for the print paste. Therefore, option (B) is the correct answer.

Quick Tip

For synthetic print thickeners, remember the key principle: "Alkali swells". You need to add a base to increase the pH and activate the thickening action. Ammonium hydroxide is a very common choice in the industry due to its effectiveness and volatility.

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45. Consider the following diagram where an oil droplet is formed on a fabric immersed in water. At equilibrium, the balance of various interfacial forces acting on the droplet is given by the following equation:

$$\gamma_{FW} = \gamma_{FO} + \gamma_{OW} \cos\theta$$

When a surfactant is added to water, assuming that γ_{OW} and γ_{FO} remain unchanged, the following happens:

(A) γ_{FW} decreases and the oil droplet tends to become rounder
(B) γ_{FW} increases and the oil droplet tends to become flatter
(C) γ_{FW} decreases and the oil droplet tends to become flatter
(D) γ_{FW} increases and the oil droplet tends to become rounder

Correct Answer: (A) γ_{FW} decreases and the oil droplet tends to become rounder

Solution:

Step 1: Understanding the Concept:
This problem deals with surface tension and the effect of surfactants at interfaces. The shape of a liquid droplet on a solid surface is governed by the balance of three interfacial tensions, described by Young's equation. A surfactant is a substance that lowers the

surface tension at an interface.

Step 2: Key Formula or Approach:
The governing equation is Young's equation for a three-phase system (fabric-oil-water):

$$\gamma_{FW} = \gamma_{FO} + \gamma_{OW} \cos\theta$$

where:

- γ_{FW} is the interfacial tension between the fabric and water.
- γ_{FO} is the interfacial tension between the fabric and oil.
- γ_{OW} is the interfacial tension between oil and water.
- θ is the contact angle of the oil droplet on the fabric, measured through the oil phase.

Step 3: Detailed Explanation:
1. Effect of Surfactant:
A surfactant added to the water will primarily act at the interfaces involving water. Its main function is to lower the interfacial tension. Therefore, the surfactant molecules will accumulate at the fabric-water interface, reducing the energy of this interface. This means γ_{FW} decreases.

2. Impact on Contact Angle (θ):
Let's rearrange Young's equation to solve for $\cos\theta$:

$$\cos\theta = \frac{\gamma_{FW} - \gamma_{FO}}{\gamma_{OW}}$$

The problem states that γ_{FO} and γ_{OW} remain unchanged. We have established that adding a surfactant to the water will decrease γ_{FW}. - Since γ_{FW} decreases, the numerator $(\gamma_{FW} - \gamma_{FO})$ becomes smaller (or more negative). - Consequently, the value of $\cos\theta$ decreases.
3. Impact on Droplet Shape:
The shape of the droplet is described by the contact angle θ. - A smaller value of $\cos\theta$ corresponds to a larger value of the angle θ (in the range of 0 to 180 degrees). For example, $\cos(60°) = 0.5$ while $\cos(90°) = 0$. - A larger contact angle θ means the oil droplet "beads up" more on the surface and does not spread. A droplet that beads up is more spherical or "rounder". A flatter droplet corresponds to a smaller θ. - Therefore, as θ increases, the oil droplet tends to become rounder.
Step 4: Final Answer:
The addition of a surfactant decreases γ_{FW}. This decrease causes $\cos\theta$ to decrease, which in turn means the contact angle θ increases. An increase in the contact angle makes the droplet more spherical or "rounder". This matches the description in option (A).

💡 Quick Tip

Remember the primary role of a surfactant is to reduce surface/interfacial tension. Identify which interface is affected (here, Fabric-Water). Then, use Young's equation to see how this change affects the contact angle θ. A large θ means poor wetting (beading up, rounder), while a small θ means good wetting (spreading, flatter).

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46. Polymer melt flowing through a capillary exhibits die-swell. The correct statement(s), amongst the following, is/are:

(A) Die-swell is due to entropic effect
(B) Die-swell is dependent on capillary length
(C) Die-swell is independent of processing temperature
(D) Die-swell is dependent on shear rate

Correct Answer: (A), (B), and (D) are correct statements.

Solution:

Step 1: Understanding the Concept:
Die-swell, also known as the Barus effect or extrudate swell, is a common phenomenon in polymer processing. When a polymer melt or solution is extruded from a capillary die, its diameter increases to a value larger than the die's diameter. This behavior is a manifestation of the viscoelastic nature of polymers.

Step 2: Detailed Explanation of Each Statement:

(A) Die-swell is due to entropic effect: This is correct.
Inside the capillary, the high shear flow forces the long polymer chains to uncoil and align in the direction of flow. This is an ordered, low-entropy state. Upon exiting the die, the shear forces are removed, and the polymer chains have time to relax back to their preferred, random, coiled, high-entropy state. This molecular relaxation causes a recovery of the elastic deformation, leading to an expansion in the diameter of the extrudate.

(B) Die-swell is dependent on capillary length: This is correct.
The length of the capillary (often considered as the ratio L/D, length to diameter) affects die-swell. In a very short capillary (low L/D), the polymer chains do not have enough time to fully align before exiting, leading to less stored elastic energy and smaller die-swell. In a very long capillary (high L/D), the flow becomes fully developed, but the extended residence time under pressure allows for some molecular relaxation to occur even before the polymer exits the die, which can reduce the swell. Therefore, die-swell has a complex

dependency on capillary length, often showing a maximum at an intermediate L/D ratio. The key point is that it is dependent.

(C) Die-swell is independent of processing temperature: This is incorrect.
Temperature has a significant effect on polymer viscosity and relaxation time. A higher processing temperature reduces the melt's viscosity and shortens the relaxation time of the polymer chains. This means the chains can disentangle and relax more quickly, both within the die and after exiting. Faster relaxation leads to less stored elastic energy at the die exit, and therefore, a reduction in die-swell.

(D) Die-swell is dependent on shear rate: This is correct.
The shear rate (related to the flow rate) is a primary factor influencing die-swell. A higher shear rate causes greater alignment and stretching of the polymer chains inside the die. This stores more elastic energy in the melt. Upon exiting the die, the recovery from this higher state of deformation leads to a larger die-swell. Generally, die-swell increases with increasing shear rate, up to a certain point.

Step 3: Final Answer:
Based on the analysis, statements (A), (B), and (D) are correct descriptions of the die-swell phenomenon. Statement (C) is incorrect.

Quick Tip

Think of die-swell as the "memory" of the polymer. The polymer chains are forced into an uncomfortable, straight alignment inside the die. When they are free, they spring back to their preferred random shape, causing the material to swell. Anything that increases this "stress" (like higher shear rate) increases swell, and anything that helps the chains "forget" or relax (like higher temperature or very long die residence time) reduces swell.

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47. Amongst the given options, the spinning technology(ies) in which the concept of spinning triangle exists is/are:

(A) Ring spinning
(B) Rotor spinning
(C) Friction spinning
(D) Compact spinning

Correct Answer: (A) and (D) are relevant. The triangle exists in (A) and is minimized/eliminated in (D).

Solution:

Step 1: Understanding the Concept:
The "spinning triangle" is a characteristic feature of the yarn formation zone in conventional ring spinning. It is the triangular-shaped region formed by the ribbon of fibers emerging from the nip of the front drafting rollers, which then converges into a circular yarn structure as twist is inserted by the traveler. The width of this triangle is a critical factor influencing yarn hairiness and strength.

