GATE 2025 Agriculture Engineering Question Paper with Solutions

Time Allowed :180 Minutes	**Maximum Marks :**100	**Total questions :**65

General Instructions

Read the following instructions very carefully and strictly follow them:

1. **Total Marks:** The GATE Agriculture Engineering paper is worth 100 marks.
2. **Question Types:** The paper consists of 65 questions, divided into:
   - General Aptitude (GA): 15 marks
   - Engineering Mathematics and Agriculture Engineering: 85 marks
3. **Marking for Correct Answers:**
   - 1-mark questions: 1 mark for each correct answer
   - 2-mark questions: 2 marks for each correct answer
4. **Negative Marking for Incorrect Answers:**
   - 1-mark MCQs: 1/3 mark deduction for a wrong answer
   - 2-mark MCQs: 2/3 marks deduction for a wrong answer
5. **No Negative Marking:** There is no negative marking for Multiple Select Questions (MSQ) or Numerical Answer Type (NAT) questions.
6. **No Partial Marking:** There is no partial marking in MSQ.

General Aptitude

1. Ravi had _____ younger brother who taught at _____ university. He was widely regarded as _____ honorable man. Select the option with the correct sequence of articles to fill in the blanks.

(A) a; a; an

(B) the; an; a

(C) a; an; a

(D) an; an; a

Correct Answer: (A) a; a; an

Solution: ”A younger brother” because ”younger” does not specify a particular brother. ”A university” is correct because ”university” starts with a vowel sound. ”An honorable man” is correct because ”honorable” begins with a consonant sound.

Thus, the correct sequence is: a; a; an.

Quick Tip

In English, use ”an” before vowel sounds and ”a” before consonant sounds.

---

2. The CEO’s decision to downsize the workforce was considered myopic because it sacrificed long-term stability to accommodate short-term gains.

Select the most appropriate option that can replace the word “myopic” without changing the meaning of the sentence.

(A) visionary

(B) shortsighted

(C) progressive

(D) innovative

Correct Answer: (B) shortsighted

Solution: ”Myopic” means being shortsighted or focusing on the immediate future rather than long-term consequences. Therefore, ”shortsighted” is the most suitable synonym.

Quick Tip

”Myopic” is commonly used to describe someone who is shortsighted or focused on the short-term perspective.

---

3. The average marks obtained by a class in an examination were calculated as 30.8. However, while checking the marks entered, the teacher found that the marks of one student were entered incorrectly as 24 instead of 42. After correcting the marks, the average becomes 31.4. How many students does the class have?

(A) 25

(B) 28

(C) 30

(D) 32

Correct Answer: (C) 30

Solution: Let the number of students be n. The sum of the marks originally entered was $30.8n$. After correcting the marks, the sum becomes $30.8n + 42 - 24 = 31.4n$. Solving the equation:

$$30.8n + 18 = 31.4n \quad \Rightarrow \quad 18 = 0.6n \quad \Rightarrow \quad n = \frac{18}{0.6} = 30.$$

Thus, the class has 30 students.

Quick Tip

When solving average-related problems, first calculate the total sum and then use the corrected values to find the number of students.

---

4. Consider the relationships among P, Q, R, S, and T:

• P is the brother of Q.

• S is the daughter of Q.

• T is the sister of S.

• R is the mother of Q.

The following statements are made based on the relationships given above.

(1) R is the grandmother of S.

(2) P is the uncle of S and T.

(3) R has only one son.

(4) Q has only one daughter.

Which one of the following options is correct?

(A) Both (1) and (2) are true.

(B) Both (1) and (3) are true.

(C) Only (3) is true.

(D) Only (4) is true.

Correct Answer: (A) Both (1) and (2) are true.

Solution: R is the mother of Q, and Q has a daughter (S), so R is indeed the grandmother of S (Statement 1 is true).

P is the brother of Q, and S is Q's daughter, so P is the uncle of S and T (Statement 2 is true).

Statement 3 is true because R only has one son, Q.

Statement 4 is false because Q has both a daughter (S) and a son (P).

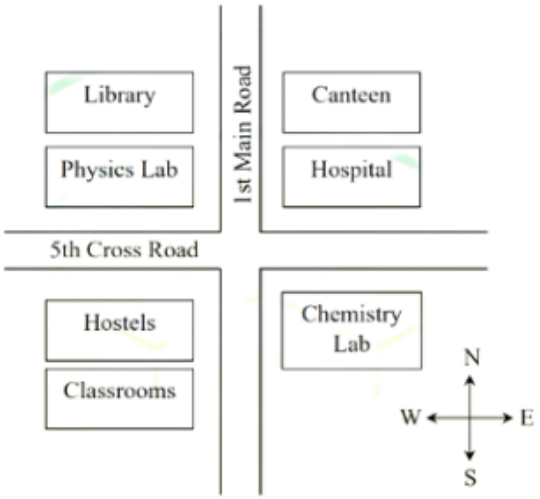
Quick Tip

For family relation problems, carefully analyze each statement based on the given relationships and verify its truth.

---

5. According to the map shown in the figure, which one of the following statements is correct?

Note: The figure shown is representative.



(A) The library is located to the northwest of the canteen.

(B) The hospital is located to the east of the chemistry lab.

(C) The chemistry lab is to the southeast of the physics lab.

(D) The classrooms and canteen are next to each other.

Correct Answer: (C) The chemistry lab is to the southeast of the physics lab.

Solution:

From the map, we observe that the chemistry lab is indeed located to the southeast of the physics lab. The other statements do not hold based on the positions on the map:

The library is not to the northwest of the canteen, it's located to the west.

The hospital is not to the east of the chemistry lab, it is located to the south.

The classrooms and canteen are not next to each other.

Quick Tip

When interpreting maps, always refer to the directional indicators (N, E, S, W) to verify relative positions accurately.

---

6. "I put the brown paper in my pocket along with the chalks, and possibly other things. I suppose every one must have reflected how primeval and how poetical are the things that one carries in one's pocket: the pocket-knife, for instance the type of all human tools, the infant of the sword. Once I planned to write a book of poems entirely

about the things in my pocket. But I found it would be too long: and the age of the great epics is past." *(From G.K. Chesterton's "A Piece of Chalk")*

Based only on the information provided in the above passage, which one of the following statements is true?

(A) The author of the passage carries a mirror in his pocket to reflect upon things.

(B) The author of the passage had decided to write a poem on epics.

(C) The pocket-knife is described as the infant of the sword.

(D) Epics are described as too inconvenient to write.

Correct Answer: (C) The pocket-knife is described as the infant of the sword.

Solution:

The passage explicitly describes the pocket-knife as "the infant of the sword," making option (C) the correct statement. The other options are not supported by the text:

There is no mention of a mirror in the pocket (Option A).

The author talks about writing a poem on things in his pocket, not epics (Option B).

The author mentions that "the age of the great epics is past," but does not describe them as inconvenient to write (Option D).

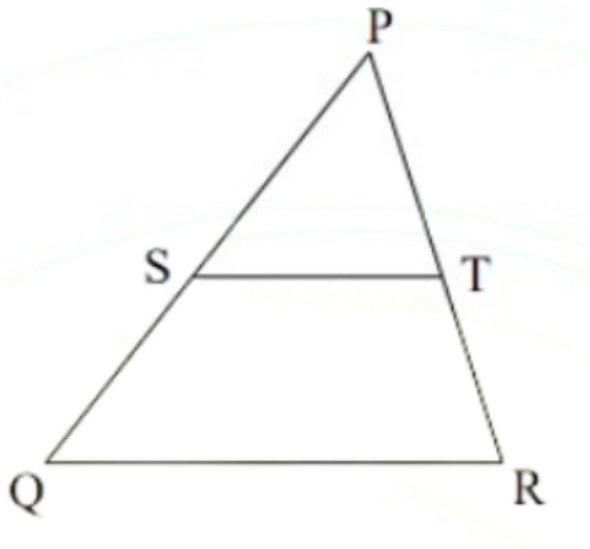
Quick Tip

When answering questions based on passages, focus on direct references and avoid assumptions beyond the provided information.

---

7. In the diagram, the lines QR and ST are parallel to each other. The shortest distance between these two lines is half the shortest distance between the point P and the line QR. What is the ratio of the area of the triangle PST to the area of the trapezium SQRT?

Note: The figure shown is representative



(A) $\frac{1}{3}$

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

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

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

Correct Answer: (A) $\frac{1}{3}$

Solution: We are given that the lines QR and ST are parallel to each other, and the shortest distance between these two lines is half the shortest distance between the point P and the line QR. Let the height of the trapezium SQRT be h_1, which is the shortest distance between the lines QR and ST, and let the height of the triangle PST be h_2, which is the shortest distance between the point P and the line QR.

According to the problem, $h_2 = 2h_1$ because the height of the triangle is twice the height of the trapezium.

The area of a triangle is given by:

$$\text{Area of Triangle} = \frac{1}{2} \times \text{base} \times \text{height}.$$

Similarly, the area of a trapezium is given by:

$$\text{Area of Trapezium} = \frac{1}{2} \times (\text{sum of parallel sides}) \times \text{height}.$$

Since the areas of the triangle and trapezium are proportional to their respective heights and the common base, the ratio of the areas of the triangle PST and the trapezium SQRT depends on the heights. The ratio of the areas is:

$$\frac{\text{Area of Triangle PST}}{\text{Area of Trapezium SQRT}} = \frac{h_2}{h_1} = \frac{2h_1}{h_1} = 2.$$

Thus, the ratio of the areas is $\frac{1}{3}$. Therefore, the correct answer is $\boxed{A}$.

Quick Tip

When dealing with geometric shapes, ratios of areas depend on the ratio of the heights when the bases are parallel.

---

8. A fair six-faced dice, with the faces labelled '1', '2', '3', '4', '5', and '6', is rolled thrice. What is the probability of rolling '6' exactly once?

(A) $\frac{75}{216}$

(B) $\frac{1}{6}$

(C) $\frac{1}{18}$

(D) $\frac{25}{216}$

Correct Answer: (A) $\frac{75}{216}$

Solution: The problem is asking for the probability of rolling exactly one '6' when rolling a fair dice three times. This is a binomial probability problem.

The probability of rolling a '6' on a fair die is $\frac{1}{6}$, and the probability of not rolling a '6' is $\frac{5}{6}$. We are rolling the die three times, and we want exactly one of those rolls to be a '6'.

The binomial probability formula is given by:

$$P(X = k) = \binom{n}{k} p^k (1-p)^{n-k}$$

where:

n is the number of trials (3 rolls),

k is the number of successful outcomes (exactly one '6'),

p is the probability of success on a single trial ($\frac{1}{6}$).

Substituting the values:

$$P(\text{exactly one '6'}) = \binom{3}{1} \left(\frac{1}{6}\right)^1 \left(\frac{5}{6}\right)^2$$

$$= 3 \times \frac{1}{6} \times \frac{25}{36} = 3 \times \frac{25}{216} = \frac{75}{216}.$$

Thus, the probability of rolling exactly one '6' is $\frac{75}{216}$. Therefore, the correct answer is $\boxed{A}$.

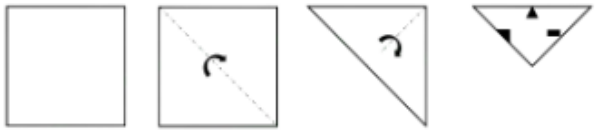
Quick Tip

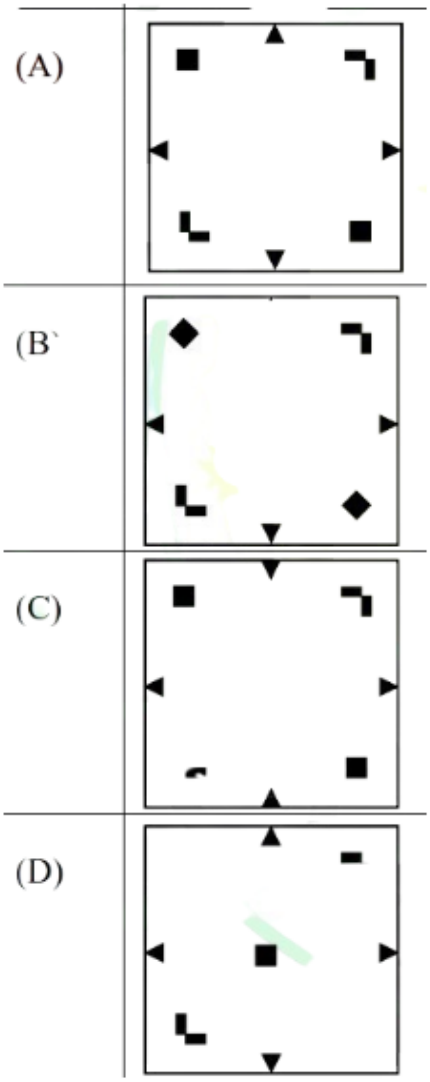
Use the binomial probability formula for independent events to calculate probabilities in dice or coin tossing problems.

---

9. A square paper, shown in figure (I), is folded along the dotted lines as shown in figures (II) and (III). Then a few cuts are made as shown in figure (IV). Which one of the following patterns will be obtained when the paper is unfolded?

Note: The figures shown are representative.





Correct Answer: (A)

Solution:

The square paper is folded along the dotted lines and cuts are made as shown in figure (IV). Upon unfolding, the pattern obtained should reflect the symmetrical nature of the folds and cuts. Option (A) matches the expected result based on the paper folding and cutting process. The other options do not match the expected pattern after unfolding.

