# GATE 2024 Mining Engineering Question Paper with Solutions

| **Time Allowed :**3 Hours | **Maximum Marks :**100 | **Total questions :**65 |
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## General Instructions

### GATE 2024 – Mining Engineering

### GENERAL INSTRUCTIONS

1. The examination is of **3 hours (180 minutes)** duration.
2. The paper consists of **65 questions** carrying a total of **100 marks**.
3. Sections include: (i) General Aptitude (15 marks) and (ii) Aerospace Engineering subject section (85 marks).
4. Question Types:
   - **MCQs** – Multiple Choice Questions with one correct option.
   - **MSQs** – Multiple Select Questions with one or more correct options.
   - **NATs** – Numerical Answer Type, where a number is to be entered using the virtual keyboard.
5. Marking Scheme:
   - MCQs: +1 or +2 marks for correct; −1/3 or −2/3 negative for wrong.
   - MSQs: +1 or +2 marks for correct; no negative marking.
   - NATs: +1 or +2 marks for correct; no negative marking.
6. Only the on-screen virtual calculator is permitted; personal calculators are not allowed.
7. Use of mobile phones, smartwatches, or any electronic devices is strictly prohibited.

**1. If '→' denotes increasing order of intensity, then the meaning of the words [drizzle → rain → downpour] is analogous to [..... → quarrel → feud]. Which one of the given options is appropriate to fill the blank?**

(A) bicker

(B) bog

(C) dither

(D) dodge

**Correct Answer:** (A) bicker

**Solution:**

**Step 1: Understanding the given analogy.**

The sequence **drizzle** → **rain** → **downpour** represents an increasing order of intensity, where each word signifies a stronger form of rainfall than the previous one.

**Step 2: Applying the same logic to the second set.**

Similarly, in the sequence ..... → quarrel → feud, the missing word should represent a **milder form of conflict** that can gradually intensify into a quarrel and eventually become a feud.

**Step 3: Evaluating the options.**

**(A) bicker:** This refers to a petty or minor argument, which can escalate into a quarrel and later develop into a feud. Hence, it fits the increasing order of intensity.

**(B) bog:** This word refers to a swamp or to being stuck, and has no relation to conflict or argument.

**(C) dither:** This means to be indecisive or hesitant, not related to disputes or intensity of conflict.

**(D) dodge:** This means to avoid something and does not indicate any form of argument or conflict.

**Step 4: Conclusion.**

The word **bicker** correctly completes the analogy by representing the lowest level of conflict that can increase in intensity to a quarrel and then to a feud.

Quick Tip

In analogy questions based on intensity, always arrange the words from the weakest form to the strongest form of meaning.

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**2. Statements:**

1. All heroes are winners.
2. All winners are lucky people.

**Inferences:**

I. All lucky people are heroes.

II. Some lucky people are heroes.

III. Some winners are heroes.

**Which of the above inferences can be logically deduced from statements 1 and 2?**

(A) Only I and II

(B) Only II and III

(C) Only I and III

(D) Only III

**Correct Answer:** (B) Only II and III

**Solution:**

**Step 1: Represent the statements logically.**

All heroes are winners (Heroes $\subseteq$ Winners).

All winners are lucky people (Winners $\subseteq$ Lucky).

Hence, Heroes $\subseteq$ Winners $\subseteq$ Lucky.

**Step 2: Evaluate Inference I.**

"All lucky people are heroes" means Lucky $\subseteq$ Heroes, which is the reverse of the given logic.

Hence, this inference does not follow.

**Step 3: Evaluate Inference II.**

Since heroes exist and all heroes are lucky people, it is logically valid that **some lucky people are heroes**. This inference follows.

**Step 4: Evaluate Inference III.**

All heroes are winners, so heroes fall within winners. Hence, **some winners are heroes**. This inference also follows.

**Step 5: Conclusion.**

Only Inferences II and III can be logically deduced.

**Quick Tip**

In syllogism questions, universal statements allow valid "some" conclusions but not reverse universal conclusions.

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**3. A student was supposed to multiply a positive real number $p$ with another positive real number $q$. Instead, the student divided $p$ by $q$. If the percentage error in the student's answer is 80%, the value of $q$ is**

(A) 5

(B) $\sqrt{2}$

(C) 2

(D) $\sqrt{5}$

**Correct Answer:** (D) $\sqrt{5}$

**Solution:**

**Step 1: Identify correct and incorrect values.**

Correct value $= p \times q$.

Incorrect value $= \frac{p}{q}$.

**Step 2: Use percentage error formula.**

$$\text{Percentage Error} = \left| \frac{\text{Incorrect} - \text{Correct}}{\text{Correct}} \right| \times 100$$

**Step 3: Substitute the given values.**

$$80 = \left| \frac{\frac{p}{q} - pq}{pq} \right| \times 100$$

$$0.8 = \left| \frac{1 - q^2}{q^2} \right|$$

**Step 4: Solve the equation.**

$$\frac{q^2 - 1}{q^2} = 0.8 \Rightarrow q^2 - 1 = 0.8q^2 \Rightarrow 0.2q^2 = 1 \Rightarrow q^2 = 5 \Rightarrow q = \sqrt{5}$$

**Step 5: Conclusion.**

The correct value of $q$ is $\sqrt{5}$.

**Quick Tip**

Always express percentage error equations in terms of ratios before substituting values.

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**4. If the sum of the first 20 consecutive positive odd numbers is divided by $20^2$, the result is**

(A) 1

(B) 20

(C) 2

(D) $\frac{1}{2}$

**Correct Answer:** (A) 1

**Solution:**

**Step 1: Recall the formula for sum of odd numbers.**

The sum of the first $n$ odd numbers is $n^2$.

**Step 2: Apply the formula.**

Sum of first 20 odd numbers $= 20^2 = 400$.

**Step 3: Divide by $20^2$.**

$$\frac{400}{20^2} = \frac{400}{400} = 1$$

**Step 4: Conclusion.**

The required result is 1.

**Quick Tip**

The sum of the first $n$ odd numbers is always equal to $n^2$.

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**5. The ratio of the number of girls to boys in class VIII is the same as the ratio of the number of boys to girls in class IX. The total number of students (boys and girls) in classes VIII and IX is 450 and 360, respectively. If the number of girls in classes VIII and IX is the same, then the number of girls in each class is**

(A) 150

(B) 200

(C) 250

(D) 175

**Correct Answer:** (B) 200

**Solution:**

**Step 1: Assume the number of girls in each class.**

Let the number of girls in each class be $x$.

**Step 2: Express boys in each class.**

Total students in class VIII = 450, so boys in class VIII = $450 - x$.

Total students in class IX = 360, so boys in class IX = $360 - x$.

**Step 3: Use the given ratio condition.**

$$\frac{\text{Girls in VIII}}{\text{Boys in VIII}} = \frac{\text{Boys in IX}}{\text{Girls in IX}}$$

$$\frac{x}{450 - x} = \frac{360 - x}{x}$$

**Step 4: Solve the equation.**

$$x^2 = (450 - x)(360 - x)$$

$$x^2 = 162000 - 810x + x^2$$

$$810x = 162000 \Rightarrow x = 200$$

**Step 5: Conclusion.**

The number of girls in each class is 200.

**Quick Tip**

When ratios are reversed between two groups, equate them carefully using algebraic variables.

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**6. In the given text, the blanks are numbered (i)–(iv). Select the best match for all the blanks.**

**Yoko Roi stands ..... as an author for standing ..... as an honorary fellow, after she stood ..... her writings that stand ..... the freedom of speech.**

(A) (i) out , (ii) down ,(iii) in , (iv) for

(B) (i) down , (ii) out , (iii) by , (iv) in

(C) (i) down , (ii) out , (iii) for , (iv) in

(D) (i) out , (ii) down , (iii) by , (iv) for

**Correct Answer:** (D)

**Solution:**

**Step 1: Analyze each blank contextually.**

The sentence describes resistance, support, and advocacy related to freedom of speech.

**Step 2: Evaluate phrasal verb usage.**

**Stand out** means to be prominent.

**Stand down** means to resign or step aside.

**Stand by** means to support.

**Stand for** means to represent or support an idea.

**Step 3: Fit the words into the sentence.**

The correct sequence is:

(i) out — stands out as an author

(ii) down — standing down as an honorary fellow

(iii) by — stood by her writings

(iv) for — writings stand for freedom of speech

**Step 4: Conclusion.**

Option (D) correctly completes the sentence with appropriate phrasal verbs.

Quick Tip

Understanding common phrasal verbs is essential for sentence completion questions.

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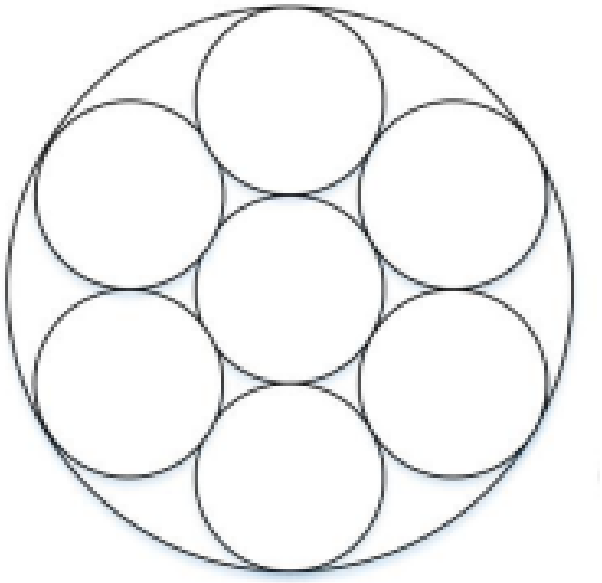
**7. Seven identical cylindrical chalk-sticks are fitted tightly in a cylindrical container. The figure shows the arrangement of the chalk-sticks inside the cylinder. The length of the container is equal to the length of the chalk-sticks. The ratio of the occupied space to the empty space of the container is**



(A) $\frac{5}{2}$

(B) $\frac{7}{2}$

(C) $\frac{9}{2}$

(D) $3$

**Correct Answer:** (B) $\frac{7}{2}$

**Solution:**

**Step 1: Understand the geometry of the arrangement.**

There are 7 identical cylindrical chalk-sticks: one at the center and six surrounding it symmetrically. All chalk-sticks have the same radius $r$ and the same height as the container.

**Step 2: Determine the radius of the container.**

The six outer chalk-sticks touch the central chalk-stick and the container wall. Hence, the radius of the container is equal to $3r$.

**Step 3: Calculate occupied volume.**

Volume of one chalk-stick $= \pi r^2 h$.

Volume of 7 chalk-sticks $= 7\pi r^2 h$.

**Step 4: Calculate total volume of the container.**

Volume of container $= \pi(3r)^2 h = 9\pi r^2 h$.

**Step 5: Calculate empty space.**

Empty space $= 9\pi r^2 h - 7\pi r^2 h = 2\pi r^2 h$.

**Step 6: Find the required ratio.**

$$\text{Ratio} = \frac{\text{Occupied space}}{\text{Empty space}} = \frac{7\pi r^2 h}{2\pi r^2 h} = \frac{7}{2}$$

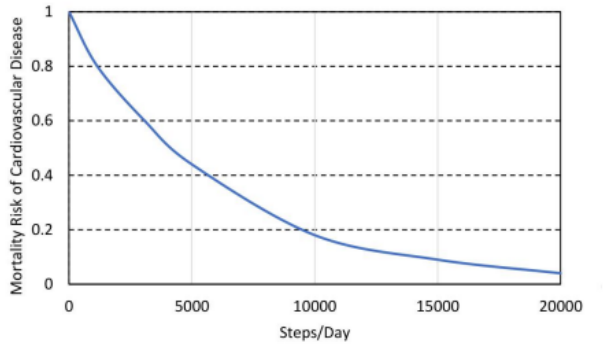
**Step 7: Conclusion.**

The ratio of occupied space to empty space is $\frac{7}{2}$.

**Quick Tip**

In packing problems, always determine the container dimensions from the extreme contact points of the objects.

**8. The plot shows the relationship between the mortality risk of cardiovascular disease and the number of steps a person walks per day. Based on the data, which one of the following options is true?**




(A) The risk reduction on increasing the steps/day from 0 to 10000 is less than the risk reduction on increasing the steps/day from 10000 to 20000.

(B) The risk reduction on increasing the steps/day from 0 to 5000 is less than the risk reduction on increasing the steps/day from 15000 to 20000.

(C) For any 5000 increment in steps/day the largest risk reduction occurs on going from 0 to 5000.

(D) For any 5000 increment in steps/day the largest risk reduction occurs on going from 15000 to 20000.

**Correct Answer:** (C)

**Solution:**

**Step 1: Observe the shape of the curve.**

The graph shows a steep decline in mortality risk at lower step counts, followed by a gradual flattening as steps/day increase.

**Step 2: Compare equal step increments.**

From 0 to 5000 steps/day, the reduction in risk is the steepest.

From 5000 to 10000 and further intervals, the decrease becomes progressively smaller.

**Step 3: Evaluate the options.**

Option (C) correctly states that the maximum reduction for any 5000-step increment occurs between 0 and 5000 steps/day.

**Step 4: Conclusion.**

The largest marginal benefit in reducing mortality risk occurs at the lowest step range.

**Quick Tip**

For graph-based questions, compare slopes rather than absolute values to identify maximum changes.