Step 2: Detailed Explanation of Each Option:

(A) Ring spinning: This is correct.
Ring spinning is the classic example where the spinning triangle exists. After the fiber strand (roving) is drafted, it emerges as a flat ribbon. Twist, propagating from the traveler, runs up to the nip point of the front rollers. The fibers at the edges of the ribbon have to travel a longer path to be incorporated into the yarn, which can lead to them being lost as fly or becoming hairiness. The geometry of this convergence zone is the spinning triangle.

(B) Rotor spinning: This is incorrect.
Rotor (or open-end) spinning uses a completely different mechanism. Individual fibers are fed into a rotor, collected by centrifugal force, and then peeled off and twisted into the yarn. There is no drafting roller system that creates a fiber ribbon, and thus no spinning triangle.

(C) Friction spinning: This is incorrect.
In friction spinning (like DREF), fibers are collected between two rotating perforated drums and twisted by the frictional forces. This yarn formation mechanism does not involve a spinning triangle.

(D) Compact spinning: This is correct in context.
Compact spinning is a modification of the ring spinning process. Its entire purpose is to manage and **eliminate** the spinning triangle. It uses an additional pneumatic suction or perforated apron zone after the main drafting system to condense the fiber strand laterally before twist is inserted. This condensation eliminates the spinning triangle, leading to better integration of edge fibers and resulting in a yarn with significantly lower hairiness and higher strength. Therefore, the concept of the spinning triangle is central to understanding why compact spinning was developed and how it works. The technology exists specifically to address the problems caused by the spinning triangle.

Step 3: Final Answer:
The concept of the spinning triangle is a defining characteristic of **Ring spinning (A)**. It is also the problem that **Compact spinning (D)** is designed to solve. Therefore, both options are directly related to the concept.

Quick Tip

The spinning triangle is unique to processes where a drafted, flat ribbon of fibers is twisted into a yarn. This is the hallmark of ring spinning. Remember that compact spinning is essentially "ring spinning without the spinning triangle".

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48. Consider the following equation $C = C_1 + C_2 - C_1C_2$ where C stands for fractional cover of a fabric, C_1 denotes the fractional cover of warp and C_2 refers to the fractional cover of weft. Amongst the given options, the fabric structure(s) in which the aforesaid equation is valid is/are:

(A) Plain woven fabric
(B) Double cloth
(C) Terry fabric
(D) Leno fabric

Correct Answer: (A) Plain woven fabric

Solution:

Step 1: Understanding the Concept:
The equation $C = C_1 + C_2 - C_1C_2$ is based on probability theory for the union of two events. If $P(A)$ is the probability of event A and $P(B)$ is the probability of event B, the probability of either A or B occurring is $P(A \cup B) = P(A) + P(B) - P(A \cap B)$. If the events are independent, $P(A \cap B) = P(A)P(B)$. In the context of fabric cover, C_1 is the fraction of area covered by warp yarns, and C_2 is the fraction covered by weft yarns. The formula assumes that the placement of warp and weft yarns are independent events. The term C_1C_2 represents the area where warp and weft yarns overlap. The total cover is the sum of the individual covers minus the overlap. This model, known as Peirce's model, is a first approximation for fabric cover.

Step 2: Detailed Explanation of Each Option:

(A) Plain woven fabric: This is correct.
For a simple, single-layer fabric like a plain weave, the warp and weft systems are largely independent. The yarns are assumed to be opaque, and the formula calculates the total projected area covered by either warp or weft yarns. This model is most commonly applied and is most valid for basic weave structures like plain, twill, and satin weaves.

(B) Double cloth: This is incorrect.
A double cloth consists of two separate layers of fabric that are stitched together. The concept of a single fractional cover C is not applicable, as there are two distinct layers. The simple probabilistic model does not account for this complex 3D structure.

(C) Terry fabric: This is incorrect.
Terry fabric, used for towels, has a three-yarn system: ground warp, pile warp, and weft. It features loops (piles) that stand up from the surface. The simple 2D cover formula cannot account for the area covered by the pile loops, which is a major component of the fabric's structure and function.

(D) Leno fabric: This is incorrect.
Leno weave is a locking-type weave where two warp yarns twist around the weft yarns to form a figure-eight pattern. This twisting and locking action creates a very stable, open structure. The assumption of independent warp and weft yarn placement is violated by this twisting interaction.

Step 3: Final Answer:
The equation is a simplified model that is valid for single-layer, non-complex weave structures where the warp and weft can be considered as two independent systems laid over each other. Among the given options, the **Plain woven fabric (A)** is the only structure for which this model is appropriate.

Quick Tip

The formula $C = C_1 + C_2 - C_1C_2$ is the classic Peirce's fabric cover model. It applies to simple, 2D woven structures. When you see complex 3D structures like pile fabrics (Terry) or multi-layered fabrics (Double cloth), or complex interlacing (Leno), this basic formula will not be valid.

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49. With reference to the KES FB-1 system, the correct statement(s) amongst the following is/are:

(A) Tensile strain is measured by angle of drum rotation
(B) Tensile strain is measured by crosshead movement
(C) Tensile force is measured by tensile load cell
(D) Tensile force is measured by torque sensor

Correct Answer: (B) and (C) are correct.

Solution:

Step 1: Understanding the Concept:
The Kawabata Evaluation System (KES) is a set of standardized instruments used to measure the low-stress mechanical properties of fabrics, which relate to hand feel. The KES-FB1 is the instrument specifically designed for measuring tensile and shear properties. We need to identify the correct measurement principles for tensile force and strain in this system.

Step 2: Detailed Explanation of Each Statement:

(A) Tensile strain is measured by angle of drum rotation: This is incorrect.
Drum rotation is typically associated with friction measurements (e.g., in the KES-FB4 for surface properties), not tensile strain.

(B) Tensile strain is measured by crosshead movement: This is correct.
Like a standard tensile tester, the KES-FB1 clamps a fabric sample between two jaws. One jaw is fixed, and the other is mounted on a moving crosshead. The fabric is stretched by the movement of this crosshead. The displacement of the crosshead, divided by the initial sample length, gives the tensile strain.

(C) Tensile force is measured by tensile load cell: This is correct.
The force required to stretch the fabric is measured by a force transducer, which is a tensile load cell. This load cell is connected to the fixed jaw and measures the resistance of the fabric to the applied deformation.

(D) Tensile force is measured by torque sensor: This is incorrect.
A torque sensor measures twisting force (torque). It would be used for measuring properties like torsional rigidity, not linear tensile force. Torque sensors are part of other KES instruments, but not for measuring tensile force in the FB1.

Step 3: Final Answer:
The KES-FB1 system measures tensile force using a **tensile load cell (C)** and measures tensile strain based on the **crosshead movement (B)**. Therefore, statements (B) and (C) are correct.

> Quick Tip
>
> For textile testing instruments, remember the basic principles of physics. Linear force is measured by a load cell. Linear displacement (for strain) is measured by crosshead movement. Torque (twisting force) is measured by a torque sensor. Angle is measured by an encoder or protractor. Match the physical quantity to the correct type of sensor.

50. With reference to cotton fibre testing systems, the correct statement(s) amongst the following is/are:

(A) Image processing principle is used to measure nep count in HVI
(B) Image processing principle is used to measure trash count in HVI
(C) Air flow principle is used to measure fibre fineness in HVI
(D) Air flow principle is used to measure fibre fineness in AFIS

Correct Answer: (B), (C), and (D) are correct.

Solution:

Step 1: Analysis of Statements:
This question assesses knowledge of High Volume Instrument (HVI) and Advanced Fiber Information System (AFIS) testing principles.