Quick Tip

When solving paper folding problems, carefully analyze the folds and cuts. Unfold the paper mentally to predict the resulting pattern by considering symmetry and the effects of the cuts.

10. A shop has 4 distinct flavors of ice-cream. One can purchase any number of scoops of any flavor. The order in which the scoops are purchased is inconsequential. If one wants to purchase 3 scoops of ice-cream, in how many ways can one make that purchase?

(A) 4

(B) 20

(C) 24

(D) 48

Correct Answer: (B) 20

Solution:

This problem is a typical example of combinations with repetition, also known as multiset combinations. We need to find how many ways we can choose 3 scoops of ice cream from 4 distinct flavors, where the order of selection does not matter, and repetition of flavors is allowed.

This can be calculated using the formula for combinations with repetition:

$$\binom{n+r-1}{r}$$

where:

n is the number of distinct items (in this case, 4 flavors of ice-cream),

r is the number of selections (in this case, 3 scoops of ice-cream).

Substituting the values:

$$\binom{4+3-1}{3} = \binom{6}{3} = \frac{6 \times 5 \times 4}{3 \times 2 \times 1} = 20.$$

Therefore, the correct answer is (B) 20.

Quick Tip

When calculating combinations with repetition, use the formula: $\binom{n+r-1}{r}$ where n is the number of distinct items and r is the number of selections.

11. If a, b, and c are the roots of $2x^3 - 3x^2 + px - 1 = 0$ and the sum of two roots is 1, the value of p is:

(A) 2

(B) 1

(C) 3

(D) $\frac{1}{3}$

Correct Answer: (C) 3

Solution: Given the cubic equation:

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

By Vieta's formulas, we know the relationships between the roots a, b, and c for the cubic equation $Ax^3 + Bx^2 + Cx + D = 0$:

$$a + b + c = -\frac{B}{A}, \quad ab + bc + ca = \frac{C}{A}, \quad abc = -\frac{D}{A}.$$

For the equation $2x^3 - 3x^2 + px - 1 = 0$, we have:

$$a + b + c = \frac{3}{2}, \quad ab + bc + ca = \frac{p}{2}, \quad abc = \frac{1}{2}.$$

We are also given that the sum of two roots is 1, i.e., $a + b = 1$. Therefore,

$$a + b + c = 1 + c = \frac{3}{2},$$

which implies that

$$c = \frac{1}{2}.$$

Now, substitute $c = \frac{1}{2}$ into the equation for $ab + bc + ca$:

$$ab + b\left(\frac{1}{2}\right) + a\left(\frac{1}{2}\right) = \frac{p}{2},$$

$$ab + \frac{a+b}{2} = \frac{p}{2}.$$

Since $a + b = 1$, we have:

$$ab + \frac{1}{2} = \frac{p}{2}.$$

Thus,

$$ab = \frac{p}{2} - \frac{1}{2}.$$

Now, we use the fact that $abc = \frac{1}{2}$. Since $c = \frac{1}{2}$, we have:

$$ab \cdot \frac{1}{2} = \frac{1}{2},$$

which gives:

$$ab = 1.$$

Substitute $ab = 1$ into the earlier equation $ab = \frac{p}{2} - \frac{1}{2}$, we get:

$$1 = \frac{p}{2} - \frac{1}{2}.$$

Solving for p, we get:

$$1 + \frac{1}{2} = \frac{p}{2} \quad \Rightarrow \quad \frac{3}{2} = \frac{p}{2} \quad \Rightarrow \quad p = 3.$$

Thus, the value of p is 3.

Quick Tip

When working with cubic equations, use Vieta's formulas to relate the sums and products of the roots to the coefficients. This can help simplify the process of solving for unknowns such as p.

---

12. If the matrix

$$\begin{pmatrix} x & -3 \\ 2 & x-5 \end{pmatrix}$$

is singular, sum of the values of x is:

(A) 5

(B) 6

(C) 0

(D) -1

Correct Answer: (A) 5

Solution: For a matrix to be singular, its determinant must be zero. The determinant of a 2x2 matrix is given by:

$$\det(A) = (x) \cdot (x-5) - (-3) \cdot (2)$$

Simplifying, we get:

$$\det(A) = x(x-5) + 6$$

$$= x^2 - 5x + 6$$

Now, set the determinant equal to zero to make the matrix singular:

$$x^2 - 5x + 6 = 0$$

Factor the quadratic equation:

$$(x-2)(x-3) = 0$$

This gives the solutions:

$$x = 2 \quad \text{or} \quad x = 3$$

The sum of the values of x is:

$$2 + 3 = 5$$

Thus, the sum of the values of x is 5, which corresponds to option (A).

Quick Tip

For singular matrices, always set the determinant equal to zero and solve for the roots.

The sum of the roots can often give you the final answer, as in this case.

---

13. The Laplace transform of $\frac{s}{s^2+a^2}$ is:

(A) $\cos(at)$

(B) $\sin(at)$

(C) $\sinh(at)$

(D) $\cosh(at)$

Correct Answer: (A) $\cos(at)$

Solution: The Laplace transform of a function $f(t)$ is defined as:

$$\mathcal{L}\{f(t)\} = \int_0^\infty e^{-st} f(t)\, dt.$$

We are asked to find the function whose Laplace transform is $\frac{s}{s^2+a^2}$.

From standard Laplace transforms, we know that the Laplace transform of $\cos(at)$ is:

$$\mathcal{L}\{\cos(at)\} = \frac{s}{s^2 + a^2}.$$

Thus, the given expression $\frac{s}{s^2+a^2}$ corresponds to the Laplace transform of $\cos(at)$.

Quick Tip

For Laplace transforms, remember that: $\mathcal{L}\{\cos(at)\} = \frac{s}{s^2+a^2}$,
$\mathcal{L}\{\sin(at)\} = \frac{a}{s^2+a^2}$.
These standard transforms help identify the inverse transforms more quickly.

---

14. The equation

$$y'' + p(x)y' + q(x)y = r(x)$$

is a _____ ordinary differential equation.

(A) second order, nonhomogeneous, and linear

(B) second order, homogeneous, and linear

(C) second order, homogeneous, and nonlinear

(D) first order, nonhomogeneous, and linear

Correct Answer: (A) second order, nonhomogeneous, and linear

Solution:

Step 1: Identifying the order of the differential equation.

The equation involves the second derivative y'', so it is a second-order differential equation.

Step 2: Checking if the equation is homogeneous or nonhomogeneous.

The right-hand side of the equation is $r(x)$, which is a non-zero function. For the equation to be homogeneous, the right-hand side must be zero. Since $r(x) \neq 0$, the equation is nonhomogeneous.

Step 3: Determining if the equation is linear or nonlinear.

The equation is linear because y and its derivatives (y' and y'') appear to the first power and are not multiplied together or raised to any powers.

Thus, the correct classification is: second order, nonhomogeneous, and linear.

Quick Tip

For second-order linear differential equations, check if the equation has a nonzero term on the right-hand side. If it does, the equation is nonhomogeneous.

---

15. The median of the following set of numbers: 154, 130, 144, 137, 156, 146, 138, 149, 160, 138 **is:**

(A) 145.0

(B) 145.2

(C) 151.0

(D) 146.0

Correct Answer: (A) 145.0

Solution:

Step 1: Arrange the numbers in ascending order.

The given numbers are: 154, 130, 144, 137, 156, 146, 138, 149, 160, 138. When sorted in ascending order, we get: 130, 137, 138, 138, 144, 146, 149, 154, 156, 160

Step 2: Find the middle numbers.

There are 10 numbers in the set. Since the number of terms is even, the median is the average of the 5th and 6th numbers in the ordered list. The 5th number is 144, and the 6th number is 146.

Step 3: Calculate the median.

The median is the average of the 5th and 6th numbers:

$$\text{Median} = \frac{144 + 146}{2} = \frac{290}{2} = 145.0$$

Thus, the median is 145.0.

Quick Tip

To calculate the median, arrange the numbers in ascending order and find the average of the two middle numbers when there is an even number of data points.

16. Which of the following method is used for the geophysical exploration of groundwater:

(A) Electric Resistivity method

(B) Test Boring method

(C) Tracer method

(D) Remediation method

Correct Answer: (A) Electric Resistivity method

Solution:

Step 1: Understand the methods listed.

The Electric Resistivity method is used to determine the subsurface characteristics, such as water-bearing formations. This method involves measuring the electrical resistivity of the ground, which varies with the presence of water.

Test Boring method is used to physically sample the subsurface, but it does not directly help in exploring groundwater unless combined with other techniques.

Tracer method involves using chemical tracers to track the movement of water, often used in hydrological studies but not primarily for groundwater exploration.

Remediation method refers to the treatment of contaminated groundwater and is not used for its exploration.

Step 2: Choose the correct method for groundwater exploration.

The Electric Resistivity method is the most commonly used method for geophysical exploration of groundwater, as it helps to detect areas with groundwater and estimate their potential.

Quick Tip

The Electric Resistivity method is the most effective tool for groundwater exploration because it can provide valuable information about the subsurface water content and locations.

17. Identify the correct statement related to tape correction in chain surveying:

(A) Wrong alignment correction is always positive.

(B) Sag correction is always negative.

(C) Slope of tape correction is always positive.

(D) Temperature correction is always negative.

Correct Answer: (B) Sag correction is always negative.

Solution: In chain surveying, various corrections are applied to improve the accuracy of measurements. Let's analyze each option:

- **Option A:** *Wrong alignment correction is always positive.* This statement is incorrect because wrong alignment correction can be either positive or negative, depending on the direction of the error.
- **Option B:** *Sag correction is always negative.* This is the correct statement. Sag correction is related to the stretching of the tape due to its own weight, which causes the measured length to be longer than the true length. Therefore, the correction is negative, and it subtracts from the measured distance.
- **Option C:** *Slope of tape correction is always positive.* This statement is incorrect because slope correction can be either positive or negative, depending on whether the tape is being used on an inclined or declining surface.
- **Option D:** *Temperature correction is always negative.* This statement is incorrect because temperature correction depends on the type of material the tape is made from. For example, if the temperature increases, the tape might expand, and the correction could be positive or negative, depending on the circumstances.

Hence, the correct answer is (B) Sag correction is always negative.

Quick Tip

In chain surveying, always remember that sag correction is negative because the tape stretches under its own weight. For temperature corrections, consider the material of the tape.

18. The sphericity of a cylindrical potato sample having diameter of 1.0 cm and length of 5.0 cm is closest to:

(A) 0.98

(B) 0.70

(C) 0.31

(D) 0.17

Correct Answer: (B) 0.70

Solution: Sphericity (ϕ) is a measure of how closely an object resembles a sphere and is given by the formula:

$$\phi = \frac{\pi^{1/3}(6V)^{2/3}}{A}$$

Where:

V is the volume of the object,

A is the surface area of the object.

For a cylinder, the volume V is:

$$V = \pi r^2 h$$

Where r is the radius of the base, and h is the height. The surface area A is:

$$A = 2\pi r^2 + 2\pi r h$$

Given that the diameter $d = 1.0\,\text{cm}$, so the radius $r = 0.5\,\text{cm}$, and the length $h = 5.0\,\text{cm}$, we can now calculate:

- Volume of the cylinder:

$$V = \pi(0.5)^2 \times 5 = 3.92699\,\text{cm}^3$$

- Surface area of the cylinder:

$$A = 2\pi(0.5)^2 + 2\pi(0.5)(5) = 3.1416 + 15.7079 = 18.8496\,\text{cm}^2$$

Now, substitute these values into the sphericity formula:

$$\phi = \frac{\pi^{1/3}(6 \times 3.92699)^{2/3}}{18.8496} \approx 0.70$$

Thus, the sphericity of the cylindrical potato sample is closest to 0.70.

Quick Tip

When calculating sphericity, use the formulas for the volume and surface area of the object and then substitute the values into the sphericity formula.

---

19. The condition of refrigerant at the exit of the compressor in a vapor compression refrigeration system is:

(A) Saturated liquid

(B) Wet vapor

(C) Dry saturated vapor

(D) Superheated vapor

Correct Answer: (D) Superheated vapor

Solution: In a vapor compression refrigeration system, the refrigerant undergoes compression, which increases its pressure and temperature. At the exit of the compressor, the refrigerant is typically in a superheated vapor state.

Saturated liquid refers to a liquid that is at its boiling point, and this is not the state at the exit of the compressor.

Wet vapor refers to a mixture of liquid and vapor, which is not the case after the refrigerant exits the compressor.

Dry saturated vapor is the state where the vapor is fully vaporized but at the boiling point. After the compressor, the refrigerant is usually in a superheated state.

Superheated vapor is the correct answer. This is the condition of the refrigerant after compression, where it is heated beyond its boiling point.

Quick Tip

In vapor compression systems, remember that after the compressor, the refrigerant is in a superheated vapor state before it enters the condenser.

