GATE 2026 Mining Engineering Question Paper with Solutions

General Instructions

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

(ii) It comprises 37 single-correct multiple-choice questions, 1 multiple-correct question and 27 numerical / integer-type questions.

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

(iv) For multiple-correct questions, all correct options must be selected to earn full marks.

(v) For numerical questions, report the answer rounded exactly as asked.

. Suresh said, "I did it yesterday."
Which one of the following options is the correct form of this sentence in indirect speech?

(A) Suresh said that I did it yesterday.

(B) Suresh says I did it yesterday.

(C) Suresh says that he did it the day before.

(D) Suresh said that he had done it the day before.

Correct Answer: (D) Suresh said that he had done it the day before.

Solution:

Step 1: Understanding the Question:

We are given a sentence in direct speech, "Suresh said, 'I did it yesterday.'" We need to convert it into indirect (reported) speech and pick the option that follows the correct grammar rules for this

conversion.

Step 2: Key Formula or Approach:

Three things change when direct speech turns into indirect speech here.

First, the reporting verb "said" (with no listener named) stays "said", it does not change to "says" or "told".

Second, since the reporting verb is in the past tense, the verb inside the quote shifts one step back in time: simple past "did" becomes past perfect "had done".

Third, the pronoun "I" changes to match who is actually speaking from the narrator's point of view, so it becomes "he", and the time word "yesterday" changes to "the day before" because we are no longer speaking on the same day as the original statement.

Step 3: Detailed Explanation:

Applying these three changes to "I did it yesterday": "I" becomes "he", "did" (simple past) becomes "had done" (past perfect), and "yesterday" becomes "the day before".

Putting it together: "Suresh said that he had done it the day before."

Now check the wrong options.

Option (A), "Suresh said that I did it yesterday", keeps "I" and "yesterday" unchanged and does not shift the tense, so none of the three rules are applied.

Option (B), "Suresh says I did it yesterday", wrongly changes the reporting verb to the present tense "says", when the original was the past tense "said", and it also skips the tense shift and pronoun change.

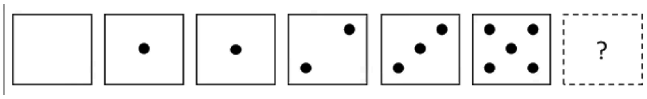
Option (C), "Suresh says that he did it the day before", gets the pronoun and time word right but still wrongly uses "says" instead of "said", and fails to shift "did" to "had done".

Step 4: Final Answer:

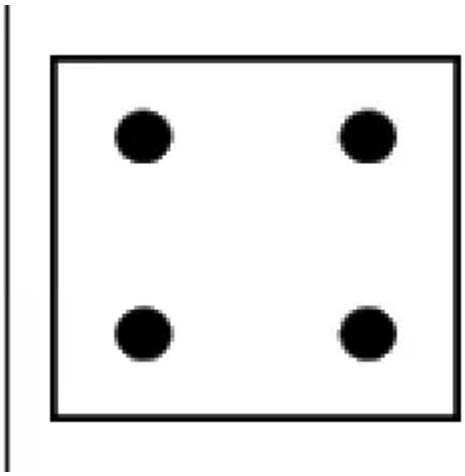
Only option (D) applies all three rules correctly: reporting verb stays "said", the verb backshifts to "had done", and "yesterday" becomes "the day before". The correct answer is option (D).

Quick Tip: Direct-to-indirect speech needs three checks: does the reporting verb "said" stay as is, does the verb inside the quote shift one tense back, and does the time word "yesterday" change to match the new point of view.

. To continue the sequence of tiles shown, the tile indicated by the question mark should be:



(A)



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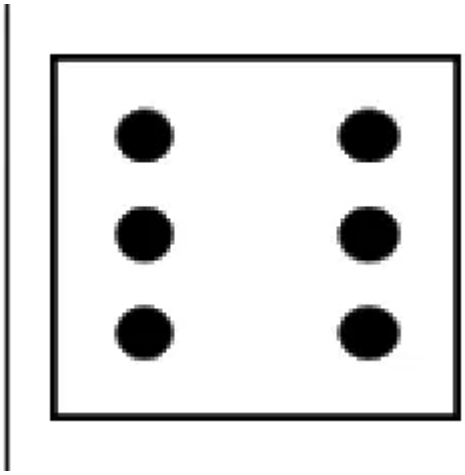
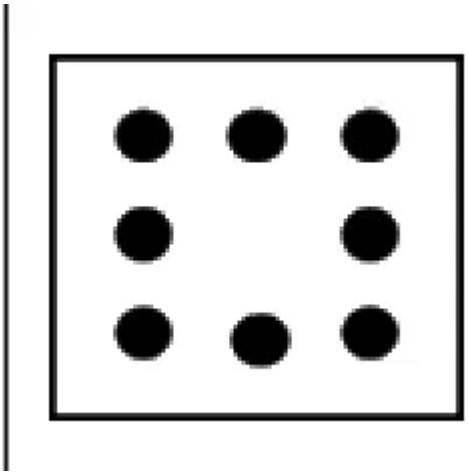
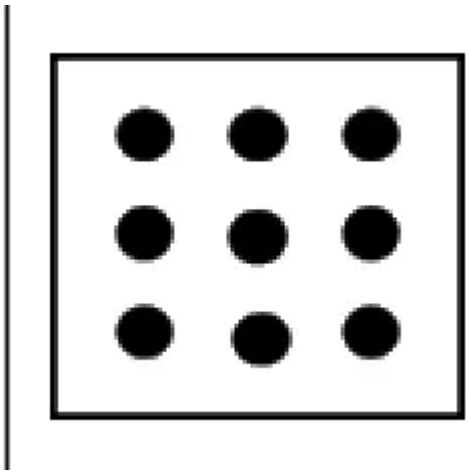


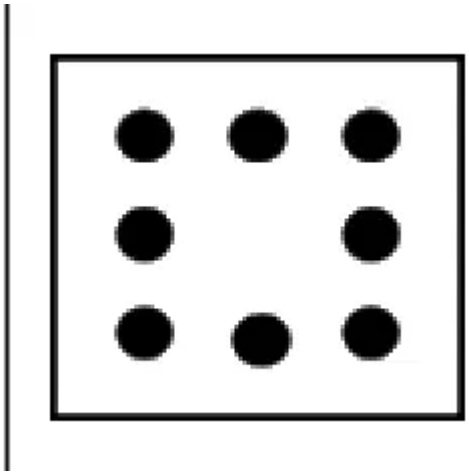
(C)



(D)



Correct Answer: (C)



Solution:

Step 1: Read the dot count in each tile.

Count the dots in the tiles from left to right: the first tile is blank (0 dots), then 1 dot, then 1 dot again, then 2 dots, then 3 dots, then 5 dots.

Step 2: Find the rule linking one tile to the next.

Look at three tiles in a row at a time. 0 and 1 add up to 1, the next tile's count. 1 and 1 add up to 2, the tile after that. 1 and 2 add up to 3, and 2 and 3 add up to 5. Each tile's dot count is the sum of the two tiles right before it. This is the Fibonacci pattern.

Step 3: Apply the rule to the missing tile.

The last two known counts are 3 and 5, so the missing tile must have 3 + 5 = 8 dots.

Step 4: Final Answer:

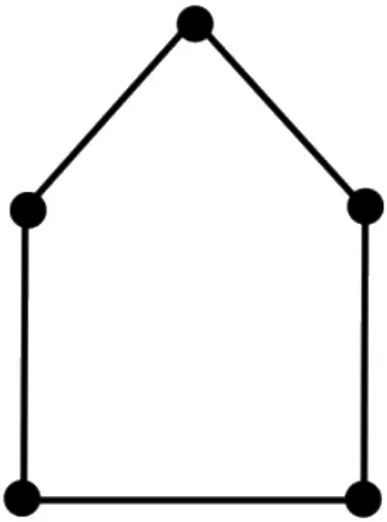
Option (A) has 4 dots, option (B) has 6 dots, and option (D) has 9 dots, none of these equal 8, so all three break the addition rule.

Option (C) has 8 dots, arranged as a ring: 3 dots across the top, 1 dot on each side in the middle, and 3 dots across the bottom, giving 3 + 1 + 1 + 3 = 8. This matches the required count exactly.

Option (C), 8 dots

Quick Tip: Count the dots in each tile in order and check whether each count is built by combining the two counts that came right before it.

. Consider an art gallery whose walkways are shown as lines in the diagram. A black dot represents a junction of two walkways. A guard may be placed at a junction to watch over the walkways that join at that junction. The minimum number of guards needed to watch all the walkways is _____.



(A) 2

(B) 3

(C) 4

(D) 5

Correct Answer: (B) 3

Solution:

Step 1: Turn the picture into a graph problem.

Each junction is a vertex, and each walkway is an edge joining two junctions. Placing a guard at a junction lets that guard watch every walkway touching that junction.

Choosing the smallest set of junctions so that every walkway touches at least one chosen junction is exactly the minimum vertex cover of the graph.

Step 2: Identify the graph.

Label the junctions T (top apex), LU (left upper), RU (right upper), LB (left bottom) and RB (right bottom).

The five walkways are T-LU, T-RU, LU-LB, RU-RB and LB-RB.

Tracing these edges gives a single closed loop T, LU, LB, RB, RU, back to T, so the graph is a cycle with 5 vertices, an odd cycle.

Step 3: Use the rule for covering an odd cycle.

For any cycle with an odd number of vertices n, the minimum vertex cover has size $\lceil n/2 \rceil$, because picking every alternate vertex always leaves exactly one edge with both ends unchosen when n is odd, so one extra vertex is always needed on top of the "every other vertex" pattern that would work for an even cycle.

Here n = 5, so the minimum vertex cover size is $\lceil 5/2 \rceil = 3$.

Step 4: Check with an actual choice of guards.

Placing guards at LU, RB and T covers T-LU (by LU or T), T-RU (by T), LU-LB (by LU), RU-RB (by RB) and LB-RB (by RB), so all five walkways are watched with only 3 guards.

No 2-guard placement can work, because 2 vertices touch at most 4 of the 5 edges in this graph, always leaving at least one walkway unwatched.

Final Answer:

The minimum number of guards needed is 3.

$\boxed{3}$

Quick Tip: Think of each junction as a vertex and each walkway as an edge, and find the smallest set of vertices that touches every edge in this closed 5-

sided loop.

. The 2nd of June is a Thursday in a certain year. Which day of the week is the 3rd of July in that year?

(A) Thursday

(B) Friday

(C) Saturday

(D) Sunday

Correct Answer: (D) Sunday

Solution:

Step 1: Understanding the Question:
We know that June 2 falls on a Thursday in some year, and we need the day of the week for July 3 in that same year.

Step 2: Key Formula or Approach:
The day of the week repeats every 7 days, so if we find the number of days between June 2 and July 3, we can take that count modulo 7 and step forward from Thursday by that many days.

Step 3: Detailed Explanation:
June has 30 days, so from June 2 to June 30 is 30 minus 2, which is 28 days.
From June 30 to July 3 is 3 more days (July 1, July 2, July 3).
So the total number of days from June 2 to July 3 is 28 plus 3, which is 31 days.
Now divide 31 by 7: $31 = 7 \times 4 + 3$, so 31 days is exactly 4 full weeks plus 3 extra days.

The 4 full weeks bring us back to a Thursday, and the 3 extra days move us forward: Thursday, then Friday (1 day), Saturday (2 days), Sunday (3 days).

Step 4: Final Answer:
July 3 falls 3 days after a Thursday, which is a Sunday.

Sunday

Quick Tip: Count the total days between June 2 and July 3, then use the fact that every group of 7 days brings you back to the same weekday.

. A coin with heads facing up is shown as (H) and a coin with tails facing up is shown as (T).
Six coins are placed in the Starting Arrangement, as shown in the figure below. A "step" is defined as interchanging a pair of adjacent coins without flipping them. The minimum number of steps needed to go from the Starting Arrangement to the Final Arrangement, as shown in the figure, is _____.

(A) 3
(B) 6
(C) 9
(D) 12

Correct Answer: (C) 9

Solution:

Step 1: Understand what a step allows.

A step swaps two coins that are sitting right next to each other, without flipping either one, so a head stays a head and a tail stays a tail throughout, only their positions change.

We start at H H H T T T and must reach T T T H H H using the fewest such adjacent swaps.

Step 2: Notice that every head must cross every tail.

In the starting row, each of the 3 heads sits to the left of each of the 3 tails.

In the final row, each of the 3 heads sits to the right of each of the 3 tails, so the left-right order of every head and tail pair has flipped.

An adjacent swap can only change the relative order of the two coins it swaps, so to flip the order of one head-tail pair, that specific head and that specific tail must be swapped past each other at least once.

Step 3: Count how many head-tail pairs need reordering.

There are 3 heads and 3 tails, so the number of (head, tail) pairs whose order must flip is $3 \times 3 = 9$.

Two heads never need to cross each other, since heads are identical and their own internal order does not matter, and the same is true among the tails, so no swaps are wasted reordering coins of the same face.

Step 4: Confirm this count is achievable.

One way to do it: repeatedly take the tail that is furthest to the left among the T's and adjacent-swap it leftward past every H still ahead of it.

Moving the first T past all 3 H's takes 3 swaps, moving the second T

past all 3 H's takes another 3 swaps, and moving the third T past all 3 H's takes 3 more swaps, giving 3 + 3 + 3 = 9 swaps in total, and this reaches T T T H H H exactly.

Final Answer:
The minimum number of steps needed is 9, so the correct option is (C).

$\boxed{9}$

Quick Tip: Think about how many times a head and a tail have to swap places directly for every head to end up on the right side and every tail on the left.

. Exacerbate : Mitigate ::

Choose the option with the correct pair of words to fill the blank.

(A) Aggravate : Alleviate

(B) Alleviate : Precipitate

(C) Aggravate : Precipitate

(D) Emancipate : Exonerate

Correct Answer: (A) Aggravate : Alleviate

Solution:

Step 1: Work out the relation between the given words.
Exacerbate means to make a problem worse. Mitigate means to make a problem less severe.

So the two words in the pair are opposites of each other, one word makes things worse and the other one eases them.

Step 2: Check option (A), Aggravate : Alleviate.
Aggravate means to make worse, the same sense as exacerbate.
Alleviate means to make less severe or ease pain, the same sense as mitigate.
So this pair carries the exact same worsen versus ease relationship as the given pair.

Step 3: Check option (B), Alleviate : Precipitate.
Alleviate does mean to ease something, but precipitate means to cause an event to happen suddenly or sooner than expected.
Precipitate is not the opposite of alleviate, so this pair does not carry the same relationship.

Step 4: Check option (C), Aggravate : Precipitate.
Aggravate fits the worsen role, but precipitate again means to trigger something suddenly, not to ease or lessen it.
The second word does not act as the opposite of the first word here, so the pair fails.

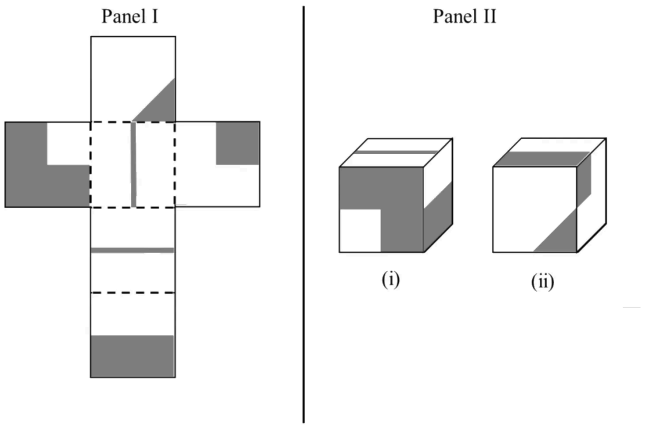
Step 5: Check option (D), Emancipate : Exonerate.
Emancipate means to set free from control or restriction, and exonerate means to clear someone of blame.
These two words are close to synonyms of each other, both about releasing someone, not opposites.

Final Answer:
Only option (A) gives a word pair, aggravate and alleviate, that are opposites of each other in the same way exacerbate and mitigate are.

Aggravate : Alleviate

Quick Tip: Think about whether the two given words are synonyms or antonyms of each other, then look for the option that keeps that same relationship.

. A paper shown in Panel I is folded along the dashed lines (- - -) to construct a cube. The shaded regions shown in Panel I appear on the outer surface of the cube. Referring to cubes shown in Panel II, which one of the options is correct?



(A) Only (i) can correspond to the unfolded cube in Panel I.

(B) Only (ii) can correspond to the unfolded cube in Panel I.

(C) Both (i) and (ii) can correspond to the unfolded cube in Panel I.

(D) Neither (i) nor (ii) can correspond to the unfolded cube in Panel I.

Correct Answer: (B) Only (ii) can correspond to the unfolded cube in Panel I.

Solution:

Step 1: Label every square of the net as a face of the cube.
Read Panel I as a vertical strip of four squares with one square attached on the left and one on the right of the second square from the top.
Call the top square Top, the square below it Front, the two side squares Left and Right, the next square down Bottom, and the last square at the very bottom Back.
This matches how a plus shaped net always folds up, the two squares that flank the middle square become the Left and Right faces, and the strip above and below the middle square become Top, Bottom and finally Back.

Step 2: Note which faces can never appear together.
When six faces close up into a cube, each face has exactly one face directly opposite it, Top is opposite Bottom, Front is opposite Back, and Left is opposite Right.
Any single 3D view of a cube can only show three faces that all meet at one corner, so it can never show a face together with its own opposite face.

Step 3: Read off the shading from the net.
The Left and Right squares in Panel I are both fully shaded dark.
The Top square carries a gray triangle cut across one of its corners, and the Back square carries a gray patch across part of it, while the Front and Bottom squares are left plain white.

Step 4: Trace the shaded corner of the Top square through the fold.
The edge of the Top square that is joined to the Front square becomes the Top-Front edge of the cube once folded.
Because the shaded triangle sits on the far corner of the Top square, away from that joining edge, it lands on the corner of the cube shared

by the Top face, the Back face and one of the side faces, not on the Top-Front corner.
So on the finished cube, any view that shows the shaded triangle sitting right next to the Front face, at the near corner of the Top face, is not consistent with the net.

Step 5: Compare with cube (i) and cube (ii).
In cube (i), the shaded triangle on the Top face is drawn touching the near, front corner of the top face, the same corner where the visible side face meets the front edge. That placement contradicts the tracing done in Step 4, so cube (i) cannot be folded from this net.
In cube (ii), the shaded triangle on the Top face sits on the far corner, away from the front edge, exactly where Step 4 places it, and the fully shaded side face matches the Left or Right square of the net. This is consistent in every corner and every shaded region.

Final Answer:
Only cube (ii) can be produced by folding the net in Panel I.

Only (ii)

Quick Tip: Label each square of the net as a face of the cube, remember opposite faces never appear together in one view, then trace where the shaded corner lands after folding.

. In a population, patients who have high cholesterol also have high blood pressure (BP). Some patients with high BP also have diabetes. There are no patients who have both high cholesterol and diabetes. Furthermore,

1. the total number of patients with at least one of these conditions is 75,
2. the number of patients with high cholesterol is 10,
3. the number of patients with high BP is 45, and
4. the number of patients with only high BP and no other conditions is 20.

Then the number of patients who have both diabetes and high BP is

(A) 0

(B) 15

(C) 20

(D) 10

Correct Answer: (B) 15

Solution:

Step 1: Set up the three groups.
Let C be the set of patients with high cholesterol, B be the set of patients with high BP, and D be the set of patients with diabetes.
The question tells us every patient with high cholesterol also has high BP, so C is completely inside B, in symbols $C \subseteq B$.
It also tells us no patient has both high cholesterol and diabetes, so C and D do not overlap at all, $C \cap D = \emptyset$.