- **(A) Nep count in HVI:** This is **incorrect**. HVI systems do not measure nep count; this is a primary function of the AFIS instrument.

- **(B) Trash count in HVI:** This is **correct**. The HVI trash meter uses a camera and image processing to scan a cotton sample's surface, identifying trash particles by optical contrast to calculate their area and count.

- **(C) Fibre fineness in HVI:** This is **correct**. HVI measures the Micronaire value, an indicator of fineness, by measuring the resistance to airflow through a compressed cotton sample. This is the air flow principle.

- **(D) Fibre fineness in AFIS:** This is **incorrect**. AFIS measures the fineness of single fibers using an optical sensor that detects the fiber's diameter. The air flow principle is a bulk measurement method (used in HVI), not a single-fiber analysis method.

Step 2: Final Answer:
Based on the operating principles, statements (B) and (C) are correct descriptions of cotton fiber testing systems.

💡 Quick Tip

To differentiate HVI and AFIS, remember: HVI is for high-volume **bulk** testing of cotton bales (think Micron**air**e). AFIS is a more detailed lab instrument for **single fiber** analysis (think Neps, Length, and Fineness distributions measured optically). Image processing is for what you can "see" on a surface, like trash particles.

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51. Amongst the given options, the condition(s) which will increase the equilibrium wicking height of water in a yarn is/are:

(A) Higher contact angle between fibre and water
(B) Lower contact angle between fibre and water
(C) Higher capillary diameter
(D) Lower capillary diameter

Correct Answer: (B) and (D) are correct.

Solution:

Step 1: Understanding the Concept:
Wicking is the spontaneous flow of a liquid into a porous material, such as a yarn, driven by capillary forces. The equilibrium wicking height is the maximum vertical height the liquid can climb against gravity. This phenomenon is governed by the properties of the liquid, the properties of the solid (fibers), and the geometry of the pores (capillaries) between the fibers.

Step 2: Key Formula or Approach:
The equilibrium wicking height (h) in a simple capillary tube is described by Jurin's Law:

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

where:

- γ is the surface tension of the liquid (water).
- θ is the contact angle between the liquid and the solid (fiber).
- ρ is the density of the liquid.
- g is the acceleration due to gravity.
- r is the radius of the capillary (related to capillary diameter).

To increase the wicking height (h), we need to maximize the numerator and minimize the denominator.

Step 3: Detailed Explanation of Each Option:
Let's analyze the factors from the given options based on the formula.

(A) Higher contact angle between fibre and water: This is **incorrect**.
The height h is proportional to $\cos\theta$. For wetting to occur, the contact angle θ must be between $0°$ and $90°$. In this range, as the contact angle θ increases, its cosine value ($\cos\theta$) decreases. A smaller $\cos\theta$ leads to a lower wicking height.

(B) Lower contact angle between fibre and water: This is **correct**.
As the contact angle θ decreases, its cosine value ($\cos\theta$) increases, approaching a maximum of 1 as θ approaches $0°$. A lower contact angle signifies better wettability of the fiber by water, which results in stronger capillary pull and a higher equilibrium wicking height.

(C) Higher capillary diameter: This is **incorrect**.
The height h is inversely proportional to the capillary radius r (or diameter $d = 2r$). If the capillary diameter increases, the denominator of the equation increases, which leads to a decrease in the wicking height. Larger pores cannot support the liquid column to the same height against gravity.

(D) Lower capillary diameter: This is **correct**.
If the capillary diameter decreases, the radius r in the denominator becomes smaller. This leads to an increase in the wicking height. Tightly packed fibers create smaller inter-fiber capillaries, which generate stronger capillary pressure and result in higher wicking.

Step 4: Final Answer:
The conditions that will increase the equilibrium wicking height are a lower contact angle and a lower capillary diameter. Therefore, statements (B) and (D) are correct.

Quick Tip

To remember the relationships for wicking, think:

1. **Wettability:** Better wetting (lower contact angle) means the water "likes" the fiber more, so it climbs higher.
2. **Pore size:** Tighter spaces (smaller capillary diameter) create a stronger "sucking" force, pulling the water up higher.

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52. Consider the following equilibrium dyeing isotherms for dyeing of polyester

with a disperse dye at 100 °C and 120 °C. Amongst the following, the correct statement(s) is/are:

(A) Rate of dyeing at 100 °C is higher than that at 120 °C
(B) Saturation dye-uptake at 120 °C is higher than that at 100 °C
(C) Dye solubility at 120 °C is higher than that at 100 °C
(D) Dye solubility at 120 °C is lower than that at 100 °C

Correct Answer: (C) Dye solubility at 120 °C is higher than that at 100 °C

Solution:

Step 1: Understanding the Concept:
A dyeing isotherm is a graph that shows the distribution of dye between the fiber and the dyebath at equilibrium, at a constant temperature. The y-axis represents the concentration of dye in the fiber (C_f), and the x-axis represents the concentration of dye in the solution (C_s). It describes the equilibrium state, not the speed (rate) at which it is reached.

Step 2: Detailed Explanation of Each Statement from the Graph:
Let's analyze the given isotherms for 100 °C and 120 °C.

(A) Rate of dyeing at 100 °C is higher than that at 120 °C: This is **incorrect**. Isotherms show equilibrium conditions and do not provide information about the rate of dyeing. However, as a general principle of chemical kinetics, the rate of dyeing increases with temperature because higher temperatures provide more energy for dye molecules to move and diffuse into the fiber structure. Therefore, the rate at 120 °C would be significantly higher than at 100 °C.

(B) Saturation dye-uptake at 120 °C is higher than that at 100 °C: This is **incorrect**.
The saturation dye-uptake is the maximum concentration of dye the fiber can hold, represented by the height of the horizontal plateau on the isotherm. By observing the graph, the plateau for the 120 °C curve is visibly lower than the plateau for the 100 °C curve. This means the fiber gets saturated with less dye at the higher temperature. This is characteristic of the exothermic nature of disperse dyeing on polyester.

(C) Dye solubility at 120 °C is higher than that at 100 °C: This is **correct**.
The point on the x-axis where the isotherm becomes horizontal indicates the concentration at which the dyebath has become saturated with dye. This concentration is the dye's solubility in water at that temperature. The plateau for the 120 °C isotherm begins at a higher "Dye in solution" value (further to the right on the x-axis) than the 100 °C

isotherm. This indicates that the dye has a higher solubility in water at 120 °C.

(D) Dye solubility at 120 °C is lower than that at 100 °C: This is **incorrect**. This statement contradicts the observation from the graph as explained for option (C).

Step 3: Final Answer:
The graph clearly shows that the dye's solubility in the solution is greater at the higher temperature. Therefore, statement (C) is the only correct conclusion that can be drawn from the provided isotherms.

Quick Tip

For disperse dyeing of polyester, remember these key temperature effects:

- **Rate:** Higher Temp → Higher Rate.
- **Equilibrium Uptake (in fiber):** Higher Temp → Lower Saturation Uptake (exothermic process).
- **Solubility (in water):** Higher Temp → Higher Solubility.

The isotherm graph visually represents the last two points.

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53. Amongst the following, the property(ies) of a disperse dye that allow(s) it to be applied on polyester by thermofixation method is/are:

(A) Sublimation tendency
(B) High extinction coefficient
(C) Low extinction coefficient
(D) High molecular weight

Correct Answer: (A) Sublimation tendency

Solution:

Step 1: Understanding the Concept:
Thermofixation (also known as the Thermosol process) is a continuous dyeing method for polyester fabrics using disperse dyes. The process involves padding the fabric with a dye dispersion, drying it, and then subjecting it to a short treatment with hot air or contact heat at high temperatures (typically 190-220 °C). The properties of the dye must be suitable for this high-temperature, dry-heat application.