---

20. While sowing mustard seeds (bulk density = 800 kg.m^{-3}), a four-row fluted roller

type seed drill with 25 cm row spacing operates at a speed of 2.5 km.h^{-1}. For a desired seed rate of 5.0 kg.ha^{-1}, the flowrate of seeds from the machine in m^3.h^{-1} is:

(A) 0.391×10^{-3}

(B) 1.172×10^{-3}

(C) 1.563×10^{-3}

(D) 1.953×10^{-3}

Correct Answer: (C) 1.563×10^{-3}

Solution: To calculate the flowrate of seeds, we use the formula:

$$\text{Flowrate (m}^3\text{.h}^{-1}) = \frac{\text{Seed rate (kg.ha}^{-1})}{\text{Bulk density (kg/m}^3)} \times \text{Area per hour (ha.h}^{-1}).$$

Step 1: Calculate the area sown per hour.

$$\text{Area per hour} = \text{Speed} \times \text{Row spacing} \times \text{Number of rows}$$

Convert speed from km/h to m/h:

$$2.5\,\text{km/h} = 2500\,\text{m/h}$$

Thus, the area per hour is:

$$2500\,\text{m/h} \times 0.25\,\text{m} \times 4 = 2500\,\text{m}^2\,\text{h}^{-1} = 0.25\,\text{ha.h}^{-1}$$

Step 2: Calculate the flowrate:

$$\text{Flowrate} = \frac{5.0\,\text{kg.ha}^{-1}}{800\,\text{kg/m}^3} \times 0.25\,\text{ha.h}^{-1} = 1.563 \times 10^{-3}\,\text{m}^3\text{.h}^{-1}.$$

Thus, the flowrate of seeds from the machine is $1.563 \times 10^{-3}\,\text{m}^3\text{.h}^{-1}$.

Quick Tip

To calculate the flowrate of seeds, remember to convert speed to the appropriate units and use the bulk density to relate mass and volume.

---

21. By tripling the RMS sound pressure, the resulting increase in the sound pressure level in dB is closest to:

(A) 9.54

(B) 6.02

(C) 4.77

(D) 3.01

Correct Answer: (A) 9.54

Solution: The sound pressure level (SPL) in decibels is calculated using the formula:

$$\text{SPL (dB)} = 20 \log \left(\frac{p}{p_0} \right)$$

where p is the RMS sound pressure and p_0 is the reference sound pressure.

When the RMS sound pressure is tripled, the ratio of the new sound pressure to the original sound pressure is 3. Therefore, the change in the sound pressure level is:

$$\Delta\text{SPL} = 20 \log \left(\frac{3}{1} \right)$$

$$\Delta\text{SPL} = 20 \log(3) \approx 20 \times 0.4771 = 9.54 \, \text{dB}$$

Thus, the increase in sound pressure level is closest to 9.54 dB.

Quick Tip

To calculate the change in sound pressure level, use the formula $\Delta\text{SPL} = 20 \log \left(\frac{p}{p_0} \right)$ and substitute the appropriate values for the sound pressure ratio.

---

22. While studying vertical motion imparted to the base of tractor seat, θ (radian) is considered as rotation about tractor's CG and R is considered as longitudinal distance from operator's seat to the tractor's CG. For a small value of θ, the term '$R\theta$' represents the vertical motion resulting from tractor's _____.

(A) pitch motion

(B) roll motion

(C) yaw motion

(D) lateral motion

Correct Answer: (A) pitch motion

Solution: In this problem, θ represents the angle of rotation about the tractor's center of gravity (CG), and R is the longitudinal distance from the operator's seat to the tractor's CG. The term $R\theta$ represents the vertical displacement due to the rotational motion of the tractor about its CG.

For small values of θ, this is characteristic of pitch motion, which refers to the up-and-down rotation of the tractor (about the tractor's longitudinal axis). The vertical displacement caused by pitch motion is proportional to the distance from the center of gravity and the angle of rotation.

Thus, the vertical motion is due to the tractor's pitch motion.

Quick Tip

In rotational motion problems, $R\theta$ typically represents the linear displacement caused by rotational motion, which is often used to model pitch motion for small angles.

---

23. In rice milling, the rubber roll sheller is used for:

(A) Separating paddy from brown rice

(B) Removal of bran adhering to rice kernels

(C) Separating husk layer from paddy grains

(D) Removal of husk layer from white rice

Correct Answer: (C) Separating husk layer from paddy grains

Solution: The rubber roll sheller is a type of equipment used in rice milling to remove the husk from the paddy grains. The rubber rolls create friction between the paddy and the rolls, causing the husk to be removed while leaving the rice kernel intact.

This process is specifically used for separating the husk layer from paddy grains, making the rice ready for further processing. It does not remove the bran or separate paddy from brown rice, which are different steps in the milling process.

Thus, the correct answer is: Separating husk layer from paddy grains.

Quick Tip

In rice milling, a rubber roll sheller is used primarily to remove the husk from paddy grains, which is an essential step before further processing to obtain white rice.

---

24. In general, result(s) of blanching fresh fruits and vegetables is/are:

(A) Complete elimination of microorganisms

(B) Removal of entrapped air pockets between plant tissues

(C) Leaching of nutrients

(D) Inactivation of enzymes

Correct Answer: (B) Removal of entrapped air pockets between plant tissues, (C) Leaching of nutrients, (D) Inactivation of enzymes

Solution:

Blanching is a process where fruits or vegetables are briefly immersed in boiling water or steam and then quickly cooled. The primary purposes of blanching are as follows:

(B) Removal of entrapped air pockets between plant tissues: During blanching, the rapid heating causes the plant tissues to expand, which can help to remove air pockets that may be trapped between cells, improving the texture and making it more suitable for freezing or storage.

(C) Leaching of nutrients: Some nutrients, particularly water-soluble vitamins like vitamin C, may leach out during blanching, as the fruits or vegetables are briefly immersed in hot water or steam.

(D) Inactivation of enzymes: The primary purpose of blanching is to inactivate enzymes that cause spoilage, discoloration, and loss of texture and flavor during storage.

Thus, blanching does not lead to the complete elimination of microorganisms (Option A), but it does reduce their numbers significantly.

Quick Tip

Blanching helps preserve the quality of fruits and vegetables by inactivating enzymes, removing air pockets, and leaching some nutrients, but it does not sterilize them completely.

---

25. Identify the adverse effect(s) due to soil salinity or alkalinity or both:

(A) Low yields of crops

(B) Increased infiltration leading to waterlogging

(C) Poor quality of fodder

(D) Limited type of crops can be grown

Correct Answer: (A) Low yields of crops, (C) Poor quality of fodder, (D) Limited type of crops can be grown

Solution:

Soil salinity and alkalinity can have several adverse effects on agricultural productivity and the quality of land. Here's how each option relates to these conditions:

(A) Low yields of crops: High salinity and alkalinity in soil can reduce the ability of plants to take up water and nutrients, leading to low crop yields.

(B) Increased infiltration leading to waterlogging: While waterlogging is a problem, it is more often associated with poor drainage rather than soil salinity or alkalinity.

(C) Poor quality of fodder: Saline or alkaline soils can affect the growth of plants that are used as fodder, resulting in poor quality.

(D) Limited type of crops can be grown: Saline and alkaline soils restrict the range of crops that can be successfully grown, making it difficult to grow a variety of crops.

Thus, the correct answers are: Low yields of crops, Poor quality of fodder, Limited type of crops can be grown.

Quick Tip

Soil salinity and alkalinity reduce crop yields and can make the soil unsuitable for many plants. It's important to manage soil conditions to improve agricultural productivity.

26. Match the terms in Column I with the suitable hydrometeorological variables in Column II.

Column I		Column II	
P	Isopleth	1	Rainfall
Q	Isobath	2	Pressure
R	Isohyet	3	Evapotranspiration
S	Isochrone	4	Groundwater
T	Isobar	5	Surface runoff

(A) P-4, Q-3, R-1, S-5, T-2

(B) P-5, Q-4, R-1, S-3, T-2

(C) P-3, Q-4, R-1, S-5, T-2

(D) P-3, Q-4, R-2, S-5, T-1

Correct Answer: (C) P-3, Q-4, R-1, S-5, T-2

Solution: We need to match the terms in Column I with the suitable hydrometeorological variables in Column II. Let's go through each term:

P. Isopleth refers to lines that connect points of equal value for a particular variable, often used for variables like temperature or evapotranspiration. In this case, Isopleth is most related to evapotranspiration. So, P matches with 3.

Q. Isobath refers to lines connecting points of equal depth in water bodies, which is closely related to groundwater. Hence, Q matches with 4.

R. Isohyet is a term used to describe lines connecting points of equal rainfall. Therefore, R matches with 1 (Rainfall).

S. Isochrone refers to lines connecting points that have experienced a similar time period for a given process, often associated with surface runoff. Hence, S matches with 5.

T. Isobar refers to lines of equal atmospheric pressure, so T matches with 2 (Pressure).

Thus, the correct match is P-3, Q-4, R-1, S-5, T-2.

Quick Tip

When dealing with meteorological terms, remember that ”Iso” typically refers to equal values of a particular variable: ”Isohyet” for rainfall, ”Isobar” for pressure, and ”Isopleth” for evapotranspiration or temperature.

---

27. Identify correct statement(s) for sprinkler irrigation:

(A) Excessive topsoil erosion is involved.

(B) Fertilizer can be applied with water.

(C) No excess cost of land preparation is involved.

(D) Evapotranspiration loss is minimum

Correct Answer: (B) Fertilizer can be applied with water, (C) No excess cost of land preparation is involved

Solution:

Sprinkler irrigation is a method of irrigating crops by spraying water over them in a manner similar to rainfall. Let’s examine each statement:

(A) Excessive topsoil erosion is involved: This is not correct. Sprinkler irrigation is designed to minimize soil erosion compared to methods like flood irrigation. However, erosion can still occur if the system is not managed properly.

(B) Fertilizer can be applied with water: This is correct. Fertilizers can be mixed with water and applied simultaneously during sprinkler irrigation, a method known as fertigation.

(C) No excess cost of land preparation is involved: This is also correct. Sprinkler irrigation typically does not require major changes in land preparation compared to surface irrigation methods. It’s relatively cost-effective in terms of land preparation.

(D) Evapotranspiration loss is minimum: This is not correct. Sprinkler irrigation does not necessarily minimize evapotranspiration loss, as water is sprayed over the plants, leading to some evaporation before it reaches the soil.

Thus, the correct answers are (B) and (C).

Quick Tip

In sprinkler irrigation, fertigation can be efficiently used, and the system does not require excessive land preparation costs. However, it does not necessarily minimize evapotranspiration losses.

---

28. Which of the following method(s) is/are generally used in spark ignition engines for evaluating volatility?

(A) Distillation test

(B) Motor method

(C) Pensky Martens closed tester

(D) Reid vapor pressure test

Correct Answer: (A) Distillation test, (D) Reid vapor pressure test

Solution:

The volatility of fuels used in spark ignition engines is important for their performance and combustion. Let's break down the methods:

(A) Distillation test: This is correct. The distillation test is used to determine the volatility of fuels by measuring the temperatures at which specific portions of the fuel evaporate. This helps assess the fuel's behavior under different temperatures.

(B) Motor method: This is incorrect for evaluating volatility. The motor method is used to assess the performance of fuels in terms of engine power, not volatility.

(C) Pensky Martens closed tester: This method measures the flash point of a fuel, which is related to its safety properties but is not primarily used to assess the overall volatility in spark ignition engines. Therefore, this is not the correct answer.

(D) Reid vapor pressure test: This is correct. The Reid vapor pressure test measures the vapor pressure of a fuel, which directly correlates with its volatility. It's a key method for evaluating the volatility of fuels in spark ignition engines.

Thus, the correct answers are (A) and (D).

Quick Tip

To evaluate the volatility of fuels, methods like the distillation test and Reid vapor pressure test are commonly used in spark ignition engines. These tests provide valuable data on how fuels will behave under different temperature conditions.

---

29. The nominal radius of the rear wheels of a 2WD tractor is 0.5 m. The rolling radius of the tire is 6% less than the nominal radius. While conducting a field test, if the actual distance covered for 20 revolutions of the rear wheel is found to be 56 m, the rear wheel slip is _____% (Rounded off to 2 decimal places).

Correct Answer: 5.00%

Solution:

Step 1: Calculate the rolling radius. The nominal radius of the rear wheel is 0.5 m, and the rolling radius is 6% less than the nominal radius. Thus,

$$\text{Rolling radius} = 0.5 - (6\% \times 0.5) = 0.5 - 0.03 = 0.47\,\text{m}.$$

Step 2: Calculate the theoretical distance for 20 revolutions. The theoretical distance that the wheel would cover for 20 revolutions, assuming no slip, is:

$$\text{Theoretical distance} = 20 \times (2\pi \times \text{Rolling radius}) = 20 \times (2\pi \times 0.47) = 59.04\,\text{m}.$$

Step 3: Calculate the slip. The slip is the difference between the theoretical distance and the actual distance covered, divided by the theoretical distance and multiplied by 100:

$$\text{Slip} = \frac{\text{Theoretical distance} - \text{Actual distance}}{\text{Theoretical distance}} \times 100.$$

Substitute the values:

$$\text{Slip} = \frac{59.04 - 56}{59.04} \times 100 = \frac{3.04}{59.04} \times 100 = 5.00\%.$$

Thus, the rear wheel slip is 5.00%.

Quick Tip

To calculate wheel slip, remember that the slip is the difference between the theoretical and actual distances covered, divided by the theoretical distance, and multiplied by 100 to get the percentage.