Step 2: Split the BP group into three non-overlapping parts.
Because C sits entirely inside B, every patient in B falls into exactly one of three groups, patients in B with cholesterol too (this is simply all of C, since C is inside B), patients in B with diabetes too (call this x,

the quantity we want), and patients in B with neither of the other two conditions (given as only high BP, which is 20).
Since C and D do not overlap, a patient in B cannot be counted in both the cholesterol part and the diabetes part at the same time, so these three parts really are separate and add up to the whole of B.

Step 3: Write this as one equation.

$$|B| = (\text{only BP}) + |C| + x$$

Fill in the known numbers, the size of B is 45, only BP is 20, and the size of C is 10.

$$45 = 20 + 10 + x$$

Step 4: Solve for x.

$$45 = 30 + x$$

$$x = 15$$

So 15 patients have both high BP and diabetes.

Step 5: Why the other options are wrong.
Option (A), 0, would mean high BP and diabetes never occur together, but the question directly states some patients with high BP also have diabetes, so 0 cannot be right.
Option (C), 20, is actually the count of patients with only high BP and

no other condition, not the overlap with diabetes, so it answers a different question.
Option (D), 10, is the total number of patients with high cholesterol, a number that has nothing to do with the BP-diabetes overlap once cholesterol is accounted for separately.

Step 6: Check the total of 75 is consistent.
This number is not even needed to answer the question, since B, C and the only-BP count already pin down x on their own, but it is worth checking the story holds together.
The union of all three sets equals $|B| + |D| - |B \cap D|$ here, because C contributes nothing extra outside B. Setting this equal to 75 with $|B| = 45$ and $|B \cap D| = 15$ gives $|D| = 45$, a sensible whole number, so the figures are consistent.

Final Answer:
The number of patients with both diabetes and high BP is 15.

$$\boxed{15}$$

Quick Tip: Draw three overlapping sets for cholesterol, BP and diabetes, use the fact that the cholesterol set sits entirely inside the BP set, and split the BP set into its three non-overlapping parts.

. Four people P, Q, R, and S, of different ages, make the following observations.

P: I am younger than S.
Q: I am neither the youngest nor the oldest.
R: P is older than me.

Based on these observations, the youngest person is .

(A) P

(B) Q

(C) R

(D) S

Correct Answer: (C) R

Solution:

Step 1: Turn each statement into an inequality.
P says I am younger than S, so $P < S$ in age.
R says P is older than me, so $R < P$.
Putting these two together gives a chain, $R < P < S$.

Step 2: Use Q's statement to place Q.
Q says I am neither the youngest nor the oldest, so Q cannot be the smallest age of all four people, and Q cannot be the largest age of all four people.

Step 3: Check whether Q could be younger than R.
Suppose Q were younger than R. Since the chain already says $R < P < S$, that would put Q below R, below P and below S all at once, making Q the youngest person overall.

That contradicts Q's own statement, so Q cannot be younger than R. This forces $R < Q$.

Step 4: Combine everything into one order.
We now know $R < P < S$ and $R < Q$.
R is smaller than P, smaller than S, and smaller than Q, so R sits below all three of the others no matter where exactly Q falls between R and S.

Step 5: Confirm R is the unique youngest.
Since every one of P, Q and S is shown to be older than R, R must be the youngest of the four, and this fits Q's statement too, because Q ends up somewhere in the middle, neither the smallest (that is R) nor necessarily the largest.

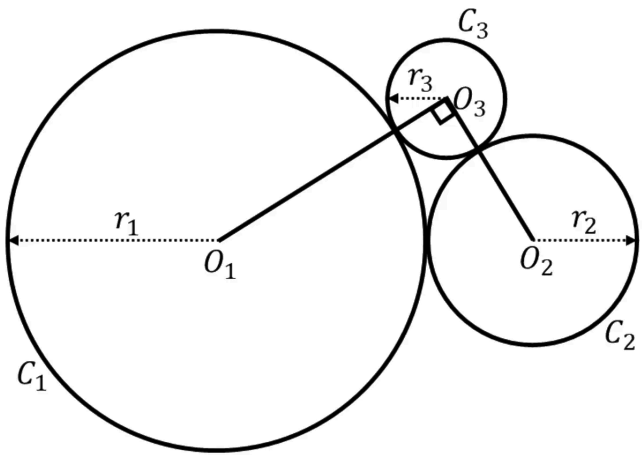
Step 6: Why the other options fail.
P cannot be youngest because R < P is given directly.
Q cannot be youngest because Q's own statement rules it out.
S cannot be youngest because both P and R are shown to be younger than S.

Final Answer:
The youngest person is R.

$\boxed{R}$

Quick Tip: Turn each statement into an inequality between ages, chain them together, then use Q's statement to rule out who can be at either extreme.

. Circles C_1, C_2, and C_3, with centers O_1, O_2, and O_3, and radii r_1, r_2, and r_3, respectively, touch each other as shown in the following figure. Given $r_1 = 2$ cm, $r_2 = 1$ cm and the angle $\angle O_1O_3O_2$ is $90°$, $r_3 =$ cm.



(A) $\frac{1}{2}\left(-3+\sqrt{17}\right)$

(B) $\frac{1}{2}\left(3+\sqrt{17}\right)$

(C) $\frac{1}{2}\left(-2+\sqrt{17}\right)$

(D) $\frac{1}{2}\left(-3+2\sqrt{17}\right)$

Correct Answer: (A) $\frac{1}{2}\left(-3+\sqrt{17}\right)$

Solution:

Step 1: Turn circles touch each other into distances between centers.

When two circles touch each other from the outside, the distance between their centers equals the sum of their two radii.

So $O_1O_3 = r_1 + r_3$, $O_2O_3 = r_2 + r_3$, and $O_1O_2 = r_1 + r_2$.

Since $r_1 = 2$ and $r_2 = 1$, the distance $O_1O_2 = 2 + 1 = 3$ cm, a fixed number that does not depend on r_3.

Step 2: Use the right angle at O_3.

We are told $\angle O_1O_3O_2 = 90°$, so triangle $O_1O_3O_2$ is a right triangle

with the right angle at O_3.
The side opposite this right angle, O_1O_2, is the hypotenuse of that triangle, and O_1O_3 and O_2O_3 are the two legs.

Step 3: Apply the Pythagorean theorem.

$$O_1O_2^2 = O_1O_3^2 + O_2O_3^2$$

Substitute the distances from Step 1,

$$3^2 = (2 + r_3)^2 + (1 + r_3)^2$$

Step 4: Expand both squared terms.

$$(2 + r_3)^2 = 4 + 4r_3 + r_3^2$$

$$(1 + r_3)^2 = 1 + 2r_3 + r_3^2$$

Adding these gives

$$9 = 5 + 6r_3 + 2r_3^2$$

Step 5: Bring everything to one side and simplify.

$$2r_3^2 + 6r_3 + 5 - 9 = 0$$

$$2r_3^2 + 6r_3 - 4 = 0$$

Dividing every term by 2,

$$r_3^2 + 3r_3 - 2 = 0$$

Step 6: Solve the quadratic with the quadratic formula.

$$r_3 = \frac{-3 \pm \sqrt{3^2 - 4(1)(-2)}}{2} = \frac{-3 \pm \sqrt{9 + 8}}{2} = \frac{-3 \pm \sqrt{17}}{2}$$

A radius cannot be negative, and $\sqrt{17} \approx 4.12$, so the minus root gives a negative number and must be thrown away.

$$r_3 = \frac{-3 + \sqrt{17}}{2} \approx 0.56 \text{ cm}$$

Step 7: Why the other options are wrong.
Option (B) flips the sign in front of the 3, giving $\frac{1}{2}(3 + \sqrt{17})$, which would only happen if the linear term in the quadratic came out negative instead of positive, a sign slip.
Option (C) uses a 2 in place of the 3, as if only one leg of the triangle had been squared correctly.
Option (D) doubles the square root term by mistake, which does not come from solving $r_3^2 + 3r_3 - 2 = 0$ correctly.

Final Answer:

$$\boxed{r_3 = \frac{1}{2}\left(-3 + \sqrt{17}\right) \text{ cm}}$$

Quick Tip: Since each pair of circles touches externally, the distance between any two centers equals the sum of their radii, then use this with the right angle at O3 and the Pythagorean theorem.

. If I is an identity matrix, the polynomial equation that satisfies the Cayley-Hamilton theorem for the matrix

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

is

(A) $P^2 - 5P + 6I = 0$

(B) $P^2 - 5P + 5I = 0$

(C) $P^2 - 6P + 5I = 0$

(D) $P^2 - 4P + 3I = 0$

Correct Answer: (A) $P^2 - 5P + 6I = 0$

Solution:

Step 1: Recall the Cayley-Hamilton theorem.

The Cayley-Hamilton theorem says every square matrix satisfies its own characteristic equation.

For a 2x2 matrix P, we get the characteristic equation from $\det(P - \lambda I) = 0$, then replace λ with P itself.

Step 2: Write the characteristic equation.

The given matrix is $P = \begin{bmatrix} 2 & 1 \\ 0 & 3 \end{bmatrix}$.

$$P - \lambda I = \begin{bmatrix} 2-\lambda & 1 \\ 0 & 3-\lambda \end{bmatrix}$$

This matrix is upper triangular, so its determinant is just the product of the diagonal terms minus the product of the off diagonal terms.

$$\det(P - \lambda I) = (2-\lambda)(3-\lambda) - (1)(0)$$

Step 3: Expand the determinant.

$$(2-\lambda)(3-\lambda) = 6 - 2\lambda - 3\lambda + \lambda^2 = \lambda^2 - 5\lambda + 6$$

So the characteristic equation is $\lambda^2 - 5\lambda + 6 = 0$.

We can check this a faster way too: for a 2x2 matrix the characteristic equation is always $\lambda^2 - (\text{trace})\lambda + \det = 0$. Here trace of P is $2 + 3 = 5$ and determinant of P is $2 \times 3 - 1 \times 0 = 6$, which gives the same $\lambda^2 - 5\lambda + 6 = 0$.

Step 4: Apply the Cayley-Hamilton theorem.

The theorem says P satisfies its own characteristic equation, so we replace λ with P and the constant term with $6I$.

$$P^2 - 5P + 6I = 0$$

Step 5: Check the wrong options.

Option B changes the constant to 5I, but the determinant of P is 6, not 5, so this is wrong.
Option C changes the middle term to 6P, but the trace of P is 5, not 6, so this is wrong.
Option D, $P^2 - 4P + 3I = 0$, belongs to a matrix with trace 4 and determinant 3, not this matrix.

Final Answer:
The matrix P satisfies $P^2 - 5P + 6I = 0$.

$$\boxed{P^2 - 5P + 6I = 0}$$

Quick Tip: Find the characteristic equation of P from $\det(P - \lambda I) = 0$, then replace λ with P itself.

. Let $\hat{i}$ and $\hat{j}$ be the unit vectors in the x and y direction, respectively. The divergence $(\nabla.\vec{F})$ of $\vec{F} = x^2y\hat{i} + y^3x\hat{j}$ at the point $(3, 2)$ is

(A) 12

(B) 24

(C) 36

(D) 48

Correct Answer: (D) 48

Solution:

Step 1: Recall the formula for divergence.
For a vector field $\vec{F} = F_1\hat{i} + F_2\hat{j}$ in two dimensions, the divergence is $\nabla.\vec{F} = \frac{\partial F_1}{\partial x} + \frac{\partial F_2}{\partial y}$.

It tells us how much the field spreads out from a point.

Step 2: Identify the components.

Here $F_1 = x^2y$ and $F_2 = y^3x$.

Step 3: Differentiate each component.

Differentiate F_1 with respect to x, treating y as constant:

$$\frac{\partial F_1}{\partial x} = \frac{\partial}{\partial x}(x^2y) = 2xy$$

Differentiate F_2 with respect to y, treating x as constant:

$$\frac{\partial F_2}{\partial y} = \frac{\partial}{\partial y}(y^3x) = 3xy^2$$

Step 4: Add the two partial derivatives.

$$\nabla.\vec{F} = 2xy + 3xy^2$$

Step 5: Substitute the point (3,2).

Put $x = 3$ and $y = 2$:

$$2(3)(2) + 3(3)(2)^2 = 12 + 3(3)(4) = 12 + 36 = 48$$

Step 6: Check the wrong options.

Option A (12) is only the first term $2xy$, missing the second term.

Option B (24) does not match either term or their correct sum.

Option C (36) is only the second term $3xy^2$, missing the first term.
We need both terms added together to get the full divergence.

Final Answer:
The divergence of $\vec{F}$ at (3,2) is 48.

$$\boxed{48}$$

Quick Tip: Use $\nabla.\vec{F} = \frac{\partial F_1}{\partial x} + \frac{\partial F_2}{\partial y}$ and put in the given point.

. Which one of the following is a non-linear, second-order, and first-degree differential equation?

(A) $\frac{d^2y}{dx^2} + \cos x \frac{dy}{dx} + e^x y = 0$

(B) $\frac{d^2y}{dx^2} + \cos y = 0$

(C) $\frac{d^2y}{dx^2} + \sin x = 0$

(D) $\left(\frac{dy}{dx}\right)^2 + 3y = 0$

Correct Answer: (B) $\frac{d^2y}{dx^2} + \cos y = 0$

Solution:

Step 1: Recall what order, degree, and linearity mean.
The order of a differential equation is the order of its highest derivative.
The degree is the power of the highest order derivative, once the equation is written as a polynomial in derivatives.
An equation is linear if the dependent variable y and all its derivatives

appear only to the first power, and no term wraps y or a derivative of y inside a non-linear function of y. Coefficients can be any function of the independent variable x.

Step 2: Check option A.

$$\frac{d^2y}{dx^2} + \cos x \frac{dy}{dx} + e^x y = 0$$

The highest derivative is $\frac{d^2y}{dx^2}$, so order is 2 and degree is 1.
The coefficients $\cos x$ and e^x are functions of x only, and y and its derivatives appear only to the first power, so this equation is linear.
Not the answer.

Step 3: Check option B.

$$\frac{d^2y}{dx^2} + \cos y = 0$$

The highest derivative is again $\frac{d^2y}{dx^2}$, so order 2, degree 1.
But the term $\cos y$ is a non-linear function of the dependent variable y itself, not of x, so this makes the equation non-linear.
This equation is non-linear, second order, and first degree, which is what the question asks for.

Step 4: Check option C.

$$\frac{d^2y}{dx^2} + \sin x = 0$$

Here $\sin x$ is a function of the independent variable x, not of y, so it is fine in a linear equation. This equation is linear, second order, first

degree, not the answer.

Step 5: Check option D.

$$\left(\frac{dy}{dx}\right)^2 + 3y = 0$$

The highest derivative here is $\frac{dy}{dx}$, so order is 1, not 2.
Its power is 2, so the degree is 2. This equation is first order, second degree, and non-linear, which does not match the required second-order, first-degree condition.

Final Answer:
Only option B is non-linear, second order, and first degree.

Option (B)

Quick Tip: Order comes from the highest derivative present, degree from its power, and linearity fails only when y itself sits inside a non-linear function.

. As per the Mohs scale of hardness, the correct sequence is

(A) Topaz > Quartz > Calcite > Talc

(B) Quartz > Topaz > Calcite > Talc

(C) Quartz > Topaz > Talc > Calcite

(D) Topaz > Calcite > Quartz > Talc

Correct Answer: (A) Topaz > Quartz > Calcite > Talc

Solution:

Step 1: Understanding the Concept.

The Mohs scale ranks common minerals by relative hardness, from softest to hardest, using ten reference minerals. A mineral higher on the scale can scratch every mineral ranked below it.

Step 2: Key Formula or Approach.

The full Mohs scale, softest (1) to hardest (10), runs: Talc (1), Gypsum (2), Calcite (3), Fluorite (4), Apatite (5), Feldspar (6), Quartz (7), Topaz (8), Corundum (9), Diamond (10).

To rank the four minerals in this question, we just read off their standard positions on this scale.

Step 3: Detailed Explanation.

Talc sits at rank 1, the softest mineral on the scale, soft enough to be scratched by a fingernail.

Calcite sits at rank 3, still soft enough to be scratched easily by a copper coin or a knife blade.

Quartz sits at rank 7, hard enough to scratch ordinary glass and steel.

Topaz sits at rank 8, harder than quartz, and is itself scratched only by corundum or diamond.

Arranged from hardest to softest by rank number: Topaz (8) > Quartz (7) > Calcite (3) > Talc (1).

Step 4: Check the wrong options.

Option B places Quartz above Topaz, but Topaz (8) is harder than Quartz (7), so this order is reversed.

Option C swaps Talc and Calcite at the end; Calcite (3) is harder than Talc (1), so Calcite must come before Talc, not after.

Option D places Calcite above Quartz, but Calcite (3) is far softer than

Quartz (7), so this order is wrong too.

Step 5: Final Answer.

The correct hardest to softest sequence is Topaz > Quartz > Calcite > Talc.

$$\boxed{\text{Topaz} > \text{Quartz} > \text{Calcite} > \text{Talc}}$$

Quick Tip: Recall the standard order of the ten Mohs scale reference minerals, from Talc (softest) to Diamond (hardest).

. Match the distribution with its corresponding probability density/mass function.

Distribution type	Probability density/mass function
(P) Binomial Distribution	(1) $f(x) = \frac{1}{\sigma\sqrt{2\pi}}\exp\left(-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right),\ \sigma > 0$
(Q) Poisson Distribution	(2) $f(x) = \binom{n}{x}p^x(1-p)^{n-x},\ x = 0, 1, 2, \ldots, n$
(R) Normal Distribution	(3) $f(x) = \frac{\mu^x}{x!}\exp(-\mu),\ x = 0, 1, 2, \ldots$
(S) Exponential Distribution	(4) $f(x) = \lambda\exp(-\lambda x),\ x > 0$

(A) P → 2, Q → 3, R → 1, S → 4

(B) P → 1, Q → 3, R → 2, S → 4

(C) P → 3, Q → 2, R → 1, S → 4

(D) P → 2, Q → 4, R → 3, S → 1

Correct Answer: (A) P → 2, Q → 3, R → 1, S → 4

Solution:

Step 1: Recall the standard form of each named distribution.

Binomial distribution gives the probability of exactly x successes in n independent trials, each with success probability p:

$$f(x) = \binom{n}{x} p^x (1-p)^{n-x}, \quad x = 0, 1, 2, \ldots, n$$

Poisson distribution models the count of rare events in a fixed interval, with mean rate μ:

$$f(x) = \frac{\mu^x}{x!} \exp(-\mu), \quad x = 0, 1, 2, \ldots$$

Normal distribution is the bell curve for a continuous variable with mean μ and standard deviation σ:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right), \quad \sigma > 0$$

Exponential distribution models the waiting time between events at a constant rate λ:

$$f(x) = \lambda \exp(-\lambda x), \quad x > 0$$

Step 2: Match P, Binomial, to its formula.

Formula (2) has the binomial coefficient $\binom{n}{x}$ with $p^x(1-p)^{n-x}$, and x runs over the discrete set 0,1,2,...,n. This is the binomial form, so P → 2.

Step 3: Match Q, Poisson, to its formula.
Formula (3) has $\mu^x/x!$ with $\exp(-\mu)$, the classic Poisson form, with x running over all non-negative integers with no upper limit n. So Q → 3.