Step 2: Detailed Explanation of the Dyeing Mechanism and Required Properties:
During thermofixation, the heat energy causes the microscopic solid dye particles on the fiber surface to turn directly into a gas (vapor) without melting. This process is called **sublimation**. The polyester fibers, when heated, swell and their molecular structure becomes more open and amorphous. The dye vapor can then penetrate this open structure and diffuse into the fiber, where it gets trapped upon cooling.

Let's evaluate the given options based on this mechanism:

(A) Sublimation tendency: This is **correct**.
This is the most critical property. For the dye to transfer from the fabric surface to the fiber interior under dry heat conditions, it must be able to sublime. Dyes with good sublimation properties are essential for the thermofixation process to be effective. Dyes are often classified as "low, medium, or high energy" based on their sublimation fastness, which relates to this tendency.

(B) High extinction coefficient: This is **incorrect** as a primary enabling property.
A high extinction coefficient means the dye has a high color strength (tinctorial value). While this is a desirable and economic property for any dye, it is not the physical property that *enables* the thermofixation method to work. The method relies on the phase change (sublimation), not the color strength.

(C) Low extinction coefficient: This is **incorrect**.
A low color strength is an undesirable property for a commercial dye.

(D) High molecular weight: This is **incorrect**.
Generally, dyes with very high molecular weight have lower vapor pressures and are less volatile. This makes them difficult to sublime. Disperse dyes used for thermofixation are typically of low to medium molecular weight to ensure they have adequate sublimation tendency at the process temperatures.

Step 3: Final Answer:
The key property that allows a disperse dye to be applied by thermofixation is its ability to sublime. Therefore, sublimation tendency is the correct answer.

> Quick Tip
>
> Associate the dyeing method with its key physical principle. **Thermo**fixation involves **thermal** energy (heat). For disperse dyes, this dry heat causes **sublimation** (solid $\rightarrow$ gas), which is the transport mechanism for the dye.

54. Consider the following function:

$$f(x) = \begin{cases} k, & \text{if } x = 1, \\ \frac{\sqrt{3x+1}-\sqrt{2x+2}}{x-1}, & \text{if } x > \frac{1}{3}, x \neq 1. \end{cases}$$

If $f(x)$ is continuous at $x = 1$, the value of k (correct up to 2 decimal places) is:

Correct Answer: 0.25

Solution:

Step 1: Understanding the Concept:
For a function $f(x)$ to be continuous at a point $x = a$, the limit of the function as x approaches a must be equal to the value of the function at that point. Mathematically, this is expressed as:

$$\lim_{x \to a} f(x) = f(a)$$

In this problem, for $f(x)$ to be continuous at $x = 1$, the value of k must be equal to the limit of the function as x approaches 1.

Step 2: Key Formula or Approach:
We need to evaluate the limit:

$$k = \lim_{x \to 1} \frac{\sqrt{3x+1} - \sqrt{2x+2}}{x-1}$$

Substituting $x = 1$ directly into the expression results in the indeterminate form $\frac{0}{0}$. We can solve this by rationalizing the numerator or by using L'Hôpital's Rule. We will use the rationalization method.

Step 3: Detailed Explanation:
To rationalize the numerator, we multiply both the numerator and the denominator by the conjugate of the numerator, which is $(\sqrt{3x+1} + \sqrt{2x+2})$.

$$k = \lim_{x \to 1} \frac{(\sqrt{3x+1} - \sqrt{2x+2})}{x-1} \times \frac{(\sqrt{3x+1} + \sqrt{2x+2})}{(\sqrt{3x+1} + \sqrt{2x+2})}$$

Using the difference of squares formula $(a-b)(a+b) = a^2 - b^2$ for the numerator:

$$k = \lim_{x \to 1} \frac{(3x+1) - (2x+2)}{(x-1)(\sqrt{3x+1} + \sqrt{2x+2})}$$

Simplify the numerator:

$$k = \lim_{x \to 1} \frac{3x+1-2x-2}{(x-1)(\sqrt{3x+1} + \sqrt{2x+2})} = \lim_{x \to 1} \frac{x-1}{(x-1)(\sqrt{3x+1} + \sqrt{2x+2})}$$

Cancel the $(x-1)$ term from the numerator and denominator:

$$k = \lim_{x \to 1} \frac{1}{\sqrt{3x+1} + \sqrt{2x+2}}$$

Now, we can substitute $x = 1$ into the simplified expression:

$$k = \frac{1}{\sqrt{3(1)+1} + \sqrt{2(1)+2}} = \frac{1}{\sqrt{4}+\sqrt{4}} = \frac{1}{2+2} = \frac{1}{4}$$

$$k = 0.25$$

Step 4: Final Answer:
The value of k for which the function is continuous at $x = 1$ is 0.25.

> Quick Tip
>
> When faced with a limit of the form $\frac{0}{0}$ involving square roots, rationalizing the expression is a standard and effective technique. Multiplying by the conjugate often simplifies the expression by removing the roots from either the numerator or denominator, allowing for cancellation of the term causing the indeterminacy.

---

55. A textile company decides to find the coefficient of correlation (r) between fibre quality (X) and yarn quality (Y). The company randomly selects 10 samples and observes the following: $\Sigma X = 50, \Sigma Y = 40, \Sigma X^2 = 260, \Sigma Y^2 = 228, \Sigma XY = 222$**, and** $r(X, Y) = 0.84$**. If the correct pairs** $(X = 4, Y = 11)$ **and** $(X = 6, Y = 9)$ **are taken wrongly as** $(X = 6, Y = 15)$ **and** $(X = 4, Y = 5)$**, respectively, then the correct value of** $r(X, Y)$**, rounded off to 2 decimal places, is:**

Correct Answer: 0.71

Solution:

Step 1: Understanding the Concept:
The problem requires us to calculate the correct coefficient of correlation after correcting errors in the data. The initial summary statistics ($\Sigma X, \Sigma Y$, etc.) are incorrect. We must first find the correct summary statistics by subtracting the contributions of the wrong pairs and adding the contributions of the correct pairs. Then, we can use the corrected sums to calculate the new correlation coefficient.

Step 2: Key Formula or Approach:
The Pearson correlation coefficient (r) is calculated using the formula:

$$r = \frac{n(\Sigma XY) - (\Sigma X)(\Sigma Y)}{\sqrt{[n(\Sigma X^2) - (\Sigma X)^2][n(\Sigma Y^2) - (\Sigma Y)^2]}}$$

We need to find the corrected values for $\Sigma X, \Sigma Y, \Sigma X^2, \Sigma Y^2, \Sigma XY$. Let's denote them with a subscript 'c'.

Correct Sum = Incorrect Sum - Sum of Wrong Values + Sum of Correct Values.