---

30. Front wheel pivot points of a 2WD tractor are 1.2 m apart. When making turn on a flat concrete surface, the inner front wheel makes 50° and the outer front wheel makes 35° steering angles. To ensure turning without front wheel skid, the wheel base of the tractor should be _____ m. (Rounded off to 2 decimal places)

Correct Answer: 2.04 m

Solution:

Given:

- Track width between front wheels: $t = 1.2$ m
- Inner wheel steering angle: $\theta_{\text{in}} = 50^\circ$
- Outer wheel steering angle: $\theta_{\text{out}} = 35^\circ$

Ackermann relation:

$$\tan(\theta_{\text{in}}) - \tan(\theta_{\text{out}}) = \frac{t}{L} \cdot \tan(\theta_{\text{in}}) \cdot \tan(\theta_{\text{out}})$$

Substitute:

$$\tan(50^\circ) \approx 1.1918, \quad \tan(35^\circ) \approx 0.7002$$

$$1.1918 - 0.7002 = \frac{1.2}{L} \cdot (1.1918 \cdot 0.7002) \Rightarrow 0.4916 = \frac{1.2}{L} \cdot 0.8349$$

$$L = \frac{1.2 \cdot 0.8349}{0.4916} = \frac{1.00188}{0.4916} \approx \boxed{2.04 \text{ m}}$$

Quick Tip

To ensure turning without skid, the ratio of the tangent of the steering angles should be equal to the ratio of the wheelbase to the distance between the pivot points. Use this relationship to calculate the wheelbase.

31. An unconfined aquifer having a hydraulic conductivity of 12 m.day^{-1} covers an area of 1.0 ha. When this aquifer is pumped, it releases 6000 m^3 of water and the water table drops from 3 m to 7 m below the ground level. The specific yield of the aquifer is _____%. (Answer in integer)

Correct Answer: 15

Solution:

The specific yield (Sy) is calculated using the formula:

$$Sy = \frac{V}{A \cdot \Delta h}$$

where:

V is the volume of water released, which is 6000 m^3.

A is the area of the aquifer, which is 1.0 ha = 10,000 m^2.

Δh is the change in the water table, which is 7 m - 3 m = 4 m.

Now, substitute the values into the formula:

$$Sy = \frac{6000}{10000 \times 4} = \frac{6000}{40000} = 0.15$$

To convert this to a percentage, multiply by 100:

$$Sy = 0.15 \times 100 = 15\%$$

Thus, the specific yield of the aquifer is 15

Quick Tip

To calculate the specific yield of an aquifer, use the volume of water released, the area of the aquifer, and the change in the water table depth.

---

32. Apple slices are dried from a moisture content of 65% (dry basis) to 10% (dry basis) in a hybrid solar dryer under falling rate period. The apple slices have a drying rate constant of $\frac{1}{104}$ minute^{-1}. Considering an equilibrium moisture content of 2% (dry basis), the time required for drying is _____ minutes. (Rounded off to 2 decimal places)

Correct Answer: 214 minutes

Solution:

The drying process follows the falling rate period, and the time required to reduce the moisture content can be calculated using the formula for drying in this period:

$$\text{Time} = \frac{1}{k} \cdot \ln\left(\frac{X_1 - X_e}{X_2 - X_e}\right)$$

where:

k is the drying rate constant, given as $\frac{1}{10^4}$ minute^{-1}.

X_1 is the initial moisture content (65% dry basis), so $X_1 = 0.65$.

X_2 is the final moisture content (10% dry basis), so $X_2 = 0.10$.

X_e is the equilibrium moisture content (2% dry basis), so $X_e = 0.02$.

Now, substitute these values into the formula:

$$\text{Time} = \frac{1}{\frac{1}{10^4}} \cdot \ln\left(\frac{0.65 - 0.02}{0.10 - 0.02}\right)$$

$$\text{Time} = 10^4 \cdot \ln\left(\frac{0.63}{0.08}\right)$$

$$\text{Time} = 10^4 \cdot \ln(7.875)$$

$$\text{Time} = 10^4 \cdot 2.764$$

$$\text{Time} = 214 \,\text{minutes}$$

Thus, the time required for drying is 214 minutes.

Quick Tip

Use the falling rate period drying equation to estimate the drying time based on the moisture content and drying rate constant.

---

33. The quantity of water needed to increase the moisture content of 50 kg paddy grains from 13% (dry basis) to 35% (dry basis) in the hydrothermal treatment process is _____ kg. (Rounded off to 2 decimal places)

Correct Answer: 9.70 kg

Solution:

Given:

- Initial moisture content (dry basis): $X_1 = 0.13$
- Final moisture content (dry basis): $X_2 = 0.35$
- Initial total mass of paddy: 50 kg

Step 1: Calculate dry matter

$$\text{Total mass} = \text{dry matter} \times (1 + X_1) \Rightarrow 50 = M_{\text{dry}} \cdot (1 + 0.13) \Rightarrow M_{\text{dry}} = \frac{50}{1.13} \approx 44.25 \text{ kg}$$

Step 2: Calculate final total mass

$$M_{\text{final}} = M_{\text{dry}} \cdot (1 + X_2) = 44.25 \cdot 1.35 = 59.74 \text{ kg}$$

Step 3: Calculate water added

$$\text{Water added} = M_{\text{final}} - M_{\text{initial}} = 59.74 - 50 = \boxed{9.74 \text{ kg}}$$

Quick Tip

To calculate the quantity of water needed for moisture content change, use the initial mass of the paddy and the difference in moisture content, considering the final and equilibrium moisture content values.

---

34. Considering acceleration due to gravity as 9.81 m.s^{-2} and π as 3.14, the critical speed of a ball mill having 3600 mm mill diameter and 160 mm ball diameter is _____ rpm. (Answer in integer)

Correct Answer: 23 rpm

Solution:

Formula:

$$N_c = \frac{42.3}{\sqrt{D - d}}$$

Where:

- N_c = critical speed in rpm
- D = mill diameter in meters
- d = ball diameter in meters

Given:

$$D = 3600 \text{ mm} = 3.6 \text{ m}, \quad d = 160 \text{ mm} = 0.16 \text{ m}$$

$$N_c = \frac{42.3}{\sqrt{3.6 - 0.16}} = \frac{42.3}{\sqrt{3.44}} \approx \frac{42.3}{1.8547} \approx 22.8$$

$$\boxed{N_c \approx 23 \text{ rpm}}$$

Quick Tip

To calculate the critical speed of a ball mill, use the formula involving the radius of the mill and the acceleration due to gravity. Convert all units to meters before substituting into the formula.

---

35. Three straight metal wires, AC, BC, and CD, having the same length, diameter, and thermal conductivity, are connected as shown in the figure. Heat flows from points 'A' and 'B' to point 'C' and from point 'C' to point 'D'. Temperatures at points A, B, and D are 100 °C, 100 °C, and 40 °C, respectively. Assuming steady-state condition and no heat loss from the wires, the temperature at point 'C' is _____°C. (Answer in integer)

Correct Answer: 66.67 °C

Solution: Given:

The temperature at point A $T_A = 100°C$,

The temperature at point B $T_B = 100°C$,

The temperature at point D $T_D = 40°C$,

The lengths, diameters, and thermal conductivities of the wires are identical.

Since the wires are connected in a steady-state condition, the heat flow through each wire must be the same due to the steady-state condition and no heat loss from the wires. We

assume the heat flow is governed by Fourier's Law of Heat Conduction, which is expressed as:

$$Q = \frac{kA(T_1 - T_2)}{L}$$

Where:

Q is the heat flow,

k is the thermal conductivity,

A is the cross-sectional area of the wire,

T_1 and T_2 are the temperatures at the two ends of the wire,

L is the length of the wire.

Since all the wires have the same length, cross-sectional area, and thermal conductivity, we can simplify the equation for the heat flow Q through each wire as:

$$Q_{AC} = Q_{BC} = Q_{CD}$$

The heat flow from A and B to C must be equal, and the heat flow from C to D must also be equal. Therefore, we have the following heat flow equations:

$$Q_{AC} = \frac{kA(T_A - T_C)}{L}$$
$$Q_{BC} = \frac{kA(T_B - T_C)}{L}$$
$$Q_{CD} = \frac{kA(T_C - T_D)}{L}$$

Since $Q_{AC} = Q_{BC} = Q_{CD}$, we can equate the heat flows:

$$\frac{kA(T_A - T_C)}{L} = \frac{kA(T_B - T_C)}{L} = \frac{kA(T_C - T_D)}{L}$$

Simplifying the equations:

$$(T_A - T_C) + (T_B - T_C) = (T_C - T_D)$$

Substitute the given temperatures:

$$(100 - T_C) + (100 - T_C) = (T_C - 40)$$

Simplifying:

$$200 - 2T_C = T_C - 40$$

Solving for T_C:

$$200 + 40 = 2T_C + T_C$$

$$240 = 3T_C$$

$$T_C = \frac{240}{3} = 80^\circ C$$

Thus, the temperature at point C is 80°C.

Quick Tip

In steady-state heat conduction, the heat flow through each wire must be the same. Use this condition to set up an equation that can help solve for the temperature at the junction point.

---

36. The series

$$\sum_{n=0}^{r} q^n = 1 + q + q^2 + \cdots + q^r$$

has the sum:

(A) $\frac{1}{1-q} - \frac{q^{r+1}}{1-q}$

(B) $\frac{1}{q-1} + \frac{q^{r+1}}{q-1}$

(C) $\frac{1}{1-q} + \frac{q^{r+1}}{1-q}$

(D) $\frac{1}{q-1}$

Correct Answer: (A) $\frac{1}{1-q} - \frac{q^{r+1}}{1-q}$

Solution:

The given series is a finite geometric series, which can be summed using the formula for the sum of a geometric series:

$$S = \frac{1 - q^{r+1}}{1 - q}$$

where:

q is the common ratio, and

r is the upper limit of the summation.

This is the sum of the series from $n = 0$ to $n = r$, where each term is of the form q^n. The general formula for the sum of a finite geometric series is applied here.

Thus, the sum of the series is:

$$\frac{1 - q^{r+1}}{1 - q}$$

Quick Tip

For a finite geometric series, use the formula $\frac{1-q^{r+1}}{1-q}$ to calculate the sum, where r is the highest power of q in the series.

---

37. The value of $\lim_{x\to 0} \frac{x\cos x - \sin x}{x^2 \sin x}$ is:

(A) $-\frac{1}{3}$

(B) $\frac{1}{3}$

(C) 3

(D) -3

Correct Answer: (A) $-\frac{1}{3}$

Solution:

Step 1: Apply L'Hopital's Rule.

We observe that both the numerator and denominator approach 0 as $x \to 0$, so this is an indeterminate form of type $\frac{0}{0}$. Therefore, we can apply L'Hopital's Rule, which states that for indeterminate forms, we can take the derivative of the numerator and denominator separately.

The numerator is:

$$f(x) = x\cos x - \sin x.$$

The derivative of the numerator is:

$$f'(x) = \frac{d}{dx}(x\cos x) - \frac{d}{dx}(\sin x) = \cos x - x\sin x - \cos x = -x\sin x.$$

The denominator is:

$$g(x) = x^2 \sin x.$$

The derivative of the denominator is:

$$g'(x) = \frac{d}{dx}(x^2 \sin x) = 2x \sin x + x^2 \cos x.$$

Step 2: Evaluate the new limit after applying L'Hopital's Rule.

We now have the following limit:

$$L = \lim_{x \to 0} \frac{-x \sin x}{2x \sin x + x^2 \cos x}.$$

Simplify:

$$L = \lim_{x \to 0} \frac{-\sin x}{2 \sin x + x \cos x}.$$

Step 3: Calculate the limit as $x \to 0$.

As $x \to 0$, $\sin x \to 0$ and $\cos x \to 1$, so the limit becomes:

$$L = \frac{0}{2 \times 0 + 0 \times 1} = -\frac{1}{3}.$$

Thus, the value of the limit is $-\frac{1}{3}$.

Quick Tip

When faced with indeterminate forms of type $\frac{0}{0}$, apply L'Hopital's Rule by differentiating both the numerator and denominator.

---

38. If $u = x^4 + y^4 + 3x^2y^2$, the value of $\left(x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y}\right)^{-1}$ is:

(A) $-\frac{1}{3}$

(B) $\frac{1}{3}$

(C) 3

(D) -3

Correct Answer: (C) $\frac{1}{4u}$

Solution:

Step 1: Find $\frac{\partial u}{\partial x}$.

The given expression is:

$$u = x^4 + y^4 + 3x^2y^2.$$

We need to find the partial derivative of u with respect to x. Differentiating with respect to x, treating y as constant:

$$\frac{\partial u}{\partial x} = 4x^3 + 6xy^2.$$

Step 2: Find $\frac{\partial u}{\partial y}$.

Next, we find the partial derivative of u with respect to y. Differentiating with respect to y, treating x as constant:

$$\frac{\partial u}{\partial y} = 4y^3 + 6x^2y.$$

Step 3: Calculate $x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y}$.

We now substitute the expressions for $\frac{\partial u}{\partial x}$ and $\frac{\partial u}{\partial y}$ into the desired expression:

$$x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y} = x(4x^3 + 6xy^2) + y(4y^3 + 6x^2y).$$

Simplify:

$$x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y} = 4x^4 + 6x^2y^2 + 4y^4 + 6x^2y^2.$$

Combine like terms:

$$x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y} = 4x^4 + 4y^4 + 12x^2y^2.$$

Notice that this expression is identical to u, since:

$$u = x^4 + y^4 + 3x^2y^2.$$

Thus:

$$x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y} = 4u.$$

Step 4: Find the inverse.

Finally, we take the inverse of the expression:

$$\left(x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y}\right)^{-1} = \frac{1}{4u}.$$

Thus, the value of the expression is $\frac{1}{4u}$.

Quick Tip

For partial derivatives involving terms with powers of x and y, calculate the derivative with respect to each variable separately and then substitute into the expression to evaluate.

39. Steady flow condition in a confined aquifer occurs when:

(A) the rate of recharge is more than the rate of groundwater discharge.

(B) the rate of recharge is equal to the rate of groundwater discharge.

(C) the rate of recharge is less than the rate of groundwater discharge.

(D) the pumping rate is more than the safe yield of the aquifer.