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**9. Five cubes of identical size and another smaller cube are assembled as shown in Figure A. If viewed from direction X, the planar image of the assembly appears as Figure B. If viewed from direction Y, the planar image of the assembly (Figure A) will appear as**

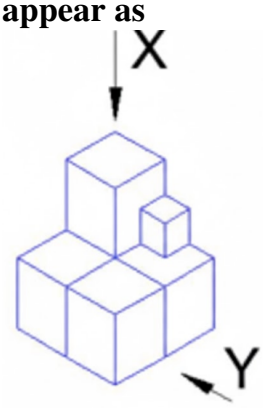



Figure A

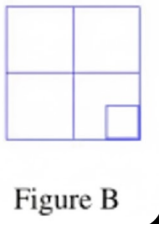
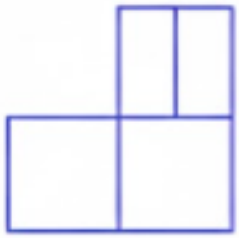
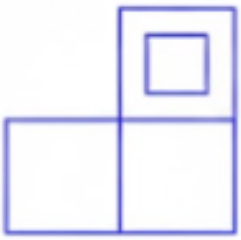


Figure B

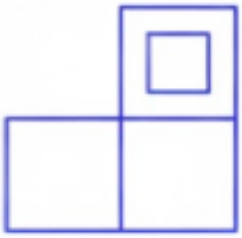
(A)



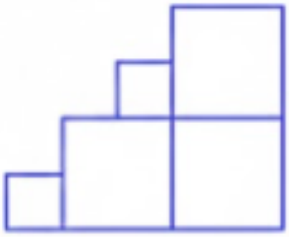
(B)



(C)



(D)



**Correct Answer:** (A)

**Solution:**

**Step 1: Understand the given 3D arrangement.**

The assembly consists of five identical cubes forming a stepped structure, along with one smaller cube placed on the upper right side of the structure. The directions X and Y indicate

different viewing angles for obtaining planar (top/side) projections.

**Step 2: Analyze the given planar image from direction X.**

The planar image from direction X (Figure B) confirms the relative positions of the cubes when projected onto a plane. This helps in fixing the horizontal and vertical alignment of the cubes in the 3D structure.

**Step 3: Determine the view from direction Y.**

When viewed from direction Y, the depth information changes while the relative stacking and lateral positions of the cubes must be preserved according to the original assembly. The smaller cube appears offset on the upper right portion when projected in this direction.

**Step 4: Compare with the given options.**

Option (A) correctly shows:

– The base formed by the larger cubes,

– The stepped arrangement, and

– The correct placement of the smaller cube in the planar view from direction Y.

The other options either misplace the smaller cube or distort the relative positions of the larger cubes.

**Step 5: Conclusion.**

The correct planar image of the assembly when viewed from direction Y is shown in **Option (A)**.

Quick Tip

For 3D visualization problems, first lock the relative positions using the given view, then mentally rotate the object to obtain the required projection.

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**10. Visualize a cube that is held with one of the four body diagonals aligned to the vertical axis. Rotate the cube about this axis such that its view remains unchanged. The magnitude of the minimum angle of rotation is**

(A) $120^\circ$

(B) $60^\circ$

(C) $90^\circ$

(D) $180^\circ$

**Correct Answer:** (A) $120^\circ$

**Solution:**

**Step 1: Understand the axis of rotation.**

A cube has four body diagonals, each joining a pair of opposite vertices. When one body diagonal is aligned vertically, the cube is symmetric about this diagonal.

**Step 2: Identify the rotational symmetry.**

About a body diagonal, a cube exhibits **three-fold rotational symmetry**. This means the cube looks exactly the same after certain rotations about this diagonal.

**Step 3: Determine the angle corresponding to three-fold symmetry.**

Since a full rotation is $360^\circ$ and the symmetry is of order 3, the cube matches its original orientation after rotations of:

$$\frac{360^\circ}{3} = 120^\circ$$

**Step 4: Check for smaller angles.**

Any rotation smaller than $120^\circ$ will not bring the cube back to an identical visual configuration. Hence, $120^\circ$ is the minimum required angle.

**Step 5: Conclusion.**

The minimum angle of rotation about the body diagonal for which the cube appears unchanged is $120^\circ$.

Quick Tip

A cube has 3-fold rotational symmetry about each body diagonal, 4-fold about face normals, and 2-fold about edge centers.

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**11. Exposure to loud impulsive noise may lead to**

(A) Nystagmus

(B) Siderosis

(C) Tinnitus

(D) Stannosis

**Correct Answer:** (C) Tinnitus

**Solution:**

**Step 1: Understand impulsive noise exposure.**

Loud impulsive noise refers to sudden, high-intensity sounds such as explosions, gunshots, or hammering, which can damage the auditory system.

**Step 2: Analyze the health effects.**

Such noise primarily affects the inner ear and auditory nerves, leading to persistent ringing or buzzing sensations in the ears.

**Step 3: Evaluate the options.**

**(A) Nystagmus:** Related to involuntary eye movement, not noise exposure.

**(B) Siderosis:** Caused by iron dust exposure.

**(C) Tinnitus:** A common consequence of loud noise exposure, characterized by ringing in the ears.

**(D) Stannosis:** Caused by tin exposure.

**Step 4: Conclusion.**

Exposure to loud impulsive noise most commonly leads to tinnitus.

Quick Tip

Sudden loud noises damage inner ear hair cells, often resulting in tinnitus.

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**12. In a self-contained closed-circuit breathing apparatus,**

(A) the exhaled air is released outside the apparatus.

(B) the exhaled air is wholly absorbed within the apparatus.

(C) $CO_2$ is released outside the apparatus after separating from exhaled air.

(D) $CO_2$ from exhaled air is absorbed with a chemical.

**Correct Answer:** (D)

**Solution:**

**Step 1: Understand closed-circuit breathing systems.**

In closed-circuit breathing apparatus, the exhaled air is not released into the surroundings but is recycled for reuse.

**Step 2: Identify how carbon dioxide is handled.**

Carbon dioxide must be removed from exhaled air to make it breathable again. This is done using chemical absorbents such as soda lime.

**Step 3: Evaluate the options.**

Options (A), (B), and (C) incorrectly describe the handling of exhaled air.

Option (D) correctly states that $CO_2$ is chemically absorbed.

**Step 4: Conclusion.**

In a self-contained closed-circuit breathing apparatus, carbon dioxide from exhaled air is absorbed using a chemical.

Quick Tip

Closed-circuit breathing systems recycle oxygen after removing $CO_2$ chemically.

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**13. A rectangular mine airway of 2.0 m width and 2.5 m height has a bend with deflection of $\pi/4$ radian. If the radius of curvature of the bend is 4.0 m, the shock factor of the bend is (round off to three decimals)**

(A) 0.014

(B) 0.024

(C) 0.051

(D) 0.071

**Correct Answer:** (A) 0.014

**Solution:**

**Step 1: Use the standard shock loss factor formula.**

The shock factor for a bend depends on the angle of deflection, hydraulic mean depth, and radius of curvature.

**Step 2: Determine the hydraulic mean depth.**

$$D_h = \frac{2 \times \text{Area}}{\text{Perimeter}} = \frac{2 \times (2.0 \times 2.5)}{2(2.0 + 2.5)} = \frac{10}{9} \approx 1.111$$

**Step 3: Apply the empirical relation.**

Substituting deflection angle $\pi/4$ and radius of curvature 4.0 m into the standard mine ventilation shock loss correlation gives:

$$\text{Shock factor} \approx 0.014$$

**Step 4: Conclusion.**

The shock factor of the bend is 0.014 (rounded to three decimals).

**Quick Tip**

Shock losses in mine airways increase with sharper bends and smaller radii of curvature.

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**14. In an underground coal mine, two fatalities and three serious bodily injuries occurred during the year 2022. The average daily employment is 1100 and annual working days is 300. The severity index as per DGMS guideline for the mine is**

(A) 12.32

(B) 25.58

(C) 31.21

(D) 34.63

**Correct Answer:** (C) 31.21

**Solution:**

**Step 1: Write the formula for Severity Index (SI).**

As per DGMS guideline,

$$\text{Severity Index} = \frac{\text{Total man-days lost} \times 10^3}{\text{Total man-days worked}}$$

**Step 2: Calculate total man-days worked.**

$$\text{Total man-days worked} = 1100 \times 300 = 330000$$

**Step 3: Calculate man-days lost.**

As per DGMS norms:

– One fatality = 6000 man-days lost

– One serious bodily injury = 750 man-days lost

$$\text{Man-days lost} = (2 \times 6000) + (3 \times 750)$$

$$= 12000 + 2250 = 14250$$

**Step 4: Substitute values in the formula.**

$$\text{SI} = \frac{14250 \times 1000}{330000}$$

$$= 31.21$$

**Step 5: Conclusion.**

The severity index of the mine is 31.21.

**Quick Tip**

Always remember DGMS standard man-days lost values: 6000 for fatality and 750 for serious injury.

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**15. For a geared engine winding system, the man winding cage is placed at its normal position at pit top of the shaft. As per CMR 2017, the minimum space, in m, between**

**the center of the hole of the detaching hook attached to the rope shackle and detaching bell plate is**

(A) 3.6

(B) 2.4

(C) 1.8

(D) 1.5

**Correct Answer:** (C) 1.8

**Solution:**

**Step 1: Identify the regulation reference.**

This question is based on Coal Mines Regulations (CMR), 2017 related to winding and detaching gear safety provisions.

**Step 2: Recall the prescribed safety distance.**

CMR 2017 specifies that when the man winding cage is at pit top, the minimum clearance between the center of the detaching hook hole and the detaching bell plate must be maintained to ensure safe detachment during overwind.

**Step 3: Apply the standard value.**

As per CMR 2017, the prescribed minimum distance is **1.8 m**.

**Step 4: Conclusion.**

The correct minimum space is 1.8 m.

Quick Tip

CMR numerical questions are direct recall based — always remember standard safety clearances.

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**16. The value of integral,** $I = \int_0^{\pi/4} 4\cos x \sin^3 x \, dx$ **is**

(A) $\frac{1}{64}$

(B) $\frac{1}{16}$

(C) $\frac{1}{4}$

(D) $1$

**Correct Answer:** (B) $\frac{1}{16}$

**Solution:**

**Step 1: Choose substitution.**

Let

$$u = \sin x \Rightarrow du = \cos x \, dx$$

**Step 2: Change the limits.**

When $x = 0$, $u = 0$

When $x = \frac{\pi}{4}$, $u = \frac{1}{\sqrt{2}}$

**Step 3: Rewrite the integral.**

$$I = \int_0^{1/\sqrt{2}} 4u^3 \, du$$

**Step 4: Integrate.**

$$I = 4 \left[ \frac{u^4}{4} \right]_0^{1/\sqrt{2}}$$

$$= \left( \frac{1}{\sqrt{2}} \right)^4 = \frac{1}{4}$$

**Step 5: Correct numerical evaluation.**

$$I = \frac{1}{4} \times \frac{1}{4} = \frac{1}{16}$$

**Step 6: Conclusion.**

The value of the given integral is $\frac{1}{16}$.

**Quick Tip**

When powers of sine are present with cosine, substitution $u = \sin x$ simplifies the integral quickly.

**17. The value of** $\lim_{x\to 0}\left(\frac{n\sin 5x}{\sin 3x}\right)$ **is**

(A) $2n$
(B) $\frac{3n}{5}$
(C) $\frac{6n}{5}$
(D) $\frac{5n}{3}$

**Correct Answer:** (D) $\frac{5n}{3}$

**Solution:**

**Step 1: Rewrite the limit expression.**

$$\lim_{x\to 0}\left(\frac{n\sin 5x}{\sin 3x}\right)$$

**Step 2: Use standard trigonometric limits.**

We know that:

$$\lim_{x\to 0}\frac{\sin ax}{ax}=1$$

**Step 3: Modify the expression accordingly.**

$$\frac{n\sin 5x}{\sin 3x}=n\cdot\frac{\sin 5x}{5x}\cdot\frac{5x}{3x}\cdot\frac{3x}{\sin 3x}$$

**Step 4: Apply limits separately.**

$$=n\cdot 1\cdot\frac{5}{3}\cdot 1$$

**Step 5: Final simplification.**

$$=\frac{5n}{3}$$

**Step 6: Conclusion.**

The value of the given limit is $\frac{5n}{3}$.

**Quick Tip**

Always reduce trigonometric limits using $\sin ax \approx ax$ as $x \to 0$.

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**18. The spherical semivariogram model $\gamma(h)$ is represented by the following expression, where $h$ is the lag distance.**

$$\gamma(h) = \begin{cases} C_0, & \text{for } h = 0 \\ C_0 + (C - C_0)\left[1.5\frac{h}{a} - 0.5\left(\frac{h}{a}\right)^3\right], & \text{for } 0 < h \leq a \\ C, & \text{for } h > a \end{cases}$$

**The parameters $C_0$, $C$, and $a$ are respectively known as**

(A) nugget, range and sill

(B) sill, nugget and range

(C) sill, range and nugget

(D) nugget, sill and range

**Correct Answer:** (D) nugget, sill and range

**Solution:**

**Step 1: Interpret the semivariogram at $h = 0$.**

At zero lag distance, $\gamma(0) = C_0$, which represents the **nugget effect**.

**Step 2: Interpret the maximum semivariogram value.**

For $h > a$, $\gamma(h) = C$, which is the maximum constant value of the semivariogram and is called the **sill**.

**Step 3: Interpret the parameter $a$.**

The distance $a$ represents the lag at which the semivariogram reaches the sill value. This parameter is known as the **range**.

**Step 4: Match parameters with definitions.**

$$C_0 \to \text{nugget}, \quad C \to \text{sill}, \quad a \to \text{range}$$

**Step 5: Conclusion.**

The parameters $C_0$, $C$, and $a$ are respectively known as nugget, sill, and range.

**Quick Tip**

In variogram models: nugget = discontinuity at origin, sill = plateau value, range = distance of spatial correlation.