Step 3: Detailed Explanation:
1. Identify Wrong and Correct Values:
- Number of samples, $n = 10$.
- Wrong pairs: (X_w, Y_w) are (6, 15) and (4, 5). - Correct pairs: (X_c, Y_c) are (4, 11) and (6, 9).
2. Calculate Corrected Sums:
- $\Sigma X_c = \Sigma X_{wrong} - (6+4) + (4+6) = 50 - 10 + 10 = 50$.
- $\Sigma Y_c = \Sigma Y_{wrong} - (15+5) + (11+9) = 40 - 20 + 20 = 40$.
- $\Sigma X_c^2 = \Sigma X_{wrong}^2 - (6^2+4^2) + (4^2+6^2) = 260 - (36+16) + (16+36) = 260 - 52 + 52 = 260$.
- $\Sigma Y_c^2 = \Sigma Y_{wrong}^2 - (15^2+5^2) + (11^2+9^2) = 228 - (225+25) + (121+81) = 228 - 250 + 202 = 180$.
- $\Sigma XY_c = \Sigma XY_{wrong} - (6\times 15 + 4\times 5) + (4\times 11 + 6\times 9) = 222 - (90+20) + (44+54) = 222 - 110 + 98 = 210$.

3. Calculate the Correct Correlation Coefficient:
Now, substitute the corrected sums into the formula for r: - Numerator: $n(\Sigma XY_c) - (\Sigma X_c)(\Sigma Y_c) = 10(210) - (50)(40) = 2100 - 2000 = 100$.
- Denominator (Part 1): $n(\Sigma X_c^2) - (\Sigma X_c)^2 = 10(260) - (50)^2 = 2600 - 2500 = 100$.
- Denominator (Part 2): $n(\Sigma Y_c^2) - (\Sigma Y_c)^2 = 10(180) - (40)^2 = 1800 - 1600 = 200$.
- Denominator (Full): $\sqrt{100\times 200} = \sqrt{20000} = \sqrt{10000\times 2} = 100\sqrt{2}$.

$$r_c = \frac{100}{100\sqrt{2}} = \frac{1}{\sqrt{2}} \approx 0.707106...$$

Step 4: Final Answer:
Rounding the correct correlation coefficient to 2 decimal places gives 0.71.

> Quick Tip
>
> In problems involving correction of statistical measures, the key is a systematic update of all the sum terms $(\Sigma X, \Sigma Y, \Sigma X^2, \Sigma Y^2, \Sigma XY)$. Be careful to subtract the contributions of the wrong values (e.g., subtract X^2, not just X) and add the contributions of the correct ones before recalculating the final statistic.

---

56. Three melt-spun fibre samples A, B, and C produced from the same polymer under different conditions are found to have densities 1.10 g/cm^3, 1.15 g/cm^3, and 1.20 g/cm^3, respectively. If the mass fraction based degree of crystallinity (x_c) of A and C is 0.45 and 0.75, respectively, then x_c for B (rounded off to 2 decimal places) is:

Correct Answer: 0.60

Solution:

Step 1: Understanding the Concept:
For a semi-crystalline polymer, the overall density (ρ) is determined by the proportions and densities of its amorphous (ρ_a) and crystalline (ρ_c) regions. The mass fraction degree of crystallinity (x_c) relates these quantities. Since all three samples are from the same polymer, ρ_a and ρ_c are constant material properties. This implies there is a linear relationship between the sample density and its degree of crystallinity.

Step 2: Key Formula or Approach:
The relationship between sample density and crystallinity is given by:

$$\frac{1}{\rho} = \frac{x_c}{\rho_c} + \frac{1 - x_c}{\rho_a}$$

However, a simpler approach is to use the linear relationship derived from this model. The degree of crystallinity can also be expressed as:

$$x_c = \frac{\rho(\rho_c - \rho_a)}{\rho_c(\rho - \rho_a)}$$

A much more direct method for this specific problem is to recognize the linear relationship and use interpolation. The change in crystallinity is proportional to the change in density.

$$\frac{x_B - x_A}{\rho_B - \rho_A} = \frac{x_C - x_A}{\rho_C - \rho_A}$$

Step 3: Detailed Explanation:
1. List the Given Data:
- Sample A: $\rho_A = 1.10$ g/cm^3, $x_A = 0.45$ - Sample B: $\rho_B = 1.15$ g/cm^3, $x_B =?$ - Sample C: $\rho_C = 1.20$ g/cm^3, $x_C = 0.75$
2. Apply the Linear Interpolation Formula:
We can set up a proportion based on the linear relationship between density and crystallinity.

$$\frac{x_B - x_A}{\rho_B - \rho_A} = \frac{x_C - x_A}{\rho_C - \rho_A}$$

Substitute the known values into the equation:

$$\frac{x_B - 0.45}{1.15 - 1.10} = \frac{0.75 - 0.45}{1.20 - 1.10}$$

Simplify the denominators and the numerator on the right side:

$$\frac{x_B - 0.45}{0.05} = \frac{0.30}{0.10}$$

$$\frac{x_B - 0.45}{0.05} = 3$$

Now, solve for x_B:

$$x_B - 0.45 = 3 \times 0.05$$

$$x_B - 0.45 = 0.15$$

$$x_B = 0.15 + 0.45 = 0.60$$

Step 4: Final Answer:
The degree of crystallinity for sample B is 0.60.

> Quick Tip
>
> When you have three data points for a property (like density) that is known to be linearly related to another property (like crystallinity), using a two-point form or linear interpolation is the fastest and most elegant way to find the unknown value. It avoids the intermediate step of calculating the fundamental constants (ρ_a and ρ_c).

---

57. A 200 m long bone-dry Nylon fibre with circular cross-section and density of 1.2 g/cm^3, absorbs 0.003 g moisture. If the moisture content of the fibre becomes 4% after moisture absorption, then the diameter (μm) of bone-dry Nylon fibre (rounded off to 1 decimal place) is:

Correct Answer: 19.9

Solution:

Step 1: Understanding the Concept:
The problem requires finding the diameter of a single fiber. We are given its length, density, and information about its moisture absorption, which allows us to first calculate its bone-dry mass. Once the mass is known, we can use the density and length to find the volume, and from the volume of a cylinder, we can calculate the diameter. Careful unit conversion is essential.

Step 2: Key Formula or Approach:

1. **Moisture Content (%MC):** $\%MC = \frac{\text{Mass of water}}{\text{Mass of dry material}} \times 100$
2. **Volume of a cylinder:** $V = \frac{\pi d^2}{4} \times L$
3. **Density:** $\rho = \frac{\text{Mass}}{V}$

Step 3: Detailed Explanation:

1. Calculate the Bone-Dry Mass (M_{dry}) of the Fibre:

We are given that the moisture content is 4% after absorbing 0.003 g of water.

$$4\% = \frac{0.003 \text{ g}}{M_{dry}} \times 100$$

Rearranging to solve for M_{dry}:

$$M_{dry} = \frac{0.003 \times 100}{4} = \frac{0.3}{4} = 0.075 \text{ g}$$

2. Calculate the Volume of the Bone-Dry Fibre:

We have the mass (M_{dry}) and density (ρ).

$$V_{dry} = \frac{M_{dry}}{\rho} = \frac{0.075 \text{ g}}{1.2 \text{ g/cm}^3} = 0.0625 \text{ cm}^3$$

3. Calculate the Diameter (d) of the Fibre:

First, ensure all units are consistent. The volume is in cm^3, so the length must be in cm.
- Length, $L = 200 \text{ m} = 200 \times 100 \text{ cm} = 20000 \text{ cm}$.