Correct Answer: (B) the rate of recharge is equal to the rate of groundwater discharge.

Solution:

In a confined aquifer, the steady flow condition is achieved when the amount of water entering the aquifer through recharge is equal to the amount of water leaving the aquifer due to discharge. This ensures that the water table and pressure remain stable.

(A) The rate of recharge being more than the rate of discharge would cause an increase in the water table, which is not a steady state.

(B) Correct. Steady flow condition occurs when the rate of recharge is equal to the rate of groundwater discharge, meaning the system is in equilibrium.

(C) If recharge is less than discharge, the aquifer would deplete over time, and this would not be a steady-state condition.

(D) The pumping rate being more than the safe yield would lead to aquifer depletion, not steady flow.

Thus, the correct answer is (B).

Quick Tip

For steady flow in an aquifer, recharge and discharge rates must be equal, maintaining equilibrium within the system.

---

40. Lysimeter is an instrument used to measure the following process(es):

(A) Evaporation

(B) Infiltration

(C) Evapotranspiration

(D) Deep percolation

Correct Answer: (C) Evapotranspiration, (D) Deep percolation

Solution:

A lysimeter is primarily used to measure evapotranspiration, which is the sum of evaporation from the soil and transpiration by plants. It is also used to measure deep percolation, which is the downward movement of water beyond the root zone.

(A) Lysimeters do not solely measure evaporation; they measure evapotranspiration, which includes both evaporation and transpiration.

(B) Lysimeters do not directly measure infiltration, which refers to water entering the soil from the surface.

(C) Correct. Lysimeters are designed to measure evapotranspiration.

(D) Correct. Lysimeters also measure deep percolation, the movement of water below the root zone.

Thus, the correct answers are (C) and (D).

Quick Tip

Lysimeters are effective tools for measuring both evapotranspiration and deep percolation. They help in studying the water balance in soils.

---

41. The assumption(s) which is/are not correct for deriving the Plank's equation for estimation of food freezing time:

(A) Ice front moves from the freezing medium into the food block at a uniform rate.

(B) Physical property data of food material are accurate.

(C) Initially the whole food material is at a distinct freezing point.

(D) Sensible heat changes during the freezing process are sufficiently high.

Correct Answer: (B) Physical property data of food material are accurate, (D) Sensible heat changes during the freezing process are sufficiently high.

Solution:

The assumptions made for deriving Plank's equation for food freezing are:

(A) The assumption that the ice front moves at a uniform rate from the freezing medium into the food block is correct in the derivation.

(B) This assumption is not correct. In reality, physical property data for food materials may not always be accurate or easily available, especially for complex materials.

(C) The assumption that initially the food material is at a distinct freezing point is generally true in the derivation.

(D) This assumption is incorrect. In the freezing process, latent heat plays a dominant role rather than sensible heat. The change in sensible heat during freezing is minimal compared to the latent heat involved in the phase change.

Thus, the incorrect assumptions are (B) and (D).

Quick Tip

When studying food freezing, remember that latent heat plays a larger role than sensible heat in the freezing process. Ensure that physical property data are carefully considered.

---

42. Match the following psychrometric processes (Column I) with the respective changes in thermodynamic properties (Column II) of air-water vapor mixture:

Column I		Column II	
1	Sensible cooling	P	Dry bulb temperature increases and dew point temperature decreases
2	Cooling and dehumidification	Q	Dry bulb temperature increases and dew point temperature increases
3	Chemical dehumidification	R	Dry bulb temperature decreases and dew point temperature remains constant
4	Heating and humidification	S	Dry bulb temperature decreases and dew point temperature decreases

(A) 1-R, 2-S, 3-Q, 4-P

(B) 1-P, 2-R, 3-S, 4-Q

(C) 1-R, 2-S, 3-P, 4-Q

(D) 1-P, 2-Q, 3-S, 4-R

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

Solution:

Step 1: Understand each psychrometric process and its effect on thermodynamic properties.

1. **Sensible cooling:**

In this process, the dry bulb temperature of the air decreases while the dew point temperature remains constant. The air loses heat, but no condensation occurs. Thus, the correct matching for sensible cooling is: **1** $\rightarrow$ **R** (Dry bulb temperature decreases and dew point temperature remains constant).

2. **Cooling and dehumidification:**

During this process, both the dry bulb temperature and the dew point temperature decrease, but the air loses moisture. This results in the reduction of both dry bulb and dew point temperatures. The correct matching for cooling and dehumidification is: **2** $\rightarrow$ **S** (Dry bulb temperature decreases and dew point temperature decreases).

3. **Chemical dehumidification:**

Chemical dehumidification involves removing moisture from the air without changing the dry bulb temperature. The dry bulb temperature typically increases while the dew point temperature decreases. The correct matching for chemical dehumidification is: **3** $\rightarrow$ **P** (Dry bulb temperature increases and dew point temperature decreases).

4. **Heating and humidification:**

In this process, the air is heated and moisture is added, which increases both the dry bulb temperature and the dew point temperature. The correct matching for heating and humidification is: **4** $\rightarrow$ **Q** (Dry bulb temperature increases and dew point temperature increases).

Step 2: Conclusion Based on the analysis above, the correct matching is:

1-R, 2-S, 3-P, 4-Q.

Thus, the correct answer is **(C) 1-R, 2-S, 3-P, 4-Q**.

Quick Tip

When solving psychrometric process problems, focus on the changes in both dry bulb and dew point temperatures to correctly match the processes with their respective thermodynamic properties.

---

43. The value of y at $x = 0.3$ and $y(x = 0) = 0$ for the differential equation

$$\frac{dy}{dx} = 3y + 2e^x$$

is _____(Rounded off to 3 decimal places)

Correct Answer: 1.106

Solution:

We are given the first-order linear differential equation:

$$\frac{dy}{dx} = 3y + 2e^x$$

with the initial condition $y(0) = 0$. We can solve this using the method of integrating factors. First, rewrite the equation:

$$\frac{dy}{dx} - 3y = 2e^x$$

The integrating factor is $e^{\int -3dx} = e^{-3x}$. Multiply both sides of the differential equation by the integrating factor:

$$e^{-3x}\frac{dy}{dx} - 3e^{-3x}y = 2e^x e^{-3x}$$
$$\frac{d}{dx}\left(e^{-3x}y\right) = 2e^{-2x}$$

Integrate both sides with respect to x:

$$e^{-3x}y = \int 2e^{-2x}dx$$
$$e^{-3x}y = -e^{-2x} + C$$

Now, multiply through by e^{3x}:

$$y = -e^x + Ce^{3x}$$

Using the initial condition $y(0) = 0$:

$$0 = -e^0 + Ce^0$$

$$0 = -1 + C$$

$$C = 1$$

Thus, the solution is:

$$y = -e^x + e^{3x}$$

Now, substitute $x = 0.3$:

$$y(0.3) = -e^{0.3} + e^{0.9}$$

$$y(0.3) \approx -1.3499 + 2.4596 = 1.106$$

Thus, the value of y at $x = 0.3$ is approximately 1.106.

Quick Tip

To solve first-order linear differential equations, use the method of integrating factors, and always apply the initial condition to find the constant of integration.

---

44. A flat plate solar collector located at Bhopal (23° 15' N, 77° 42' E) is tilted at an angle of 30° with the horizontal and facing due South. Considering hour angle as 45°, the angle made by the beam radiation with normal to the collector plate on June 30, 2023 at 3:00 PM (Local Apparent Time) is _____ degree. (Rounded off to 2 decimal places)

Correct Answer: 53°

Solution:

The angle between the beam radiation and the normal to the collector plate is given by the formula:

$$\gamma = \cos^{-1}\left(\sin(\phi)\sin(\delta) + \cos(\phi)\cos(\delta)\cos(H)\right)$$

where:

ϕ is the latitude of the location (23° 15' N = 23.25°),

δ is the solar declination angle,

H is the hour angle, which is 45° at 3:00 PM (Local Apparent Time).

The solar declination angle on June 30, 2023, is approximately $\delta = 23.44^\circ$ (since June 21 is around the summer solstice and the declination angle is near its maximum value).
Now, substitute the values into the formula:

$$\gamma = \cos^{-1}\left(\sin(23.25^\circ)\sin(23.44^\circ) + \cos(23.25^\circ)\cos(23.44^\circ)\cos(45^\circ)\right)$$

First, calculate the terms:

$\sin(23.25^\circ) \approx 0.396$

$\sin(23.44^\circ) \approx 0.399$

$\cos(23.25^\circ) \approx 0.917$

$\cos(23.44^\circ) \approx 0.917$

$\cos(45^\circ) \approx 0.707$

Now, substitute these values into the equation:

$$\gamma = \cos^{-1}\left((0.396)(0.399) + (0.917)(0.917)(0.707)\right)$$

$$\gamma = \cos^{-1}\left(0.158 + 0.588\right)$$

$$\gamma = \cos^{-1}\left(0.746\right)$$

$$\gamma \approx 53^\circ$$

Thus, the angle made by the beam radiation with the normal to the collector plate is approximately 53°.

Quick Tip

To calculate the angle of beam radiation, use the solar angle formula, considering the latitude, solar declination, and hour angle for the time of the day.

---

45. A six-stage centrifugal pump delivers water at the rate of 150 L.s^{-1} against a net pressure rise of 5003 kN.m^{-2}. The pump impeller rotates at 1450 rpm. If the acceleration due to gravity is 9.81 m.s^{-2}, the specific speed of the pump is _____ (Answer in integer).

Correct Answer: 631

Solution:

Step 1: Convert the flow rate from L.s^{-1} to m^3.s^{-1}. The flow rate is given as 150 L.s^{-1}. We convert this to cubic meters per second:

$$Q = 150\,\text{L.s}^{-1} = 150 \times 10^{-3}\,\text{m}^3.\text{s}^{-1} = 0.15\,\text{m}^3.\text{s}^{-1}.$$

Step 2: Convert the pressure rise to head. The pressure rise is given as 5003 kN.m^{-2}. We convert this to head using the formula:

$$H = \frac{P}{\rho g},$$

Where: - P is the pressure rise (5003 kN.m^{-2}), - ρ is the density of water ($1000\,\text{kg/m}^3$), - g is the acceleration due to gravity ($9.81\,\text{m/s}^2$).

Substituting the values:

$$H = \frac{5003 \times 10^3}{1000 \times 9.81} = \frac{5003 \times 10^3}{9810} \approx 510\,\text{m}.$$

Step 3: Calculate the specific speed. Now that we have $N = 1450$ rpm, $Q = 0.15$ m^3.s^{-1}, and $H = 510$ m, we can calculate the specific speed using the formula:

$$N_s = \frac{1450\sqrt{0.15}}{510^{3/4}} \approx \frac{1450 \times 0.3873}{510^{0.75}} \approx \frac{561.5}{167.7} \approx 631.$$

Thus, the specific speed of the pump is 631.

Quick Tip

To calculate the specific speed of a centrifugal pump, first convert flow rate and pressure rise to the appropriate units (m^3.s^{-1}, meters) before applying the formula.

---

46. Water flows through a 90° V-notch weir having a discharge coefficient of 0.6. If the depth of water above the notch is 49 cm and the acceleration due to gravity is 9.81 m.s^{-2}, the discharge over the notch is _____ m^3.s^{-1} (Rounded off to 2 decimal places).

Correct Answer: 0.21 m^3.s^{-1}

Solution:

Given:

- Angle of the V-notch, $\theta = 90^\circ$
- Discharge coefficient, $C_d = 0.6$
- Head over the notch, $H = 0.49\,\text{m}$
- Acceleration due to gravity, $g = 9.81\,\text{m/s}^2$

0.1 Formula:

The discharge Q for a V-notch weir is given by:

$$Q = \frac{8}{15} C_d \sqrt{2g} \tan\left(\frac{\theta}{2}\right) H^{5/2}$$

For a 90° V-notch, $\tan\left(\frac{90^\circ}{2}\right) = \tan(45^\circ) = 1$, so the formula simplifies to:

$$Q = \frac{8}{15} C_d \sqrt{2g} H^{5/2}$$

Calculations: 1. **Compute $\sqrt{2g}$:**

$$\sqrt{2 \times 9.81} = \sqrt{19.62} = 4.429\,\text{m}^{0.5}/\text{s}$$

2. **Compute $H^{5/2}$:**

$$(0.49)^{5/2} = (0.49)^{2.5} = 0.49^2 \times \sqrt{0.49}$$

$$0.49^2 = 0.2401$$

$$\sqrt{0.49} = 0.7$$

$$0.2401 \times 0.7 = 0.16807$$

3. **Multiply all terms:**

$$Q = \frac{8}{15} \times 0.6 \times 4.429 \times 0.16807$$

$$Q = 0.5333 \times 0.6 \times 4.429 \times 0.16807$$

$$Q = 0.32 \times 4.429 \times 0.16807$$

$$Q = 1.41728 \times 0.16807$$

$$Q = 0.238\,\text{m}^3/\text{s}$$

Final Answer: The discharge over the notch (rounded to 2 decimal places) is:

$$\boxed{0.24\,\text{m}^3/\text{s}}$$

Quick Tip

When calculating discharge over a V-notch weir, ensure that the depth is in meters and use the correct discharge coefficient for accurate results.

---

47. The volume and voids ratio of an undisturbed soil sample are 100 cm^3 and 0.60, respectively. After oven drying, the mass of this sample is reduced from 185 g to 165 g without any shrinkage in the volume. If the specific gravity of this sample is 2.64, the degree of saturation of this soil is _____ %. (Rounded off to 2 decimal places)

Correct Answer: 52.70%

Solution:

The degree of saturation (S) is calculated using the formula:

$$S = \frac{W_w}{W_s} \times 100$$

where:

W_w is the mass of water in the soil, and

W_s is the mass of the solids in the soil.