Step 4: Match R, Normal, to its formula.
Formula (1) has $\exp\left(-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right)$ divided by $\sigma\sqrt{2\pi}$, the bell curve density with continuous x. So R → 1.

Step 5: Match S, Exponential, to its formula.
Formula (4), $\lambda \exp(-\lambda x)$ for $x > 0$, is the standard exponential density with a single rate parameter and no factorial or binomial term. So S → 4.

Step 6: Check the wrong options.
Option B sends P to formula 1 (Normal) and R to formula 2 (Binomial), a swap.
Option C sends P to formula 3 (Poisson) and Q to formula 2 (Binomial), also a swap.
Option D sends Q to formula 4 (Exponential) and S to formula 1 (Normal), mixing a discrete and a continuous distribution.

Final Answer:
The correct matching is P → 2, Q → 3, R → 1, S → 4.

$$\boxed{P \to 2,\ Q \to 3,\ R \to 1,\ S \to 4}$$

Quick Tip: Split the four formulas into discrete (pmf) and continuous (pdf) types, then match by the presence of a binomial coefficient, factorial, squared

exponential, or plain exponential term.

. As per the UNFC mineral resources classification system, the highest category of resource is indicated by

(A) 111

(B) 122

(C) 333

(D) 334

Correct Answer: (A) 111

Solution:

Step 1: Understanding the Question.

The United Nations Framework Classification (UNFC) for mineral resources sorts every deposit using a three digit code. Each digit stands for one axis of confidence: economic viability (E), the stage of the project (F), and how well the geology is known (G). The question asks which three digit code marks the highest, most certain category of resource.

Step 2: Key Formula or Approach.

In UNFC-2009, a lower digit on every axis always means a stronger, better known deposit. E1 means the deposit is economically viable right now. F1 means a feasibility study or mining is already confirmed and in progress. G1 means the geology has been explored in detail with high confidence, close to what used to be called "proved reserves." So the strongest possible category is the one where every digit is 1.

Step 3: Detailed Explanation.

Option (A) 111 combines E1, F1 and G1: economically viable, a confirmed feasibility or mining stage, and detailed geological knowledge. This is the top class, equal to a proved and mineable reserve.

Option (B) 122 mixes E1 with F2 and G2, a lower stage of project development and less detailed geology, so it ranks below 111.

Option (C) 333 has E3, F3 and G3, which marks a resource not yet shown to be economic and known only at a preliminary level, far from the top class.

Option (D) 334 is even weaker on the geological axis (G4), the least explored category in the system.

Step 4: Final Answer.

The code with the lowest, strongest digit on every axis is 111, so that marks the highest category of mineral resource under UNFC.

111

Quick Tip: Remember that in UNFC, a lower digit on each of the three axes (economic, feasibility, geological) means a stronger, more certain resource.

. The best combination of explosive and initiation system for underwater blasting for rock breakage is

(A) ANFO and electric detonator

(B) emulsion and non-electric detonator

(C) HANFO and safety fuse

(D) PETN and electronic detonator

Correct Answer: (B) emulsion and non-electric detonator

Solution:

Step 1: Understanding the Question.

Underwater blasting means the blastholes are wet or fully submerged, so both the explosive and the way it is fired must survive water without failing or becoming a safety hazard. The question asks which explosive and initiation system pairing works best under these wet conditions.

Step 2: Key Formula or Approach.

Two properties decide the answer here. First, water resistance of the explosive: an explosive used underwater must not dissolve, desensitize or wash out while it sits in water during charging and firing. Second, safety of the initiation system: any electrical circuit lying in wet ground or water is at risk from stray currents, static charge and leakage, so a non-electric firing method is safer underwater.

Step 3: Detailed Explanation.

Option (A) ANFO and electric detonator fails on both counts. ANFO is a mixture of ammonium nitrate prills and fuel oil, and ammonium nitrate dissolves readily in water, so ANFO loses its explosive strength almost at once when wet. An electric detonator also adds stray current risk in a wet hole.

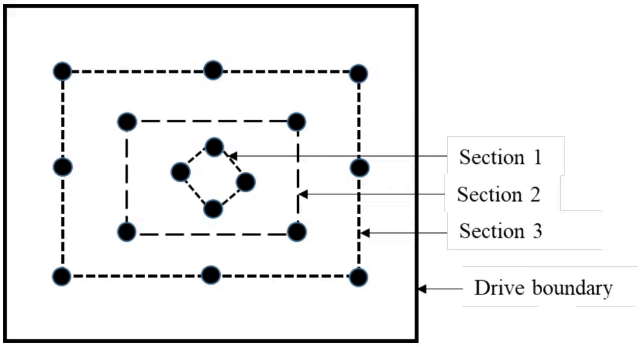
Option (B) emulsion and non-electric detonator fits both requirements. An emulsion explosive is a water in oil system, tiny droplets of ammonium nitrate solution held inside a continuous oil and wax phase, so water cannot get in to dissolve it and it keeps its strength even fully submerged. A non-electric (shock tube) detonator

carries its signal as a shock wave inside a plastic tube, not as an electric current, so it is not affected by water conductivity or stray currents.
Option (C) HANFO and safety fuse is weaker. HANFO (heavy ANFO) blends some emulsion into ANFO and so resists water better than plain ANFO, but it is still not as water resistant as pure emulsion, and a plain safety fuse burns on the outside, so water can put it out or delay it unpredictably.
Option (D) PETN and electronic detonator is not the standard choice either. PETN is mainly used inside detonating cord and boosters rather than as the main column charge, and electronic detonators are costly, sensitive units, not the routine choice for rough underwater rounds.

Step 4: Final Answer.
The pairing that survives water and avoids electrical hazards is emulsion explosive fired with a non-electric detonator.
This corresponds to option (B).

Quick Tip: Think about which explosive resists water without dissolving, and which type of detonator avoids relying on an electric current in wet ground.

. The firing sequence in a drivage is shown. The charge per hole for Sections 1, 2, and 3 are 2.0 kg, 3.0 kg, and 1.0 kg, respectively, and the delay between each section is 25 milliseconds. The maximum charge per delay, in *kg*, is



(A) 8.0

(B) 12.0

(C) 20.0

(D) 28.0

Correct Answer: (B) 12.0

Solution:

Step 1: Read the blast layout.

The figure shows three concentric rings of blastholes drilled in the face of a drivage, fired in sequence. The innermost diamond of holes is Section 1, the next ring out is Section 2, and the outer ring closest to the drive boundary is Section 3. Counting the dots in the figure, Section 1 has 4 holes, Section 2 has 4 holes, and Section 3 has 8 holes.

Step 2: Find the total charge fired in each section.

Each hole in a section carries the same charge, and every hole in one section fires together on the same delay number, so the total charge of a section is its hole count times its charge per hole.

Section 1: $4 \times 2.0 = 8.0$ kg
Section 2: $4 \times 3.0 = 12.0$ kg
Section 3: $8 \times 1.0 = 8.0$ kg

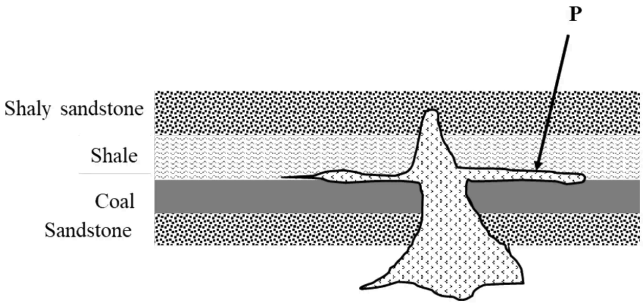
Step 3: Decide whether charges from different sections add together.
For ground vibration purposes, charges that fire within about 8 milliseconds of one another behave as one combined instantaneous charge, since the ground and the seismograph cannot separate blasts spaced that close together. Here the gap between sections is 25 milliseconds, well above that 8 millisecond limit, so Sections 1, 2 and 3 fire as three separate, independent delays. Their charges are never added across sections.

Step 4: Pick the maximum charge per delay.
The maximum charge per delay (often written MCD) is simply the largest total charge that goes off on any single delay. Comparing the three section totals, 8.0 kg, 12.0 kg and 8.0 kg, the biggest is Section 2 at 12.0 kg.

12.0 kg

Quick Tip: Work out the total charge fired in each section, then check whether the 25 ms gap between sections is enough to keep them on separate delays instead of adding together.

. The igneous intrusion along the bedding plane of the coal seam, as indicated by P, is known as



(A) dyke

(B) washout

(C) sill

(D) seam split

Correct Answer: (C) sill

Solution:

Step 1: Understanding the Question.

The figure shows layers of shaly sandstone, shale, coal and sandstone lying one above another, and a body of igneous rock marked P that has pushed in and spread out along the boundary between two of these layers, following the bedding rather than cutting across it. The question asks what this kind of intrusion is called.

Step 2: Key Formula or Approach.

Igneous intrusions are classed by how they sit relative to the layering (bedding) of the rock they invade. A body that forces its way in and spreads out parallel to the bedding planes is called a sill. A body that cuts straight across the bedding, climbing through different layers, is called a dyke instead. Washout and seam split are not igneous features at all; they describe erosion or splitting of the coal seam itself

by sedimentary processes.

Step 3: Detailed Explanation.
In the figure, P sits right at the contact between the coal seam and the sandstone above it, and the intruded rock body spreads sideways along that contact rather than crossing up through the shale and shaly sandstone layers above. That sideways, bedding parallel geometry is the defining shape of a sill.
Option (A) dyke is wrong because a dyke would show as a near vertical body cutting across the layering, not hugging one bedding plane.
Option (B) washout is wrong because a washout is a channel cut into the coal seam by a later stream, filled with sandstone, and has nothing to do with molten igneous rock.
Option (D) seam split is wrong because a seam split is where a single coal seam divides into two thinner seams separated by non-coal rock, again a sedimentary feature with no igneous intrusion involved.
Only option (C) sill matches an igneous body that intrudes and spreads along the bedding plane of the coal seam.

Step 4: Final Answer.
An igneous intrusion that runs parallel to and along the bedding plane of a coal seam is called a sill.
This corresponds to option (C).

Quick Tip: Compare how the intruded rock sits relative to the layering: does it run parallel to the bedding or cut across it?

. In remote sensing, the order of the wavelength bands of electromagnetic radiation used for data acquisition is

(A) Visible < Near Infrared < Thermal Infrared < Microwave

(B) Thermal Infrared < Near Infrared < Visible < Microwave

(C) Microwave < Near Infrared < Thermal Infrared < Visible

(D) Near Infrared < Thermal Infrared < Microwave < Visible

Correct Answer: (A) Visible < Near Infrared < Thermal Infrared < Microwave

Solution:

Step 1: Understanding the Question.
Remote sensing instruments collect electromagnetic energy from different parts of the spectrum, and each band is defined by its wavelength. The question asks us to arrange the visible, near infrared, thermal infrared and microwave bands in order of increasing wavelength.

Step 2: Key Formula or Approach.
Every named band in remote sensing has a standard wavelength range: visible light runs from about 0.4 to 0.7 micrometres, near infrared from about 0.7 to 1.3 micrometres, thermal infrared from about 3 to 14 micrometres, and microwave from about 1 millimetre to 1 metre, thousands of times longer than thermal infrared. Arranging the bands from shortest to longest wavelength gives the correct order.

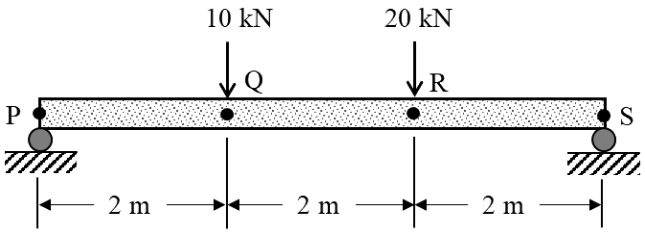
Step 3: Detailed Explanation.
Starting from the shortest wavelength, visible light comes first since our eyes and most cameras use this narrow band.
Next comes near infrared, just beyond red light, still measured in a

fraction of a micrometre.
After that comes thermal infrared, tied to heat radiated by objects, which sits at a much longer wavelength, several micrometres.
Microwave radiation comes last, with wavelengths in the millimetre to metre range, far longer than any of the other three bands, which is why radar and passive microwave sensors can see through cloud and haze that block the shorter bands.
Option (A) Visible < Near Infrared < Thermal Infrared < Microwave follows exactly this shortest to longest order.
Option (B) puts thermal infrared before near infrared and visible, which is backwards since thermal infrared has a longer wavelength than both.
Option (C) starts with microwave, the longest wavelength band of all, so this sequence runs from longest to shortest, the reverse of what is asked.
Option (D) places visible, the shortest band, at the very end, which is also backwards.

Step 4: Final Answer.
Ordered from shortest to longest wavelength, the sequence is Visible, then Near Infrared, then Thermal Infrared, then Microwave.
This corresponds to option (A).

Quick Tip: Recall the approximate wavelength range of each band, visible, near infrared, thermal infrared and microwave, and arrange them from shortest to longest.

. A simply supported beam is shown. The location at which the zero shear force is acting on the beam is



(A) P

(B) Q

(C) R

(D) S

Correct Answer: (C) R

Solution:

Step 1: Find the support reactions.

The beam is simply supported at P and S, with a 10 kN load at Q (2 m from P) and a 20 kN load at R (4 m from P). The span PS is 6 m.

Take moments about P and set the sum to zero:

$$R_S \times 6 = 10 \times 2 + 20 \times 4$$

$$R_S \times 6 = 20 + 80 = 100$$

$$R_S = \frac{100}{6} = 16.67 \text{ kN}$$

The total downward load is $10 + 20 = 30$ kN, so

$$R_P = 30 - 16.67 = 13.33 \text{ kN}$$

Step 2: Work out the shear force in each segment.

Between two point loads the shear force stays constant, it only changes at a load or a reaction.

From P to Q, the only force to the left of the section is R_P, so $V_{PQ} = 13.33$ kN.

At Q the 10 kN load pulls the shear down, so from Q to R, $V_{QR} = 13.33 - 10 = 3.33$ kN.

At R the 20 kN load pulls the shear down again, so from R to S, $V_{RS} = 3.33 - 20 = -16.67$ kN.

Just after S, the reaction $R_S = 16.67$ kN brings the shear back to zero, which closes the diagram correctly.

Step 3: Find where the shear force diagram crosses zero.

The shear is a constant $+3.33$ kN right up to R and a constant -16.67 kN right after R, so the sign flips exactly at R. On the shear force diagram this shows up as the vertical drop line at R crossing the zero axis, so R is the point of zero shear inside the span.

This point also separates the sagging and hogging tendency of the beam, so it marks where the bending moment is greatest.

The zero values at P and S are trivial, they are just where the diagram starts and ends at the supports, not an interior sign change.

Final Answer:

The zero shear force location is R.

$$\boxed{R}$$

Quick Tip: Remember that for point loads only, shear force stays constant between loads and only changes at a load or reaction point, find where its sign flips.

. In a Slake Durability Index (SDI) test, a rock sample of 500 g undergoes two standard cycles of wetting and drying. The mass of the sample retained after the test is 400 g. The SDI of the sample, in %, is

(A) 10

(B) 40

(C) 20

(D) 80

Correct Answer: (D) 80

Solution:

Step 1: Recall what the Slake Durability Index means.

The Slake Durability Index (SDI), from the Franklin slake durability test, tells us how well a rock resists breaking down when it is repeatedly wetted, dried and tumbled.

A sample of known dry mass is placed in a rotating drum with a 2 mm mesh, run through wetting and drying cycles, and the mass that stays on the mesh, meaning it did not slake away, is weighed again.

Step 2: Write the SDI formula.

$$SDI = \frac{\text{mass retained after the test}}{\text{initial dry mass}} \times 100$$

This ratio is simply the fraction of the original rock that survived the

cycles, turned into a percentage.

Step 3: Put in the numbers.
The initial mass is 500 g and the mass retained after the two standard cycles is 400 g.

$$SDI = \frac{400}{500} \times 100 = 80 \text{ percent}$$

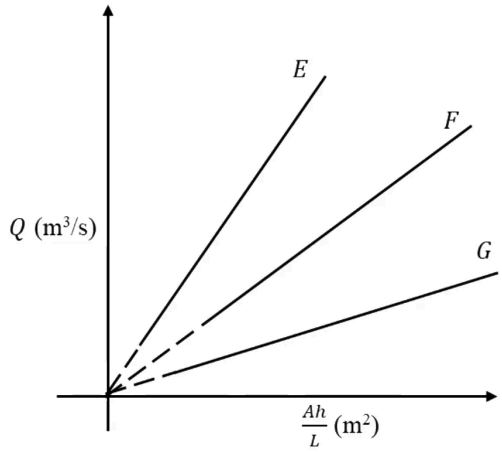
A rock with an SDI of 80 percent or more is generally classed as highly durable, so this sample slakes only a little.
Options (A) 10, (B) 40 and (C) 20 would all mean the sample lost most of its mass, which is far more slaking than 400 g out of 500 g retained actually shows, so they are wrong.

Final Answer:
The SDI of the sample is 80 percent.

$$\boxed{80\%}$$

Quick Tip: SDI is the percentage of the original sample mass that remains after the wetting and drying cycles.

. Results from the permeability test of rock samples, E, F, and G are shown. The correct order of hydraulic conductivity (k) of the rock samples is



Note: Q is water flow rate, A is area of cross-section of the sample, h is water head, L is length of the sample

Note: Q is water flow rate, A is area of cross-section of the sample, h is water head, L is length of the sample.

(A) $k_E > k_F > k_G$

(B) $k_E < k_F < k_G$

(C) $k_E = k_F = k_G$

(D) $k_F > k_G > k_E$

Correct Answer: (A) $k_E > k_F > k_G$

Solution:

Step 1: Recall Darcy's law.

For flow through a rock sample, Darcy's law states

$$Q = k\,i\,A$$

where Q is the flow rate, k is the hydraulic conductivity, i is the

hydraulic gradient and A is the cross section area.
The hydraulic gradient is $i = h/L$, where h is the head loss and L is the length of the sample, so the law can be written as

$$Q = k\left(\frac{Ah}{L}\right)$$

Step 2: Read what the graph plots.
The graph plots Q on the vertical axis against $\frac{Ah}{L}$ on the horizontal axis for each sample.
Comparing this to $Q = k\left(\frac{Ah}{L}\right)$, the plotted line for each sample is a straight line through the origin whose slope is exactly k for that sample.

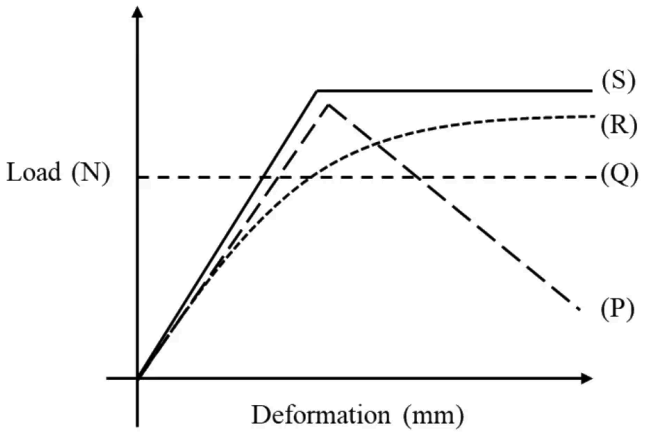
Step 3: Compare the slopes.
A steeper line means a larger k, because the sample lets more flow Q pass for the same value of $\frac{Ah}{L}$.
Reading the three lines drawn from the origin, line E rises the steepest, line F is next, and line G is the flattest of the three.
So the hydraulic conductivities rank in the same order as the slopes: $k_E > k_F > k_G$.