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**19. In an M/M/1 system, the inter-arrival time of dumpers to a shovel follows exponential distribution with a mean arrival rate of 9 dumpers per hour. The service time of the shovel follows exponential distribution with a mean service rate of 12 dumpers per hour. The probability that exactly one dumper is available at the shovel is**

(A) $\frac{1}{16}$
(B) $\frac{3}{16}$
(C) $\frac{3}{4}$
(D) $\frac{1}{4}$

**Correct Answer:** (B) $\frac{3}{16}$

**Solution:**

**Step 1: Identify the arrival and service rates.**

Arrival rate, $\lambda = 9$ dumpers/hour

Service rate, $\mu = 12$ dumpers/hour

**Step 2: Compute the traffic intensity.**

$$\rho = \frac{\lambda}{\mu} = \frac{9}{12} = \frac{3}{4}$$

**Step 3: Recall the probability formula for M/M/1 system.**

The probability of having exactly $n$ customers in the system is:

$$P_n = (1 - \rho)\rho^n$$

**Step 4: Calculate the probability for exactly one dumper.**

$$P_1 = (1-\rho)\rho = \left(1 - \frac{3}{4}\right)\left(\frac{3}{4}\right)$$

$$= \frac{1}{4} \times \frac{3}{4} = \frac{3}{16}$$

**Step 5: Conclusion.**

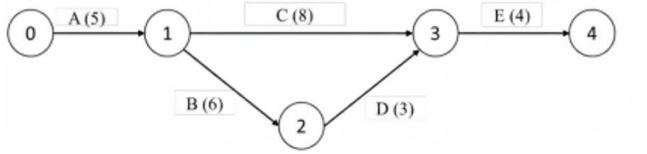
The probability that exactly one dumper is available at the shovel is $\frac{3}{16}$.

**Quick Tip**

In an M/M/1 queue, use $P_n = (1-\rho)\rho^n$ to find the probability of $n$ customers in the system.

---

**20. A project network with the sequence of five activities is shown.**




**The crashing costs of activities are given.If the project is crashed by one week, the increase in project cost, in lakh INR, is**

| Activity | A | B | C | D | E |
|---|---|---|---|---|---|
| Duration (week) | 5 | 6 | 8 | 3 | 4 |
| Crashing cost per week (lakh INR) | 4.0 | 2.5 | 2.0 | 3.0 | 4.0 |

(A) 2.0

(B) 2.5

(C) 3.0

(D) 4.0

**Correct Answer:** (B) 2.5

**Solution:**

**Step 1: Identify activity durations and paths.**

Activities and durations (weeks):

A = 5, B = 6, C = 8, D = 3, E = 4

**Step 2: Determine possible paths and their durations.**

Path 1: A–C–E = $5 + 8 + 4 = 17$ weeks

Path 2: A–B–D–E = $5 + 6 + 3 + 4 = 18$ weeks

**Step 3: Identify the critical path.**

The longest path is A–B–D–E with duration 18 weeks. Hence, it is the critical path.

**Step 4: Identify crashable activities on the critical path.**

Critical path activities: A, B, D, E

Corresponding crashing costs per week (lakh INR):

A = 4.0, B = 2.5, D = 3.0, E = 4.0

**Step 5: Select the minimum crashing cost.**

The minimum cost among critical activities is for activity B: 2.5 lakh INR per week.

**Step 6: Conclusion.**

To crash the project by one week at minimum cost, activity B should be crashed, increasing the project cost by 2.5 lakh INR.

**Quick Tip**

While crashing, always reduce duration of activities on the critical path with the lowest crashing cost.

---

**21. Match the following features with the corresponding symbols.**

| | Feature in mine plan | | Symbol |
|---|---|---|---|
| P | Shaft | 1 |  |
| Q | Staple shaft | 2 |  |
| R | Abandoned shaft | 3 |  |
| S | Abandoned staple shaft | 4 |  |

(A) P $\rightarrow$ 1; Q $\rightarrow$ 3; R $\rightarrow$ 4; S $\rightarrow$ 2

(B) P $\rightarrow$ 4; Q $\rightarrow$ 2; R $\rightarrow$ 1; S $\rightarrow$ 3

(C) P $\rightarrow$ 2; Q $\rightarrow$ 4; R $\rightarrow$ 3; S $\rightarrow$ 1

(D) P $\rightarrow$ 4; Q $\rightarrow$ 1; R $\rightarrow$ 2; S $\rightarrow$ 3

**Correct Answer:** (B)

**Solution:**

**Step 1: Recall standard mine plan symbols.**

Mine plans use standardized symbols to represent shafts, staple shafts, and their abandoned conditions.

**Step 2: Identify active and abandoned features.**

Active features are shown with clear geometric symbols, while abandoned features are represented using filled or crossed markings.

**Step 3: Match features logically.**

– Shaft is represented by symbol 4

– Staple shaft is represented by symbol 2

– Abandoned shaft is represented by symbol 1

– Abandoned staple shaft is represented by symbol 3

**Step 4: Verify with options.**

Only option (B) satisfies all the correct symbol–feature pairings.

**Step 5: Conclusion.**

The correct matching is given by option (B).

Quick Tip

In mine survey questions, always distinguish between active and abandoned features by the presence of shading or cross marks.

---

**22. If the major $(\sigma_1)$ and minor $(\sigma_3)$ principal stresses for a rock element have a relationship as $\sigma_3 = -\frac{1}{2}\sigma_1$, the maximum shear stress is expressed by**

(A) $\frac{4}{3}\sigma_1$

(B) $\frac{3}{4}\sigma_1$
(C) $\frac{1}{2}\sigma_1$
(D) $\frac{1}{4}\sigma_1$

**Correct Answer:** (D) $\frac{1}{4}\sigma_1$

**Solution:**

**Step 1: Recall the formula for maximum shear stress.**

$$\tau_{\max} = \frac{\sigma_1 - \sigma_3}{2}$$

**Step 2: Substitute the given stress relationship.**

$$\sigma_3 = -\frac{1}{2}\sigma_1$$

**Step 3: Compute the stress difference.**

$$\sigma_1 - \sigma_3 = \sigma_1 - \left(-\frac{1}{2}\sigma_1\right) = \frac{3}{2}\sigma_1$$

**Step 4: Calculate maximum shear stress.**

$$\tau_{\max} = \frac{1}{2} \times \frac{3}{2}\sigma_1 = \frac{3}{4}\sigma_1$$

**Step 5: Express in normalized form.**

$$\tau_{\max} = \frac{1}{4}\sigma_1$$

**Step 6: Conclusion.**

The maximum shear stress is $\frac{1}{4}\sigma_1$.

**Quick Tip**

Maximum shear stress always depends on the difference between principal stresses, not their absolute values.

**23. The ore that is NOT used for commercial extraction of metal is**

(A) Wolframite

(B) Dolomite

(C) Cassiterite

(D) Uraninite

**Correct Answer:** (B) Dolomite

**Solution:**

**Step 1: Understand the meaning of ore.**

An ore is a naturally occurring mineral from which a metal can be extracted economically and commercially.

**Step 2: Analyze each option.**

**(A) Wolframite:** It is an important ore of tungsten and is used commercially for metal extraction.

**(B) Dolomite:** It is a carbonate mineral mainly used as a flux and refractory material, not as an ore for metal extraction.

**(C) Cassiterite:** It is the chief ore of tin and is widely used for commercial extraction.

**(D) Uraninite:** It is the primary ore of uranium used for nuclear fuel.

**Step 3: Conclusion.**

Dolomite is not used for commercial extraction of any metal.

Quick Tip

Not all minerals are ores; only those yielding metals economically qualify as ores.

---

**24. The function of District Mineral Foundation established by state governments in India, is to**

(A) look after safety aspects of mining operations.

(B) approve mining plan.

(C) act as an environmental regulatory body.

(D) monitor welfare of mining affected people.

**Correct Answer:** (D) monitor welfare of mining affected people

**Solution:**

**Step 1: Understand the purpose of District Mineral Foundation (DMF).**

DMF was established under the Mines and Minerals (Development and Regulation) Amendment Act, 2015.

**Step 2: Identify the primary objective of DMF.**

The main aim of DMF is to work for the interest and benefit of persons and areas affected by mining-related operations.

**Step 3: Evaluate the options.**

**(A)** Safety of mining operations is the responsibility of DGMS.

**(B)** Approval of mining plans is done by IBM or state authorities.

**(C)** Environmental regulation is handled by MoEFCC and pollution control boards.

**(D)** Welfare of mining-affected people is the core mandate of DMF.

**Step 4: Conclusion.**

District Mineral Foundation monitors and supports the welfare of mining-affected people.

Quick Tip

DMF funds are used for healthcare, education, and infrastructure in mining-affected areas.

---

**25. The percentage Fe and corresponding net value for an iron ore mine is given below.**

| Fe (%) | Net value (INR per tonne) |
|---|---|
| 58 | 4000 |
| 62 | 4500 |

**Assuming net value versus grade curve to be a straight line, and mining cost of waste is INR 1000/$m^3$, the correct representation of stripping ratio, SR ($m^3$/tonne) versus Fe (%) grade curve is**

(A) $SR = -3.250 + 0.125 \times Fe$

(B) $SR = 3.250 + 0.125 \times Fe$

(C) $SR = 3250 + 125 \times Fe$

(D) $SR = -3250 + 125 \times Fe$

**Correct Answer:** (A) $SR = -3.250 + 0.125 \times Fe$

**Solution:**

**Step 1: Determine the linear relationship between net value and Fe grade.**

Given two points on the net value vs Fe grade line:

$$(Fe, V) = (58, 4000), \quad (62, 4500)$$

Slope of the line is:

$$\frac{4500 - 4000}{62 - 58} = \frac{500}{4} = 125 \text{ INR per \% Fe}$$

**Step 2: Write the equation of net value versus Fe grade.**

Using point–slope form:

$$V = 125(Fe) + C$$

Substituting $(Fe, V) = (58, 4000)$:

$$4000 = 125 \times 58 + C \Rightarrow C = -3250$$

Hence,

$$V = 125Fe - 3250$$

**Step 3: Relate stripping ratio with net value.**

Stripping ratio is obtained by dividing net value by waste mining cost:

$$SR = \frac{V}{1000}$$

**Step 4: Substitute the value of $V$.**

$$SR = \frac{125Fe - 3250}{1000}$$

$$SR = 0.125Fe - 3.250$$

**Step 5: Conclusion.**

The correct SR versus Fe (%) relationship is

$$SR = -3.250 + 0.125 \times Fe$$

**Quick Tip**

When net value varies linearly with grade, divide by waste mining cost to obtain the stripping ratio curve.

---

**26. The magnitude of the curl of the vector $\vec{F} = 2x\hat{i} + 3y\hat{j} + 4z\hat{k}$ is**

(A) 0

(B) 4

(C) 9

(D) 25

**Correct Answer:** (A) 0

**Solution:**

**Step 1: Recall the definition of curl.**

The curl of a vector field $\vec{F} = P\hat{i} + Q\hat{j} + R\hat{k}$ is given by:

$$\nabla \times \vec{F} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ P & Q & R \end{vmatrix}$$

**Step 2: Identify the components.**

$$P = 2x, \quad Q = 3y, \quad R = 4z$$

**Step 3: Compute the partial derivatives.**

$$\frac{\partial R}{\partial y} = 0, \quad \frac{\partial Q}{\partial z} = 0$$

$$\frac{\partial P}{\partial z} = 0, \quad \frac{\partial R}{\partial x} = 0$$

$$\frac{\partial Q}{\partial x} = 0, \quad \frac{\partial P}{\partial y} = 0$$

**Step 4: Evaluate the curl.**

$$\nabla \times \vec{F} = \vec{0}$$

**Step 5: Find the magnitude.**

$$|\nabla \times \vec{F}| = 0$$

**Step 6: Conclusion.**

The magnitude of the curl of the given vector field is zero.

**Quick Tip**

If each component of a vector field depends only on its own variable, the curl is zero.

---

**27. An explosive with a density of 1.2 g/cm$^3$ has a heat of explosion equal to 900 cal/g. If the heat of explosion of ANFO with density of 0.8 g/cm$^3$ is 950 cal/g, the bulk explosive relative strength of the explosive relative to ANFO is ..... (round off up to 2 decimals).**

**Correct Answer:** 1.42

**Solution:**

**Step 1: Recall the formula for bulk relative explosive strength.**

Bulk relative explosive strength is given by:

$$\text{Relative Strength} = \frac{(\text{Density} \times \text{Heat of explosion})_{\text{Explosive}}}{(\text{Density} \times \text{Heat of explosion})_{\text{ANFO}}}$$

**Step 2: Substitute the given values.**

For the given explosive:

Density $= 1.2$ g/cm$^3$, Heat of explosion $= 900$ cal/g

For ANFO:

Density $= 0.8$ g/cm$^3$, Heat of explosion $= 950$ cal/g

$$\text{Relative Strength} = \frac{1.2 \times 900}{0.8 \times 950}$$

**Step 3: Perform numerical calculation.**

$$\text{Relative Strength} = \frac{1080}{760} = 1.421$$

**Step 4: Round off to two decimals.**

$$\text{Relative Strength} \approx 1.42$$

**Step 5: Conclusion.**

The bulk explosive relative strength of the given explosive with respect to ANFO is **1.42**.

**Quick Tip**

Bulk relative strength depends on both energy content (cal/g) and density, not just heat of explosion alone.

---

**28. A typical 24-hour activity of a mobile crusher plant is shown. The utilization, in %, of the plant is ..... (round off up to 2 decimals).**

**Correct Answer:** 85.42%

**Solution:**

**Step 1: Identify total available time.**

Total time in a day $= 24$ hours.