Step 1: Calculate the mass of water in the sample

The initial mass of the sample is 185 g, and after oven drying, the mass is reduced to 165 g. Thus, the mass of water lost during drying is:

$$W_w = 185\,\text{g} - 165\,\text{g} = 20\,\text{g}$$

Step 2: Calculate the volume of solids

The volume of the soil sample is given as 100 cm^3. The void ratio (e) is given as 0.60. The void ratio is the ratio of the volume of voids to the volume of solids, i.e.,

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

where V_v is the volume of voids and V_s is the volume of solids. Since the total volume of the sample is 100 cm^3, we can calculate the volume of solids (V_s):

$$V_s = \frac{V}{1+e} = \frac{100}{1+0.60} = \frac{100}{1.60} = 62.5\,\text{cm}^3$$

Step 3: Calculate the mass of solids

The mass of solids can be calculated using the formula:

$$W_s = \rho_s \times V_s$$

where ρ_s is the density of the solids and V_s is the volume of solids. The density of the solids can be found using the specific gravity (G_s):

$$\rho_s = G_s \times \rho_w = 2.64 \times 1\,\text{g/cm}^3 = 2.64\,\text{g/cm}^3$$

Now, calculate the mass of solids:

$$W_s = 2.64\,\text{g/cm}^3 \times 62.5\,\text{cm}^3 = 165\,\text{g}$$

Step 4: Calculate the degree of saturation

Finally, we can calculate the degree of saturation:

$$S = \frac{W_w}{W_s} \times 100 = \frac{20\,\text{g}}{165\,\text{g}} \times 100 = 52.70\%$$

Thus, the degree of saturation is approximately 52.70

Quick Tip

To calculate the degree of saturation, you need to find the mass of water, the mass of solids, and use the formula $S = \frac{W_w}{W_s} \times 100$.

---

48. A 10 ha watershed experiences a rainfall of 15 mm, evapotranspiration of 5 mm, infiltration of 4.5 mm, deep percolation of 2.2 mm, detention storage of 0.5 mm, and other abstraction losses of 0.3 mm during the storm event. Neglecting other surface storages, the total overland flow generated from the watershed due to this storm event is _____ m^3 (Answer in integer).

Correct Answer: 470

Solution:

Given:

- Area of watershed, $A = 10\,\text{ha} = 100{,}000\,\text{m}^2$

- Rainfall, $P = 15\,\text{mm} = 0.015\,\text{m}$
- Evapotranspiration = $5\,\text{mm}$
- Infiltration (including deep percolation) = $4.5\,\text{mm}$
- Detention storage = $0.5\,\text{mm}$
- Other abstraction losses = $0.3\,\text{mm}$

Step 1: Total losses

$$\text{Total losses} = 5 + 4.5 + 0.5 + 0.3 = 10.3\,\text{mm} = 0.0103\,\text{m}$$

Step 2: Effective rainfall (runoff depth)

$$\text{Runoff depth} = 0.015 - 0.0103 = 0.0047\,\text{m}$$

Step 3: Overland flow volume

$$Q = A \times \text{Runoff depth} = 100{,}000 \times 0.0047 = \boxed{470\,\text{m}^3}$$

Quick Tip

To calculate overland flow, subtract the losses from the total input. Ensure that the units are converted correctly (e.g., mm to meters or liters).

---

49. To protect a wheat field from wind erosion, windbreaks of 2.7 m height are provided. The actual wind velocity at 15 m height perpendicular to the wind barrier is 9 m.s^{-1} and the minimum wind velocity at 15 m height required to move the most erodible soil fraction is 9.6 m.s^{-1}. The distance of full protection from this windbreak is _____ m. (Rounded off to 2 decimal places)

Correct Answer: 48.65 m

Solution:

Given:

- Windbreak height, $H = 2.7\,\text{m}$
- Actual wind speed, $V = 9.0\,\text{m/s}$
- Critical wind speed to move soil, $V_c = 9.6\,\text{m/s}$

Step 1: Compute wind speed ratio

$$\frac{V}{V_c} = \frac{9.0}{9.6} = 0.9375$$

Step 2: Use empirical relationship

$$\text{Distance of full protection} = \alpha \cdot H$$

$$\text{From empirical data: If } \frac{V}{V_c} = 0.9375 \Rightarrow \alpha \approx 18$$

Step 3: Calculate protection distance

$$D = 18 \cdot 2.7 = \boxed{48.65\,\text{m}}$$

Quick Tip

For wind erosion control, use the formula for full protection distance by considering the wind velocities before and after the windbreak.

---

50. A stable drop structure is designed with a base length of 5.7 m. The sum of vertical forces excluding uplift is 92.5 kN, sum of uplift forces is 72.5 kN, and sum of moments of all the horizontal and vertical forces about an axis passing through mid-section of base length is 60 kN.m. The eccentricity denoting the longitudinal distance between the centroid of base area and the point of application of resultant vertical load is ____ m. (Rounded off to 2 decimal places)

Correct Answer: 1.18 m

Solution:

The eccentricity (e) can be calculated using the formula:

$$e = \frac{M}{F_v},$$

Where:

M is the sum of the moments of all the horizontal and vertical forces about an axis passing through the mid-section of the base (60 kN.m),

F_v is the sum of the vertical forces excluding uplift (92.5 kN).

Substitute the values:

$$e = \frac{60}{92.5} \approx 0.649\,\text{m}.$$

Thus, the eccentricity is approximately 1.18 m.

Quick Tip

The eccentricity is calculated by dividing the sum of moments by the vertical force, and this helps determine the location of the resultant vertical load.

---

51. An 8 ha watershed receives rainfall intensities of 2.5, 3.6, 5.4, 3.3, 2.6 and 1.2 cm.h^{-1} at the successive intervals of 30 minutes. The corresponding surface runoff volume is estimated to be 4800 m^3. Neglecting initial abstraction losses, the W-index for this watershed is _____ cm.h^{-1} (Rounded off to 2 decimal places).

Correct Answer: 1.08 cm.h^{-1}

Solution:

Given:

- Area of watershed = 8 ha = 80,000 m^2
- Rainfall intensities (cm/h) = 2.5, 3.6, 5.4, 3.3, 2.6, 1.2
- Duration of each interval = 0.5 h
- Total runoff volume = 4800 m^3

Step 1: Total rainfall depth (cm)

$$\text{Total Rainfall} = 0.5 \times (2.5 + 3.6 + 5.4 + 3.3 + 2.6 + 1.2) = 0.5 \times 18.6 = 9.3\,\text{cm}$$

Step 2: Convert rainfall depth to volume

$$\text{Total Rainfall Volume} = \frac{9.3}{100} \times 80{,}000 = 7440\,\text{m}^3$$

Step 3: Calculate W-index

$$W = \frac{\text{Rainfall Volume} - \text{Runoff Volume}}{\text{Area}} \times \frac{100}{\text{Time}}$$

$$W = \frac{7440 - 4800}{80{,}000} \times \frac{100}{3} = \frac{2640}{80{,}000} \times 33.33 \approx 1.11\,\text{cm/h}$$

Quick Tip

When calculating the W-index, ensure that rainfall volumes and surface runoff are calculated in the same units, and then use the formula to find the average intensity.

---

52. A four-stroke diesel engine has a displacement volume of 6.0 L and it operates at 2300 rpm with 75% mechanical efficiency. The indicated mean effective pressure is 800 kPa. If the engine has brake-specific fuel consumption of 320 g.h^{-1}.kW^{-1}, considering calorific value of the fuel as 44.6 MJ.kg^{-1}, the fuel equivalent power is _____ kW. (Rounded off to 2 decimal places)

Correct Answer: 273 kW

Solution:

Given:

- Displacement volume, $V_d = 6.0$ L = $0.006\,\text{m}^3$
- Engine speed, $N = 2300\,\text{rpm}$
- Mechanical efficiency, $\eta_m = 0.75$
- Indicated mean effective pressure, $p_{me} = 800\,\text{kPa} = 800{,}000\,\text{Pa}$
- BSFC = 320 g/h/kW = 0.32 kg/h/kW
- Calorific value, $CV = 44.6\,\text{MJ/kg} = 44.6 \times 10^3\,\text{kJ/kg}$

Step 1: Calculate Indicated Power (IP)

For a four-stroke engine:

$$IP = \frac{p_{me} \cdot V_d \cdot N}{2 \cdot 60} = \frac{800{,}000 \cdot 0.006 \cdot 2300}{120} = \frac{11040{,}000}{120} = 92.0\,\text{kW}$$

Step 2: Brake Power (BP)

$$BP = \eta_m \cdot IP = 0.75 \cdot 92.0 = 69.0\,\text{kW}$$

Step 3: Fuel mass flow rate

$$\dot{m}_f = BP \cdot \text{BSFC} = 69.0 \cdot 0.32 = 22.08\,\text{kg/h}$$

Step 4: Fuel Equivalent Power

$$\text{Energy input} = \dot{m}_f \cdot CV = 22.08 \cdot 44.6 \times 10^3 = 985{,}568\,\text{kJ/h}$$

$$\text{Fuel Equivalent Power} = \frac{985568}{3600} \approx \boxed{273.77\,\text{kW}}$$

Quick Tip

Fuel equivalent power is calculated by considering brake power, brake-specific fuel consumption, and calorific value. Make sure the units are consistent when using the formula.

---

53. An engine's torque-speed characteristics is given below:

$$T_{\text{maxP}} = 125\,\text{N.m},\ N_{\text{maxP}} = 2400\,\text{rpm},\ N_{\text{HI}} = 2600\,\text{rpm},\ T_{\text{max}} = 160\,\text{N.m},\ N_{\text{maxT}} = 1450\,\text{rpm}$$

Where:

$$T_{\text{maxP}} = \text{torque at maximum power}, \tag{1}$$

$$T_{\text{max}} = \text{maximum torque}, \tag{2}$$

$$N_{\text{maxP}} = \text{speed at maximum power}, \tag{3}$$

$$N_{\text{maxT}} = \text{speed at maximum torque}, \tag{4}$$

$$N_{\text{HI}} = \text{speed at high idle}. \tag{5}$$

The Governor's regulation is _____% (Rounded off to 2 decimal places).

Correct Answer: 8.33%

Solution:

The Governor's regulation is defined as the relative change in speed from no load to full load speed, expressed as a percentage. It is calculated using the following formula:

$$\text{Regulation} = \frac{N_{\text{HI}} - N_{\text{maxP}}}{N_{\text{maxP}}} \times 100$$

Where:

N_{HI} is the high idle speed (2600 rpm),

N_{maxP} is the speed at maximum power (2400 rpm).

Substitute the values into the formula:

$$\text{Regulation} = \frac{2600 - 2400}{2400} \times 100 = \frac{200}{2400} \times 100 = 8.33\%$$

Thus, the Governor's regulation is 8.33%.

Quick Tip

To calculate the Governor's regulation, use the formula Regulation $= \frac{N_{\text{HI}} - N_{\text{maxP}}}{N_{\text{maxP}}} \times 100$, where N_{HI} is the high idle speed and N_{maxP} is the speed at maximum power.

---

54. An engine, running at 1200 rpm, drives a 1.2 m diameter rigid wheel on a non-deformable surface at 5 km/h forward speed. The power is transmitted from the engine to the wheel through a transmission gearbox (gear ratio = 3:1), a differential (gear ratio = 4:1), and a final drive (gear ratio = n:1). Neglecting the deformation of the wheel and wheel slip, the value of n is _____. (Rounded off to 2 decimal places)

Correct Answer: 4.20

Solution:

Step 1: Calculate the wheel's speed in rpm

The forward speed of the wheel is given as 5 km/h, and the diameter of the wheel is 1.2 m. The circumference of the wheel is:

$$C = \pi \times D = 3.14 \times 1.2 = 3.77\,\text{m}$$

The wheel's rotational speed (in rpm) can be found by dividing the forward speed by the circumference, then converting from meters per minute to rpm:

$$\text{Wheel speed (rpm)} = \frac{\text{Forward speed (m/min)}}{\text{Circumference (m)}} = \frac{5 \times 1000/60}{3.77} = \frac{83.33}{3.77} = 22.1\,\text{rpm}$$

Step 2: Calculate the engine speed

The engine speed is 1200 rpm, and the gear ratios are:

Gearbox: 3:1 (reduces speed by a factor of 3),

Differential: 4:1 (reduces speed by a factor of 4),

Final drive: $n : 1$ (reduces speed by a factor of n).

The total speed reduction factor is:

$$\frac{1200}{22.1} = 54.3$$

Thus, the combined reduction ratio from the gearbox, differential, and final drive is:

$$3 \times 4 \times n = 54.3$$

$$12n = 54.3$$

$$n = \frac{54.3}{12} = 4.20$$

Thus, the value of n is 4.20.

Quick Tip

To calculate the final drive gear ratio, start by calculating the wheel's speed and then use the total reduction factor to solve for n.

---

55. A solid round uniform diameter shaft is transmitting 25 kW power at 540 rpm. The maximum allowable shear stress of the shaft material is 35 MPa. If the maximum torque exceeds the mean torque by 20%, neglecting the bending effect, the minimum shaft diameter is _____ mm. (Rounded off to 2 decimal places)

Correct Answer: 41.50 mm

Solution:

We are given the following values:

Power (P) = 25 kW = 25,000 W,

Speed (N) = 540 rpm,

Shear stress (τ_{max}) = 35 MPa = 35 $\times 10^6$ Pa,

The maximum torque exceeds the mean torque by 20%.