Final Answer:
Sample E is the most permeable and sample G is the least permeable.

$$\boxed{k_E > k_F > k_G}$$

Quick Tip: The slope of the Q versus Ah/L line for each sample equals its hydraulic conductivity by Darcy's law.

. The ideal load-deformation characteristic curve of a hydraulic prop is



(A) P

(B) Q

(C) R

(D) S

Correct Answer: (D) S

Solution:

Step 1: Recall how a hydraulic prop is meant to behave.

A hydraulic prop is a yielding roof support. It is set against the roof and floor with an initial setting load, and as the roof converges further, the prop is designed to keep resisting at a steady, constant load rather than either breaking or flattening out at a low load. This constant resisting load, reached after the initial elastic rise, protects the roof strata from sudden overload while still allowing some safe convergence.

Step 2: Read the four curves against this idea.

All four curves rise in a straight, elastic line at first as the prop takes up load, then they behave differently once the load builds up.

Curve P rises to a peak and then the load falls away as deformation continues, this is the failure pattern of a prop that cannot sustain its load once it is overstressed.
Curve Q rises only to a fairly low load and then stays flat there, this represents a prop that yields too early at an insufficient resisting force.
Curve R rises close to the peak, then gradually softens and settles to a lower plateau, this is closer to the ideal but still loses some of its resisting capacity as it yields.
Curve S rises to the highest load of the four and then stays perfectly flat at that load as deformation continues, with no drop and no early softening.

Step 3: Match the ideal behaviour to a curve.
The ideal hydraulic prop should reach its rated, set load and then hold exactly that load constant while it yields, so the strata pressure on the prop never exceeds the design value and never falls short of it either.
Curve S is the only one of the four that keeps a fully constant load once the elastic rise is over, so it is the ideal characteristic.

Final Answer:
The ideal load-deformation curve of a hydraulic prop is S.

$\boxed{S}$

Quick Tip: An ideal hydraulic prop should hold a constant resisting load once it reaches its set pressure, not drop off or plateau early.

. A 20 m thick orebody is dipping at an angle of 75°. The orebody and host rock are strong. It is proposed to deploy a 150-200 mm diameter drill for production. The suitable stoping method is

(A) block caving

(B) long hole stoping

(C) shrinkage stoping

(D) post and pillar stoping

Correct Answer: (B) long hole stoping

Solution:

Step 1: List the deposit conditions that decide the stoping method.
The choice of stoping method mainly depends on dip, thickness, and the strength of the orebody and the host rock.
Here the orebody is 20 m thick, which is a wide orebody, it dips steeply at 75°, and both the ore and the host rock are strong. A large 150-200 mm diameter drill is planned for production drilling.

Step 2: Check what a steep, thick, strong deposit calls for.
A dip of 75° is steep enough for broken ore to flow down by gravity, so the method should take advantage of that.
Because the deposit is thick, at 20 m, and strong, open stopes can be cut wide without needing the ore to be left in place as a working floor, and the walls can stand without immediate support.
Large diameter, 150-200 mm, blastholes are the mark of mechanised longhole, or sublevel, drilling, drilled in long parallel rows from sublevels above and below the stope and blasted in one go, then the broken ore is drawn from the bottom.

Step 3: Rule out the other options.

Block caving needs the ore, and usually the host rock, to be weak or moderately jointed so that it caves and breaks up on its own once undercut, a strong ore and strong host rock will simply not cave, so option (A) does not fit.
Shrinkage stoping uses the broken ore itself as a working platform and is drilled with smaller diameter jackleg or stoper drills, it also becomes hard to manage in a 20 m wide stope because so much broken ore has to be held in the stope at once, so option (C) does not fit either.
Post and pillar stoping is meant for flat to gently dipping deposits, where pillars can be left standing under gravity, a steep 75° dip makes this impractical, so option (D) is ruled out.

Final Answer:
Long hole stoping fits a steep, thick, strong orebody with strong host rock and large diameter production drilling.

Long hole stoping

Quick Tip: Match the method to a steep, thick, strong orebody drilled with large diameter blastholes, think about which method uses that kind of production drilling.

. A gradually expanding duct fitted to the outlet of an exhaust fan is known as

(A) chimney

(B) diffuser

(C) evasee

(D) equivalent orifice

Correct Answer: (C) evasee

Solution:

Step 1: Understanding the Question:
The question asks for the specific mining ventilation term used for a duct that flares outward gradually where it is fitted onto the outlet of an exhaust or main mine fan.

Step 2: Key Formula or Approach:
In mine ventilation practice, a duct that widens gradually in cross section slows down the air as it leaves the fan. This converts some of the fast moving air's kinetic energy back into useful static pressure, so the fan pushes air through the mine more efficiently.
This particular fitting has its own name in mining terminology, separate from the general engineering word for a flaring outlet.

Step 3: Detailed Explanation:
A chimney is a vertical shaft or duct built to carry exhaust air or gases away. It says nothing about a gradually expanding shape, so option (A) is wrong.
A diffuser is the general mechanical engineering word for any duct that slows a flow by widening its area. It describes the same idea but is not the specific word mining engineers use for this fan fitting, so option (B) does not fit.
An evasee is exactly this gradually flaring outlet duct fitted on a mine

fan. It lowers the air's exit velocity, cuts the exit loss, and recovers static pressure, letting the fan work more effectively.
An equivalent orifice is a mine ventilation network concept used to combine the resistance of several airways in series or parallel into one imaginary opening. It has nothing to do with the shape of a duct at a fan outlet, so option (D) is wrong.

Step 4: Final Answer:
The gradually expanding duct fitted to the outlet of an exhaust fan is called an evasee.

Evasee

Quick Tip: Think about the specific mining ventilation term, not the general engineering word, for a duct that flares out at a mine fan's outlet.

. The cobweb-like appearance in the radiograph of the lung of a miner can be diagnosed as

(A) silicosis

(B) asbestosis

(C) talcosis

(D) coal workers' pneumoconiosis

Correct Answer: (B) asbestosis

Solution:

Step 1: Understanding the Question:
This question tests knowledge of chest X-ray patterns linked to

specific dust diseases seen in miners, and asks which disease gives a fine, web like or cobweb pattern on the radiograph.

Step 2: Key Formula or Approach:
The shape of the mineral dust particle decides how the lung scars. Rounded, blunt edged particles such as silica and coal dust tend to build up as rounded, well defined nodular opacities. Long, thin, fibrous particles such as asbestos fibres get trapped along the connective tissue framework of the lung and instead build up as fine, irregular, linear shadows.

Step 3: Detailed Explanation:
Silicosis (option A) is caused by silica dust, which is more rounded in shape, and shows up as well defined rounded or nodular opacities, mainly in the upper and mid lung zones, not as a cobweb pattern.
Talcosis (option C) can show a mix of nodular and irregular shadows and often pleural plaques, but its hallmark is not the fine cobweb-like network seen here.
Coal workers' pneumoconiosis (option D) is caused by coal dust, which is also fairly rounded, and produces small rounded opacities that can later join up into large masses called progressive massive fibrosis. This is again a nodular pattern, not a cobweb pattern.
Asbestosis (option B) is caused by long, thin asbestos fibres that lodge deep in the smallest airways and the interstitial tissue of the lung. This builds a fine, irregular, net like web of streaky fibrous shadows, mostly in the lower lung zones, which radiologists commonly describe as a cobweb-like or reticular pattern. It can also blur the outline of the heart, sometimes called a "shaggy heart" sign.

Step 4: Final Answer:

The cobweb-like radiograph appearance in a miner's lung points to asbestosis.

Asbestosis

Quick Tip: Think about which dust disease is caused by long, thin fibres rather than rounded dust particles, since the fibre shape decides the pattern seen on the X-ray.

. In firedamp explosion, the methane concentration in the stoichiometric methane-air mixture, in % by volume, is
Assume the air contains 79% nitrogen and 21% oxygen, by volume.

(A) 5.4

(B) 9.5

(C) 10.8

(D) 14.8

Correct Answer: (B) 9.5

Solution:

Step 1: Understanding the Question:
Firedamp is the methane gas found in coal mines, and it can explode when mixed with air in the right proportion. A stoichiometric mixture is the exact ratio of fuel to oxidiser at which the fuel burns completely, using up exactly all the oxygen supplied, with none left over. We need the volume percent of methane in air that gives this exact ratio.

Step 2: Key Formula or Approach:

Methane burns in oxygen by the reaction

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

So one volume of methane needs exactly two volumes of oxygen to burn completely. Air is only 21% oxygen by volume, with the rest being nitrogen that does not take part in the burning but still occupies volume in the mixture. So the volume of air needed to supply 2 volumes of oxygen is

$$V_{air} = \frac{V_{O_2}}{0.21}$$

Step 3: Detailed Explanation:

Take 1 volume of methane as the basis. It needs 2 volumes of oxygen, so the air needed is

$$V_{air} = \frac{2}{0.21} = 9.524 \text{ volumes}$$

The total volume of the methane-air mixture is the methane plus this air:

$$V_{total} = 1 + 9.524 = 10.524 \text{ volumes}$$

The percentage of methane by volume in the stoichiometric mixture is then

$$\%CH_4 = \frac{1}{10.524} \times 100 = 9.5\%$$

Step 4: Final Answer:

Option (A), 5.4%, is close to the lower explosive limit of methane in air, not the stoichiometric value. Option (D), 14.8%, is close to the upper explosive limit of methane, again not the stoichiometric point. Option (C), 10.8%, does not come from the correct oxygen balance shown above, so it is also wrong. The stoichiometric methane concentration works out to 9.5% by volume.

$$\boxed{9.5\%}$$

Quick Tip: Write the balanced combustion equation for methane in oxygen first, then use the fact that air is only 21% oxygen by volume to find how much air one volume of methane needs.

. Which of the following statements about Fourier series is/are correct?

(A) The Fourier series of an even function contains only cosine terms

(B) The Fourier series of an odd function contains only cosine terms

(C) The Fourier series of an odd function contains only sine terms

(D) The Fourier series of an even function contains only sine terms

Correct Answer: (A) The Fourier series of an even function contains only cosine terms ; (C) The Fourier series of an odd function contains only sine terms

Solution:

Step 1: Understanding the Question:

A Fourier series writes a periodic function as a sum of a constant term plus cosine and sine terms:

$$f(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty} (a_n \cos(n\omega x) + b_n \sin(n\omega x))$$

We need to check what happens to the coefficients a_n and b_n when $f(x)$ is even or odd, since that decides whether the series keeps only cosine terms, only sine terms, or both.

Step 2: Key Formula or Approach:

Over a symmetric interval $[-L, L]$, the coefficients are

$$a_n = \frac{1}{L} \int_{-L}^{L} f(x) \cos(n\omega x)\, dx, \qquad b_n = \frac{1}{L} \int_{-L}^{L} f(x) \sin(n\omega x)\, dx$$

The integral of an odd function over a symmetric interval is always zero, while the integral of an even function over a symmetric interval is twice the integral over the positive half. We use this together with the rules: even times even is even, odd times odd is even, and even times odd is odd.

Step 3: Detailed Explanation:

Case 1, $f(x)$ even: $\cos(n\omega x)$ is always even, so $f(x)\cos(n\omega x)$ is even times even, which is even, and its integral over $[-L, L]$ is generally nonzero, so a_n survives. But $\sin(n\omega x)$ is odd, so $f(x)\sin(n\omega x)$ is even times odd, which is odd, and its integral over the symmetric interval is zero. So $b_n = 0$ for every n, and the series of an even function keeps only the constant term and cosine terms. This matches option (A) and rules out option (D).

Case 2, $f(x)$ odd: now $f(x)\cos(n\omega x)$ is odd times even, which is odd, so its integral is zero and $a_n = 0$ for all n, including a_0. But $f(x)\sin(n\omega x)$ is odd times odd, which is even, so its integral survives and b_n is generally nonzero. So the series of an odd function keeps only sine terms. This matches option (C) and rules out option (B).

Step 4: Final Answer:
An even function's Fourier series has only cosine terms, and an odd function's Fourier series has only sine terms. So statements (A) and (C) are correct, while (B) and (D) are the reversed, incorrect versions of these facts.

A and C

Quick Tip: Work out whether $f(x)\cos(n\omega x)$ and $f(x)\sin(n\omega x)$ are even or odd for an even $f(x)$ and for an odd $f(x)$, then recall that an odd function integrates to zero over a symmetric interval.

. A circular curve having a radius of curvature of 1000 m is set out by connecting two straights with a deflection angle of 60°. The apex distance, in m, is . (Rounded off to three decimal places)

Correct Answer: 154.701

Solution:

Step 1: Understand the geometry of the curve.
When two straight roads meet at a point called the point of intersection (PI), a circular curve is inserted between them to give a smooth turn. The angle between the two straights, measured as the

change in direction, is the deflection angle Δ.
The apex distance (also called the external distance) is the length measured from the point of intersection straight along the bisector of Δ up to the curve. It tells a surveyor how far back from the PI the curve actually bulges.

Step 2: Write the formula for apex distance.
Consider the centre of the curve O, radius R, and the point of intersection I. The line OI bisects the deflection angle, so the angle between OI and either tangent line is $\Delta/2$.
In the right triangle formed by O, the tangent point, and I, the distance OI equals $R/\cos(\Delta/2)$, because R is the side adjacent to the angle $\Delta/2$ and OI is the hypotenuse.
The apex distance E is the part of OI that lies beyond the curve, so

$$E = OI - R = R\left(\sec\frac{\Delta}{2} - 1\right)$$

Step 3: Substitute the given values.
Here $R = 1000$ m and $\Delta = 60°$, so $\Delta/2 = 30°$.

$$\cos 30° = 0.866025$$

$$\sec 30° = \frac{1}{0.866025} = 1.154701$$

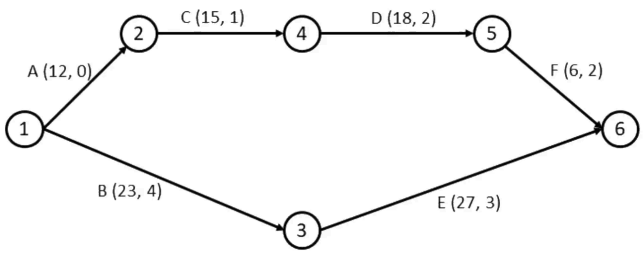
$$E = 1000 \times (1.154701 - 1) = 1000 \times 0.154701$$

Final Answer:

$$\boxed{E = 154.701 \text{ m}}$$

Quick Tip: Use the geometry of the curve centre, the point of intersection, and the tangent point to relate the radius and half the deflection angle to the apex distance.

. The expected time (P days) and standard deviation (Q days) of the different activities (A to F) in a project are indicated in the network diagram as (P, Q). The standard deviation of the project completion time, in days, is . (Rounded off to one decimal place)



Correct Answer: 3.0

Solution:

Step 1: Find the length of every path from node 1 to node 6.

The network has two routes from the start node 1 to the end node 6.

Path 1 goes through activities A, C, D, F: $1 \rightarrow 2 \rightarrow 4 \rightarrow 5 \rightarrow 6$.

Path 2 goes through activities B, E: $1 \rightarrow 3 \rightarrow 6$.

The expected duration of each activity is the first number P in its (P, Q) label.

Step 2: Add up the expected durations on each path.

Path 1: $A + C + D + F = 12 + 15 + 18 + 6 = 51$ days.

Path 2: $B + E = 23 + 27 = 50$ days.

Step 3: Identify the critical path.

The critical path in a PERT network is the longest path, since it decides the earliest possible completion time of the whole project. Path 1 (51 days) is longer than Path 2 (50 days), so activities A, C, D, F form the critical path.

Step 4: Add the variances of the critical activities.

For a PERT network, the variance of the project completion time is the sum of the variances of only the activities lying on the critical path. The variance of an activity is the square of its standard deviation Q.

$$\sigma_A^2 = 0^2 = 0, \quad \sigma_C^2 = 1^2 = 1, \quad \sigma_D^2 = 2^2 = 4, \quad \sigma_F^2 = 2^2 = 4$$

$$\sigma_{project}^2 = 0 + 1 + 4 + 4 = 9$$

Final Answer:

$$\sigma_{project} = \sqrt{9}$$

$$\boxed{\sigma_{project} = 3.0 \text{ days}}$$

Quick Tip: First find which chain of activities is the critical (longest) path, then add the squared standard deviations of only those activities.

. The shaft of a motor rotating at 50 rev s^{-1} is uniformly retarded to 20 rev s^{-1} in 15 s. The number of complete rotations the shaft makes in the given time is . (Answer in integer)

Correct Answer: 525

Solution:

Step 1: Note what uniform retardation means.
Uniform retardation means the angular speed decreases at a constant rate with time, just like uniform deceleration in straight-line motion. For such motion, the angular speed changes linearly from the initial value to the final value.

Step 2: Use the average angular speed to find total rotations.
Because the speed drops linearly, the average speed over the interval is simply the mean of the initial and final speeds.

$$N_{avg} = \frac{N_i + N_f}{2} = \frac{50 + 20}{2} = 35 \text{ rev/s}$$

The total number of rotations equals this average speed multiplied by the time taken.

$$n = N_{avg} \times t$$

Step 3: Substitute the values.

$$n = 35 \times 15 = 525$$

Final Answer:

The shaft makes 525 complete rotations while its speed drops from 50 rev/s to 20 rev/s in 15 s.

$$\boxed{n = 525}$$

Quick Tip: Since the retardation is uniform, the angular speed falls linearly, so the average speed times the time gives the total rotations.

. In an underground mine, an airflow of 30 $m^3\ s^{-1}$ is delivered through a circular opening having a diameter of 5 m and a length of 500 m. Assuming that there is no change in the surface characteristics, the diameter of the opening, in m, required to double the quantity of airflow at the same pressure loss is . (Rounded off to two decimal places)

Correct Answer: 6.60

Solution:

Step 1: Recall Atkinson's equation for airway pressure loss.

The frictional pressure loss H in a mine airway is given by Atkinson's equation:

$$H = k\frac{PLQ^2}{A^3}$$

where k is the friction factor of the airway surface, P is the perimeter

of the cross-section, L is the length of the airway, Q is the quantity of airflow, and A is the cross-sectional area.

Step 2: Write P and A in terms of the diameter for a circular airway.
For a circular opening of diameter D,

$$P = \pi D, \qquad A = \frac{\pi D^2}{4}$$

Substituting these into Atkinson's equation gives

$$H = k\frac{(\pi D)LQ^2}{(\pi D^2/4)^3} = \frac{64\,kLQ^2}{\pi^2 D^5}$$

So for a fixed k and L, the pressure loss depends on the airflow and diameter as $H \propto Q^2/D^5$.

Step 3: Apply the condition of equal pressure loss.
The surface characteristics (so k) and the length L stay the same, and the pressure loss H must stay the same while the airflow doubles from $Q_1 = 30$ to $Q_2 = 60\ \mathrm{m^3/s}$.

$$\frac{Q_1^2}{D_1^5} = \frac{Q_2^2}{D_2^5}$$

$$D_2^5 = D_1^5\left(\frac{Q_2}{Q_1}\right)^2$$

Step 4: Substitute the numbers and solve for D2.

$$D_2^5 = 5^5 \times \left(\frac{60}{30}\right)^2 = 3125 \times 4 = 12500$$

$$D_2 = 12500^{1/5}$$

$$D_2 = 6.5975 \text{ m}$$

Final Answer:

$$\boxed{D_2 = 6.60 \text{ m}}$$

Quick Tip: Use Atkinson's equation for airway pressure loss and note how it depends on the diameter of a circular opening through the perimeter and area.