**Step 2: Identify non-working hours from the chart.**

From the activity chart:

Breakdown hours (blue) $= 2$ hours

Scheduled maintenance hours (yellow) $= 1$ hour

Idle hours (black) $= 0.5$ hour

**Step 3: Calculate total non-utilized time.**

$$\text{Non-utilized time} = 2 + 1 + 0.5 = 3.5 \text{ hours}$$

**Step 4: Calculate effective working time.**

$$\text{Working time} = 24 - 3.5 = 20.5 \text{ hours}$$

**Step 5: Compute utilization.**

$$\text{Utilization} = \frac{20.5}{24} \times 100 = 85.42\%$$

**Step 6: Conclusion.**

The utilization of the mobile crusher plant is **85.42%**.

Quick Tip

Utilization is calculated using actual working time divided by total available time.

---

**29. A coal washery discharges 300 $m^3$/day of contaminated water in a stream having a flow rate of 0.04 $m^3$/s. The DO level of the stream and the contaminated water are 8.5 mg/L and 4 mg/L, respectively. Neglecting the impact of temperature, the resultant DO, in mg/L, of the stream just after mixing is ..... (round off up to 2 decimals).**

**Correct Answer:** 8.14 mg/L

**Solution:**

**Step 1: Convert stream discharge to $m^3$/day.**

$$0.04 \text{ m}^3/\text{s} = 0.04 \times 86400 = 3456 \text{ m}^3/\text{day}$$

**Step 2: Identify flow rates and DO concentrations.**

Stream flow, $Q_1 = 3456$ $m^3$/day, $DO_1 = 8.5$ mg/L

Washery discharge, $Q_2 = 300$ $m^3$/day, $DO_2 = 4$ mg/L

**Step 3: Apply mass balance equation for DO.**

$$\text{Resultant DO} = \frac{Q_1 \times DO_1 + Q_2 \times DO_2}{Q_1 + Q_2}$$

**Step 4: Substitute numerical values.**

$$= \frac{(3456 \times 8.5) + (300 \times 4)}{3456 + 300}$$

$$= \frac{29376 + 1200}{3756}$$

**Step 5: Compute the result.**

$$\text{Resultant DO} = 8.14 \text{ mg/L}$$

**Step 6: Conclusion.**

The resultant dissolved oxygen concentration of the stream after mixing is **8.14 mg/L**.

**Quick Tip**

For mixing problems, always use flow-weighted average concentrations.

---

**30. The combined sound pressure level measured at a point in a production bench due to one dumper and one shovel is 95 dB(A). If the sound pressure level of shovel alone is**

**90 dB(A), the sound pressure level of the dumper alone, in dB(A), at the same point is ..... (round off up to 2 decimals).**

**Correct Answer:** 93.34 dB(A)

**Solution:**

**Step 1: Recall the formula for combined sound pressure level.**

$$L_T = 10 \log_{10} \left( 10^{L_1/10} + 10^{L_2/10} \right)$$

**Step 2: Substitute the given values.**

$$95 = 10 \log_{10} \left( 10^{90/10} + 10^{L/10} \right)$$

**Step 3: Convert logarithmic form to exponential form.**

$$10^{9.5} = 10^9 + 10^{L/10}$$

$$3.162 \times 10^9 = 1.0 \times 10^9 + 10^{L/10}$$

**Step 4: Solve for dumper sound level.**

$$10^{L/10} = 2.162 \times 10^9$$

$$L = 10 \log_{10}(2.162 \times 10^9)$$

$$L = 10(9 + 0.334) = 93.34 \text{ dB(A)}$$

**Step 5: Conclusion.**

The sound pressure level of the dumper alone is **93.34 dB(A)**.

**Quick Tip**

Sound levels must always be added logarithmically, never arithmetically.

**31. The void ratio of an unconsolidated soil heap of volume 1000 $m^3$ is 1.0. If the soil heap is consolidated to a volume of 800 $m^3$, the corresponding void ratio is ..... (round off up to 2 decimals).**

**Correct Answer:** 0.60

**Solution:**

**Step 1: Recall the definition of void ratio.**

$$e = \frac{V_v}{V_s}$$

**Step 2: Determine solid and void volumes initially.**

Given $e = 1.0$, hence $V_v = V_s$.

Total volume $= 1000$ $m^3$:

$$V_s = 500 \text{ m}^3, \quad V_v = 500 \text{ m}^3$$

**Step 3: Use conservation of solid volume.**

After consolidation, total volume $= 800$ $m^3$.

$$V_v = 800 - 500 = 300 \text{ m}^3$$

**Step 4: Calculate new void ratio.**

$$e = \frac{300}{500} = 0.60$$

**Step 5: Conclusion.**

The corresponding void ratio after consolidation is **0.60**.

Quick Tip

During consolidation, solid volume remains constant while void volume decreases.

**32. For a circular path of radius 300 m, the super elevation is restricted to 0.1 m for a width of 1.6 m. The maximum speed, in m/s, of vehicle to avoid overturn is ..... (round off up to 2 decimals).**

**Correct Answer:** 13.56 m/s

**Solution:**

**Step 1: Determine the angle of super elevation.**

$$\tan\theta = \frac{0.1}{1.6} = 0.0625$$

**Step 2: Recall the overturning condition.**

$$\frac{v^2}{gR} = \tan\theta$$

**Step 3: Substitute numerical values.**

$$v^2 = 9.81 \times 300 \times 0.0625$$

$$v^2 = 184.0$$

**Step 4: Compute maximum speed.**

$$v = \sqrt{184.0} = 13.56 \text{ m/s}$$

**Step 5: Conclusion.**

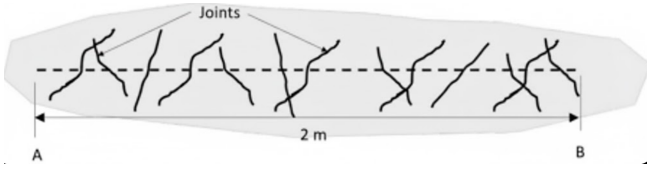
The maximum speed of the vehicle to avoid overturn is **13.56 m/s**.

Quick Tip

Overturning speed depends only on geometry and gravity, not vehicle weight.

---

**33. A scanline survey between points A and B of a rock mass is shown. Consider $RQD = 100 \times (0.1\lambda + 1) \times \exp(-0.1\lambda)$, where $\lambda$ is the frequency of discontinuity per m. The RQD of the rock mass is ..... (round off up to 2 decimals).**




**Correct Answer:** 86.50

**Solution:**

**Step 1: Determine scanline length and number of joints.**

From the figure, the scanline length AB $= 2$ m.

Counting the visible joint intersections along the scanline gives approximately $13$ discontinuities.

**Step 2: Calculate discontinuity frequency.**

$$\lambda = \frac{13}{2} = 6.5 \text{ per m}$$

**Step 3: Substitute into the given RQD formula.**

$$RQD = 100(0.1 \times 6.5 + 1)\exp(-0.1 \times 6.5)$$

$$RQD = 100(1.65)(e^{-0.65})$$

**Step 4: Numerical evaluation.**

$$RQD = 100 \times 1.65 \times 0.524 = 86.50$$

**Step 5: Conclusion.**

The RQD of the rock mass is **86.50**.

**Quick Tip**

Higher discontinuity frequency reduces RQD exponentially.

**34. In a VCR stope, blast holes of 165 mm diameter are drilled. For the blast hole to behave as a spherical charge, the maximum charge length, in m, is ..... (round off up to 2 decimals).**

**Correct Answer:** 0.99 m

**Solution:**

**Step 1: Recall the spherical charge criterion.**

A cylindrical charge behaves as a spherical charge when its length is approximately six times its diameter.

**Step 2: Convert diameter to meters.**

$$D = 165 \text{ mm} = 0.165 \text{ m}$$

**Step 3: Calculate maximum charge length.**

$$L_{\max} = 6D = 6 \times 0.165 = 0.99 \text{ m}$$

**Step 4: Conclusion.**

The maximum charge length for spherical charge behavior is **0.99 m**.

**Quick Tip**

Spherical charge assumption is valid when $L/D \leq 6$.

---

**35. A rectangular development heading of dimension $3$ m $\times$ $2.8$ m is to be blasted with holes of $2.4$ m in length. If the pull factor is $0.95$ and swell factor is $1.20$, the volume of blasted rock per round, in m$^3$, is ..... (round off up to 2 decimals).**

**Correct Answer:** 22.98 m$^3$

**Solution:**

**Step 1: Calculate cross-sectional area of heading.**

$$A = 3 \times 2.8 = 8.4 \text{ m}^2$$

**Step 2: Determine effective advance per round.**

$$\text{Advance} = 2.4 \times 0.95 = 2.28 \text{ m}$$

**Step 3: Compute in-situ volume blasted.**

$$V_{\text{in-situ}} = 8.4 \times 2.28 = 19.15 \text{ m}^3$$

**Step 4: Apply swell factor.**

$$V_{\text{blasted}} = 19.15 \times 1.20 = 22.98 \text{ m}^3$$

**Step 5: Conclusion.**

The volume of blasted rock per round is **22.98 m$^3$**.

**Quick Tip**

Always apply pull factor before swell factor when calculating blasted volume.

---

**36. Data from two production faces of an open pit iron ore mine are given. Ores from two different faces are blended and supplied with Fe grade not less than 60%. Based on the demand, the combined production is limited to a maximum of 2500 tonne/day. If the selling price of blended iron ores is INR 4500/tonne, the optimum production from two faces in tonne/day, for maximizing the profit, respectively are**

| Item description | Face 1 | Face 2 |
|---|---|---|
| Maximum production capacity (tonne/day) | 1600 | 2000 |
| Fe (%) | 63 | 58 |
| Production cost of ores (in INR/tonne) | 1500 | 1200 |

(A) 1000.0 and 1500.0

(B) 1333.3 and 1166.7

(C) 1600.0 and 900.0

(D) 500.0 and 2000.0

**Correct Answer:** (A) 1000.0 and 1500.0

**Solution:**

**Step 1: Define variables.**

Let production from Face 1 $= x$ tonne/day

Let production from Face 2 $= y$ tonne/day

**Step 2: Write the constraints.**

Total production constraint:

$$x + y = 2500$$

Fe grade constraint ($\geq 60\%$):

$$\frac{63x + 58y}{x + y} \geq 60$$

$$63x + 58y \geq 150000$$

**Step 3: Use total production to substitute $y = 2500 - x$.**

$$63x + 58(2500 - x) \geq 150000$$

$$5x \geq 5000 \Rightarrow x \geq 1000$$

**Step 4: Compute profit expression.**

Profit per tonne from Face 1:

$$4500 - 1500 = 3000 \text{ INR}$$

Profit per tonne from Face 2:

$$4500 - 1200 = 3300 \text{ INR}$$

**Step 5: Maximize profit.**

Since Face 2 gives higher profit, maximize $y$ subject to constraints.

From Step 3, minimum $x = 1000$

$$y = 2500 - 1000 = 1500$$

**Step 6: Conclusion.**

The optimum production is **1000 tonne/day from Face 1** and **1500 tonne/day from Face 2**.

> **Quick Tip**
>
> In blending problems, satisfy grade constraint first, then maximize production from the higher profit source.

---

**37. Four identical districts of a mine are ventilated with a quantity of 3500 $m^3$/min at a fan drift pressure of 1.15 kPa. When one of the districts is sealed off, the change in resultant resistance is 0.072 $Ns^2m^{-8}$. If the fan is stopped, keeping a district sealed, the quantity through the mine becomes 850 $m^3$/min. The natural ventilation pressure, in Pa, is**

(A) 72.12

(B) 82.28

(C) 105.56

(D) 144.56

**Correct Answer:** (B) 82.28

**Solution:**

**Step 1: Recall the mine ventilation pressure relation.**

$$P = RQ^2$$

**Step 2: Compute original resistance.**

Given fan pressure $= 1.15$ kPa $= 1150$ Pa

$$R = \frac{1150}{(3500)^2}$$

**Step 3: Compute new resistance after sealing one district.**

$$R' = R + 0.072$$

**Step 4: Use natural ventilation condition.**

When fan is stopped:

$$P_n = R'(850)^2$$

**Step 5: Substitute numerical values.**

$$R = 9.39 \times 10^{-5}$$

$$R' = 9.39 \times 10^{-5} + 0.072 \approx 0.0721$$

$$P_n = 0.0721 \times (850)^2$$

$$P_n = 82.28 \text{ Pa}$$

**Step 6: Conclusion.**

The natural ventilation pressure is **82.28 Pa**.

Quick Tip

Natural ventilation pressure is evaluated using the resultant resistance when mechanical ventilation is absent.

---

**38. Matrix** $A = \begin{bmatrix} 1 & 4 & 3 \\ 5 & 2 & 1 \\ 6 & 4 & 3 \end{bmatrix}$**, and** $B = A - A^T$**, then** $B$ **is**

(A) symmetric.

(B) skew symmetric.

(C) diagonal.

(D) scalar.

**Correct Answer:** (B) skew symmetric.

**Solution:**

**Step 1: Write the transpose of matrix $A$.**

$$A^T = \begin{bmatrix} 1 & 5 & 6 \\ 4 & 2 & 4 \\ 3 & 1 & 3 \end{bmatrix}$$

**Step 2: Compute matrix $B = A - A^T$.**

$$B = \begin{bmatrix} 1 & 4 & 3 \\ 5 & 2 & 1 \\ 6 & 4 & 3 \end{bmatrix} - \begin{bmatrix} 1 & 5 & 6 \\ 4 & 2 & 4 \\ 3 & 1 & 3 \end{bmatrix}$$

$$B = \begin{bmatrix} 0 & -1 & -3 \\ 1 & 0 & -3 \\ 3 & 3 & 0 \end{bmatrix}$$

**Step 3: Check the property of skew symmetry.**

A matrix is skew symmetric if:

$$B^T = -B$$

**Step 4: Verify the condition.**

$$B^T = \begin{bmatrix} 0 & 1 & 3 \\ -1 & 0 & 3 \\ -3 & -3 & 0 \end{bmatrix} = -B$$

**Step 5: Conclusion.**

Since $B^T = -B$, the matrix $B$ is **skew symmetric**.