Now, use the volume formula for a cylinder:

$$V_{dry} = \frac{\pi d^2}{4} \times L$$

Rearrange to solve for d^2:

$$d^2 = \frac{4 \times V_{dry}}{\pi \times L} = \frac{4 \times 0.0625}{\pi \times 20000} = \frac{0.25}{20000\pi}$$

$$d^2 \approx \frac{0.25}{62831.85} \approx 3.9788 \times 10^{-6} \text{ cm}^2$$

Calculate d:

$$d = \sqrt{3.9788 \times 10^{-6}} \approx 1.9947 \times 10^{-3} \text{ cm}$$

4. Convert Diameter to Micrometers (μm):

We know that $1 \text{ cm} = 10^4 \mu\text{m}$.

$$d = (1.9947 \times 10^{-3}) \times 10^4 \mu\text{m} = 19.947 \mu\text{m}$$

Step 4: Final Answer:

Rounding the diameter to 1 decimal place gives 19.9 μm.

> **Quick Tip**
>
> In fiber science calculations, unit consistency is the most common source of errors. Always convert all quantities to a base set of units (e.g., grams, centimeters, seconds) before substituting them into formulas. Remember that $1 \text{ m} = 100 \text{ cm}$ and $1 \text{ cm} = 10,000 \mu\text{m}$.

58. A parallel fibre strand of 30 tex count is coming out from the nip of the front delivery rollers of a ring spinning machine. This strand is given twist to produce a yarn such that the length of the yarn becomes 0.95 times the length of the parallel fibre strand. If 600 turns are present in 1 m length of the yarn, then the twist factor (tpm.tex$^{0.5}$) of the yarn (rounded off to the nearest integer) is:

Correct Answer: 3372

Solution:

Step 1: Understanding the Concept:
This problem requires the calculation of the twist factor, a normalized measure of twist level in a yarn. The twist factor accounts for the yarn's linear density (count). The key steps are to determine the final count of the twisted yarn, which is affected by twist contraction, and then to use the given twist per meter (tpm) to calculate the twist factor.

Step 2: Key Formula or Approach:

1. **Yarn Count (Tex):** The linear density of the final yarn (Tex_{yarn}) is higher than the input strand (Tex_{strand}) due to contraction.

$$Tex_{yarn} = \frac{Tex_{strand}}{\text{Length of yarn/Length of strand}}$$

2. **Twist Factor (K):**

$$K = \text{Twist (tpm)} \times \sqrt{Tex_{yarn}}$$

Step 3: Detailed Explanation:
1. Calculate the Final Yarn Count (Tex_{yarn}):
- Count of the parallel fibre strand, $Tex_{strand} = 30$ tex.
- The length of the yarn is 0.95 times the length of the untwisted strand. This is the contraction factor.
- The mass of the strand is conserved, but it is now packed into a shorter length.

$$Tex_{yarn} = \frac{30}{0.95} \approx 31.5789 \text{ tex}$$

2. Identify the Yarn Twist:
- The problem states there are 600 turns in 1 meter of yarn. - This gives a twist level, $T = 600$ turns per meter (tpm).

3. Calculate the Twist Factor (K):
- Now apply the twist factor formula using the final yarn count.

$$K = T \times \sqrt{Tex_{yarn}}$$

$$K = 600 \times \sqrt{31.5789}$$
$$K \approx 600 \times 5.6195$$
$$K \approx 3371.7$$

Step 4: Final Answer:
The question asks to round the twist factor to the nearest integer.

$$K \approx 3372$$

The twist factor of the yarn is 3372 (tpm $\cdot$ tex$^{0.5}$).

Quick Tip

A common mistake is to use the count of the untwisted sliver/strand instead of the final yarn count when calculating the twist factor. Always remember that twist insertion causes the yarn to contract in length (twist contraction), which increases its linear density (tex). You must use the final yarn tex in the formula.

---

59. A plied yarn is prepared by twisting two single yarns (A and B). Yarn A has a mean count of 20 tex and a coefficient of variation (CV) of count of 20%. Yarn B has a mean count of 30 tex and a CV of count of 10%. Neglecting twist contraction during plying, the CV (%) of the count of the plied yarn (in integer) is:

Correct Answer: 10

Solution:

Step 1: Understanding the Concept:
When two or more yarns are plied together, their linear densities (in a direct system like tex) are additive. Similarly, if the component yarns are independent, their variances are also additive. The coefficient of variation (CV) of the plied yarn can be calculated from the resultant mean and resultant variance.

Step 2: Key Formula or Approach:

1. Mean Count of Plied Yarn (T_p): $T_p = T_A + T_B$
2. Standard Deviation (σ) from CV: $\sigma = \text{Mean} \times \frac{\text{CV\%}}{100}$
3. Variance (Var): $Var = \sigma^2$

4. Variance of Plied Yarn (Var_p): $Var_p = Var_A + Var_B$

5. CV of Plied Yarn (CV_p): $CV_p(\%) = \frac{\sqrt{Var_p}}{T_p} \times 100$

Step 3: Detailed Explanation:

1. Calculate the Mean Count of the Plied Yarn (T_p):

$$T_p = T_A + T_B = 20 \text{ tex} + 30 \text{ tex} = 50 \text{ tex}$$

2. Calculate the Variance of Each Component Yarn:

For Yarn A:

$$\sigma_A = 20 \times \frac{20}{100} = 4.0$$

$$Var_A = \sigma_A^2 = (4.0)^2 = 16$$

For Yarn B:

$$\sigma_B = 30 \times \frac{10}{100} = 3.0$$

$$Var_B = \sigma_B^2 = (3.0)^2 = 9$$

3. Calculate the Variance of the Plied Yarn (Var_p):

$$Var_p = Var_A + Var_B = 16 + 9 = 25$$

4. Calculate the CV(%) of the Plied Yarn (CV_p):

First, find the standard deviation of the plied yarn:

$$\sigma_p = \sqrt{Var_p} = \sqrt{25} = 5.0$$

Now, calculate the CV(%):

$$CV_p(\%) = \frac{\sigma_p}{T_p} \times 100 = \frac{5.0}{50} \times 100 = 0.1 \times 100 = 10\%$$

Step 4: Final Answer:

The CV (%) of the count of the plied yarn is 10.

> Quick Tip
>
> For plied yarns in direct systems (like tex or denier), means add and variances add. This makes calculations straightforward. Remember the relationship $Var = (\text{Mean} \times \text{CV})^2$. Do not add the CVs or standard deviations directly.

---

60. A plain woven fabric with square construction, prepared from yarns of 0.2 mm diameter, has a fractional cover of 0.7. The distance (mm) between the two adjacent ends (rounded off to 2 decimal places) is:

Correct Answer: 0.44

Solution:

Step 1: Understanding the Concept:
For a woven fabric, the fractional cover (C) represents the proportion of the total fabric area covered by yarns. For a square construction, the warp cover (C_1) and weft cover (C_2) are equal. The distance between adjacent ends is the yarn spacing or pitch (p).

Step 2: Key Formula or Approach:

1. **Total Cover (Peirce's Formula):** $C = C_1 + C_2 - C_1C_2$
2. **For Square Fabric:** $C_1 = C_2 = C_w$, so $C = 2C_w - C_w^2$
3. **Single Cover:** $C_w = \frac{\text{Yarn Diameter (d)}}{\text{Yarn Spacing (p)}}$

Step 3: Detailed Explanation:
1. Calculate the Single Cover (C_w):
Given total cover $C = 0.7$. We use the formula for a square fabric:

$$0.7 = 2C_w - C_w^2$$

Rearranging this into a standard quadratic equation ($ax^2 + bx + c = 0$):

$$C_w^2 - 2C_w + 0.7 = 0$$

We solve for C_w using the quadratic formula, $C_w = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$:

$$C_w = \frac{2 \pm \sqrt{(-2)^2 - 4(1)(0.7)}}{2(1)} = \frac{2 \pm \sqrt{4 - 2.8}}{2} = \frac{2 \pm \sqrt{1.2}}{2}$$

$$C_w \approx \frac{2 \pm 1.0954}{2}$$

This gives two possible solutions: $C_w \approx 1.55$ (which is impossible as cover cannot exceed 1) or $C_w \approx \frac{2-1.0954}{2} = \frac{0.9046}{2} = 0.4523$.
So, the warp/weft cover is $C_w = 0.4523$.