. In an underground mine atmosphere, the alcohol of a Kata thermometer took 60 s to fall from 38°C to 35°C. The Kata factor of the thermometer is 480 milli-calories cm^{-2}. The Kata cooling power, in $W\,m^{-2}$, is . (Rounded off to one decimal place)

Correct Answer: 334.9

Solution:

Step 1: Recall the working of a Kata thermometer.

A Kata thermometer is an alcohol-in-glass thermometer used to measure the cooling power of mine air, which combines the effects of

air temperature, humidity and velocity into one number. It is first warmed above a marked upper temperature and then allowed to cool in the air being tested. The time it takes for the alcohol column to fall between two marked temperatures is recorded.
Each thermometer carries its own Kata factor F, stamped on the stem, which represents the heat lost per unit area of the bulb while the alcohol falls through that marked range.

Step 2: Write the formula for dry Kata cooling power.
The dry cooling power H is the heat lost per unit area per second, found by dividing the Kata factor by the time taken for the fall.

$$H = \frac{F}{t}$$

where F is in milli-calories per cm^2 and t is in seconds, so H comes out in milli-calories $\text{cm}^{-2}\ \text{s}^{-1}$.

Step 3: Substitute the given values.
Here $F = 480$ milli-calories cm^{-2} and $t = 60$ s (the time for the alcohol to fall from 38°C to 35°C).

$$H = \frac{480}{60} = 8 \text{ milli-cal cm}^{-2}\text{s}^{-1}$$

Step 4: Convert milli-calories per cm squared per second into watts per m squared.
One calorie equals 4.186 J, so one milli-calorie equals 4.186×10^{-3} J.

$$H = 8 \times 4.186 \times 10^{-3} \text{ J cm}^{-2}\text{s}^{-1} = 0.033488 \text{ W cm}^{-2}$$

One m^2 has 10^4 cm^2, so multiply by 10^4 to convert cm^2 to m^2.

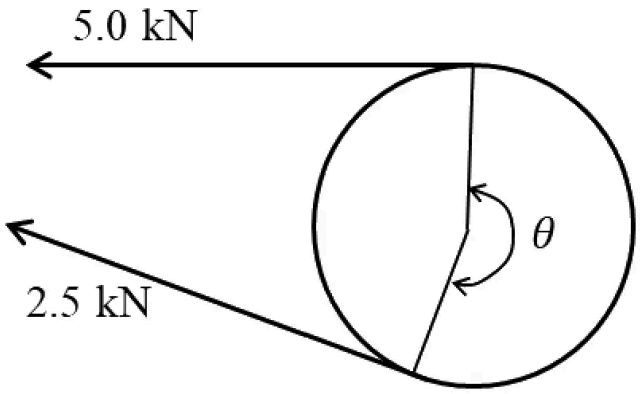
$$H = 0.033488 \times 10^4 = 334.88 \text{ W m}^{-2}$$

Final Answer:

$$\boxed{H = 334.9 \text{ W m}^{-2}}$$

Quick Tip: Divide the Kata factor by the fall time to get the cooling power in milli-calories per cm squared per second, then convert the units to W per m squared.

. A belt is wrapped around a pulley as shown in the figure. The coefficient of friction between the belt and pulley is 0.3. If there is no slippage between the belt and pulley, the angle of wrap (θ), in degrees, is . (Rounded off to two decimal places)



Correct Answer: 132.38

Solution:

Step 1: Identify which formula governs belt friction.

When a flat belt wraps around a pulley without slipping, the tension is different on the two sides because friction between the belt and the pulley surface holds part of the load. The relationship between the tight side tension T_1 and the slack side tension T_2 at the point of slipping is given by the belt friction (capstan) equation:

$$\frac{T_1}{T_2} = e^{\mu\theta}$$

where μ is the coefficient of friction and θ is the angle of wrap in radians.

Step 2: Identify the tight and slack side tensions.

From the figure, the belt pulls with 5.0 kN on one side and 2.5 kN on the other side. The larger pull is the tight side, so $T_1 = 5.0$ kN and $T_2 = 2.5$ kN.

Step 3: Solve the capstan equation for the angle of wrap.

Taking the natural log of both sides of the equation,

$$\ln\left(\frac{T_1}{T_2}\right) = \mu\theta$$

$$\theta = \frac{1}{\mu}\ln\left(\frac{T_1}{T_2}\right)$$

Step 4: Substitute the given values.

$$\frac{T_1}{T_2} = \frac{5.0}{2.5} = 2$$

$$\theta = \frac{\ln 2}{0.3} = \frac{0.693147}{0.3} = 2.31049 \text{ rad}$$

Converting radians to degrees by multiplying by $180/\pi$:

$$\theta = 2.31049 \times \frac{180}{\pi} = 132.38^\circ$$

Final Answer:

$$\boxed{\theta = 132.38^\circ}$$

Quick Tip: Use the belt friction (capstan) equation relating the tight side and slack side tensions to the coefficient of friction and the angle of wrap.

. The value of the determinant of the Hessian of $f(x, y) = x^2 + y^2 + xy - 8x - 7y$ at its stationary point is

(A) 2

(B) 3

(C) 4

(D) 5

Correct Answer: (B) 3

Solution:

Step 1: Find the stationary point.

A stationary point is where both first partial derivatives are zero.

$$f_x = \frac{\partial f}{\partial x} = 2x + y - 8$$

$$f_y = \frac{\partial f}{\partial y} = 2y + x - 7$$

Set both equal to zero: $2x + y - 8 = 0$ and $x + 2y - 7 = 0$.
From the first equation, $y = 8 - 2x$. Put this into the second equation: $x + 2(8 - 2x) - 7 = 0$, so $x + 16 - 4x - 7 = 0$, giving $-3x + 9 = 0$, so $x = 3$.
Then $y = 8 - 2(3) = 2$. The stationary point is $(3, 2)$.

Step 2: Write the Hessian matrix.
The Hessian collects the second partial derivatives.

$$f_{xx} = 2, \quad f_{yy} = 2, \quad f_{xy} = f_{yx} = 1$$

$$H = \begin{pmatrix} f_{xx} & f_{xy} \\ f_{yx} & f_{yy} \end{pmatrix} = \begin{pmatrix} 2 & 1 \\ 1 & 2 \end{pmatrix}$$

Since f is a plain quadratic in x and y, these second derivatives are constants, so the Hessian is the same at every point, not just at $(3, 2)$.

Step 3: Compute the determinant.

$$\det(H) = f_{xx}f_{yy} - (f_{xy})^2 = (2)(2) - (1)^2 = 4 - 1 = 3$$

Option (C) 4 is what you get if you multiply the diagonal terms and forget to subtract the square of the off diagonal term. Options (A) 2

and (D) 5 come from similar slips in combining the four entries.

Final Answer:
The determinant of the Hessian at the stationary point is 3.

$$\boxed{3}$$

Quick Tip: Find the stationary point, then look at the second partial derivatives. For a quadratic function these do not change with position.

. Given the data in the following table, Newton's divided difference interpolation polynomial is

$$y = b_0 + b_1(x - 2) + b_2(x - 2)(x - 2.5)$$

If the values of b_0 and b_1 are 3 and 1, respectively, then the value of b_2 is

x	2.0	2.5	3.0
y	3.0	3.5	5.0

(A) 2

(B) 3

(C) 4

(D) 5

Correct Answer: (A) 2

Solution:

Step 1: Recall what b0, b1, b2 mean in Newton's divided difference form.

For the polynomial $y = b_0 + b_1(x - x_0) + b_2(x - x_0)(x - x_1)$, the coefficients are the divided differences: $b_0 = f[x_0]$, $b_1 = f[x_0, x_1]$, and $b_2 = f[x_0, x_1, x_2]$.

Here $x_0 = 2.0$, $x_1 = 2.5$, $x_2 = 3.0$, with y values 3.0, 3.5 and 5.0.

Step 2: Check b0 and b1 against the table.

$$b_0 = f[x_0] = 3.0$$

$$b_1 = f[x_0, x_1] = \frac{f(x_1) - f(x_0)}{x_1 - x_0} = \frac{3.5 - 3.0}{2.5 - 2.0} = \frac{0.5}{0.5} = 1.0$$

Both match the values 3 and 1 given in the question, so the table is being read correctly.

Step 3: Find the second divided difference b2.

First get $f[x_1, x_2]$:

$$f[x_1, x_2] = \frac{f(x_2) - f(x_1)}{x_2 - x_1} = \frac{5.0 - 3.5}{3.0 - 2.5} = \frac{1.5}{0.5} = 3.0$$

Now combine it with $f[x_0, x_1]$ over the full span $x_2 - x_0$:

$$b_2 = f[x_0, x_1, x_2] = \frac{f[x_1, x_2] - f[x_0, x_1]}{x_2 - x_0} = \frac{3.0 - 1.0}{3.0 - 2.0} = \frac{2.0}{1.0} = 2.0$$

Option (B) 3 comes from mistakenly using $f[x_1, x_2]$ alone without subtracting $f[x_0, x_1]$. Option (C) 4 comes from dividing by $x_1 - x_0 = 0.5$ instead of the correct span $x_2 - x_0 = 1.0$.

Final Answer:

The value of b2 is 2.

$$\boxed{2}$$

Quick Tip: Recall that Newton's divided difference coefficients are the successive divided differences: b0, then b1, then b2.

. Given $\mathbf{x} = \begin{pmatrix} 1 \\ 2 \\ 1 \end{pmatrix}$, $\mathbf{b} = \begin{pmatrix} -16 \\ -3 \\ 7 \end{pmatrix}$, $\mathbf{P}^{-1} = \begin{pmatrix} e & -6 & -7 \\ f & 9 & 11 \\ -1 & -2 & g \end{pmatrix}$ and $\mathbf{Px} = \mathbf{b}$.

If $\mathbf{Py} = \mathbf{d}$ with $\mathbf{y} = \begin{pmatrix} y_1 \\ y_2 \\ y_3 \end{pmatrix}$ and $\mathbf{d} = \begin{pmatrix} -16 \\ 0 \\ 7 \end{pmatrix}$, the value of y_2 is

(A) 29

(B) 27

(C) 25

(D) 5

Correct Answer: (A) 29

Solution:

Step 1: Turn Px=b into a usable equation for the unknowns in P^{-1}.

We are told $\mathbf{Px} = \mathbf{b}$. Multiplying both sides on the left by $\mathbf{P}^{-1}$ gives $\mathbf{P}^{-1}\mathbf{Px} = \mathbf{P}^{-1}\mathbf{b}$, and since $\mathbf{P}^{-1}\mathbf{P} = I$, this simplifies to $\mathbf{x} = \mathbf{P}^{-1}\mathbf{b}$.

So the known vectors $\mathbf{x}$ and $\mathbf{b}$ let us pin down the unknown entries e, f, g inside $\mathbf{P}^{-1}$, without ever needing $\mathbf{P}$ itself.

Step 2: Write out the three scalar equations.

Row 1: $e(-16) + (-6)(-3) + (-7)(7) = 1$

Row 2: $f(-16) + (9)(-3) + (11)(7) = 2$

Row 3: $(-1)(-16) + (-2)(-3) + g(7) = 1$

Step 3: Solve each row for its unknown.

Row 1: $-16e + 18 - 49 = 1 \Rightarrow -16e - 31 = 1 \Rightarrow -16e = 32 \Rightarrow e = -2.$

Row 2: $-16f - 27 + 77 = 2 \Rightarrow -16f + 50 = 2 \Rightarrow -16f = -48 \Rightarrow f = 3.$

Row 3: $16 + 6 + 7g = 1 \Rightarrow 22 + 7g = 1 \Rightarrow 7g = -21 \Rightarrow g = -3.$

So $\mathbf{P}^{-1} = \begin{pmatrix} -2 & -6 & -7 \\ 3 & 9 & 11 \\ -1 & -2 & -3 \end{pmatrix}$.

Step 4: Apply the same P^{-1} to the new system.

By the same logic as Step 1, $\mathbf{Py} = \mathbf{d}$ means $\mathbf{y} = \mathbf{P}^{-1}\mathbf{d}$, using the exact $\mathbf{P}^{-1}$ just found in full.

y_2 comes from row 2 of $\mathbf{P}^{-1}$:

$$y_2 = (3)(-16) + (9)(0) + (11)(7) = -48 + 0 + 77 = 29$$

Options (B) 27, (C) 25 and (D) 5 come from arithmetic slips, such as dropping a sign on the -48 term or picking the wrong row of $\mathbf{P}^{-1}$.

Final Answer:

The value of y2 is 29.

$$\boxed{29}$$

Quick Tip: Use Px=b to pin down the unknown entries of P inverse first, then apply the same P inverse to the new vector d.

. Match the type of rock with its metamorphic form.

Igneous/Sedimentary rock	Metamorphic rock
(P) Shale	(1) Gneiss
(Q) Limestone	(2) Quartzite
(R) Granite	(3) Marble
(S) Sandstone	(4) Slate

(A) P → 4, Q → 3, R → 1, S → 2

(B) P → 3, Q → 1, R → 4, S → 2

(C) P → 4, Q → 3, R → 2, S → 1

(D) P → 3, Q → 4, R → 2, S → 1

Correct Answer: (A) P → 4, Q → 3, R → 1, S → 2

Solution:

Step 1: Understanding the Question.

The question gives four parent rocks, shale, limestone, granite and sandstone, and asks which metamorphic rock each one turns into under heat and pressure.

Step 2: Key Concept.

Metamorphism changes a rock's texture and mineral makeup without melting it. Each parent rock has a well known metamorphic product.
Shale (a fine grained, clay rich sedimentary rock) turns into slate at low grade, and into phyllite, schist or gneiss as the grade rises.
Limestone (mostly calcite) recrystallises into marble.
Quartz rich sandstone recrystallises into quartzite.
Granite (an igneous rock rich in quartz, feldspar and mica) develops banding of light and dark minerals under strong regional metamorphism and becomes gneiss.

Step 3: Match each pair.

(P) Shale → Slate, which is (4).

(Q) Limestone → Marble, which is (3).

(R) Granite → Gneiss, which is (1).

(S) Sandstone → Quartzite, which is (2).

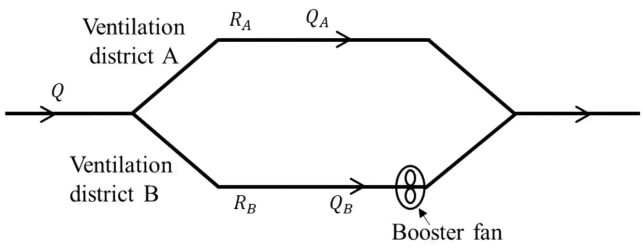
Option (B) swaps shale's and limestone's products. Options (C) and (D) both send granite to quartzite and sandstone to gneiss, which is backwards, granite has no quartz sand texture to turn into quartzite, and sandstone does not build the coarse banding that defines gneiss.

Step 4: Final Answer.

P → 4, Q → 3, R → 1, S → 2, which is option (A).

Quick Tip: Think about what each parent rock turns into under contact or regional metamorphism.

. In an underground coal mine, the air quantities Q_A and Q_B pass through ventilation districts A and B, respectively, as shown, with a pressure drop of ΔP across them. The air quantity in district B is to be increased to Q'_B by installing a booster fan, as shown, without affecting the air quantity in ventilation district A. The capacity of the booster fan (P_B) can be expressed as



(A) $P_B = \Delta P\left(\frac{Q_B}{Q'_B}\right)^2 - \Delta P$

(B) $P_B = \Delta P\left(\frac{Q'_B}{Q_B}\right)^2 - \Delta P$

(C) $P_B = \Delta P - \Delta P\left(\frac{Q'_B}{Q_B}\right)^2$

(D) $P_B = \Delta P + \Delta P\left(\frac{Q'_B}{Q_B}\right)^2$

Correct Answer: (B) $P_B = \Delta P\left(\frac{Q'_B}{Q_B}\right)^2 - \Delta P$

Solution:

Step 1: Set up the pressure balance for the two parallel airways.

Ventilation districts A and B run in parallel between the same two junctions, so the pressure drop across each one must be the same value ΔP, even though the air quantities Q_A and Q_B can differ if the resistances differ.

Using the mine ventilation square law, pressure drop equals resistance times the square of the airflow:

$$\Delta P = R_A Q_A^2 = R_B Q_B^2$$

Step 2: Get the resistance of district B before the booster fan is added.

From $\Delta P = R_B Q_B^2$:

$$R_B = \frac{\Delta P}{Q_B^2}$$

This resistance R_B is a property of the airway itself, its size, shape and

roughness, so it does not change when the booster fan is switched on.

Step 3: Work out the new frictional drop once the flow rises to Q_B'.
The airway still obeys the same square law, just at the new higher flow:

$$R_B(Q'_B)^2 = \frac{\Delta P}{Q_B^2}(Q'_B)^2 = \Delta P\left(\frac{Q'_B}{Q_B}\right)^2$$

Since the problem states that Q_A, and therefore the pressure available between the two junctions, must stay at ΔP, only ΔP of pressure is available naturally to push air through district B. Anything beyond that has to come from the booster fan.

Step 4: Find the fan capacity.
The fan must supply the extra pressure not covered by the available ΔP:

$$P_B = \Delta P\left(\frac{Q'_B}{Q_B}\right)^2 - \Delta P$$

Option (A) inverts the ratio of Q_B and Q'_B, which would mean the fan capacity shrinks as the flow rises, the opposite of what a booster fan does. Options (C) and (D) get the sign of the subtraction wrong, either flipping which term is subtracted from which, or adding instead of subtracting.

Final Answer:

The booster fan capacity is $P_B = \Delta P\left(\frac{Q'_B}{Q_B}\right)^2 - \Delta P$, which is option (B).

$$\boxed{P_B = \Delta P\left(\frac{Q'_B}{Q_B}\right)^2 - \Delta P}$$

Quick Tip: Write the pressure balance for the two parallel airways and see what extra head the fan must supply once B's flow goes up.

.

Match the shaft sinking method with its applicability.

Shaft sinking method	Applicability
(P) Piling system	(1) Strata consisting of alternate strong and loose soil, and drum sinks down by its own weight
(Q) Caisson method	(2) Sinking through the loose ground near the surface
(R) Cementation	(3) Heavily watery strata, including quick sand
(S) Freezing	(4) Fissured water bearing strata without running sand

(A) $P \to 2,\ Q \to 3,\ R \to 4,\ S \to 1$

(B) $P \to 4,\ Q \to 1,\ R \to 2,\ S \to 3$

(C) $P \to 2,\ Q \to 1,\ R \to 4,\ S \to 3$

(D) $P \to 4,\ Q \to 3,\ R \to 2,\ S \to 1$

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

Solution:

Step 1: Know what each shaft sinking method actually does.

Piling system uses timber or steel piles driven ahead of the excavation to hold back the ground. It works only in shallow, loose ground close to the surface, because piles cannot be driven very deep.

Caisson (drum) method sinks a rigid cylindrical curb, called a caisson, under its own weight. The cutting edge of the caisson bites into loose ground while the strong bands of strata support the caisson's weight as it goes down, so this method suits strata with alternating strong and loose layers.

Cementation seals the ground by pumping cement grout under pressure into the fissures and cracks of the rock, so it works on fissured, water bearing strata, but only when there is no running or quick sand, because a fast flow of sand and water would wash the grout away before it sets.

Freezing turns the water in the ground into ice around the shaft, forming a temporary ice wall strong enough to sink through. It is kept for the worst conditions, heavily watery ground that includes running or quick sand, where cementation cannot be trusted.

