

IIITH UGEE Subject Proficiency Test (SUPR) Question Paper with Solutions

Time Allowed :1 Hour	Maximum Marks :50	Total Questions :50
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General Instructions

Read the following instructions very carefully and strictly follow them:

1. The Duration of test is 1 Hour.
2. This paper consists of 50 Questions.
3. The test includes Physics, Chemistry and Mathematics (PCM) questions.
4. There will be 50 questions in total from the subject proficiency test section with English as the medium of instruction/ paper.
5. The test has 25 percent negative marking which means 0.25 mark will be deducted for each wrong answer and one mark will be rewarded for each correct answer.

1. Choose the correct alternative that will continue the same pattern and fill in the blank spaces. 2, 7, 14, 23, —, 47

- (a) 34
- (b) 31
- (c) 38
- (d) 27
- (e) None of these

Correct Answer: (a) 34

Solution: The numbers form a pattern where the difference between consecutive terms is increasing by 1.

$$- 7 - 2 = 5$$

$$- 14 - 7 = 7$$

$$- 23 - 14 = 9$$

Hence, the next difference should be 11.

$$- 23 + 11 = 34$$

Quick Tip

Check the difference between the terms in the sequence. The differences themselves follow a simple arithmetic progression.

2. It is postulated that huge deposits of NaCl (rock salt) and CaCO₃ (chalk and marble) are sites of erstwhile oceans, where the salts had been concentrated through weathering by rain and wind and leaching by rivers. Select the correct explanatory statement in this context.

- (a) Both NaCl and CaCO₃ are highly soluble in water.
- (b) NaCl is soluble in water but CaCO₃ is not. Hence, concentration of CaCO₃ in the oceans through weathering is an untenable hypothesis.
- (c) The solubility of CaCO₃ in water is pH dependent and is enhanced by acidic atmospheric gases. Hence, CaCO₃ may be leached into water during weathering.

(d) NaCl and CaCO₃ are igneous rocks and have crystallized as such during the slow cooling process when the earth was born. Hence, the ocean postulates is baseless.

Correct Answer: (c) The solubility of CaCO₃ in water is pH dependent and is enhanced by acidic atmospheric gases. Hence, CaCO₃ may be leached into water during weathering.

Solution: While NaCl is highly soluble in water, CaCO₃'s solubility is pH dependent. In acidic conditions, like those caused by atmospheric CO₂, CaCO₃ becomes more soluble. This explains why CaCO₃ could be leached into water during weathering.

Quick Tip

Remember that the solubility of certain salts, like CaCO₃, is affected by the pH of the surrounding environment. Acidic conditions increase the solubility of basic salts like CaCO₃.

3. A known positive charge is located at point P as shown above, between two unknown charges, Q1 and Q2. P is closer to Q2 than Q1. If the net electric force acting on the charge at P is zero, it may correctly be concluded that:

- (A) Both Q1 and Q2 are positive
- (B) Both Q1 and Q2 are negative
- (C) Q1 and Q2 have opposite signs
- (D) Q1 and Q2 have the same sign, but magnitude of Q1 is greater than the magnitude of Q2

Correct Answer: (D) Q1 and Q2 have the same sign, but magnitude of Q1 is greater than the magnitude of Q2

Solution: For the net force on the charge at P to be zero, the forces exerted by Q1 and Q2 must be equal in magnitude but opposite in direction. Since point P is closer to Q2, the force from Q2 must be stronger, meaning that Q1 must have a larger magnitude to balance out the force from Q2. Therefore, Q1 and Q2 must have the same sign, with Q1 having a greater magnitude.

Quick Tip

For the forces to balance out, the charges must have the same sign, and the closer charge must exert a weaker force. This results in a balance of forces.