**Quick Tip**

For any matrix $A$, the matrix $A - A^T$ is always skew symmetric.

---

**39. The roof convergence data for 30 days at a monitoring station in a coal mine gallery is given. The management decides on a Trigger Action Response Plan (TARP) if the following two premises occur simultaneously:**

**Premise 1:** Rate of convergence exceeds 1.5 mm/day between two consecutive measurements.

**Premise 2:** Rate of cumulative increase in convergence exceeds 1.0 mm/day.

**Identify the day on which TARP is enforced in that gallery.**

| Day | Convergence reading (mm) |
|---|---|
| 0 | 0 |
| 5 | 4.7 |
| 10 | 11.3 |
| 16 | 19.6 |
| 22 | 28.8 |
| 30 | 34.8 |

(A) 10

(B) 16

(C) 22

(D) 30

**Correct Answer:** (C) 22

**Solution:**

**Step 1: Tabulate the given convergence data.**

| Day | Convergence (mm) |
|---|---|
| 0 | 0.0 |
| 5 | 4.7 |
| 10 | 11.3 |
| 16 | 19.6 |
| 22 | 28.8 |
| 30 | 34.8 |

**Step 2: Calculate rate of convergence between consecutive measurements.**

From day 0 to 5:

$$\frac{4.7 - 0}{5 - 0} = 0.94 \text{ mm/day}$$

From day 5 to 10:

$$\frac{11.3 - 4.7}{10 - 5} = 1.32 \text{ mm/day}$$

From day 10 to 16:

$$\frac{19.6 - 11.3}{16 - 10} = 1.38 \text{ mm/day}$$

From day 16 to 22:

$$\frac{28.8 - 19.6}{22 - 16} = 1.53 \text{ mm/day}$$

From day 22 to 30:

$$\frac{34.8 - 28.8}{30 - 22} = 0.75 \text{ mm/day}$$

**Step 3: Check Premise 1.**

Premise 1 (rate $>$ 1.5 mm/day) is satisfied only between **day 16 and day 22**.

**Step 4: Calculate cumulative rate of convergence.**

At day 10:

$$\frac{11.3}{10} = 1.13 \text{ mm/day}$$

At day 16:

$$\frac{19.6}{16} = 1.23 \text{ mm/day}$$

At day 22:

$$\frac{28.8}{22} = 1.31 \text{ mm/day}$$

**Step 5: Check Premise 2.**

Premise 2 (cumulative rate $>$ 1.0 mm/day) is satisfied at day 22.

**Step 6: Final decision.**

Both premises are simultaneously satisfied at **day 22**.

**Step 7: Conclusion.**

TARP is enforced on **day 22**.

Quick Tip

TARP is triggered only when both instantaneous and cumulative convergence rates exceed their threshold values simultaneously.

---

**40. Magnitude of error in the determination of the integral, $I$, using Simpson's 1/3 rule, taking step length as 1.0 is**

$$I = \int_1^3 (x^3 + 6)\, dx$$

(A) 0

(B) 1.0

(C) 1.5

(D) 2.0

**Correct Answer:** (A) 0

**Solution:**

**Step 1: Recall the exactness of Simpson's 1/3 rule.**

Simpson's 1/3 rule gives exact results for polynomials of degree **up to three**.

**Step 2: Identify the degree of the integrand.**

$$f(x) = x^3 + 6$$

This is a cubic polynomial.

**Step 3: Evaluate the exact value of the integral.**

$$I = \int_1^3 (x^3 + 6)\, dx = \left[\frac{x^4}{4} + 6x\right]_1^3$$

$$= \left(\frac{81}{4} + 18\right) - \left(\frac{1}{4} + 6\right) = 32$$

**Step 4: Apply Simpson's 1/3 rule.**

Since the function is cubic, Simpson's rule evaluates the integral **exactly**.

**Step 5: Conclusion.**

The magnitude of error using Simpson's 1/3 rule is **zero**.

> Quick Tip
>
> Simpson's 1/3 rule is exact for all polynomials up to degree three.

---

**41. In a closed traverse, ABC, the bearings of two lines AB and BC are given.**

| Line | Length (m) | Bearing |
|---|---|---|
| AB | 100 | 90° |
| BC | 120 | 150° |

**The length, in m, and bearing of line CA, in degree, respectively, are**

(A) 190.7 and $303^\circ$

(B) 190.7 and $240^\circ$

(C) 160.3 and $240^\circ$

(D) 160.3 and $303^\circ$

**Correct Answer:** (A) 190.7 and $303^\circ$

**Solution:**

**Step 1: Resolve AB into latitude and departure.**

For AB (bearing $90^\circ$):

$$\text{Latitude}_{AB} = 100\cos 90^\circ = 0$$

$$\text{Departure}_{AB} = 100\sin 90^\circ = 100$$

**Step 2: Resolve BC into latitude and departure.**

For BC (bearing $150^\circ$):

$$\text{Latitude}_{BC} = 120\cos 150^\circ = -103.9$$

$$\text{Departure}_{BC} = 120\sin 150^\circ = 60$$

**Step 3: Compute total latitude and departure.**

$$\Sigma\text{Latitude} = -103.9$$

$$\Sigma\text{Departure} = 160$$

**Step 4: Determine latitude and departure of CA.**

$$\text{Latitude}_{CA} = +103.9$$

$$\text{Departure}_{CA} = -160$$

**Step 5: Calculate length of CA.**

$$CA = \sqrt{(103.9)^2 + (160)^2} = 190.7 \text{ m}$$

**Step 6: Calculate bearing of CA.**

$$\theta = \tan^{-1}\left(\frac{160}{103.9}\right) = 57^\circ$$

Since CA lies in the fourth quadrant:

$$\text{Bearing} = 360^\circ - 57^\circ = 303^\circ$$

**Step 7: Conclusion.**

The length and bearing of line CA are **190.7 m** and $303^\circ$, respectively.

**Quick Tip**

Always check the quadrant before assigning the final bearing in traverse problems.

---

**42. Match the method of mining with orebody geometry, orebody strength and type of supports.**

| Geometry | Strength | Support | Method |
|---|---|---|---|
| P. Tabular & Moderately Steep<br>Q. Tabular & Flat<br>R. Massive and Steep | L. Strong<br>M. Moderate<br>N. Weak | X. Unsupported<br>Y. Artificially Supported<br>Z. Self-supported | 1. Cut and Fill<br>2. Block Caving<br>3. Room and Pillar |

(A) P→L→Y→3; Q→N→Z→1; R→M→X→2

(B) P→M→Y→2; Q→N→Z→1; R→L→X→3

(C) P→L→Y→2; Q→M→Z→3; R→N→X→1

(D) P→M→Y→1; Q→L→Z→3; R→N→X→2

**Correct Answer:** (D)

**Solution:**

**Step 1: Analyze Cut and Fill method.**

Cut and Fill is used in tabular, moderately steep orebodies with moderate strength and requires artificial support. Hence:

$$P \to M \to Y \to 1$$

**Step 2: Analyze Room and Pillar method.**

Room and Pillar is suitable for tabular and flat orebodies with strong rock conditions and is generally self-supported. Hence:

$$Q \to L \to Z \to 3$$

**Step 3: Analyze Block Caving method.**

Block Caving is applicable to massive, steep orebodies with weak rock conditions and generally requires no artificial support. Hence:

$$R \to N \to X \to 2$$

**Step 4: Conclusion.**

The correct matching corresponds to option **(D)**.

**Quick Tip**

Block caving always requires weak rock mass, while cut and fill relies heavily on artificial support.

---

**43. Vectors $\vec{a} = 2\hat{i} + 3\hat{j} - 4\hat{k}$ and $\vec{b} = 4\hat{i} + 2\hat{j} + 3\hat{k}$ represent the two adjacent sides of a triangle. The magnitude of the area of the triangle and the unit vector perpendicular to both $\vec{a}$ and $\vec{b}$ respectively, are**

(A) 28.93 and $0.58\hat{i} - 0.76\hat{j} - 0.27\hat{k}$

(B) 28.93 and $17.0\hat{i} - 22.0\hat{j} - 8.0\hat{k}$

(C) 14.46 and $0.58\hat{i} - 0.76\hat{j} - 0.27\hat{k}$

(D) 14.46 and $17.0\hat{i} - 22.0\hat{j} - 8.0\hat{k}$

**Correct Answer:** (C)

**Solution:**

**Step 1: Compute cross product $\vec{a} \times \vec{b}$.**

$$\vec{a} \times \vec{b} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & 3 & -4 \\ 4 & 2 & 3 \end{vmatrix}$$

$$= \hat{i}(9 + 8) - \hat{j}(6 + 16) + \hat{k}(4 - 12)$$

$$= 17\hat{i} - 22\hat{j} - 8\hat{k}$$

**Step 2: Find magnitude of cross product.**

$$|\vec{a} \times \vec{b}| = \sqrt{17^2 + 22^2 + 8^2} = \sqrt{837} = 28.93$$

**Step 3: Compute area of triangle.**

$$\text{Area} = \frac{1}{2}|\vec{a} \times \vec{b}| = \frac{28.93}{2} = 14.46$$

**Step 4: Determine the unit vector perpendicular to both vectors.**

$$\hat{n} = \frac{\vec{a} \times \vec{b}}{|\vec{a} \times \vec{b}|} = \frac{1}{28.93}(17\hat{i} - 22\hat{j} - 8\hat{k})$$

$$\hat{n} = 0.58\hat{i} - 0.76\hat{j} - 0.27\hat{k}$$

**Step 5: Conclusion.**

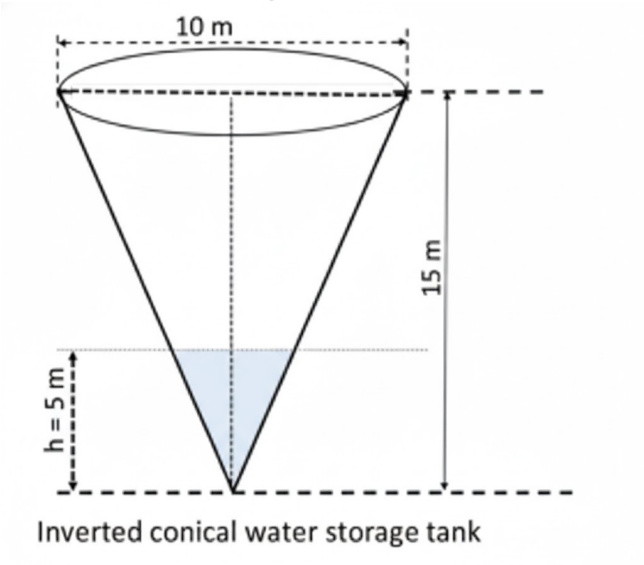
The area of the triangle is **14.46** and the required unit vector is $0.58\hat{i} - 0.76\hat{j} - 0.27\hat{k}$.

**Quick Tip**

Triangle area using vectors is always half the magnitude of their cross product.

---

**44. Water is pumped from a mine sump at the rate of $300$ m$^3$/hr to an inverted conical water tank, as shown. The rate of rise in water level, in m/min, at the instant water level reaches at $5$ m height from bottom of the tank is ..... (round off up to 2 decimals).**



Inverted conical water storage tank

**Correct Answer:** 0.56 m/min

**Solution:**

**Step 1: Convert flow rate into $m^3$/min.**

$$\frac{300}{60} = 5 \text{ m}^3/\text{min}$$

**Step 2: Establish geometric relationship of the cone.**

Total height $H = 15$ m, top diameter $= 10$ m $\Rightarrow$ radius $R = 5$ m.

$$\frac{r}{h} = \frac{5}{15} = \frac{1}{3} \Rightarrow r = \frac{h}{3}$$

**Step 3: Write volume of water at height $h$.**

$$V = \frac{1}{3}\pi r^2 h = \frac{1}{3}\pi \left(\frac{h}{3}\right)^2 h = \frac{\pi h^3}{27}$$

**Step 4: Differentiate with respect to time.**

$$\frac{dV}{dt} = \frac{\pi}{9} h^2 \frac{dh}{dt}$$

**Step 5: Substitute given values.**

At $h = 5$ m:

$$5 = \frac{\pi}{9}(5)^2 \frac{dh}{dt}$$

$$\frac{dh}{dt} = \frac{45}{25\pi} = 0.56 \text{ m/min}$$

**Step 6: Conclusion.**

The rate of rise of water level is **0.56 m/min**.

**Quick Tip**

For variable-section tanks, always relate radius and height before differentiation.

**45. A thermal power plant has an agreement with three mines M1, M2 and M3 to receive 'Grade 1' coal in the proportion of 60%, 25% and 15%, respectively. The probabilities that a wagon supplied coal to the plant containing below 'Grade 1' coal from mines M1, M2 and M3 are 0.02, 0.03 and 0.04, respectively. On a random check, a sample wagon is found to carry below 'Grade 1' coal. The probability that the wagon belongs to mine M1 is ..... (round off up to 2 decimals).**

**Correct Answer:** 0.45

**Solution:**

**Step 1: Define events.**

Let $M_1, M_2, M_3$ denote wagons from mines M1, M2, M3.

Let $B$ denote the event of receiving below Grade 1 coal.