Step 2: Match P, Q, R, S against 1, 2, 3, 4.

P (Piling system) needs shallow, loose ground near the surface, which is description (2).

Q (Caisson method) needs alternating strong and loose soil with the drum sinking under its own weight, which is description (1).

R (Cementation) needs fissured water bearing strata without running sand, which is description (4).

S (Freezing) needs heavily watery strata including quick sand, which is description (3).

Step 3: Check why the other options fail.

Option (A) sends P to (2) correctly but puts Q against (3), which is freezing's job, not caisson's.

Options (B) and (D) both put P against (4), but piling cannot handle fissured water bearing strata, that needs cementation.

Final Answer:

The correct match is P to 2, Q to 1, R to 4, S to 3.

$$\boxed{P \to 2,\ Q \to 1,\ R \to 4,\ S \to 3}$$

Quick Tip: Think about which method can handle running or quick sand, and which one only works in shallow, loose ground near the surface.

.

A shovel needs to be selected from four models of different capacities, S1 to S4, for loading of dumpers. The operational data for the shovel-dumper combination are provided. The mean arrival rate of the dumpers at the loading point is 5 per hour and the waiting cost of dumper is ₹200 per hour. The inter-arrival time of dumpers and loading time of shovel follows exponential distribution. Ignoring the shovel hiring cost, the shovel type that will have minimum total cost (waiting and operating cost) is

Model	Operating cost of shovel (₹ per hour)	Mean loading rate of shovel (number of dumpers per hour)
S1	800	8
S2	850	9
S3	920	10
S4	1000	11

(A) S1

(B) S2

(C) S3

(D) S4

Correct Answer: (B) S2

Solution:

Step 1: Recognise the queueing model.

Dumpers arrive at random (exponential inter-arrival time) and each shovel loads one dumper at a time, also at a random (exponential) rate. That makes this a single server queue, model M/M/1, one queue for each shovel choice.

The mean arrival rate is $\lambda = 5$ dumpers per hour, and each shovel model has its own mean service (loading) rate μ.

Step 2: Write the total cost formula.

For an M/M/1 queue, the expected number of dumpers in the system, waiting plus being loaded, is

$$L_s = \frac{\lambda}{\mu - \lambda}$$

The total cost per hour for a shovel model is its fixed operating cost plus the waiting cost charged on every dumper present in the system:

$$TC = C_{operating} + C_{wait} \times L_s$$

Here $C_{wait} = 200$ rupees per dumper per hour.

Step 3: Compute L_s and the waiting cost for each model.

For S1: $\mu = 8$, so $\mu - \lambda = 3$, $L_s = 5/3 = 1.667$, waiting cost $= 200 \times 1.667 = 333.33$.

For S2: $\mu = 9$, so $\mu - \lambda = 4$, $L_s = 5/4 = 1.25$, waiting cost $= 200 \times 1.25 = 250$.

For S3: $\mu = 10$, so $\mu - \lambda = 5$, $L_s = 5/5 = 1$, waiting cost $= 200 \times 1 = 200$.

For S4: $\mu = 11$, so $\mu - \lambda = 6$, $L_s = 5/6 = 0.833$, waiting cost $= 200 \times 0.833 = 166.67$.

Step 4: Add operating cost to get total cost, and compare.

S1: $800 + 333.33 = 1133.33$

S2: $850 + 250 = 1100.00$

S3: $920 + 200 = 1120.00$

S4: $1000 + 166.67 = 1166.67$

Final Answer:

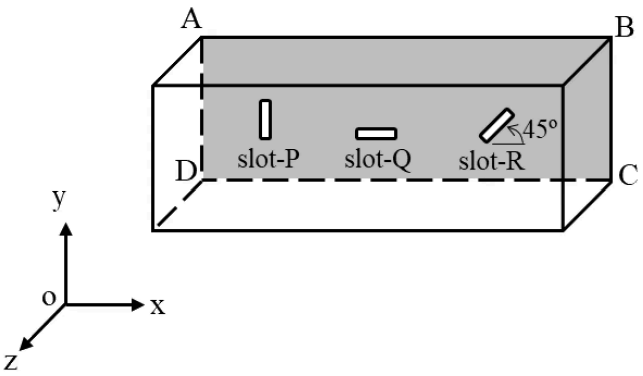
S2 gives the lowest total cost, ₹1100 per hour, even though its operating cost is not the cheapest of the four. A slower, cheaper shovel like S1 looks good on paper, but it makes dumpers queue up for longer, and that waiting cost outweighs the saving on the shovel. A faster, pricier shovel like S3 or S4 clears the queue fast, but its high operating cost is not worth paying once the queue is already short.

$\boxed{S2}$

Quick Tip: Set up an M/M/1 queue for each shovel and add its waiting cost, from the expected number of dumpers in the system, to its operating cost.

.

The *in-situ* stresses are determined by the Flat-jack method by making three slots (P, Q, and R) on the wall (ABCD) of a mine gallery as shown. The *in-situ* stresses σ_P, σ_Q, and σ_R are determined at slot-P, slot-Q, and slot-R, respectively. If $\sigma_P > \sigma_Q$, and $\sigma_R = 0$, the shear stress on the wall is



(A) $\frac{\sigma_P + \sigma_Q}{2}$

(B) $\frac{\sigma_P - \sigma_Q}{2}$

(C) $-\left(\frac{\sigma_P + \sigma_Q}{2}\right)$

(D) $-\left(\frac{\sigma_P - \sigma_Q}{2}\right)$

Correct Answer: (A) $\frac{\sigma_P + \sigma_Q}{2}$

Solution:

Step 1: Set up what the flat jack actually measures.

A flat jack slot is cut into the rock, and the surrounding rock tries to close that slot. The pressure needed in the jack to just stop the closure equals the in-situ normal stress acting perpendicular to the slot's flat face, in the plane of the wall.

Slot-P is cut as a vertical slit, so its flat face is vertical, and it measures the normal stress acting along the horizontal direction of the wall, call this σ_x. So $\sigma_P = \sigma_x$.

Slot-Q is cut as a horizontal slit, so it measures the normal stress acting along the vertical direction of the wall, call this σ_y. So $\sigma_Q = \sigma_y$.

Slot-R is cut at 45 degrees to the horizontal. The stress it measures acts perpendicular to its own flat face, which is 90 degrees away from the slot's own line, so the direction it measures is at 135 degrees from the horizontal x-axis, not 45 degrees.

Step 2: Write the normal stress transformation formula.

For a 2D stress state with components σ_x, σ_y and shear τ_{xy}, the normal stress on a plane whose outward normal makes angle θ with the x-axis is

$$\sigma_\theta = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2}\cos(2\theta) + \tau_{xy}\sin(2\theta)$$

Step 3: Apply it to slot-R's direction, $\theta = 135°$.

At $\theta = 135°$, $2\theta = 270°$, so $\cos(2\theta) = 0$ and $\sin(2\theta) = -1$.

$$\sigma_R = \frac{\sigma_x + \sigma_y}{2} + 0 - \tau_{xy}$$

Since $\sigma_x = \sigma_P$ and $\sigma_y = \sigma_Q$, this becomes

$$\sigma_R = \frac{\sigma_P + \sigma_Q}{2} - \tau_{xy}$$

Step 4: Solve for the shear stress.

$$\tau_{xy} = \frac{\sigma_P + \sigma_Q}{2} - \sigma_R$$

We are told $\sigma_R = 0$, so

$$\tau_{xy} = \frac{\sigma_P + \sigma_Q}{2}$$

The condition $\sigma_P > \sigma_Q$ only tells us the two normal stresses are unequal, it does not change this formula for the shear stress.

Final Answer:

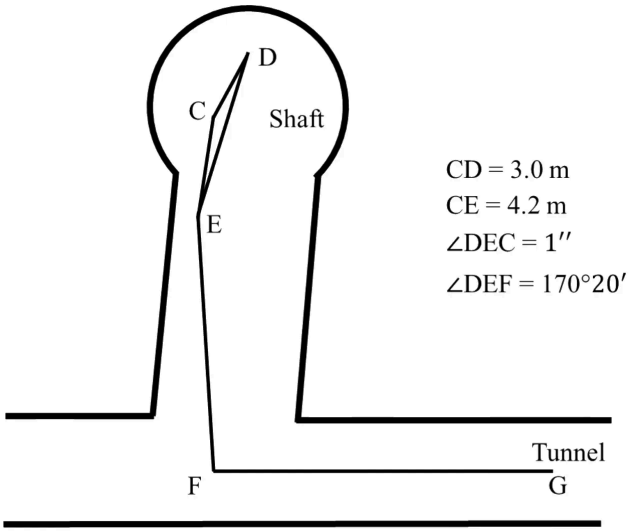
The shear stress on the wall is $(\sigma_P + \sigma_Q)/2$, which rules out the options with a minus sign inside the bracket (those would come from mixing up σ_P and σ_Q) and the options with an overall negative sign in front (those would come from wrongly treating slot-R's measuring direction as 45 degrees instead of the correct 135 degrees).

$$\tau = \frac{\sigma_P + \sigma_Q}{2}$$

Quick Tip: Remember a flat jack reads the stress perpendicular to its own slot direction, not along it, so the 45 degree slot actually measures the 135 degree direction.

.

The observations from a correlation survey are shown. If the coordinates of points C and D are (East: 375 m, North: 1120 m) and (East: 376 m, North: 1121 m), respectively, the whole circle bearing of the line EF is



CD = 3.0 m

CE = 4.2 m

$\angle DEC = 1''$

$\angle DEF = 170°20'$

(A) $215^\circ\,19'\,59.6''$

(B) $35^\circ\,19'\,59.6''$

(C) $215^\circ\,20'\,1.4''$

(D) $35^\circ\,20'\,1.4''$

Correct Answer: (C) $215^\circ\,20'\,1.4''$

Solution:

Step 1: Get the bearing of CD from the coordinates.

The whole circle bearing of a line is measured clockwise from north, and for a line from point 1 to point 2 it is found from $\theta = \tan^{-1}\left(\frac{\Delta E}{\Delta N}\right)$, taking the correct quadrant.

$\Delta E = 376 - 375 = 1$ m, $\Delta N = 1121 - 1120 = 1$ m, both positive, so line CD lies in the northeast quadrant.

$$\theta_{CD} = \tan^{-1}\left(\frac{1}{1}\right) = 45^\circ$$

So the bearing of C to D is 45°, and the reverse bearing, D to C, is $45^\circ + 180^\circ = 225^\circ$.

Step 2: Solve the Weisbach (near-collinear) triangle CDE for the small angle at D.

Points D, C and E lie almost in a straight line down the shaft; the angle at E between the two wires, $\angle DEC = 1''$, is tiny because C and D are close together while E is well below. By the sine rule in triangle CDE, side CD is opposite the angle at E, and side CE is opposite the angle at D:

$$\frac{CD}{\sin(\angle E)} = \frac{CE}{\sin(\angle D)} \quad \Rightarrow \quad \sin(\angle D) = \frac{CE}{CD}\sin(\angle E)$$

Because $1''$ is such a tiny angle, $\sin(\angle E) \approx \angle E$ in radians, and the same holds for $\angle D$, so

$$\angle D \approx \frac{CE}{CD} \times \angle E = \frac{4.2}{3.0} \times 1'' = 1.4''$$

Step 3: Carry this small angle onto the bearing of DE, then reverse it to get the bearing of ED.

The direction D to E deviates from the direction D to C by this small angle $\angle D$, so

$$\text{bearing}(D \to E) = 225^\circ + 1.4'' = 225^\circ 00' 01.4''$$

Reversing this line gives the bearing E to D:

$$\text{bearing}(E \to D) = 225^\circ 00' 01.4'' - 180^\circ = 45^\circ 00' 01.4''$$

Step 4: Add the measured angle DEF to reach the bearing of EF.

The angle $\angle DEF = 170^\circ 20'$ is measured clockwise from line ED to line EF at station E, so

$$\text{bearing}(E \to F) = 45^\circ 00' 01.4'' + 170^\circ 20' 00'' = 215^\circ 20' 01.4''$$

Final Answer:

Working the coordinates and the Weisbach triangle through cleanly gives $215^\circ 20' 1.4''$, option (C). Note for the student: the official key for this question was marked MTA (marks awarded to all candidates),

most likely because the sign of the tiny correction angle at D (which side the wires deviate to, as seen from station E) cannot be pinned down from a flat page diagram alone, and reading it the other way lands about 2.8 seconds away from this value, close to but not exactly matching option (A). This working supports option (C).

$$\boxed{215°20'1.4''}$$

Quick Tip: Find the bearing of CD from the coordinates first, then use the sine rule on the tiny angle DEC to carry that bearing down to station E before adding angle DEF.

. A closed-circuit self-contained breathing apparatus (SCBA) contains 2 liters of O_2 at 200 bar. If a miner uses O_2 at a rate of 2 liters $\mathbf{min}^{-1}$, the maximum duration that the apparatus can supply O_2, in *min*, is . *(answer in integer)*

Correct Answer: 200

Solution:

Step 1: Find the free air volume stored in the cylinder.
The SCBA cylinder holds 2 liters of oxygen, but that oxygen is packed in at 200 bar. To find how much oxygen this really is once it expands to normal breathing pressure of 1 bar, multiply the stored volume by the pressure.

$$V_{free} = V_{cylinder} \times P = 2 \times 200 = 400 \text{ liters}$$

So the apparatus effectively carries 400 liters of oxygen measured at

normal atmospheric pressure.

Step 2: Divide the free air volume by the breathing rate.
The miner uses oxygen at 2 liters per minute, and this rate is already stated at normal pressure, so it can be compared directly with the free air volume found in Step 1.

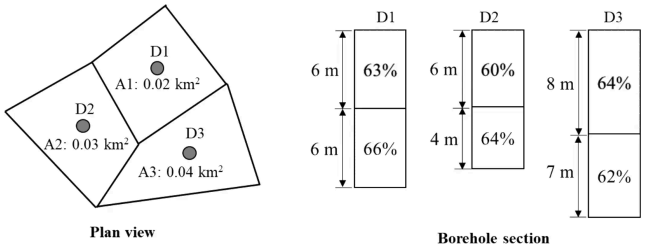
$$t = \frac{V_{free}}{\text{rate}} = \frac{400}{2} = 200 \text{ min}$$

Final Answer:
The SCBA can supply oxygen for 200 minutes before it runs out.

$$\boxed{200 \text{ min}}$$

Quick Tip: Turn the cylinder volume and pressure into an equivalent free air volume, then divide by the breathing rate.

. The borehole data for resource estimation for an iron ore deposit are shown.



Index:
D1 to D3: Exploratory Borehole ID
A1 to A3: Corresponding Polygonal Area

The average grade of the deposit, in %, is . *(rounded off to two decimal places)*

Correct Answer: 62.98

Solution:

Step 1: Find the thickness-weighted average grade inside each borehole.

Each borehole cuts through two ore bands of different thickness and grade. Within one borehole, the grade must first be averaged over its own two intercepts, weighting each by how thick it is, since a thicker band carries more ore.

Borehole D1 has 6 m at 63% and 6 m at 66%:

$$g_{D1} = \frac{6(63) + 6(66)}{6 + 6} = \frac{378 + 396}{12} = 64.50\%$$

Borehole D2 has 6 m at 60% and 4 m at 64%:

$$g_{D2} = \frac{6(60) + 4(64)}{6 + 4} = \frac{360 + 256}{10} = 61.60\%$$

Borehole D3 has 8 m at 64% and 7 m at 62%:

$$g_{D3} = \frac{8(64) + 7(62)}{8 + 7} = \frac{512 + 434}{15} = 63.07\%$$

Step 2: Weight each borehole's grade by its share of ore volume.

Each borehole represents a polygon of influence with plan area A1 = 0.02 km2 (D1), A2 = 0.03 km2 (D2), and A3 = 0.04 km2 (D3). The tonnage a borehole represents depends on both the area it covers and the thickness of ore it meets, so the correct weight for combining grades is area times thickness, not area alone.

$$W_{D1} = 0.02 \times 12 = 0.24, \quad W_{D2} = 0.03 \times 10 = 0.30, \quad W_{D3} = 0.04 \times 15 = 0.60$$

Step 3: Combine into the overall average grade.

The deposit's average grade is the tonnage-weighted mean of the three borehole grades.

$$\bar{g} = \frac{W_{D1}g_{D1} + W_{D2}g_{D2} + W_{D3}g_{D3}}{W_{D1} + W_{D2} + W_{D3}}$$

$$\bar{g} = \frac{0.24(64.50) + 0.30(61.60) + 0.60(63.07)}{0.24 + 0.30 + 0.60} = \frac{15.48 + 18.48 + 37.84}{1.14} = \frac{71.80}{1.14} = 62.98\%$$

Final Answer:

The average grade of the deposit is about 62.98%.

$$\boxed{62.98\%}$$

Quick Tip: First average the grade inside each borehole by intercept thickness, then combine the three boreholes using area times thickness as the weight.

. A mine workshop needs to assign 4 jobs to 4 service engineers. The cost for performing a job by an individual service engineer is given. A typical job can be assigned to only one service engineer. If the service engineer S1 cannot perform the job J3, and S3 cannot perform the job J4, the optimal cost for completion of jobs is . *(answer in integer)*

Service Engineer	J1	J2	J3	J4
S1	50	50	---	20
S2	70	40	20	70
S3	90	30	50	---
S4	70	20	60	30

Correct Answer: 130

Solution:

Step 1: Set up the cost matrix and block the forbidden pairs.
This is a standard assignment problem: 4 engineers, 4 jobs, one job per engineer, minimize total cost. Since S1 cannot do J3 and S3 cannot do J4, replace those two cells with a very large cost M so the algorithm never picks them.

	$J1$	$J2$	$J3$	$J4$
$S1$	50	50	M	20
$S2$	70	40	20	70
$S3$	90	30	50	M
$S4$	70	20	60	30

Step 2: Reduce rows and columns (Hungarian method).

Subtract each row's smallest entry from that row. Row minimums are 20, 20, 30 and 20 for S1 to S4.

	$J1$	$J2$	$J3$	$J4$
$S1$	30	30	M	0
$S2$	50	20	0	50
$S3$	60	0	20	M
$S4$	50	0	40	10

Now subtract each column's smallest remaining entry. Only column J1 still has a nonzero minimum (30), so subtract 30 from column J1. Columns J2, J3 and J4 already contain a zero each.

	$J1$	$J2$	$J3$	$J4$
$S1$	0	30	M	0
$S2$	20	20	0	50
$S3$	30	0	20	M
$S4$	20	0	40	10

Step 3: Try a complete zero assignment, adjust if it is blocked.

S2's only zero is J3, so S2 must take J3. S3 and S4 both only show a zero at J2, so they compete for it, while S1's zeros sit at J1 and J4. Covering every zero needs only 3 lines (row S1, column J2, column J3), which is fewer than the matrix size of 4, so the matrix is not yet optimal. By the Hungarian rule, subtract the smallest uncovered value (10, at S4-J4) from every uncovered cell and add it to cells covered twice.

This reshuffles the zeros so S1 keeps J1 and J4 as zeros, S2 keeps J3,

S3's only zero becomes J2, and a fresh zero opens up at S4-J4, giving a complete assignment: S1-J1, S2-J3, S3-J2, S4-J4.

Step 4: Add up the actual costs for this assignment.

$$\text{Cost} = 50\ (S1\text{-}J1) + 20\ (S2\text{-}J3) + 30\ (S3\text{-}J2) + 30\ (S4\text{-}J4) = 130$$

Final Answer:
The optimal (minimum) cost for completing all four jobs is 130.

$$\boxed{130}$$

Quick Tip: Use the Hungarian assignment method, blocking S1-J3 and S3-J4 with a very high cost so they never get picked.