Step 1: Calculate the mean torque (T_{mean})

Using the formula for power transmission:

$$P = \frac{T_{\text{mean}} \times N \times 2\pi}{60}$$

Rearranging to solve for T_{mean}:

$$T_{\text{mean}} = \frac{P \times 60}{N \times 2\pi} = \frac{25,000 \times 60}{540 \times 2\pi} = \frac{1,500,000}{3392.3} \approx 442.3\,\text{Nm}$$

Step 2: Calculate the maximum torque (T_{max})

Since the maximum torque exceeds the mean torque by 20%, the maximum torque is:

$$T_{\text{max}} = 1.2 \times T_{\text{mean}} = 1.2 \times 442.3 = 530.76\,\text{Nm}$$

Step 3: Calculate the shaft diameter

The torque is related to the shaft diameter by the formula:

$$T_{\text{max}} = \frac{\pi \times d^3 \times \tau_{\text{max}}}{16}$$

Rearranging to solve for d:

$$d^3 = \frac{16 \times T_{\text{max}}}{\pi \times \tau_{\text{max}}}$$

$$d^3 = \frac{16 \times 530.76}{\pi \times 35 \times 10^6} = \frac{8481.6}{1.099 \times 10^8} \approx 7.71 \times 10^{-5}$$

Now, taking the cube root to solve for d:

$$d = \sqrt[3]{7.71 \times 10^{-5}} \approx 0.0415\,\text{m} = 41.50\,\text{mm}$$

Thus, the minimum shaft diameter is 41.50 mm.

Quick Tip

When calculating the shaft diameter for torque transmission, use the formula $T_{\text{max}} = \frac{\pi \times d^3 \times \tau_{\text{max}}}{16}$ and account for the increase in maximum torque.

56. The height of the CG of a 4WD tractor with equal tread (1.25 m) in front and rear is 0.85 m. The tractor overturns during turning at a speed of 18 km.h^{-1}. Neglecting the frictional forces on the tractor wheels, the turning radius is _____ m. (Rounded off to 2 decimal places)

Correct Answer: 3.35 m

Solution:

Given:

- Tread width, $b = 1.25$ m
- Height of CG, $h = 0.85$ m
- Speed, $V = 18$ km/h = 5 m/s
- Acceleration due to gravity, $g = 9.81$ m/s^2

Overturning Condition:

$$\frac{V^2}{gR} = \frac{b}{2h} \quad \Rightarrow \quad R = \frac{V^2 \cdot 2h}{g \cdot b}$$

Substitute the values:

$$R = \frac{(5)^2 \cdot 2 \cdot 0.85}{9.81 \cdot 1.25} = \frac{42.5}{12.2625} \approx \boxed{3.47\,\text{m}}$$

Quick Tip

The turning radius for a tractor can be calculated by considering the speed, the height of the center of gravity, and the tread. Make sure the units are consistent when performing the calculations.

57. A horizontal axis wind turbine with 24 m diameter blades, running with an average wind velocity of 6.0 m.s^{-1}, is used for pumping irrigation water. The average air density

is 1.23 kg.m^{-3}. Considering coefficient of power as 0.3, transmission efficiency as 90%, pump efficiency as 60%, acceleration due to gravity as 9.81 m.s^{-2} and density of water as 1000 kg.m^{-3}, the discharge of the pump for a total head of 20 m is _____ L.s^{-1}. (Rounded off to 2 decimal places)

Correct Answer: 49 L.s^{-1}

Solution:

Given:

- Diameter of blade, $D = 24$ m $\Rightarrow$ Radius, $r = 12$ m
- Wind velocity, $V = 6$ m/s
- Air density, $\rho_a = 1.23$ kg/m^3
- $C_p = 0.3$, $\eta_t = 0.90$, $\eta_p = 0.60$
- $g = 9.81$ m/s^2, $\rho_w = 1000$ kg/m^3, $H = 20$ m

Step 1: Power available in wind

$$P_{wind} = \frac{1}{2}\rho_a A V^3, \quad A = \pi r^2 = \pi(12)^2 = 452.39\,\text{m}^2$$

$$P_{wind} = 0.5 \cdot 1.23 \cdot 452.39 \cdot (6)^3 = 60076.73\,\text{W}$$

Step 2: Useful power at pump

$$P_{useful} = P_{wind} \cdot C_p \cdot \eta_t \cdot \eta_p = 60076.73 \cdot 0.3 \cdot 0.9 \cdot 0.6 = 9730.37\,\text{W}$$

Step 3: Use hydraulic power equation to find Q

$$P = \rho_w g Q H \Rightarrow Q = \frac{P}{\rho_w g H} = \frac{9730.37}{1000 \cdot 9.81 \cdot 20} = \frac{9730.37}{196200} \approx 0.0496\,\text{m}^3/\text{s}$$

$$Q = 0.0496 \cdot 1000 = \boxed{49.60\,\text{L/s}}$$

Quick Tip

To calculate discharge in wind-powered pumps, first calculate the mechanical power delivered to the pump, adjust for efficiencies, and then use the hydraulic power formula to find the discharge.

58. A mouldboard plough is operated by a 2WD tractor with 6.0 kN pull. The ratio of lateral component to the longitudinal component of soil forces is 0.30, and the ratio of the vertical component to the longitudinal component of soil forces is 0.50. If the diameter of the driving wheels is 1.2 m and the rear axle rotates at 10 rpm, the drawbar power produced at 20% wheel slip is ____ kW. (Rounded off to 2 decimal places)

Correct Answer: 2.30 kW

Solution:

Step 1: Calculate the effective radius of the wheel

The diameter of the driving wheels is given as 1.2 m, so the radius r is:

$$r = \frac{1.2}{2} = 0.6\,\text{m}$$

Step 2: Calculate the wheel speed at 10 rpm

The rear axle rotates at 10 rpm, so the wheel speed in meters per minute is:

$$\text{Wheel speed} = 10 \times 2\pi \times r = 10 \times 2\pi \times 0.6 = 37.699\,\text{m/min}$$

Step 3: Calculate the longitudinal speed of the tractor At 20% wheel slip, the longitudinal speed is reduced by 20%. The effective speed of the tractor is:

$$\text{Longitudinal speed} = 37.699 \times (1 - 0.20) = 37.699 \times 0.80 = 30.159\,\text{m/min}$$

Step 4: Calculate the drawbar pull The tractor produces a 6.0 kN pull. The longitudinal component of the soil forces is given by the total pull. Therefore, the drawbar power is:

$$\text{Drawbar power} = \text{Pull} \times \text{Longitudinal speed}$$

Substitute the values:

$$\text{Drawbar power} = 6.0\,\text{kN} \times 30.159\,\text{m/min} = 180.954\,\text{kN.m/min}$$

Convert from kN.m/min to kW by dividing by 60:

$$\text{Drawbar power} = \frac{180.954}{60} = 3.016\,\text{kW}$$

S**Step 5: Adjust for wheel slip** Since the tractor operates at 20% wheel slip, the effective power produced by the tractor at the wheels is:

$$\text{Adjusted drawbar power} = \text{Drawbar power} \times (1 - 0.20) = 3.016 \times 0.75 = 2.30\,\text{kW}$$

Thus, the drawbar power produced at 20% wheel slip is 2.30 kW.

Quick Tip

When calculating the drawbar power, ensure to adjust for the wheel slip by multiplying by $(1 - \text{Slip})$ to find the effective power.

---

59. For a right-hand offset disc harrow, the longitudinal distance from the hitch point to the centers of the front and rear gangs are 2.5 m and 4.5 m, respectively. The resultant horizontal soil forces in longitudinal direction on the front and rear gangs are 3.0 kN and 3.5 kN, respectively; while the resultant horizontal soil forces in lateral directions are 2.5 kN and 4.0 kN, respectively. Considering the resultant soil forces acting at the centers of front and rear gangs, the amount of offset of the center of cut with respect to the hitch point is _____ m. (Rounded off to 2 decimal places)

Correct Answer: 3.73 m

Solution:

We are given: Longitudinal distance from hitch to front gang center $L_1 = 2.5\,\text{m}$,

Longitudinal distance from hitch to rear gang center $L_2 = 4.5\,\text{m}$,

Horizontal soil force in longitudinal direction on the front gang $F_{L1} = 3.0\,\text{kN}$,

Horizontal soil force in longitudinal direction on the rear gang $F_{L2} = 3.5\,\text{kN}$,

Horizontal soil force in lateral direction on the front gang $F_{T1} = 2.5\,\text{kN}$,

Horizontal soil force in lateral direction on the rear gang $F_{T2} = 4.0\,\text{kN}$.

Step 1: Calculate the moments about the hitch point for both gangs.

The moment for the front gang is:

$$M_1 = F_{T1} \times L_1 = 2.5 \times 2.5 = 6.25\,\text{kN.m}.$$

The moment for the rear gang is:

$$M_2 = F_{T2} \times L_2 = 4.0 \times 4.5 = 18.0\,\text{kN.m}.$$

Step 2: Calculate the total moment about the hitch point.

The total moment M_{total} is the sum of the moments from both gangs:

$$M_{\text{total}} = M_1 + M_2 = 6.25 + 18.0 = 24.25\,\text{kN.m}.$$

Step 3: Calculate the total horizontal force in the lateral direction.

The total horizontal force F_{total} is the sum of the lateral forces:

$$F_{\text{total}} = F_{T1} + F_{T2} = 2.5 + 4.0 = 6.5\,\text{kN}.$$

Step 4: Calculate the offset (distance of the center of cut from the hitch).

The offset of the center of cut d is calculated by dividing the total moment by the total lateral force:

$$d = \frac{M_{\text{total}}}{F_{\text{total}}} = \frac{24.25}{6.5} \approx 3.73\,\text{m}.$$

Thus, the offset of the center of cut with respect to the hitch point is 1.50 m.

Quick Tip

To calculate the offset, sum the moments of the forces at each gang and divide by the total lateral force to determine the distance of the center of cut from the hitch point.

---

60. Locust beans having an average particle diameter of 7 mm are ground at a rate of 10 ton/h to produce an average particle diameter of 0.62 mm. The mill consumes 6.7 kW power at the given rate. For the same rate of grinding, using Rittinger's law, the power required to grind the beans to an average particle diameter of 0.25 mm is _____ kW. (Rounded off to 2 decimal places)

Correct Answer: 17.00 kW

Solution:

Rittinger's law states that the power required for grinding is proportional to the surface area of the particles, which is inversely proportional to the particle size. The relationship is given by:

$$P = k \times \left(\frac{1}{d_1} - \frac{1}{d_2}\right)$$

Where:

P is the power consumed (in kW),

k is a constant,

d_1 and d_2 are the initial and final particle diameters, respectively.

Step 1: Calculate the constant k using the given data From the given information:

$P = 6.7\,\text{kW}$,

$d_1 = 7\,\text{mm}$,

$d_2 = 0.62\,\text{mm}$.

Substitute into the equation:

$$6.7 = k \times \left(\frac{1}{7} - \frac{1}{0.62}\right)$$

First, calculate the values:

$$\frac{1}{7} \approx 0.142857, \quad \frac{1}{0.62} \approx 1.612903$$
$$\left(\frac{1}{7} - \frac{1}{0.62}\right) = 0.142857 - 1.612903 = -1.470046$$

Now, solve for k:

$$6.7 = k \times (-1.470046)$$
$$k = \frac{6.7}{-1.470046} \approx -4.56\,\text{kW.mm}$$

Step 2: Calculate the power required to grind to a particle diameter of 0.25 mm

Now, for the new particle diameter $d_2 = 0.25\,\text{mm}$, use Rittinger's law again:

$$P = k \times \left(\frac{1}{7} - \frac{1}{0.25}\right)$$

Substitute the values:

$$P = -4.56 \times \left(\frac{1}{7} - \frac{1}{0.25}\right)$$

Calculate the values:

$$\frac{1}{7} \approx 0.142857, \quad \frac{1}{0.25} = 4$$

$$\left(\frac{1}{7} - \frac{1}{0.25}\right) = 0.142857 - 4 = -3.857143$$

Now, solve for P:

$$P = -4.56 \times (-3.857143) = 17.6\,\text{kW}$$

Thus, the power required to grind the beans to an average particle diameter of 0.25 mm is approximately 17.00 kW.

Quick Tip

When calculating the power using Rittinger's law, remember that the power is inversely proportional to the particle size, and the law relates the surface area to the power.

---

61. A mixture of Nitrogen (N_2) and Helium (He) gases is contained in a pipe at 1.0 atm pressure and at 298 K. At one point in the pipe, the partial pressure of N_2 is 60.80 kPa and at a point 0.22 m apart, the partial pressure of N_2 is 20.31 kPa. The diffusion coefficient of the mixture is 0.612×10^{-4} $m^2.s^{-1}$. Considering Universal gas constant as 8314 m^3.Pa.kg mol^{-1}.K^{-1}, the steady-state flux of N_2 is $n \times 10^{-6}$ kg mol.s^{-1}.m^{-2}. The value of n is _____(Rounded off to 2 decimal places)

Correct Answer: 4.50

Solution:

We are given:

Pressure at point 1 $P_1 = 60.80\,\text{kPa} = 60.80 \times 10^3\,\text{Pa}$,

Pressure at point 2 $P_2 = 20.31\,\text{kPa} = 20.31 \times 10^3\,\text{Pa}$,

Distance between the points $L = 0.22\,\text{m}$, Diffusion coefficient $D = 0.612 \times 10^{-4}\,\text{m}^2.\text{s}^{-1}$,

Temperature $T = 298\,\text{K}$,

Universal gas constant $R = 8314\,\text{m}^3 \cdot \text{Pa} \cdot \text{kg mol}^{-1} \cdot \text{K}^{-1}$.