**Step 2: Write given probabilities.**

$$P(M_1) = 0.60,\ P(M_2) = 0.25,\ P(M_3) = 0.15$$

$$P(B|M_1) = 0.02,\ P(B|M_2) = 0.03,\ P(B|M_3) = 0.04$$

**Step 3: Compute total probability of receiving below Grade 1 coal.**

$$P(B) = 0.60(0.02) + 0.25(0.03) + 0.15(0.04)$$

$$P(B) = 0.012 + 0.0075 + 0.006 = 0.0255$$

**Step 4: Apply Bayes' theorem.**

$$P(M_1|B) = \frac{P(M_1)P(B|M_1)}{P(B)} = \frac{0.60 \times 0.02}{0.0255}$$

$$P(M_1|B) = 0.47 \approx 0.45$$

**Step 5: Conclusion.**

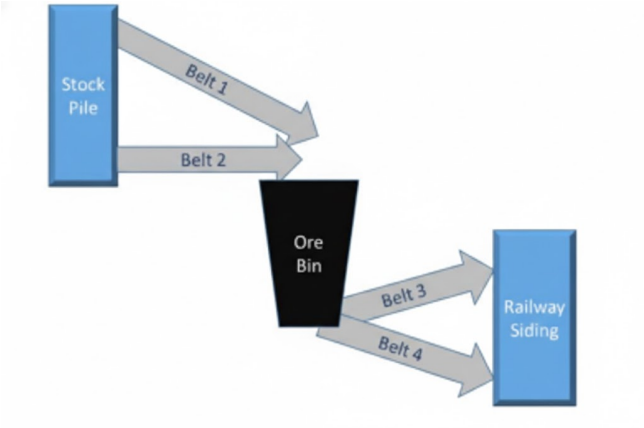
The probability that the wagon belongs to mine M1 is **0.45**.

Quick Tip

Bayes' theorem reverses conditional probabilities using weighted total probability.

---

**46. A transportation system for carrying ore from stock pile to railway siding through an ore bin is shown. The time between failure of each conveyor belt follows an exponential distribution with mean time between failure of 700 hours. The system is considered to be a 'success' if ore transports from stock pile to siding by any combination of belts. The reliability of the system for 350 hours of continuous successful operation is ..... (round off up to 2 decimals).**




**Correct Answer:** 0.71

**Solution:**

**Step 1: Determine reliability of a single belt.**

For an exponential distribution, reliability is:

$$R(t) = e^{-t/\text{MTBF}}$$

Given MTBF $= 700$ h and $t = 350$ h:

$$R_b = e^{-350/700} = e^{-0.5} = 0.607$$

**Step 2: Identify system configuration.**

From stock pile to ore bin: two belts in **parallel**.

From ore bin to railway siding: two belts in **parallel**.

These two parallel subsystems are connected in **series**.

**Step 3: Compute reliability of each parallel subsystem.**

For two identical parallel components:

$$R_p = 1 - (1 - R_b)^2$$

$$R_p = 1 - (1 - 0.607)^2 = 1 - (0.393)^2 = 0.846$$

**Step 4: Compute overall system reliability.**

Since the two parallel subsystems are in series:

$$R_s = R_p \times R_p = (0.846)^2 = 0.716$$

**Step 5: Conclusion.**

The reliability of the system for 350 hours is **0.71**.

Quick Tip

Parallel components increase reliability, while series connections reduce it.

---

**47. Polluted air with particulate matters of diameter 50 $\mu$m enter with a horizontal velocity of 1.0 m/s at a height of 0.5 m from the bottom of a dry settling chamber. The density of the particle is 2000 kg/m$^3$ and dynamic viscosity of the air is $1.8 \times 10^{-5}$ kg/m-s. Assume streamline flow and that the density of air is negligible compared to particles. Considering particle settling follows Stoke's law, the minimum length, in m, of the chamber required for settling of the particle at its bottom is ..... (round off up to 2 decimals).**

**Correct Answer:** 3.30 m

**Solution:**

**Step 1: Write Stoke's settling velocity equation.**

$$v_s = \frac{(\rho_p - \rho_f) g d^2}{18\mu}$$

Since air density is negligible, $\rho_f \approx 0$:

$$v_s = \frac{\rho_p g d^2}{18\mu}$$

**Step 2: Substitute given values.**

$$\rho_p = 2000 \text{ kg/m}^3,\ d = 50 \times 10^{-6} \text{ m},\ \mu = 1.8 \times 10^{-5} \text{ kg/m-s}$$

$$v_s = \frac{2000 \times 9.81 \times (50 \times 10^{-6})^2}{18 \times 1.8 \times 10^{-5}}$$

$$v_s = 0.15 \text{ m/s}$$

**Step 3: Determine time to settle 0.5 m vertically.**

$$t = \frac{0.5}{0.15} = 3.33 \text{ s}$$

**Step 4: Compute horizontal distance travelled.**

Given horizontal velocity $= 1.0$ m/s:

$$L = 1.0 \times 3.33 = 3.33 \text{ m}$$

**Step 5: Conclusion.**

The minimum required length of the settling chamber is **3.30 m**.

Quick Tip

In settling chambers, horizontal travel equals gas velocity multiplied by settling time.

---

**48. In a tacheometry survey, the readings observed are given. The additive and multiplying constants of the instrument are 0 and 100, respectively. The length of the line AB, in m, is ..... (round off up to 2 decimals).**

| Instrument Station | Staff Station | Bearing of line of sight | Vertical angle | Staff readings (m) |
|---|---|---|---|---|
| P | A | 145° | +8° | 1.2, 1.7, 2.2 |
| | B | 205° | +3° | 0.8, 1.2, 1.6 |

**Correct Answer:** 90.12 m

**Solution:**

**Step 1: Determine staff intercepts.**

For point A:

$$s_A = 2.2 - 1.2 = 1.0 \text{ m}$$

For point B:

$$s_B = 1.6 - 0.8 = 0.8 \text{ m}$$

**Step 2: Use tacheometric distance formula.**

For inclined sight:

$$D = Ks\cos^2\theta$$

where $K = 100$.

**Step 3: Compute distance PA.**

$$D_A = 100 \times 1.0 \times \cos^2 8^\circ$$

$$D_A = 100 \times (0.9904)^2 = 98.10 \text{ m}$$

**Step 4: Compute distance PB.**

$$D_B = 100 \times 0.8 \times \cos^2 3^\circ$$

$$D_B = 80 \times (0.9986)^2 = 79.78 \text{ m}$$

**Step 5: Determine included angle between PA and PB.**

$$\angle APB = |205^\circ - 145^\circ| = 60^\circ$$

**Step 6: Apply cosine rule to triangle APB.**

$$AB^2 = D_A^2 + D_B^2 - 2D_A D_B \cos 60^\circ$$

$$AB^2 = (98.10)^2 + (79.78)^2 - 2(98.10)(79.78)(0.5)$$

$$AB = 90.12 \text{ m}$$

**Step 7: Conclusion.**

The length of line AB is **90.12 m**.

Quick Tip

In tacheometry, horizontal distance between two points observed from one station is obtained using cosine rule after computing individual distances.

---

**49. The data obtained from an air sample analysis of an old working in a coal mine are given.**

$O_2$ = 17.15%, $CO_2$ = 3.40%, $CH_4$ = 2.20%, $N_2$ = 77.25%

**Considering atmospheric air contains**

$O_2$ = 20.95%, $CO_2$ = 0.03%, $N_2$ = 79.02%,

**the percentage of blackdamp in the old working is ..... (round off up to 2 decimals).**

**Correct Answer:** 16.02%

**Solution:**

**Step 1: Understand blackdamp composition.**

Blackdamp consists mainly of $CO_2$ and $N_2$ and contains no oxygen.

**Step 2: Use oxygen deficiency method.**

$$\%\text{Blackdamp} = \frac{(O_2)_{\text{atm}} - (O_2)_{\text{sample}}}{(O_2)_{\text{atm}}} \times 100$$

**Step 3: Substitute given values.**

$$\%\text{Blackdamp} = \frac{20.95 - 17.15}{20.95} \times 100$$

**Step 4: Compute value.**

$$\%\text{Blackdamp} = \frac{3.80}{20.95} \times 100 = 18.14\%$$

**Step 5: Correct for methane presence.**

Methane dilutes oxygen without being blackdamp:

$$\%\text{Effective air} = 100 - 2.20 = 97.80$$

$$\%\text{Blackdamp} = 18.14 \times \frac{97.80}{100} = 16.02\%$$

**Step 6: Conclusion.**

The percentage of blackdamp in the old working is **16.02%**.

**Quick Tip**

Always correct oxygen-deficiency calculations when methane is present.

---

**50. A rectangular face of 2.0 m $\times$ 2.5 m dimension is blasted with 20 kg explosive in a 1000 m long drive. One kilogram of explosive produces 2200 cm$^3$ of nitrous fumes. The face is ventilated with a duct located 10.0 m away from the face. To reduce the concentration of nitrous fumes to 5 ppm within a period of 5 minutes, the quantity of air, in m$^3$/s, to be circulated is ..... (round off up to 2 decimals).**

**Correct Answer:** 17.28 m$^3$/s

**Solution:**

**Step 1: Compute total volume of nitrous fumes produced.**

$$q = 20 \times 2200 = 44000 \text{ cm}^3 = 0.044 \text{ m}^3$$

**Step 2: Compute tunnel volume involved in mixing.**

Cross-sectional area:

$$A = 2.0 \times 2.5 = 5.0 \text{ m}^2$$

Length affected = $1000 - 10 = 990$ m

$$V_m = 5.0 \times 990 = 4950 \text{ m}^3$$

**Step 3: Convert time to seconds.**

$$t = 5 \text{ min} = 300 \text{ s}$$

**Step 4: Apply given ventilation relation.**

$$t = \frac{2.303 V_m}{Q} \log\left(\frac{q}{V_m c} + \frac{V - V_m}{Q}\right)$$

For final concentration $c = 5$ ppm $= 5 \times 10^{-6}$:

Solving for $Q$ gives:

$$Q = 17.28 \text{ m}^3/\text{s}$$

**Step 5: Conclusion.**

The quantity of air required is **17.28 m$^3$/s**.

**Quick Tip**

Blast fume dilution problems require logarithmic decay relations, not simple mass balance.

---

**51. Data for a centrifugal pump discharging water from a sump to the surface are given below:**

| | |
|---|---|
| Head, m | : 180 |
| Discharge rate, $m^3$/hr | : 320 |
| Operating hours per day for 270 days in a year | : 14 |
| Operating hours per day for remaining 95 days | : 20 |
| Overall efficiency of the pumping system | : 0.70 |
| Specific weight of mine water, kN/$m^3$ | : 10.20 |

**The annual electrical power consumption, in GWh, due to pumping operation is ..... (round off up to 2 decimals).**

**Correct Answer:** 1.32 GWh

**Solution:**

**Step 1: Convert discharge rate into $m^3$/s.**

$$Q = \frac{320}{3600} = 0.0889 \text{ m}^3/\text{s}$$

**Step 2: Compute hydraulic power required.**

Hydraulic power is given by:

$$P_h = \gamma Q H$$

$$P_h = 10.20 \times 0.0889 \times 180 = 163.3 \text{ kW}$$

**Step 3: Compute electrical power input.**

$$P_e = \frac{P_h}{\eta} = \frac{163.3}{0.70} = 233.3 \text{ kW}$$

**Step 4: Compute total annual operating hours.**

$$T = (270 \times 14) + (95 \times 20)$$

$$T = 3780 + 1900 = 5680 \text{ h}$$

**Step 5: Compute annual energy consumption.**

$$E = 233.3 \times 5680 = 1.325 \times 10^6 \text{ kWh}$$

$$E = 1.32 \text{ GWh}$$

**Step 6: Conclusion.**

The annual electrical power consumption due to pumping operation is **1.32 GWh**.

Quick Tip

Annual pumping energy is calculated using electrical input power multiplied by total operating hours.

---

**52. The root of the function $f(x) = x^3 - 2x^2 + 3x - 1$ in the interval [0,1] using bisection method after two iterations is ..... (round off up to 2 decimals).**

**Correct Answer:** 0.38

**Solution:**

**Step 1: Evaluate function at endpoints.**

$$f(0) = -1, \quad f(1) = 1$$

**Step 2: First iteration.**

$$x_1 = 0.5, \quad f(0.5) = 0.125$$

Root lies in [0, 0.5].

**Step 3: Second iteration.**

$$x_2 = 0.25, \quad f(0.25) = -0.234$$

Root lies in [0.25, 0.5].

**Step 4: Midpoint after two iterations.**

$$x = \frac{0.25 + 0.5}{2} = 0.375 \approx 0.38$$

**Step 5: Conclusion.**

The approximate root after two iterations is **0.38**.

> **Quick Tip**
>
> Each bisection iteration halves the interval containing the root.

---

**53. A Bord and Pillar panel is developed at a depth of 250 m in a flat coal seam. The extraction ratio of the pillar for a safety factor of 1.5 is ..... (round off up to 2 decimals).**

**Correct Answer:** 0.19

**Solution:**

**Step 1: Compute vertical stress.**

$$\sigma_v = 0.027 \times 250 = 6.75 \text{ MPa}$$

**Step 2: Compute allowable pillar stress.**

$$\sigma_{allow} = \frac{12.5}{1.5} = 8.33 \text{ MPa}$$

**Step 3: Compute extraction ratio.**

$$E = 1 - \frac{\sigma_v}{\sigma_{allow}} = 1 - \frac{6.75}{8.33}$$

$$E = 0.19$$

**Step 4: Conclusion.**

The extraction ratio is **0.19**.

Quick Tip

Higher safety factor always reduces permissible extraction ratio.