. Using linear regression (least squares), the best-fit line for the given dataset is $y = 2.2x + 2.3$. Given the residual sum of squares is 25.8, the coefficient of determination (r^2) is . *(rounded off to two decimal places)*

x	2	3	4	5
y	8	9	7	16

Correct Answer: 0.48

Solution:

Step 1: Recall what the coefficient of determination measures.
r^2 tells us what fraction of the total spread in y is explained by the

regression line, out of the total spread the data actually has around its own mean. It is defined as

$$r^2 = 1 - \frac{SSE}{SST}$$

where SSE is the residual sum of squares (the error the line cannot explain) and SST is the total sum of squares (the total variation in y about its mean).

Step 2: Find the mean of y and then SST.

The four y values are 8, 9, 7 and 16.

$$\bar{y} = \frac{8 + 9 + 7 + 16}{4} = \frac{40}{4} = 10$$

SST is the sum of the squared distance of each y value from this mean.

$$SST = (8 - 10)^2 + (9 - 10)^2 + (7 - 10)^2 + (16 - 10)^2 = 4 + 1 + 9 + 36 = 50$$

Step 3: Substitute SSE and SST into the r^2 formula.

We are told SSE = 25.8.

$$r^2 = 1 - \frac{25.8}{50} = 1 - 0.516 = 0.484$$

Final Answer:

Rounded to two decimal places, $r^2 = 0.48$.

$$\boxed{0.48}$$

Quick Tip: Find SST from the spread of the y values about their mean, then use $r^2 = 1 - SSE/SST$.

. A plug dam is to be constructed in a mine gallery of size 3.5 m × 2.5 m. The interfacial shear strength between the surrounding rock and plug dam is 1.0 MPa. The minimum thickness of the dam, in *m*, to withstand a water pressure of 10.0 MPa, is . *(rounded off to two decimal places)*

Correct Answer: 7.29

Solution:

Step 1: Find the total force the water pressure pushes on the dam face.

The plug dam seals a gallery that is 3.5 m wide and 2.5 m high, so the face area the water pushes against is

$$A = 3.5 \times 2.5 = 8.75 \text{ m}^2$$

Water pressure acts uniformly over this face, so the total pushing force is pressure times area. Since 1 MPa equals 1 MN per square meter, this comes out directly in MN.

$$F = P \times A = 10.0 \times 8.75 = 87.5 \text{ MN}$$

Step 2: Find how the dam resists this force.

The dam does not resist the water by its own strength alone, it resists through shear that develops all around its edge, where the dam's outer surface grips the surrounding rock. That gripping surface runs

around the full perimeter of the gallery and extends back into the rock over the dam's thickness t.
Perimeter of the gallery:

$$p = 2(3.5 + 2.5) = 12 \text{ m}$$

Shear resisting force equals shear strength times the contact area (perimeter times thickness):

$$F_{resist} = \tau \times p \times t = 1.0 \times 12 \times t$$

Step 3: Set the resisting force equal to the water force and solve for t.
For the minimum safe thickness, the resisting shear force must just balance the water force.

$$12t = 87.5$$

$$t = \frac{87.5}{12} = 7.29 \text{ m}$$

Final Answer:
The plug dam needs a minimum thickness of about 7.29 m to hold back the water.

$$\boxed{7.29 \text{ m}}$$

Quick Tip: Balance the total water force on the dam face against the shear

resistance developed around its perimeter.

. A shovel costing (P) Rs. 20 crores has a salvage value (S) of Rs. 2 crores with a useful life (n) of 10 years. The annual depreciation is evaluated using the declining balance method as given by

$$\text{Depreciation rate} = 1 - (S/P)^{1/n}$$

The depreciated cost of the shovel, in *crores*, in its 2nd year is Rs. .
(rounded off to two decimal places)

Correct Answer: 12.62

Solution:

Step 1: Find the annual depreciation rate.
In the declining balance (reducing balance) method, the book value drops by a fixed percentage every year, instead of a fixed rupee amount. That percentage is given by

$$r = 1 - (S/P)^{1/n} = 1 - (2/20)^{1/10}$$

$$(0.1)^{1/10} = 0.7943$$

$$r = 1 - 0.7943 = 0.2057, \text{ about } 20.57\% \text{ per year}$$

Step 2: Apply this rate twice to bring the book value down to the end

of year 2.

Each year the shovel loses 20.57% of whatever value it still has, so the value remaining gets multiplied by $(1 - r) = 0.7943$ each time.

Book value at the end of year 1:

$$BV_1 = P(1 - r) = 20 \times 0.7943 = 15.89 \text{ crores}$$

Book value at the end of year 2:

$$BV_2 = P(1 - r)^2 = 20 \times (0.7943)^2 = 20 \times 0.6310 = 12.62 \text{ crores}$$

Final Answer:

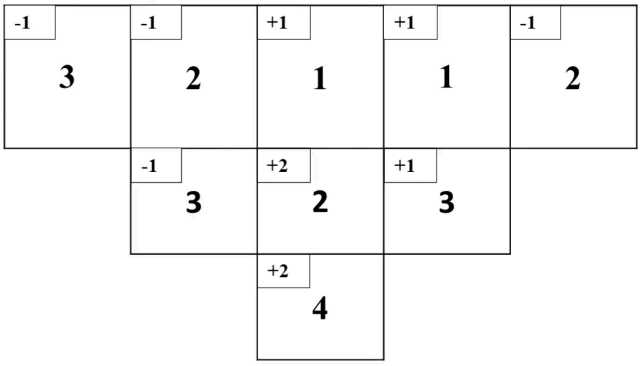
The depreciated cost of the shovel at the end of its 2nd year is about Rs. 12.62 crores.

$$\boxed{Rs.\ 12.62 \text{ crores}}$$

A different reading of "depreciated cost in its 2nd year" takes it as the amount of value lost during year 2 alone, not the value left over. That amount is $BV_1 - BV_2 = 15.89 - 12.62 = 3.27$ crores. Both numbers come from the same rate and the same two book values, they just answer slightly different questions, and this solution takes the remaining book value as the answer.

Quick Tip: Find the yearly declining-balance depreciation rate from S, P and n, then apply it twice to shrink the book value down to the end of year 2.

. An economic block model along with extraction sequence is shown. The numbers given at the centre of the block represent the year of extraction, and that at the corners represent the block economic value in Rs. (lakhs). If the discount rate is 10%, the net present value (NPV), in *lakhs*, is Rs. . *(rounded off to two decimal place)*



Correct Answer: 2.43

Solution:

Step 1: Read the value and extraction year of every block.

The block model has 9 blocks in three rows. Each block carries two numbers: the small corner number is its economic value in lakhs (positive or negative), and the large centre number is the year it gets mined out.

Top row (left to right): (-1, year 3), (-1, year 2), (+1, year 1), (+1, year 1), (-1, year 2).

Middle row (left to right): (-1, year 3), (+2, year 2), (+1, year 3).

Bottom row: (+2, year 4).

Step 2: Recall the NPV formula for a sequenced block model.

Each block's value is received (or paid, if negative) in the year it is extracted, so it must be discounted back to the present by that many years before adding it to the total.

$$NPV = \sum_i \frac{V_i}{(1+r)^{t_i}}$$

where V_i is the block's economic value, t_i is its extraction year, and $r = 0.10$ is the discount rate.

Step 3: Discount each block and add them up.

$-1/(1.1)^3 = -0.7513$ $-1/(1.1)^2 = -0.8264$ $+1/(1.1)^1 = +0.9091$
$+1/(1.1)^1 = +0.9091$ $-1/(1.1)^2 = -0.8264$ $-1/(1.1)^3 = -0.7513$
$+2/(1.1)^2 = +1.6529$ $+1/(1.1)^3 = +0.7513$ $+2/(1.1)^4 = +1.3660$

Adding all nine discounted values:

$$NPV = -0.7513 - 0.8264 + 0.9091 + 0.9091 - 0.8264 - 0.7513 + 1.6529 + 0.7513 + 1.3660 = 2.43$$

Final Answer:

The net present value of the block sequence is about Rs. 2.43 lakhs.

$$\boxed{Rs.\ 2.43 \text{ lakhs}}$$

Quick Tip: Discount each block's economic value back to the present using its own extraction year, then add all nine discounted values.

. A main mechanical ventilator installed for an underground mine develops a pressure of 25 mm wg. A natural ventilation pressure (NVP) of 15 mm wg acting in the mine aids the ventilator, and a total 500 $\mathbf{m^3\ min^{-1}}$ of air is circulated in the mine. Considering the same NVP aiding the ventilator, the pressure required, in mm wg, to be generated by the ventilator to circulate 1000 $\mathbf{m^3\ min^{-1}}$ of air, is . (answer in integer)

Correct Answer: 145

Solution:

Step 1: Set up the total pressure at the first duty point.
When an NVP aids the ventilator, the two pressures add together to push air through the mine. So the total pressure driving the airflow at the first condition is $P_1 = 25 + 15 = 40$ mm wg, moving $Q_1 = 500\ \mathbf{m^3\ min^{-1}}$ of air.

Step 2: Apply the mine resistance law.
For a fixed set of airways the resistance R does not change, and total pressure varies with the square of the airflow, $P = RQ^2$. This is the mine characteristic curve. Since R is the same at both duty points, $\frac{P_2}{P_1} = \left(\frac{Q_2}{Q_1}\right)^2$.

Step 3: Find the total pressure needed at 1000 m3/min.
Here $Q_2 = 1000\ \mathbf{m^3\ min^{-1}}$, so $\frac{Q_2}{Q_1} = 2$. Then $P_2 = P_1 \times 2^2 = 40 \times 4 = 160$ mm wg. This 160 mm wg is the total pressure the airways demand at the higher flow.

Step 4: Take out the NVP contribution.
The question says the same NVP is still aiding the ventilator, so it still supplies 15 mm wg of the total. The ventilator only has to make up the

rest: $P_{fan,2} = 160 - 15 = 145$ mm wg.

Final Answer:
The ventilator must generate 145 mm wg to circulate 1000 m3/min of air through the mine.

$$\boxed{145 \text{ mm wg}}$$

Quick Tip: Total pressure overcoming a fixed set of airways follows a square law with airflow, and NVP simply adds to the ventilator pressure when it is aiding.

. Dust particles from a blasting operation rise up in the atmosphere to a height of 500 m. The viscosity of air is $1.80 \times 10^{-5}\ \text{kg m}^{-1}\ \text{s}^{-1}$. Assume the particles have quiescent settling (no turbulence) in atmosphere. Neglecting air density, the settling time, in days, of a dust particle of 2.5 μ m diameter and 3600 kg m^{-3} density is . (rounded off to two decimal places)

Correct Answer: 8.49

Solution:

Step 1: Pick the governing law for a tiny settling particle.
A very small particle falling through still (quiescent) air settles at a constant terminal velocity given by Stokes' law, valid for the low Reynolds number of dust-sized particles:

$$v_t = \frac{(\rho_p - \rho_a)\, g\, d^2}{18\mu}$$

where ρ_p is particle density, ρ_a is air density, g is gravity, d is particle diameter and μ is the air viscosity.

Step 2: Simplify using the problem's assumption.

The question tells us to neglect air density, so $\rho_a = 0$ and the formula reduces to

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

Step 3: Substitute the numbers.

Convert the diameter to metres: $d = 2.5\,\mu\text{m} = 2.5 \times 10^{-6}$ m, so $d^2 = 6.25 \times 10^{-12}\ \text{m}^2$. With $\rho_p = 3600\ \text{kg m}^{-3}$, $g = 9.81\ \text{m s}^{-2}$ and $\mu = 1.80 \times 10^{-5}\ \text{kg m}^{-1}\,\text{s}^{-1}$:

$$v_t = \frac{3600 \times 9.81 \times 6.25 \times 10^{-12}}{18 \times 1.80 \times 10^{-5}} = \frac{2.207 \times 10^{-7}}{3.24 \times 10^{-4}} \approx 6.81 \times 10^{-4}\ \text{m/s}$$

Step 4: Find the time to fall 500 m.

Since the particle settles at this constant speed, time is height divided by speed:

$$t = \frac{500}{6.81 \times 10^{-4}} \approx 733945\ \text{s}$$

Converting to days by dividing by 86400 s/day:

$$t = \frac{733945}{86400} \approx 8.49\ \text{days}$$

Final Answer:

The dust particle takes about 8.49 days to settle back down through 500 m of still air.

$$\boxed{8.49 \text{ days}}$$

Quick Tip: A dust-sized particle in still air settles at a constant Stokes' law terminal velocity; divide the fall height by that velocity to get the time.

. In a biochemical oxygen demand (BOD) test, 15 ml of wastewater sample was diluted with distilled water to completely fill a 300 ml BOD bottle and incubated at 20 °C for 5 days. The dissolved oxygen (DO) level before and after incubation are 9.2 mg liter^{-1} and 4.4 mg liter^{-1}, respectively. The BOD of the sample, in mg liter^{-1}, is . (answer in integer)

Correct Answer: 96

Solution:

Step 1: Find the dilution factor.

Only a small volume of the raw wastewater is placed in the bottle, and the rest is made up with clean distilled water so the oxygen sensors can be read properly. The dilution factor tells us how many times the sample was diluted:

$$P = \frac{\text{volume of BOD bottle}}{\text{volume of sample}} = \frac{300}{15} = 20$$

Step 2: Find the oxygen used up during incubation.

The drop in dissolved oxygen over the 5 day incubation shows how

much oxygen the microorganisms in the sample consumed while breaking down the organic matter:

$$\Delta DO = DO_i - DO_f = 9.2 - 4.4 = 4.8 \text{ mg/liter}$$

Step 3: Scale this back up to the strength of the undiluted sample. Since the sample itself was diluted 20 times before this drop was measured, the true BOD of the full strength wastewater is 20 times the observed drop:

$$BOD = \Delta DO \times P = 4.8 \times 20 = 96 \text{ mg/liter}$$

Final Answer:

The BOD of the wastewater sample is 96 mg per liter.

$$\boxed{96 \text{ mg/liter}}$$

Quick Tip: Scale the observed drop in dissolved oxygen up by the dilution factor of the BOD bottle to get the BOD of the original sample.

. A rake of wagons, with inter-wagon gap of 100 cm, is moving at a speed of 0.4 km per hour under a silo loading system. The dimensions of the wagon are 8 m (L) × 3 m (W) × 3 m (H). The silo stops discharging the material between the wagons. Considering the fill factor of the wagon as 0.95 and the bulk density of coal as 1.2 tonne per cubic meter, the loading rate of the silo, in tonne per hour, is . (rounded off to nearest integer)

Correct Answer: 3648

Solution:

Step 1: Find the coal loaded into one wagon.

The wagon box has volume $8 \times 3 \times 3 = 72\ \text{m}^3$, but it is not filled to the brim, only to 0.95 of that volume, so the actual coal volume per wagon is $72 \times 0.95 = 68.4\ \text{m}^3$. Multiplying by the bulk density gives the mass loaded per wagon:

$$m = 68.4 \times 1.2 = 82.08 \text{ tonne}$$

Step 2: Find how long it takes one wagon to pass the loading point.

Because the silo stops discharging over the gap between wagons, the time available to load each wagon is the time it takes for one wagon length plus one gap to pass under the silo. This distance is $8 + 1 = 9\ \text{m}$ (the 100 cm gap is 1 m). The rake moves at $0.4\ \text{km/h} = 400\ \text{m/h}$, so the time per wagon is:

$$t = \frac{9}{400} = 0.0225\ \text{h}$$

Step 3: Find the loading rate.

The loading rate is the mass loaded per wagon divided by the time that wagon takes to pass:

$$\text{Rate} = \frac{82.08}{0.0225} = 3648 \text{ tonne/hour}$$

Final Answer:

The silo loads coal at a rate of about 3648 tonnes per hour.

3648 tonne/hour

Quick Tip: Work out the coal mass one wagon carries, then the time one wagon length plus the inter-wagon gap takes to pass the silo at the given speed.

. A turbine pump is designed to generate water head of 60 m. The impeller speed of the pump is 2000 rpm and the manometric efficiency is 70%. Neglecting the impeller blade curvature, the impeller diameter of the pump, in cm, is . (rounded off to two decimal places)

Correct Answer: 27.69

Solution:

Step 1: Apply the assumption of no blade curvature.

When blade curvature is neglected, the pump behaves as if the water leaves the impeller tip carrying the full peripheral (tip) speed as its whirl velocity, so $V_{w2} = u_2$. Euler's pump equation for the ideal (theoretical) head then simplifies to

$$H_{th} = \frac{u_2 V_{w2}}{g} = \frac{u_2^2}{g}$$

Step 2: Bring in the manometric efficiency.

Manometric efficiency compares the actual delivered head to this ideal head: $\eta_{man} = \frac{H_m}{H_{th}}$, so the ideal head is

$$H_{th} = \frac{H_m}{\eta_{man}} = \frac{60}{0.70} = 85.71 \text{ m}$$

Step 3: Solve for the impeller tip speed.

From Step 1, $u_2 = \sqrt{gH_{th}} = \sqrt{9.81 \times 85.71} \approx \sqrt{840.86} \approx 29.00$ m/s

Step 4: Convert tip speed to impeller diameter.

The tip speed of a rotating impeller relates to its diameter and rotational speed by $u_2 = \frac{\pi DN}{60}$, where N is in rpm. Rearranging,

$$D = \frac{60\,u_2}{\pi N} = \frac{60 \times 29.00}{\pi \times 2000} \approx 0.2769 \text{ m} = 27.69 \text{ cm}$$

Final Answer:

The impeller diameter of the pump is about 27.69 cm.

$$\boxed{27.69 \text{ cm}}$$

Quick Tip: Neglecting blade curvature means the exit whirl velocity equals the impeller tip speed, so the ideal head is u2 squared over g; link that to the manometric efficiency and the diameter formula.

. The information for a dragline operation is given:
Bucket capacity: 20 m^3
Bucket fill factor: 0.9
Digging and filling time: 20 s
Swinging (to and fro) time: 32 s
Dumping time: 10 s
Dragline utilization: 90%
The output of the dragline, in $\mathrm{m}^3\,\mathrm{h}^{-1}$, is . (rounded off to one decimal place)

Correct Answer: 940.6

Solution:

Step 1: Find the effective load per bucket.
The bucket rarely fills all the way to its rated capacity, so the fill factor scales it down to the load actually dug each cycle:

$$V_{eff} = 20 \times 0.9 = 18\ \mathrm{m}^3$$

Step 2: Find the total cycle time.
One full dragline cycle is digging and filling, then swinging out to the dump point and back, then dumping. The swing time given, 32 s, is already the full to and fro swing, so it is used as it is, not doubled:

$$t_{cycle} = 20 + 32 + 10 = 62\ \mathrm{s}$$

Step 3: Find the theoretical number of cycles per hour.
There are 3600 s in an hour, so the number of cycles possible in one hour is

$$n = \frac{3600}{62} \approx 58.06 \text{ cycles/h}$$

Step 4: Find the theoretical and actual output.