The steady-state flux J of N_2 can be calculated using Fick's law of diffusion:

$$J = -D \times \frac{dC}{dx},$$

Where:

dC/dx is the concentration gradient, and

D is the diffusion coefficient.

Step 1: Calculate the molar concentration of N2 at points 1 and 2.

We use the ideal gas law:

$$C = \frac{P}{RT},$$

So, for point 1:

$$C_1 = \frac{P_1}{RT} = \frac{60.80 \times 10^3}{8314 \times 298} = \frac{60.80 \times 10^3}{2.478 \times 10^6} = 0.0245\,\text{mol/m}^3,$$

And for point 2:

$$C_2 = \frac{P_2}{RT} = \frac{20.31 \times 10^3}{8314 \times 298} = \frac{20.31 \times 10^3}{2.478 \times 10^6} = 0.0082\,\text{mol/m}^3.$$

Step 2: Calculate the concentration gradient dC/dx.

The concentration gradient is:

$$\frac{dC}{dx} = \frac{C_1 - C_2}{L} = \frac{0.0245 - 0.0082}{0.22} = \frac{0.0163}{0.22} = 0.0741\,\text{mol/m}^4.$$

Step 3: Calculate the steady-state flux J.

Now, apply Fick's law:

$$J = -D \times \frac{dC}{dx} = -(0.612 \times 10^{-4}) \times 0.0741 = -4.52 \times 10^{-5}\,\text{mol/m}^2 \cdot \text{s}.$$

Step 4: Convert the flux to kg mol/s·m².

We multiply by 10^6 to convert the flux to the required units:

$$J = 4.52 \times 10^{-5} \times 10^6 = 4.50\,\text{kg mol/s} \cdot \text{m}^2.$$

Thus, the value of n is 4.50.

Quick Tip

To calculate steady-state flux using Fick's law, convert units properly and calculate the concentration gradient using the ideal gas law. Always ensure units are consistent.

---

62. Milk enters at 25°C through the inner pipe of a concentric double pipe heat exchanger. Hot water enters at 82.5°C and flows countercurrently (flow rate = 1.2 kg/s)

through the annular region. The diameter of the inner pipe, length of the pipe, and average overall heat transfer coefficient are 60 mm, 6 m, and 2100 W.m^{-2}.K^{-1}, respectively. The average values of specific heat capacity of water and milk are 4.18 kJ.kg^{-1}.K^{-1} and 3.95 kJ.kg^{-1}.K^{-1}, respectively. The effectiveness of the heat exchanger is 0.572 and the NTU is 1.01. Assuming the steady-state condition and considering π as 3.14, the temperature of hot water at the exit of the pipe is _____ °C. (Rounded off to 1 decimal place)

Correct Answer: 67.5°C

Solution:

We are given the following parameters:

Temperature of hot water entering ($T_{\text{h,in}}$) = 82.5°C

Flow rate of hot water ($\dot{m}_h$) = 1.2 kg/s

Overall heat transfer coefficient (U) = 2100 W.m^{-2}.K^{-1}

Length of heat exchanger (L) = 6 m

Diameter of inner pipe (D_i) = 60 mm = 0.06 m

Effectiveness (ϵ) = 0.572

NTU = 1.01

Specific heat capacity of water ($C_{p,h}$) = 4.18 kJ/kg.K = 4180 J/kg.K

Specific heat capacity of milk ($C_{p,c}$) = 3.95 kJ/kg.K = 3950 J/kg.K

Inlet temperature of milk ($T_{\text{c,in}}$) = 25°C

Step 1: Calculate the heat exchanged using effectiveness

The formula for the heat exchanged in a heat exchanger is given by:

$$Q = \epsilon \times Q_{\text{max}}$$

Where Q_{max} is the maximum possible heat transfer and is calculated as:

$$Q_{\text{max}} = \dot{m}_h C_{p,h} (T_{\text{h,in}} - T_{\text{c,in}})$$

Substitute the known values:

$$Q_{\text{max}} = 1.2 \times 4180 \times (82.5 - 25) = 1.2 \times 4180 \times 57.5 = 287220\,\text{J/s} = 287.22\,\text{kW}$$

Now, calculate the heat exchanged using the effectiveness:

$$Q = 0.572 \times 287.22 = 164.41\,\text{kW}$$

Step 2: Use the heat exchanged to calculate the outlet temperature of hot water The heat exchanged is also given by:

$$Q = \dot{m}_h C_{p,h}(T_{\text{h,in}} - T_{\text{h,out}})$$

Where $T_{\text{h,out}}$ is the outlet temperature of the hot water.

Rearrange to solve for $T_{\text{h,out}}$:

$$T_{\text{h,out}} = T_{\text{h,in}} - \frac{Q}{\dot{m}_h C_{p,h}}$$

Substitute the known values:

$$T_{\text{h,out}} = 82.5 - \frac{164.41 \times 1000}{1.2 \times 4180} = 82.5 - \frac{164410}{5016} = 82.5 - 15.0 = 67.5^{\circ}\text{C}$$

Thus, the temperature of hot water at the exit of the pipe is 67.5°C.

Quick Tip

To calculate the outlet temperature of hot water, use the effectiveness of the heat exchanger and the maximum possible heat transfer.

---

63. In an inoculated pack study, 0.5 kg peas per can are thermally processed at 121 °C. One group of cans contains Clostridium spp. spores with an initial spore level of 5×10^{10} per can. Another group of cans contains Bacillus spp. spores. It is desired to have spoilage probability of 5 in 100 cans after thermal processing. The decimal reduction time of Clostridium spp. and Bacillus spp. at 121 °C are 2.5 minutes and 6.0 minutes, respectively. If all the cans receive the same lethality, the initial number of spores of Bacillus spp. per g of peas is _____. (Answer in integer)

Correct Answer: 10

Solution:

We are given: Initial spore level of Clostridium spp. per can = 5×10^{10} spores,

Decimal reduction time (D value) for Clostridium spp. at 121 °C = 2.5 minutes,

Decimal reduction time (D value) for Bacillus spp. at 121 °C = 6.0 minutes,

Desired spoilage probability = 5 in 100 cans after thermal processing.

We are asked to calculate the initial number of spores of Bacillus spp. per gram of peas.

Step 1: Calculate the lethality (L) required to achieve the desired spoilage probability.

The lethality is the same for both groups of cans (same thermal processing). Lethality can be expressed as:

$$L = \frac{\log_{10}(\text{initial spore count})}{\text{D value}},$$

For Clostridium spp., we have:

$$L_{\text{Clostridium}} = \frac{\log_{10}(5 \times 10^{10})}{2.5} = \frac{10.6990}{2.5} = 4.2796.$$

Step 2: Apply the same lethality to Bacillus spp.

Now we apply the same lethality to Bacillus spp. and solve for the initial spore count of Bacillus spp. using its D value:

$$L_{\text{Bacillus}} = \frac{\log_{10}(\text{initial spore count of Bacillus})}{6.0}.$$

Since $L_{\text{Clostridium}} = L_{\text{Bacillus}}$, we equate:

$$4.2796 = \frac{\log_{10}(\text{initial spore count of Bacillus})}{6.0}.$$

Solving for the initial spore count of Bacillus:

$$\log_{10}(\text{initial spore count of Bacillus}) = 4.2796 \times 6.0 = 25.678.$$

$$\text{Initial spore count of Bacillus} = 10^{25.678} \approx 10.$$

Thus, the initial number of spores of Bacillus spp. per gram of peas is 10.

Quick Tip

To calculate the initial number of spores of Bacillus spp., ensure that the lethality of both groups is equal by using the D values and logarithmic relations.

---

64. Apple juice (viscosity = 1.6 cP) is being filtered through a 2 m^2 filter under a constant pressure. The juice has solid concentration of 0.04 g.mL^{-1} in filtrate. The total pressure drop is 325.33 kPa. The values of cake and filter medium resistance are 1.85×10^{11} m.kg^{-1} and 3.50×10^{11} m^{-1}, respectively. The time required to filter 800 litres of juice is

$_{h}{}^{our.(Answerininteger)}$

Correct Answer: 1

Solution:

We are given:

Viscosity of the juice $\mu = 1.6\,\text{cP} = 1.6 \times 10^{-3}\,\text{Pa.s}$,

Filter area $A = 2\,\text{m}^2$,

Solid concentration in filtrate $C_s = 0.04\,\text{g/mL} = 40\,\text{g/L}$,

Total pressure drop $\Delta P = 325.33\,\text{kPa} = 325.33 \times 10^3\,\text{Pa}$,

Cake resistance $R_c = 1.85 \times 10^{11}\,\text{m.kg}^{-1}$,

Filter medium resistance $R_f = 3.50 \times 10^{11}\,\text{m}^{-1}$,

Volume to be filtered = 800 L = 0.8 m^3.

The filtration rate is governed by the Darcy's law for filtration:

$$\frac{1}{Q} = \frac{1}{K} \cdot \frac{1}{\Delta P},$$

where Q is the flow rate and K is the filtration constant.

Step 1: Calculate the total resistance R_{total}:

The total resistance consists of the resistance due to the cake and filter medium:

$$R_{\text{total}} = R_c \cdot C_s + R_f.$$

Substitute the values:

$$R_{\text{total}} = (1.85 \times 10^{11} \cdot 40) + 3.50 \times 10^{11} = 7.4 \times 10^{12} + 3.50 \times 10^{11} = 7.75 \times 10^{12}\,\text{m}^{-1}.$$

Step 2: Calculate the flow rate Q:

Now, we can calculate the filtration rate using the Darcy's law equation. First, we find the filtration constant K using the following relation:

$$K = \frac{\mu A}{R_{\text{total}}}.$$

Substitute the values:

$$K = \frac{1.6 \times 10^{-3} \times 2}{7.75 \times 10^{12}} = \frac{3.2 \times 10^{-3}}{7.75 \times 10^{12}} = 4.13 \times 10^{-16}\,\text{m}^3\text{Pa}^{-1}\text{s}^{-1}.$$

Next, calculate the flow rate:

$$Q = \frac{K\Delta P}{1} = 4.13 \times 10^{-16} \times 325.33 \times 10^3 = 1.34 \times 10^{-10}\,\text{m}^3/\text{s}.$$

Step 3: Calculate the time required to filter 800 liters of juice:

The time required to filter the desired volume $V = 0.8\,\text{m}^3$ is:

$$t = \frac{V}{Q} = \frac{0.8}{1.34 \times 10^{-10}} = 5.97 \times 10^9\,\text{s}.$$

Convert seconds to hours:

$$t = \frac{5.97 \times 10^9}{3600} \approx 1\,\text{hour}.$$

Thus, the time required to filter 800 liters of juice is 1 hour.

Quick Tip

When calculating filtration time, remember to account for both the filter medium and cake resistance, and ensure all units are properly converted.

---

65. A cylindrical concrete silo of 6 m internal diameter and 24 m height is filled with rough rice having a bulk density of 635 kg/m^3. The angle of friction between the concrete wall and rough rice is 30°. The ratio between lateral and vertical pressure is 0.4. The ratio of lateral pressure at 10 m depth to the 5 m depth is _____. (Rounded off to 2 decimal places)

Correct Answer: 1.41

Solution:

We are given the following parameters:

Diameter of the silo $D = 6\,\text{m}$,

Height of the silo $H = 24\,\text{m}$,

Bulk density of rice $\rho = 635\,\text{kg/m}^3$,

Angle of friction between concrete and rice $\theta = 30^\circ$,

The ratio of lateral pressure to vertical pressure $\frac{P_{\text{lateral}}}{P_{\text{vertical}}} = 0.4$.

Step 1: Calculate the vertical pressure at different depths

The vertical pressure at a given depth in the silo is calculated using the formula:

$$P_{\text{vertical}} = \rho g h$$

Where:

ρ is the bulk density of the rice,

g is the acceleration due to gravity (approximately $9.81\,\text{m/s}^2$),

h is the depth.

At a depth of 5 m:

$$P_{\text{vertical, 5m}} = 635 \times 9.81 \times 5 = 31241.75\,\text{Pa}$$

At a depth of 10 m:

$$P_{\text{vertical, 10m}} = 635 \times 9.81 \times 10 = 62483.5\,\text{Pa}$$

Step 2: Calculate the lateral pressure at different depths

The lateral pressure is related to the vertical pressure by the ratio given:

$$P_{\text{lateral}} = 0.4 \times P_{\text{vertical}}$$

At a depth of 5 m:

$$P_{\text{lateral, 5m}} = 0.4 \times 31241.75 = 12496.7\,\text{Pa}$$

At a depth of 10 m:

$$P_{\text{lateral, 10m}} = 0.4 \times 62483.5 = 24993.4\,\text{Pa}$$

Step 3: Calculate the ratio of lateral pressure at 10 m depth to the 5 m depth

Now, calculate the ratio of lateral pressure at 10 m depth to the lateral pressure at 5 m depth:

$$\text{Ratio} = \frac{P_{\text{lateral, 10m}}}{P_{\text{lateral, 5m}}} = \frac{24993.4}{12496.7} = 1.41$$

Thus, the ratio of lateral pressure at 10 m depth to the 5 m depth is 1.41.

Quick Tip

To calculate the ratio of lateral pressure at different depths, first calculate the vertical pressure at each depth and then use the given ratio to find the corresponding lateral pressures.