2. Calculate the Distance Between Ends (p):
The distance between adjacent ends is the pitch, p.

$$C_w = \frac{d}{p} \implies p = \frac{d}{C_w}$$

Given yarn diameter $d = 0.2$ mm:

$$p = \frac{0.2}{0.4523} \approx 0.44218 \text{ mm}$$

Step 4: Final Answer:
Rounding the distance to 2 decimal places gives 0.44 mm.

> **Quick Tip**
>
> When solving the quadratic equation for fabric cover, one root will always be physically impossible (greater than 1). Always choose the root that is less than 1. The distance between yarns (pitch) will always be greater than the yarn diameter for a fabric with a cover less than 1.

---

61. Two shuttle looms (A and B), running at the same picks per minute, have the same mass of sley and associated system for beat up. The crank radius (r) and the eccentricity ratio (e) of the looms are $r_A = 10$ cm, $e_A = 0.5$; $r_B = 6$ cm, $e_B = 0.4$. The ratio of the beat up force of loom A to that of loom B (rounded off to 1 decimal place) is:

Correct Answer: 1.8

Solution:

Step 1: Understanding the Concept:
The beat-up force in a loom is the inertial force generated by the sley as it reaches its foremost position to push the new pick into the fabric. This force is a product of the sley's mass and its maximum acceleration. The acceleration depends on the loom's speed (angular velocity ω), crank radius (r), and the geometry of the drive system (eccentricity ratio e).

Step 2: Key Formula or Approach:
The maximum acceleration (a_{max}) of the sley at the beat-up point is given by:

$$a_{max} = \omega^2 r(1 + e)$$

The beat-up force (F) is:

$$F = m \cdot a_{max} = m\omega^2 r(1 + e)$$

We need to find the ratio $\frac{F_A}{F_B}$.

Step 3: Detailed Explanation:
1. Set up the Ratio:

$$\frac{F_A}{F_B} = \frac{m_A \omega_A^2 r_A (1 + e_A)}{m_B \omega_B^2 r_B (1 + e_B)}$$

2. Substitute Known Conditions:
- Same picks per minute $\implies \omega_A = \omega_B$. - Same mass of sley $\implies m_A = m_B$. The terms for mass and angular velocity cancel out, simplifying the ratio to:

$$\frac{F_A}{F_B} = \frac{r_A(1 + e_A)}{r_B(1 + e_B)}$$

3. Calculate the Ratio:
Substitute the given values for crank radius and eccentricity ratio:

$$\frac{F_A}{F_B} = \frac{10 \text{ cm} \times (1 + 0.5)}{6 \text{ cm} \times (1 + 0.4)} = \frac{10 \times 1.5}{6 \times 1.4} = \frac{15}{8.4}$$

$$\frac{F_A}{F_B} \approx 1.7857$$

Step 4: Final Answer:
Rounding the ratio to 1 decimal place gives 1.8.

> Quick Tip
>
> For comparative problems like this, always write out the full formula for each case and then form the ratio. This allows you to quickly identify and cancel out any parameters that are stated to be the same, simplifying the calculation significantly.

---

62. A polyester fiber of circular cross-section has a density of 1.38 g/cm^3 and a diameter of 20 μm. The fineness (denier) of the fiber (rounded off to 1 decimal place) is:

Correct Answer: 3.9

Solution:

Step 1: Understanding the Concept:
Denier is a unit of linear density used for fibers and filaments. It is defined as the mass in grams per 9000 meters. To calculate the denier, we need to find the volume of a 9000-meter length of the fiber and then use its density to find the corresponding mass.

Step 2: Key Formula or Approach:

1. **Denier:** Mass (g) of 9000 m length.
2. **Mass:** Mass = Density (ρ) $\times$ Volume (V)

3. **Volume of a Cylinder:** $V = \text{Area} \times \text{Length} = \frac{\pi d^2}{4} \times L$

Step 3: Detailed Explanation:
1. Unify the Units:
It's best to convert all units to grams and centimeters. - Length, $L = 9000 \text{ m} = 9000 \times 100 \text{ cm} = 9 \times 10^5$ cm. - Diameter, $d = 20\mu\text{m} = 20 \times 10^{-4} \text{ cm} = 2 \times 10^{-3}$ cm. - Density, $\rho = 1.38 \text{ g/cm}^3$.
2. Calculate the Volume of 9000 m of Fiber:

$$V = \frac{\pi d^2}{4} \times L = \frac{\pi(2 \times 10^{-3} \text{ cm})^2}{4} \times (9 \times 10^5 \text{ cm})$$

$$V = \frac{\pi \times 4 \times 10^{-6}}{4} \times 9 \times 10^5 = (\pi \times 10^{-6}) \times (9 \times 10^5) = 0.9\pi \text{ cm}^3$$

3. Calculate the Mass (Denier):

$$\text{Mass} = \rho \times V = 1.38 \text{ g/cm}^3 \times 0.9\pi \text{ cm}^3$$

$$\text{Mass} = 1.242\pi \approx 3.8998 \text{ g}$$

This mass is the fineness in denier.

Step 4: Final Answer:
Rounding the value to 1 decimal place gives 3.9 denier.

Quick Tip

The most crucial step in fineness calculations is unit conversion. A useful combined formula for denier is: Denier $= \rho \times \frac{\pi d^2}{4} \times 900000$, where ρ is in g/cm^3 and d is in cm. Or, Denier $= 0.00707 \times \rho \times d^2$ where d is in microns.

---

63. The relationship between tensile stress (σ) and tensile strain (ϵ) of a yarn is given by $\sigma = 1.5\sqrt{\epsilon}$. If the breaking strain of the yarn is 1.2, the work factor of the yarn (rounded off to 2 decimal places) is:

Correct Answer: 0.67

Solution:

Step 1: Understanding the Concept:
The work factor is a measure of the shape of the stress-strain curve. It is the ratio of the actual energy required to break the material (work of rupture) to the energy that would be required if the material were perfectly elastic with the same breaking point. The work

of rupture is the area under the stress-strain curve.

Step 2: Key Formula or Approach:

1. **Work of Rupture (W_r):** $W_r = \int_0^{\epsilon_b} \sigma \, d\epsilon$, where ϵ_b is the breaking strain.
2. **Work Factor (WF):** $WF = \frac{W_r}{\sigma_b \times \epsilon_b}$, where σ_b is the breaking stress.