The theoretical hourly output is cycles per hour times the effective bucket volume:

$$Q_{theo} = 58.06 \times 18 \approx 1045.16 \text{ m}^3/\text{h}$$

The dragline is not digging every minute of the hour, only 90% of the time (utilization), so the actual achievable output is:

$$Q = 1045.16 \times 0.90 \approx 940.6 \text{ m}^3/\text{h}$$

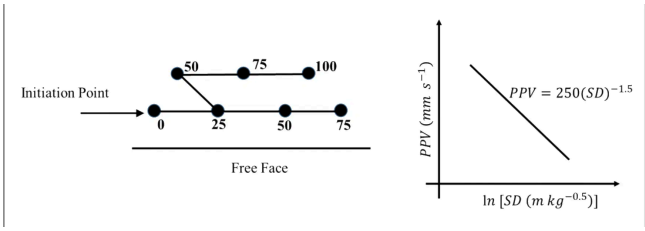
Final Answer:

The dragline delivers about 940.6 cubic metres of material per hour.

$$\boxed{940.6 \text{ m}^3/\text{h}}$$

Quick Tip: Add up the digging, swinging and dumping times for one full cycle, find cycles per hour, then multiply by the effective bucket load and the utilization factor.

. In a bench blasting, as shown, 49 kg of explosive is put in each hole. The detonation time of holes, in millisecond, and the associated scale distance (SD) vs. peak particle velocity (PPV) plot for the given blast pattern is shown.



The PPV at a distance of 100 m, in $\mathbf{mm\,s^{-1}}$, is . (rounded off to two decimal places)

Correct Answer: 7.79

Solution:

Step 1: Read the delay pattern from the figure.
The layout shows two rows of holes. The row nearer the free face fires at 0, 25, 50 and 75 ms after initiation, and the back row fires at 50, 75 and 100 ms. Every hole carries the same charge of 49 kg.

Step 2: Find the maximum charge firing at any single instant.
Ground vibration is governed by the largest charge that detonates within the same delay interval, since that is what produces the highest single vibration pulse. Looking at the delay numbers, two holes share the 50 ms mark (one from each row) and two holes share the 75 ms mark, so at those instants 49 + 49 = 98 kg of explosive fires together. This 98 kg is the maximum charge per delay, W.

Step 3: Calculate the scaled distance.

The scale distance combines the monitoring distance and the charge per delay as

$$SD = \frac{D}{\sqrt{W}} = \frac{100}{\sqrt{98}} \approx \frac{100}{9.90} \approx 10.10 \text{ m kg}^{-0.5}$$

Step 4: Apply the given attenuation law.

The plot gives the site's vibration prediction equation, $PPV = 250\,(SD)^{-1.5}$. Substituting the scaled distance:

$$PPV = 250 \times (10.10)^{-1.5} \approx \frac{250}{32.11} \approx 7.79 \text{ mm/s}$$

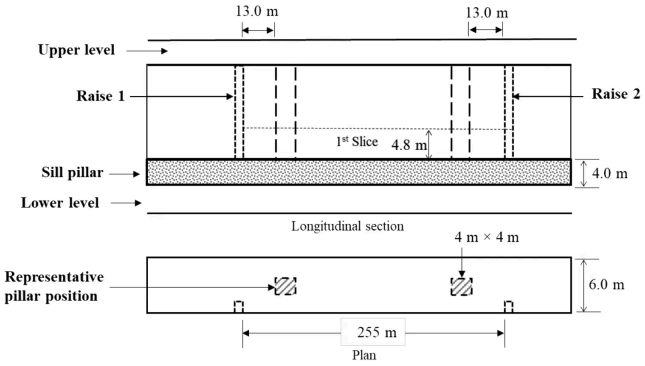
Final Answer:

The peak particle velocity expected 100 m from the blast is about 7.79 mm/s.

$$\boxed{7.79 \text{ mm/s}}$$

Quick Tip: Find the largest charge weight that detonates in the same delay from the firing time diagram, use it to scale the distance, then plug into the given PPV versus scaled distance equation.

. A regular shaped cut and fill stope is shown. Pillars of size $4\ \text{m} \times 4\ \text{m}$ are left at an interval of $13\ \text{m}$ along the length of the stope. If the density of the mined ore is $2.5\ \text{tonne/m}^3$, and slices are extracted to the full stope width, the total tonnage of ore recovered from the 1st slice of the stope is $\times 10^3$. (rounded off to one decimal place)



Correct Answer: 15.5

Solution:

Step 1: Read the pillar layout off the figure.

The plan view shows the stope running $255\ \text{m}$ along its length, with a stope width of $6.0\ \text{m}$. Pillars are $4\ \text{m} \times 4\ \text{m}$, and the $13\ \text{m}$ marked in the drawing is the gap between the edges of neighbouring pillars, not the centre spacing. So pillar centres are $4 + 13 = 17\ \text{m}$ apart.

Number of pillars along the length $= 255/17 = 15$.

Step 2: Read the slice height off the longitudinal section.

The 1st slice is shown with a height of $4.8\ \text{m}$, separate from the $4.0\ \text{m}$ sill pillar left lower down near the base. This $4.8\ \text{m}$ is the vertical thickness of ore taken in the first pass.

Step 3: Work out the gross volume of the slice, then remove the pillars.

Gross volume of the 1st slice $=$ length $\times$ width $\times$ height $= 255 \times 6.0 \times 4.8 = 7344\ \text{m}^3$.

Each pillar occupies $4 \times 4 = 16\ \text{m}^2$ in plan, over the full $4.8\ \text{m}$ slice height, so each pillar removes $16 \times 4.8 = 76.8\ \text{m}^3$ of ore that is left unmined.
With 15 pillars in this slice, volume left in pillars $= 15 \times 76.8$ $= 1152\ \text{m}^3$.
Net ore volume actually recovered $= 7344 - 1152 = 6192\ \text{m}^3$.

Step 4: Convert volume to tonnage.
Mass = volume × density $= 6192 \times 2.5 = 15480$ tonnes.
Expressed to the asked precision, this is 15.48×10^3 tonnes, which rounds to 15.5×10^3 tonnes.

Final Answer:
The 1st slice recovers about 15.5×10^3 tonnes of ore.

$$\boxed{15.5}$$

Quick Tip: Work out how many 4 m pillars actually fit along the stope length once you account for the 13 m gap between them, then think about what volume that removes from the slice you are costing out.

. A coal seam of $2.4\ \text{m}$ thickness is mined with a DERD shearer at a cutting speed of $0.6\ \text{km/h}$. The web depth of the cut is $0.5\ \text{m}$. The average cross-sectional area of coal on the AFC during transportation is $0.24\ \text{m}^2$. For the evacuation of cut coal from the face with 10% spillage, the required minimum velocity of the AFC, in $m\ s^{-1}$, is . (rounded off to two decimal places)

Correct Answer: 0.75

Solution:

Step 1: Understand where the coal volume comes from.

As a shearer advances along the face, it cuts a slice of coal whose cross-section is the seam thickness times the web depth of the cut. Moving at the cutting speed, this gives a steady volume of coal produced per unit time, which the AFC (armoured face conveyor) must carry away.

Step 2: Convert the cutting speed and find the cutting rate.

$0.6\ \text{km/h} = 600\ \text{m/h} = 600/3600 = 0.1667\ \text{m/s}$.

Volumetric rate of coal cut = thickness × web depth × cutting speed

$= 2.4 \times 0.5 \times 0.1667 = 0.2\ \text{m}^3/\text{s}$.

Step 3: Account for the 10% spillage.

Spillage means 10% of the coal that is cut never actually loads onto the conveyor, it falls off the face before reaching the AFC. So the AFC only has to carry the remaining 90% of the cut volume.

Volume the AFC must actually handle $= 0.9 \times 0.2 = 0.18\ \text{m}^3/\text{s}$.

Step 4: Find the minimum belt velocity.

The volumetric capacity of a conveyor is its cross-sectional area times belt velocity, so $0.18 = 0.24 \times v$.

$v = 0.18/0.24 = 0.75\ \text{m/s}$.

Final Answer:

The AFC needs a minimum velocity of about $0.75\ \text{m/s}$ to clear the cut coal.

$\boxed{0.75}$

Quick Tip: Find the volume of coal the shearer cuts each second from the seam thickness, web depth and cutting speed, then think about how much of that actually has to be carried away once some of it spills off the face.

. A bord and pillar panel has 24 developed pillars of size $40\ \text{m} \times 40\ \text{m}$ (centre to centre) under extraction. The following information is given:
Gallery width = $4\ \text{m}$
Extraction height = $3\ \text{m}$
Extraction ratio during depillaring = 80%
Specific gravity of coal = 1.4
Incubation period = 6 months
Average working days per month = 25
In order to extract the panel within the incubation period, the minimum rate of production, in tonne per day, is . (rounded off to one decimal place)

Correct Answer: 696.7

Solution:

Step 1: Find the actual size of a developed pillar.
The 40 m figure given is the centre to centre spacing between pillars, which includes the gallery driven around each pillar during development. The true solid pillar width is this spacing minus the gallery width: $40 - 4 = 36\ \text{m}$. So each pillar measures $36\ \text{m} \times 36\ \text{m}$ in plan.

Step 2: Find the total coal standing in the pillars.
Volume of coal in all 24 pillars $= 24 \times 36 \times 36 \times 3 = 93312\ \text{m}^3$, using the given extraction height of 3 m.

Step 3: Apply the extraction ratio for depillaring.

Only 80% of the coal standing in the pillars is actually won during depillaring, the rest is lost as stooks or left for safety.

Recoverable volume $= 0.8 \times 93312 = 74649.6\ \text{m}^3$.

Step 4: Convert to tonnage and divide by the time available.

Specific gravity 1.4 means density $= 1.4\ \text{tonne/m}^3$.

Mass to be extracted $= 74649.6 \times 1.4 = 104509.44$ tonnes.

Time available $= 6$ months $\times$ 25 days/month $= 150$ days.

Minimum daily production rate $= 104509.44/150$

$= 696.7296$ tonne/day, which rounds to 696.7 tonne/day.

Final Answer:

The panel must be worked at a minimum of about 696.7 tonne/day to clear the incubation period.

$$\boxed{696.7}$$

Quick Tip: Work out the true size of each pillar once the gallery width is taken out of the centre to centre spacing, then think about how much coal that leaves to recover within the given incubation period.

. Following observations were taken using a Tacheometer with staff held vertical. The additive and multiplying constants of the instrument are 0 and 100, respectively. The reduced level (RL) of the staff station R, in m, is . (rounded off to two decimal places)

Instrument station	Staff station	Staff reading (m)	Vertical angle	Remarks
P	Q	1.4, 2.7, 3.9	7°	RL of Q = 102 m
P	R	2.1, 2.8, 3.6	5°	

Correct Answer: 84.68

Solution:

Step 1: Recall the tacheometric formulae for a vertical staff.

For an angle of elevation θ, with multiplying constant m and additive constant C, the staff intercept is s = upper stadia reading minus lower stadia reading, and the vertical intercept above the line of collimation is

$$V = \frac{ms}{2}\sin(2\theta) + C\sin\theta$$

Since the additive constant here is 0, this reduces to $V = \frac{ms}{2}\sin(2\theta)$.

Step 2: Use station Q, whose RL is known, to fix the elevation of the line of sight.

For Q the readings are 1.4, 2.7, 3.9, so $s_Q = 3.9 - 1.4 = 2.5$ m and the middle hair reading is 2.7 m.

$V_Q = \frac{100\times2.5}{2}\sin(14°) = 125 \times 0.2419 = 30.24$ m.

Since the sight to Q is an elevation, RL of Q equals the instrument axis elevation H plus V_Q minus the middle hair reading: $102 = H$

$+ 30.24 - 2.7$, so $H = 102 - 30.24 + 2.7 = 74.46$ m.

Step 3: Apply the same instrument axis elevation to station R.

For R the readings are 2.1, 2.8, 3.6, so $s_R = 3.6 - 2.1 = 1.5$ m and the middle hair reading is 2.8 m.

$V_R = \frac{100 \times 1.5}{2} \sin(10°) = 75 \times 0.17365 = 13.02$ m.

Step 4: Find the RL of R.

RL of R $= H + V_R -$ middle reading$_R = 74.46 + 13.02 - 2.8 = 84.68$ m.

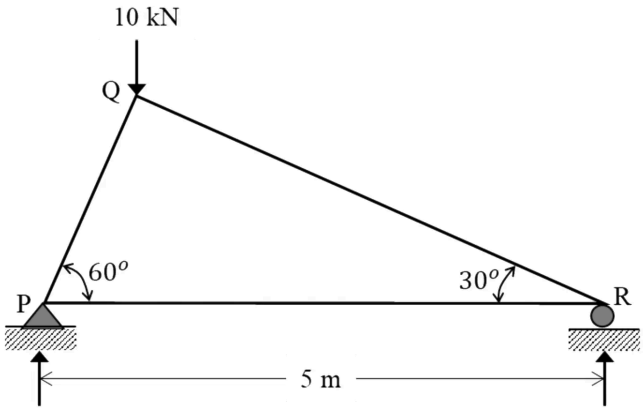
Final Answer:

The reduced level of station R is about 84.68 m.

$$\boxed{84.68}$$

Quick Tip: Use the vertical intercept formula on the Q sighting to pin down the elevation of the instrument's line of sight, then apply that same elevation to the R sighting.

. A truss PQR carries a vertical load of 10 kN at Q as shown. The force in member PR, in *kN*, is . (rounded off to two decimal places)



Correct Answer: 4.33

Solution:

Step 1: Work out the geometry of the truss.

The figure shows the base PR is 5 m, with the member at P making $60°$ with PR and the member at R making $30°$ with PR. Since the three angles of triangle PQR add to $180°$, the angle at Q is $180 - 60 - 30 = 90°$.

By the sine rule, $PQ = PR\dfrac{\sin(30°)}{\sin(90°)} = 5 \times 0.5 = 2.5$ m and $QR = PR\dfrac{\sin(60°)}{\sin(90°)} = 5 \times 0.8660 = 4.33$ m.

Step 2: Find the support reactions.

P is a pin support (can push in any direction) and R is a roller (vertical reaction only). The horizontal distance of Q from P is $PQ\cos 60° = 2.5 \times 0.5 = 1.25$ m.

Taking moments about P: $R_R \times 5 = 10 \times 1.25$, so $R_R = 2.5$ kN (upward).

Vertical equilibrium of the whole truss gives $R_P = 10 - 2.5 = 7.5$ kN (upward); there is no applied horizontal load, so the horizontal reaction at P is zero.

Step 3: Apply the method of joints at R.

At joint R, member QR pulls up and to the left at $30°$ above the horizontal, and member PR runs horizontally toward P. Taking tension as positive:

Vertical: $F_{QR}\sin 30° + R_R = 0 \Rightarrow F_{QR} = -\dfrac{2.5}{0.5} = -5$ kN (compression).

Horizontal: $-F_{QR}\cos 30° - F_{PR} = 0 \Rightarrow F_{PR} = -F_{QR}\cos 30° = 5 \times 0.8660 = 4.33$ kN.

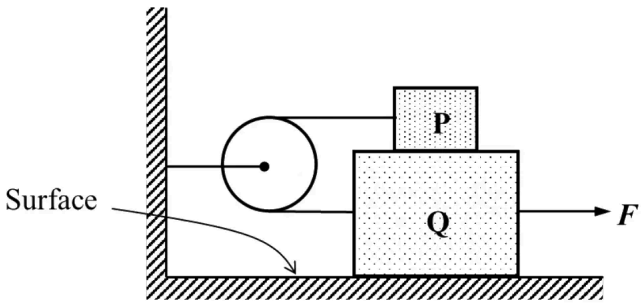
Step 4: Final Answer.

The positive sign shows member PR is in tension, carrying **4.33 kN**.

$$\boxed{4.33}$$

Quick Tip: Work out the missing angle of the triangle to place joint Q, find the support reactions first, then apply the method of joints at one of the supports.

. Two blocks P and Q weighing **100 kN** and **200 kN**, respectively, are connected by a string passing through a massless and frictionless pulley as shown. The friction coefficient between blocks P and Q is 0.4, and that between block Q and surface is 0.3. The minimum force, F, in kN, required to pull the block Q, is . (answer in integer)



Correct Answer: 170

Solution:

Step 1: Understand the arrangement in the figure.

Block P (weight 100 kN) rests on top of block Q (weight 200 kN), which sits on the ground. A single string runs from block P to a pulley fixed on the wall and back to block Q, so the same tension T pulls both blocks toward the wall.

Step 2: Find the friction between P and Q, and hence the string tension.

The only horizontal forces on P are the string tension and the friction from Q sliding beneath it. The normal force between P and Q equals the weight of P, 100 kN, so this friction is $0.4 \times 100 = 40$ kN.

Since P stays in place (held in position by the string), this friction must be balanced entirely by the string tension, so $T = 40$ kN. By Newton's third law, Q feels a 40 kN friction reaction from P, opposing its motion.

Step 3: Find the friction between Q and the ground.

The ground supports the weight of both blocks, since P's weight is transmitted down through Q. Normal force on the ground $= 100 + 200 = 300$ kN.

Friction between Q and the ground $= 0.3 \times 300 = 90$ kN.

Step 4: Add up every force resisting F.

To pull Q, F must overcome: the 40 kN friction reaction from P, the 90 kN friction from the ground, and the 40 kN string tension, which also pulls Q back toward the wall through the same pulley.

$F = 40 + 90 + 40 = 170$ kN.

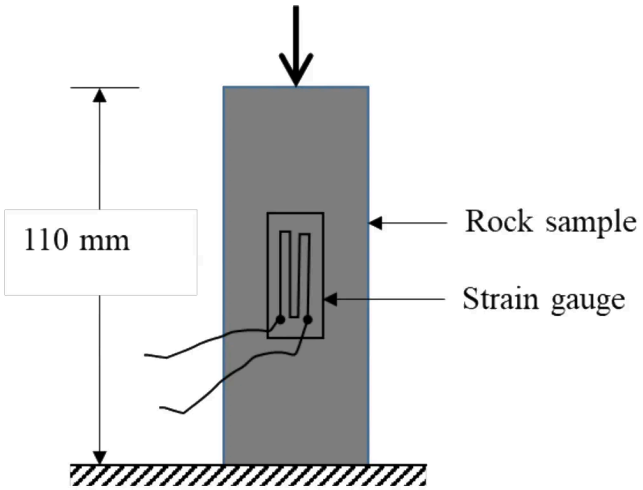
Final Answer:

The minimum force needed to pull block Q is 170 kN.

$$\boxed{170}$$

Quick Tip: Notice the same string ties both blocks to the fixed pulley on the wall, so think about how the tension needed to hold block P also acts back on block Q.

. In a uniaxial compressive strength test, a 120 Ω strain gauge of gauge factor 2.0 is pasted on the rock sample as shown. At the end of the test, the change in resistance of the strain gauge is 0.5 Ω. The longitudinal deformation of the sample, in *mm*, is . (rounded off to two decimal places)



Correct Answer: 0.23

Solution:

Step 1: Recall what the gauge factor means.

The gauge factor (GF) of a strain gauge is the ratio of the fractional change in its resistance to the strain it experiences:

$$GF = \frac{\Delta R/R}{\varepsilon}$$

where $\varepsilon = \Delta L/L$ is the longitudinal strain of the sample it is bonded to.

Step 2: Find the fractional change in resistance.

$\Delta R/R = 0.5/120 = 0.004167.$

Step 3: Find the strain from the gauge factor.

$\varepsilon = (\Delta R/R)/GF = 0.004167/2.0 = 0.002083.$

Step 4: Find the deformation using the sample's original length.

From the figure, the gauge length of the rock sample is $L = 110$ mm.

$\Delta L = \varepsilon \times L = 0.002083 \times 110 = 0.2292$ mm, which rounds to 0.23 mm.

Final Answer:

The sample shortens by about 0.23 mm under the load.

$$\boxed{0.23}$$

Quick Tip: Use the gauge factor definition to turn the measured change in resistance into a strain value, then apply that strain to the sample's original length.