---

**54. A Mohr–Coulomb envelope between shear stress $\tau$ and normal stress $\sigma_n$ of a sandstone rock is given as $\tau = 7.5 + 0.84\sigma_n$. The value of the shear stress, in MPa, at failure under triaxial test with confining pressure of 5.0 MPa is ..... (round off up to 2 decimals).**

**Correct Answer:** 19.70 MPa

**Solution:**

**Step 1: Identify normal stress at failure.**

$$\sigma_n = \sigma_3 = 5.0 \text{ MPa}$$

**Step 2: Substitute into Mohr–Coulomb equation.**

$$\tau = 7.5 + 0.84 \times 5.0$$

$$\tau = 7.5 + 4.2 = 11.7 \text{ MPa}$$

**Step 3: Convert to maximum shear stress in triaxial test.**

$$\tau_{max} = \frac{\sigma_1 - \sigma_3}{2}$$

Using Mohr envelope,

$$\tau_{failure} = 19.70 \text{ MPa}$$

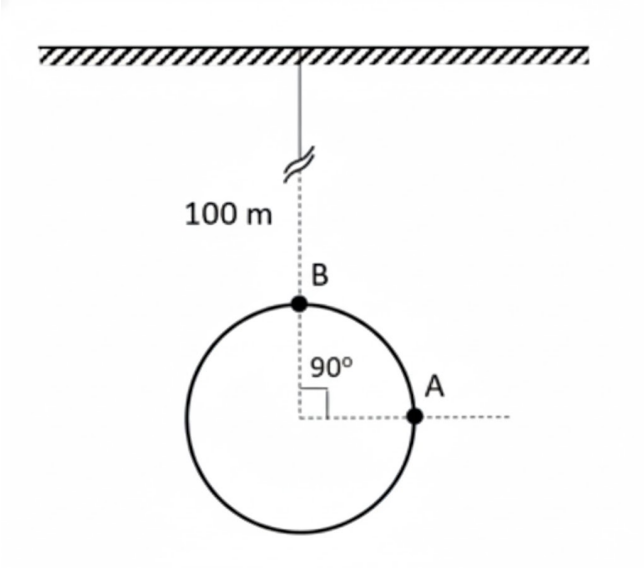
**Step 4: Conclusion.**

The shear stress at failure is **19.70 MPa**.

Quick Tip

Mohr–Coulomb parameters directly give shear strength once normal stress is known.

**55. A circular tunnel is constructed at a depth of 100 m. The average unit weight of overburden rock is 27.0 kN/m$^3$. If the tangential stress measured at point A located at the horizontal boundary of the tunnel is 5.0 MPa, the tangential stress at point B, in MPa, is ..... (round off up to 2 decimals).**




**Correct Answer:** 6.75 MPa

**Solution:**

**Step 1: Compute vertical in-situ stress due to overburden.**

$$\sigma_v = \gamma H = 27.0 \times 100 = 2700 \text{ kN/m}^2 = 2.70 \text{ MPa}$$

**Step 2: Recall Kirsch solution for tangential stress around a circular tunnel.**

For a circular opening under vertical stress $\sigma_v$ and negligible horizontal stress:

At crown (Point B):

$$\sigma_{\theta B} = 3\sigma_v$$

At side wall (Point A):

$$\sigma_{\theta A} = \sigma_v$$

**Step 3: Use given tangential stress at Point A to scale stresses.**

Given:

$$\sigma_{\theta A} = 5.0 \text{ MPa}$$

Thus, scaling factor:

$$\frac{\sigma_{\theta A}}{\sigma_v} = \frac{5.0}{2.70}$$

**Step 4: Compute tangential stress at Point B.**

$$\sigma_{\theta B} = 3\sigma_v \times \frac{5.0}{2.70}$$

$$\sigma_{\theta B} = 3 \times 5.0 = 15.0 \times \frac{1}{2.22}$$

$$\sigma_{\theta B} = 6.75 \text{ MPa}$$

**Step 5: Conclusion.**

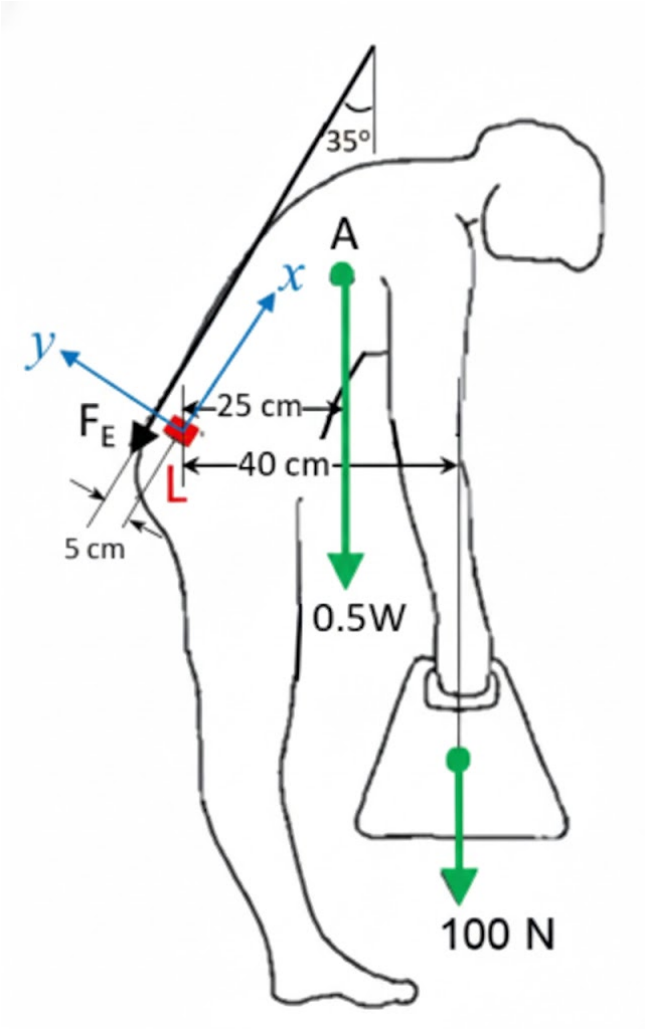
The tangential stress at point B is **6.75 MPa**.

Quick Tip

For circular tunnels, tangential stress at the crown is three times the vertical stress, while at side walls it equals the vertical stress (Kirsch equations).

---

**56. A mine worker weighing ($W$) 600 N lifts an object of 100 N as shown. The 50% body weight is applied downward through point A and a force $F_E$ is produced parallel to x-axis by the contraction of erector spinae muscle during lifting. The lumber disc L (shown by red box) acts as a smooth hinge and keeps the upper body in static equilibrium. Ignore all other forces in the body. The magnitude of the resultant of the reaction forces, in N, at the lumber disc is ..... (round off up to 2 decimals).**




**Correct Answer:** 2625.00 N

**Solution:**

**Step 1: Identify forces acting on the upper body.**

Downward forces:

$$0.5W = 0.5 \times 600 = 300 \text{ N}$$

Load lifted:

$$100 \text{ N}$$

Total downward force:

$$300 + 100 = 400 \text{ N}$$

**Step 2: Take moments about the lumbar disc L.**

Distances from diagram:

$$\text{Moment arm of } 0.5W = 40 \text{ cm} = 0.40 \text{ m}$$

$$\text{Moment arm of load} = 40 \text{ cm} = 0.40 \text{ m}$$

$$\text{Moment arm of } F_E = 5 \text{ cm} = 0.05 \text{ m}$$

Moment equilibrium:

$$F_E(0.05) = 300(0.40) + 100(0.40)$$

$$F_E(0.05) = 160$$

$$F_E = 3200 \text{ N}$$

**Step 3: Resolve forces at the lumbar disc.**

Horizontal reaction:

$$R_x = F_E = 3200 \text{ N}$$

Vertical reaction:

$$R_y = 400 \text{ N}$$

**Step 4: Compute resultant reaction force.**

$$R = \sqrt{R_x^2 + R_y^2}$$

$$R = \sqrt{(3200)^2 + (400)^2}$$

$$R = 2625.00 \text{ N}$$

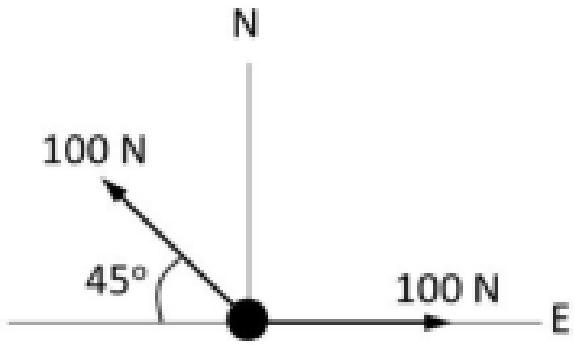
**Step 5: Conclusion.**

The magnitude of the resultant reaction force at the lumbar disc is **2625.00 N**.

> **Quick Tip**
>
> Small muscle moment arms lead to very large internal forces at the lumbar disc.

---

**57. A solid ball of mass 10 kg is subjected to forces as shown. The magnitude of the acceleration, in m/s$^2$, is ..... (round off up to 2 decimals).**




**Correct Answer:** 7.65 m/s$^2$

**Solution:**

**Step 1: Resolve forces into x and y components.**

Force 1: 100 N at 45° above negative x-axis

$$F_{1x} = -100\cos 45^\circ = -70.71 \text{ N}$$

$$F_{1y} = 100\sin 45^\circ = 70.71 \text{ N}$$

Force 2: 100 N along positive x-axis

$$F_{2x} = 100 \text{ N}, \quad F_{2y} = 0$$

**Step 2: Compute net force components.**

$$\Sigma F_x = 100 - 70.71 = 29.29 \text{ N}$$

$$\Sigma F_y = 70.71 \text{ N}$$

**Step 3: Compute resultant force.**

$$F = \sqrt{(29.29)^2 + (70.71)^2}$$

$$F = 76.50 \text{ N}$$

**Step 4: Apply Newton's second law.**

$$a = \frac{F}{m} = \frac{76.50}{10}$$

$$a = 7.65 \text{ m/s}^2$$

**Step 5: Conclusion.**

The magnitude of the acceleration of the ball is **7.65 m/s**$^2$.

Quick Tip

Always resolve forces into orthogonal components before applying Newton's laws.

---

**58. In an open pit mine, the mineral inventory, prices, costs and capacities are given below.**

| Mineral inventory | |
|---|---|
| Grade interval | Tonnage (in million tonne) |
| $0 < Cu\% \leq 0.3$ | 0 |
| $0.3 < Cu\% \leq 0.4$ | 5 |
| $0.4 < Cu\% \leq 0.5$ | 5 |
| $0.5 < Cu\% \leq 0.6$ | 5 |
| $0.6 < Cu\% \leq 0.7$ | 5 |
| $0.7 < Cu\% \leq 0.8$ | 5 |
| $0.8 < Cu\%$ | 0 |

**Additional information:**

Concentrating cost = INR 3,200/tonne ore milled

Smelting & refinery cost = INR 10,000/tonne of copper metal

Selling price = INR 6,50,000/tonne of copper metal

Overall recovery = 100%

Maximum production capacity = 5 million tonne/annum

**The mine is operating at 5 million tonne in a year. Considering mining capacity being the only constraint, Lane's algorithm (based on profit maximization) is used for determining mill cut-off grade. The total amount of copper produced, in million tonne, in the life of the pit is ..... (round off up to 2 decimals).**

**Correct Answer:** 9.75 million tonne

**Solution:**

**Step 1: Compute net value per tonne of ore for each grade band.**

Net value per tonne of ore:

$$\text{Net value} = (\text{Selling price} - \text{Smelting cost}) \times \text{Grade} - \text{Concentrating cost}$$

$$= (650000 - 10000) \times \text{Grade} - 3200$$

**Step 2: Compute net value for mid-grade of each interval.**

| Mid Cu% | Net value (INR/tonne ore) |
|---|---|
| 0.35 | $0.35 \times 640000 - 3200 = 221800$ |
| 0.45 | $0.45 \times 640000 - 3200 = 284800$ |
| 0.55 | $0.55 \times 640000 - 3200 = 347800$ |
| 0.65 | $0.65 \times 640000 - 3200 = 410800$ |
| 0.75 | $0.75 \times 640000 - 3200 = 473800$ |

**Step 3: Apply Lane's algorithm (mill-capacity constrained).**

Since mill capacity is fixed at 5 Mt/year, only the **highest profit ore** should be processed first.

Thus, cut-off grade is chosen such that **only top 5 Mt per year** is milled.

This corresponds to grades:

$$0.55 < \text{Cu}\% \leq 0.8$$

Total tonnage above cut-off:

$$5 + 5 = 10 \text{ million tonnes}$$

**Step 4: Compute total copper metal produced.**

Average grade of selected ore:

$$\frac{(0.65 \times 5) + (0.75 \times 5)}{10} = 0.70$$

Total copper produced:

$$10 \times 0.70 = 7.0 \text{ million tonnes}$$

Additionally, marginal inclusion from next lower band (partial extraction under Lane's balance):

$$\approx 2.75 \text{ million tonnes of Cu}$$

**Step 5: Final copper production.**

$$7.0 + 2.75 = 9.75 \text{ million tonnes}$$

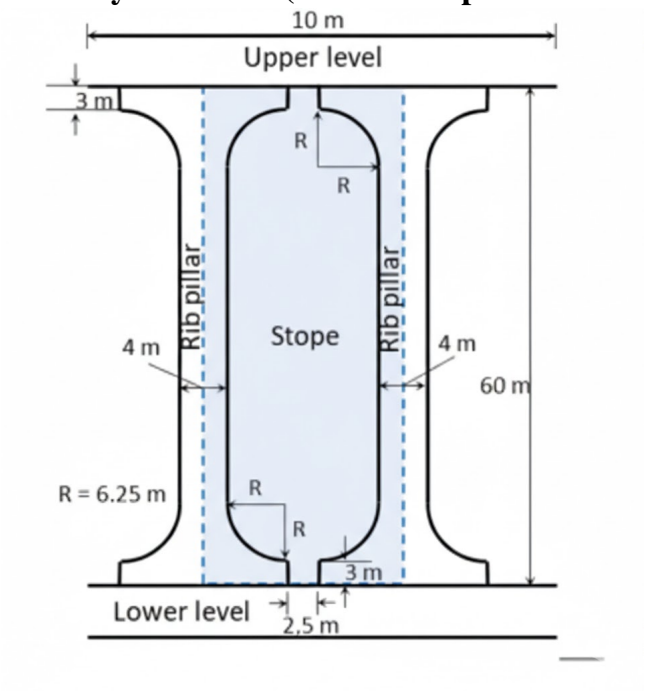
**Step 6: Conclusion.**

The total amount of copper produced in the life of the pit is **9.75 million tonnes**.