Step 3: Detailed Explanation:

1. Calculate the Breaking Stress (σ_b):

Substitute the breaking strain $\epsilon_b = 1.2$ into the given relationship:

$$\sigma_b = 1.5\sqrt{1.2}$$

2. Calculate the Work of Rupture (W_r):

Integrate the stress function from 0 to $\epsilon_b = 1.2$:

$$W_r = \int_0^{1.2} 1.5\sqrt{\epsilon} \, d\epsilon = \int_0^{1.2} 1.5\epsilon^{1/2} \, d\epsilon$$

$$W_r = 1.5 \left[\frac{\epsilon^{3/2}}{3/2} \right]_0^{1.2} = 1.5 \times \frac{2}{3} [\epsilon^{3/2}]_0^{1.2} = 1 \times [1.2^{3/2} - 0] = 1.2^{3/2}$$

3. Calculate the Work Factor (WF):

Now substitute the expressions for W_r and σ_b into the work factor formula:

$$WF = \frac{W_r}{\sigma_b \times \epsilon_b} = \frac{1.2^{3/2}}{(1.5\sqrt{1.2}) \times 1.2}$$

Since $\sqrt{1.2} = 1.2^{1/2}$ and $1.2 = 1.2^1$, we can simplify the expression:

$$WF = \frac{1.2^{3/2}}{1.5 \times 1.2^{1/2} \times 1.2^1} = \frac{1.2^{3/2}}{1.5 \times 1.2^{3/2}}$$

The term $1.2^{3/2}$ cancels out:

$$WF = \frac{1}{1.5} = \frac{1}{3/2} = \frac{2}{3}$$

$$WF \approx 0.6666...$$

Step 4: Final Answer:

Rounding the work factor to 2 decimal places gives 0.67.

> **Quick Tip**
>
> For stress-strain curves of the form $\sigma = K\epsilon^n$, the work factor is always $1/(n+1)$. In this problem, $\sigma = 1.5\epsilon^{0.5}$, so $n = 0.5$. The work factor is $1/(0.5+1) = 1/1.5 = 2/3$. Recognizing this shortcut can save a lot of time.

64. A ballistic type impact tester is shown below. The test specimen is connected to the bob of the pendulum of 10 N weight. The pendulum is released from a height of 1 m from the base, and this results in the rupture of the test specimen. Considering no frictional losses and neglecting the weight of the connecting rod, if the work of rupture of the specimen is 10 N-m, then the total swing angle (in integer) that the pendulum makes during its travel is:

Correct Answer: 90

Solution:

Step 1: Understanding the Concept:
This problem applies the principle of conservation of energy. The initial potential energy of the pendulum is converted into kinetic energy as it swings down. At the bottom of the swing, some of this energy is used to break the test specimen (work of rupture). Any remaining energy is then converted back into potential energy as the pendulum swings up on the other side.

Step 2: Key Formula or Approach:

- **Principle of Energy Conservation:** Initial Energy = Final Energy + Work Done
- **Potential Energy (PE):** $PE = W \times h$, where W is weight and h is vertical height.
- Let's assume a common setup for this type of problem where "released from a height of 1 m from the base" implies the pendulum's arm length is 1 m and it is released from a horizontal position (90° from the vertical).

Step 3: Detailed Explanation:
1. Calculate the Initial Potential Energy ($PE_{initial}$):
- Weight of pendulum, $W = 10$ N. - Initial height, $h_{initial} = 1$ m.

$$PE_{initial} = W \times h_{initial} = 10 \text{ N} \times 1 \text{ m} = 10 \text{ N} \cdot \text{m} = 10 \text{ Joules}$$

2. Apply the Energy Conservation Equation:
The initial energy is entirely potential energy. This energy is used for the work of rupture (W_r) and the final potential energy (PE_{final}) at the peak of the subsequent swing.

$$PE_{initial} = W_r + PE_{final}$$

We are given that the work of rupture is $W_r = 10 \text{ N} \cdot \text{m}$.

$$10 \text{ J} = 10 \text{ J} + PE_{final}$$

$$PE_{final} = 10 - 10 = 0 \text{ J}$$

3. Determine the Final Position and Angle:
Since the final potential energy is zero, the final height of the pendulum is zero ($h_{final} = 0$). This means the pendulum comes to a complete stop at the very bottom of its swing (the base).

4. Calculate the Total Swing Angle:
- Based on the assumption that the pendulum was released from a horizontal position, the initial angle was 90° from the vertical. - The final position is at the vertical, which is 0°. - Therefore, the total angle the pendulum travels through is from 90° to 0°, which is a swing of 90°.
Step 4: Final Answer:
The total swing angle during its travel is 90 degrees.

> Quick Tip
>
> In ballistic pendulum problems, always start with the energy balance. The initial potential energy is the "energy budget". This budget is spent on breaking the sample and on the final potential energy of the pendulum.

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65. A 200 m long bone-dry Nylon fibre with circular cross-section and density of 1.2 g/cm^3, absorbs 0.003 g moisture. If the moisture content of the fibre becomes 4% after moisture absorption, then the diameter (μm) of bone-dry Nylon fibre (rounded off to 1 decimal place) is:

Correct Answer: 19.9

Solution:

Step 1: Understanding the Concept:
The problem requires finding the diameter of a single fiber. We are given its length, density, and information about its moisture absorption, which allows us to first calculate its bone-dry mass. Once the mass is known, we can use the density and length to find the volume, and from the volume of a cylinder, we can calculate the diameter. Careful unit conversion is essential.

Step 2: Key Formula or Approach:

1. **Moisture Content (%MC):** $\%MC = \frac{\text{Mass of water}}{\text{Mass of dry material}} \times 100$
2. **Volume of a cylinder:** $V = \frac{\pi d^2}{4} \times L$

3. **Density:** $\rho = \frac{\text{Mass}}{V}$

Step 3: Detailed Explanation:

1. Calculate the Bone-Dry Mass (M_{dry}) of the Fibre:

We are given that the moisture content is 4% after absorbing 0.003 g of water.

$$4\% = \frac{0.003 \text{ g}}{M_{dry}} \times 100$$

Rearranging to solve for M_{dry}:

$$M_{dry} = \frac{0.003 \times 100}{4} = \frac{0.3}{4} = 0.075 \text{ g}$$

2. Calculate the Volume of the Bone-Dry Fibre:

We have the mass (M_{dry}) and density (ρ).

$$V_{dry} = \frac{M_{dry}}{\rho} = \frac{0.075 \text{ g}}{1.2 \text{ g/cm}^3} = 0.0625 \text{ cm}^3$$

3. Calculate the Diameter (d) of the Fibre:

First, ensure all units are consistent. The volume is in cm^3, so the length must be in cm.

- Length, $L = 200 \text{ m} = 200 \times 100 \text{ cm} = 20000 \text{ cm}$.

Now, use the volume formula for a cylinder:

$$V_{dry} = \frac{\pi d^2}{4} \times L$$

Rearrange to solve for d^2:

$$d^2 = \frac{4 \times V_{dry}}{\pi \times L} = \frac{4 \times 0.0625}{\pi \times 20000} = \frac{0.25}{20000\pi}$$

$$d^2 \approx \frac{0.25}{62831.85} \approx 3.9788 \times 10^{-6} \text{ cm}^2$$

Calculate d:

$$d = \sqrt{3.9788 \times 10^{-6}} \approx 1.9947 \times 10^{-3} \text{ cm}$$

4. Convert Diameter to Micrometers (μm):

We know that 1 cm $= 10^4 \mu$m.

$$d = (1.9947 \times 10^{-3}) \times 10^4 \mu\text{m} = 19.947 \mu\text{m}$$

Step 4: Final Answer:

Rounding the diameter to 1 decimal place gives 19.9 μm.

> **Quick Tip**
>
> In fiber science calculations, unit consistency is the most common source of errors. Always convert all quantities to a base set of units (e.g., grams, centimeters, seconds) before substituting them into formulas. Remember that 1 m $=$ 100 cm and 1 cm $= 10,000\mu$m.