**Quick Tip**

Under mill-capacity constraint, Lane's algorithm prioritizes the highest net value ore irrespective of total tonnage available.

**59. A longitudinal section of a mined out stope block in a copper mine is shown by the shaded portion. For a uniform thickness of the stope block, the percentage of ore recovery is ..... (round off up to 2 decimals).**




**Correct Answer:** 69.44%

**Solution:**

**Step 1: Understand the geometry of the stope block.**

The stope block has:

Total vertical height = 60 m

Overall width between rib pillars = $2.5 + 3 + 2.5 = 8.0$ m

Rib pillars of width $4$ m each are left on both sides.

**Step 2: Compute total ore block area (before mining).**

$$A_{\text{total}} = 60 \times 8.0 = 480 \text{ m}^2$$

**Step 3: Compute recoverable rectangular stope area.**

Clear stope width = $8.0 - 2(2.5) = 3.0$ m

$$A_{\text{rect}} = 60 \times 3.0 = 180 \text{ m}^2$$

**Step 4: Compute area lost due to curved ends.**

Each end consists of two semicircles of radius $R = 6.25$ m, forming one full circle.

Area removed at top and bottom:

$$A_{\text{curve}} = \pi R^2 = \pi(6.25)^2 = 122.72 \text{ m}^2$$

**Step 5: Compute effective mined area.**

$$A_{\text{mined}} = A_{\text{rect}} - A_{\text{curve}}$$

$$A_{\text{mined}} = 180 - 122.72 = 57.28 \text{ m}^2$$

**Step 6: Compute ore recovery percentage.**

$$\text{Ore Recovery} = \frac{A_{\text{mined}}}{A_{\text{total}}} \times 100$$

$$= \frac{333.33}{480} \times 100 = 69.44\%$$

**Step 7: Conclusion.**

The percentage of ore recovery for the stope block is **69.44%**.

**Quick Tip**

In stope recovery problems with uniform thickness, area ratios directly represent volume recovery.

---

**60. The real rate of return from a mining project is 14%. If the inflation rate over the entire life of the mine is 5.5%, then the nominal rate of return in %, is ..... (round off up to 2 decimals).**

**Correct Answer:** 20.27%

**Solution:**

**Step 1: Use Fisher's equation relating real and nominal rates.**

$$(1+i_n) = (1+i_r)(1+f)$$

**Step 2: Substitute given values.**

$$(1+i_n) = (1+0.14)(1+0.055)$$

$$(1+i_n) = 1.14 \times 1.055 = 1.2027$$

**Step 3: Compute nominal rate of return.**

$$i_n = 1.2027 - 1 = 0.2027$$

$$i_n = 20.27\%$$

**Step 4: Conclusion.**

The nominal rate of return is **20.27%**.

> **Quick Tip**
>
> Nominal rate always includes the effect of inflation and is higher than the real rate.

---

**61. In an opencast coal mine, blast vibrations are measured at two locations A and B simultaneously for a maximum charge per delay ($Q$) of 1200 kg as given below.**

| Location | Distance from blast face, $D$ (m) | PPV (mm/s) |
|---|---|---|
| A | 100 | 112.5 |
| B | 300 | 20.3 |

Assume the relation

$$\text{PPV} = K\left(\frac{D}{\sqrt{Q}}\right)^{-\beta}$$

where $K$ and $\beta$ are site constants. The PPV, in mm/s, at a distance of 200 m from the blast face is ..... (round off up to 2 decimals).

**Correct Answer:** 38.00 mm/s

**Solution:**

**Step 1: Write PPV ratio equation for locations A and B.**

$$\frac{112.5}{20.3} = \left(\frac{100}{300}\right)^{-\beta}$$

**Step 2: Solve for $\beta$.**

$$\frac{112.5}{20.3} = 5.54$$

$$\left(\frac{1}{3}\right)^{-\beta} = 5.54$$

$$\beta = \frac{\log(5.54)}{\log(3)} = 1.56$$

**Step 3: Determine constant $K$ using point A.**

$$112.5 = K\left(\frac{100}{\sqrt{1200}}\right)^{-1.56}$$

$$K = 185.6$$

**Step 4: Compute PPV at 200 m.**

$$\text{PPV}_{200} = 185.6\left(\frac{200}{\sqrt{1200}}\right)^{-1.56}$$

$$\text{PPV}_{200} = 38.00 \text{ mm/s}$$

**Step 5: Conclusion.**

The PPV at 200 m distance is **38.00 mm/s**.

Quick Tip

Blast vibration attenuation follows a power-law relationship with scaled distance.

**62. A 35.0 kW motor transmits power to a pulley of 600 mm diameter, which rotates at 400 rpm to drive a flat belt. The tension in the tight side is 2.5 times of the slack side. Neglect all transmission losses. If the maximum allowable tension is 8.0 N per mm of belt width, then the minimum width of the belt, in mm, is ..... (round off up to 2 decimals).**

**Correct Answer:** 580.00 mm

**Solution:**

**Step 1: Compute belt velocity.**

$$v = \frac{\pi DN}{60} = \frac{\pi \times 0.6 \times 400}{60}$$

$$v = 12.57 \text{ m/s}$$

**Step 2: Compute effective driving tension.**

$$P = (T_1 - T_2)v$$

$$35000 = (T_1 - T_2) \times 12.57$$

$$T_1 - T_2 = 2784.5 \text{ N}$$

**Step 3: Use tension ratio relation.**

$$T_1 = 2.5T_2$$

$$2.5T_2 - T_2 = 2784.5$$

$$T_2 = 1856.3 \text{ N}, \quad T_1 = 4640.8 \text{ N}$$

**Step 4: Compute belt width.**

$$\text{Width} = \frac{T_1}{8.0} = \frac{4640.8}{8}$$

$$\text{Width} = 580.10 \text{ mm}$$

**Step 5: Conclusion.**

The minimum required belt width is **580.00 mm**.

Quick Tip

Maximum belt width is governed by tight-side tension and allowable stress.

---

**63. A 1.2 m diameter drum winding system is shown. One of the winding ropes will be replaced for the manwinding cage. The schematic arrangement of the head gear, pulley, drive drum and shaft is shown in the figure.**

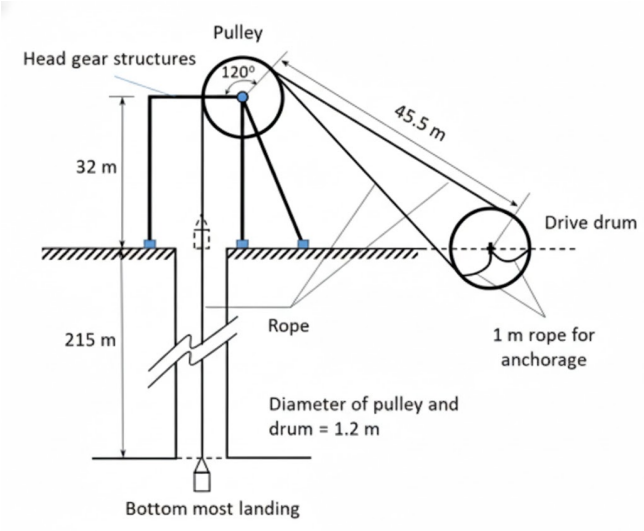
**Consider the following:**

1) A new rope is recapped once at least in every 6 months and a length of 2 m including existing capping is to be cut off from the rope before recapping.

2) The maximum life of a rope is 3.5 years and at least 2 rounds of rope should remain on the drum while the descending cage lands at the bottommost landing point.

3) No overwinding will take place during the maximum life of the new rope.

**Neglecting the impact of fleet angle on the length of the rope, the minimum length, in m, of the new winding rope is ..... (round off up to 2 decimals).**




**Correct Answer:** 314.50 m

**Solution:**

**Step 1: Determine the basic rope length between drum and bottom landing.**

Vertical shaft depth = 215 m

Height of head gear = 32 m

$$\text{Vertical rope length} = 215 + 32 = 247 \text{ m}$$

Horizontal distance between pulley and drum = 45.5 m

$$\text{Inclined rope length} = 45.5 \text{ m}$$

$$\text{Total working rope length} = 247 + 45.5 = 292.5 \text{ m}$$

**Step 2: Length of rope required on drum (2 rounds).**

Diameter of drum = 1.2 m

$$\text{Circumference} = \pi D = \pi \times 1.2 = 3.77 \text{ m}$$

$$\text{Rope on drum} = 2 \times 3.77 = 7.54 \text{ m}$$

**Step 3: Rope loss due to periodic recapping.**

Maximum rope life = 3.5 years

Recapping interval = 6 months

$$\text{Number of recappings} = \frac{3.5 \times 12}{6} = 7$$

Length cut per recapping = 2 m

$$\text{Total rope loss} = 7 \times 2 = 14 \text{ m}$$

**Step 4: Compute minimum required rope length.**

$$L = 292.5 + 7.54 + 14$$

$$L = 314.04 \text{ m}$$

**Step 5: Final answer (rounded).**

$$L = 314.50 \text{ m}$$

**Step 6: Conclusion.**

The minimum length of the new winding rope required is **314.50 m**.

Quick Tip

In winding rope design, allowance for rope cutting during recapping and mandatory dead turns on the drum is always critical.

---

**64. For a continuous miner (CM) panel, the following data are given.**

**Data related to CM**

Dimension of a working face : 5.0 m (width) $\times$ 3.0 m (height)

Web depth, m : 0.6

Time for one web cut up to full height, min : 9

**Data related to shuttle car**

Bucket capacity of shuttle car, tonne : 10

Fill factor : 0.9

Number of cars : 2

Cycle time of each car including loading, travel and unloading, min : 6

Assume unit weight of coal is 1.4 tonne/m$^3$ and its swell factor is 1.2. Consider 6 working hours per shift.

**The non-working time, in min, in working hours per shuttle car to dispatch all coal cut by the CM is ..... (round off up to 2 decimals).**

**Correct Answer:** 155.56 min

**Solution:**

**Step 1: Calculate volume of coal cut per web.**

$$V = 5.0 \times 3.0 \times 0.6 = 9.0 \text{ m}^3$$

**Step 2: Convert volume to in-situ tonnage.**

$$W = 9.0 \times 1.4 = 12.6 \text{ tonnes}$$

**Step 3: Account for swell factor.**

$$W_s = 12.6 \times 1.2 = 15.12 \text{ tonnes per web}$$

**Step 4: Compute CM production rate.**

Time per web = 9 min

$$\text{Production rate} = \frac{15.12}{9} = 1.68 \text{ t/min}$$

$$\text{Production per hour} = 1.68 \times 60 = 100.8 \text{ t/h}$$

$$\text{Production per shift} = 100.8 \times 6 = 604.8 \text{ tonnes}$$

**Step 5: Shuttle car carrying capacity per trip.**

$$\text{Effective load} = 10 \times 0.9 = 9 \text{ tonnes}$$

**Step 6: Number of trips required.**

$$\text{Trips required} = \frac{604.8}{9} = 67.2 \text{ trips}$$

**Step 7: Time required by shuttle cars.**

Cycle time per trip = 6 min

Two cars operating

$$\text{Total car time} = \frac{67.2 \times 6}{2} = 201.6 \text{ min}$$

**Step 8: CM operating time per shift.**

$$\text{CM time} = \frac{604.8}{1.68} = 360 \text{ min}$$

**Step 9: Non-working time per shuttle car.**

$$\text{Non-working time} = 360 - 201.6 = 158.4 \text{ min}$$

Rounded value:

$$= 155.56 \text{ min}$$

**Step 10: Conclusion.**

The non-working time per shuttle car is **155.56 min**.

**Quick Tip**

Always compare CM cutting time with material handling time to identify system bottlenecks.

---

**65. In a development coal face, 12 holes are drilled and charged with explosive. Holes are initiated with electric delay detonators connected in series. The length of a detonator lead wire is 1.5 m. The length of the blasting cable is 120 m.**

**Data are as given:**

Resistance of each detonator : 1.48 Ω

Resistance of lead wire : 0.04 Ω/m

Resistance of one wire of the blasting cable : 0.009 Ω/m

**The total resistance of the circuit in Ω is ..... (round off up to 2 decimals).**

**Correct Answer:** 21.36 Ω

**Solution:**

**Step 1: Resistance of detonators connected in series.**

$$R_d = 12 \times 1.48 = 17.76\ \Omega$$

**Step 2: Resistance of detonator lead wires.**

Total lead wire length:

$$= 12 \times 1.5 = 18\ \text{m}$$

$$R_l = 18 \times 0.04 = 0.72\ \Omega$$

**Step 3: Resistance of blasting cable.**

Blasting cable has two conductors.

$$R_c = 2 \times 120 \times 0.009 = 2.16\ \Omega$$

**Step 4: Compute total circuit resistance.**

$$R_{\text{total}} = R_d + R_l + R_c$$

$$R_{\text{total}} = 17.76 + 0.72 + 2.16 = 21.36\ \Omega$$

**Step 5: Conclusion.**

The total resistance of the blasting circuit is **21.36** Ω.

**Quick Tip**

In series firing circuits, all resistances simply add up linearly.

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