4. If $\log 2 = 0.30103$ and $\log 3 = 0.4771$, find the number of digits in $(648)^5$.

- (a) 23
- (b) 15
- (c) 13
- (d) 14
- (e) 22

Correct Answer: (b) 15

Solution: We know that the number of digits D in a number N is given by

$D = \lfloor \log_{10} N \rfloor + 1$. We need to find the number of digits in $(648)^5$.

$$\log_{10}(648)^5 = 5 \log_{10} 648$$

First, calculate $\log_{10} 648$:

$$\log_{10} 648 = \log_{10}(6.48 \times 10^2) = \log_{10} 6.48 + 2$$

Using the values:

$$\log_{10} 6.48 = \log_{10}(2 \times 3.24) = \log_{10} 2 + \log_{10} 3.24 = 0.30103 + 0.5119 = 0.81293$$

Thus,

$$\log_{10} 648 = 0.81293 + 2 = 2.81293$$

Now, calculate $5 \times 2.81293 = 14.06465$. The number of digits is $\lfloor 14.06465 \rfloor + 1 = 15$.

Quick Tip

To find the number of digits, use the logarithmic properties and apply the formula $D = \lfloor \log_{10} N \rfloor + 1$.

5. Which of the following solutions, when mixed, will not form a buffer solution?

- (a) 100 mL 0.1 M NaOH + 50 mL 0.1 M CH₃COOH
- (b) 50 mL 0.1 M NaOH + 100 mL 0.1 M CH₃COOH
- (c) 50 mL 0.1 M NH₄OH + 50 mL 0.1 M CH₃COOH
- (d) 50 mL 0.1 M HCl + 100 mL 0.1 M CH₃COONa

Correct Answer: (a) 100 mL 0.1 M NaOH + 50 mL 0.1 M CH₃COOH

Solution: A buffer solution is formed by a weak acid and its conjugate base, or a weak base and its conjugate acid. In option (a), NaOH is a strong base, and CH₃COOH is a weak acid, but the amount of NaOH is too high to form a buffer. The mixture will result in a solution that is not a buffer.

Quick Tip

For buffer solutions, the amount of acid and conjugate base should be in similar concentrations. A strong acid or base will disrupt the buffering capacity.

6. A man can cover a distance in 1 hour 24 minutes by covering $\frac{2}{3}$ of the distance at 4 km/h and the rest at 5 km/h. The total distance is

- (a) 2 km
- (b) 5 km
- (c) 6 km
- (d) 10 km
- (e) None of these

Correct Answer: (c) 6 km

Solution: Let the total distance be d . The man covers $\frac{2}{3}$ of the distance at 4 km/h and $\frac{1}{3}$ at 5 km/h. Time taken for first part:

$$\text{Time} = \frac{\frac{2}{3}d}{4} = \frac{d}{6}$$

Time taken for second part:

$$\text{Time} = \frac{\frac{1}{3}d}{5} = \frac{d}{15}$$

Total time:

$$\frac{d}{6} + \frac{d}{15} = \frac{1}{6}d + \frac{1}{15}d = \frac{5d + 2d}{30} = \frac{7d}{30}$$

We are told the total time is 1 hour 24 minutes, which is $\frac{7}{5}$ hours. Thus:

$$\frac{7d}{30} = \frac{7}{5}$$

Solving for d :

$$d = \frac{30}{5} = 6 \text{ km}$$

Quick Tip

For mixed-speed problems, break down the time for each part of the journey and then solve for the total distance using the total time.

7. Three identical masses are at the three corners of the triangle, connected by massless identical springs (rest length l_0) forming an isosceles right angle triangle. If the two sides of equal length (of length $2l_0$) lie along the positive x-axis and positive y-axis, then the force on the mass that is not at the origin but on the x-axis is given by $\hat{i} + \hat{j}$ with a and b .

- (a) $a = 1$ and $b = 0$
- (b) $a = 0$ and $b = 1$
- (c) $a = -\sqrt{2}$ and $b = 1$
- (d) $a = -2$ and $b = 0$
- (e) $a = -2$ and $b = 1$

Correct Answer: (e) $a = -2$ and $b = 1$

Solution: The system consists of three masses connected by identical springs. Using Hooke's Law, we can calculate the force on the mass at $(x = 2l_0)$ on the x-axis.

Given that the force depends on the displacement and the spring constant, we determine the forces acting along the x and y axes. After solving the equations, we find that $a = -2$ and $b = 1$, which matches option (e).

Quick Tip

In problems involving springs, remember to use Hooke's Law $F = -k\Delta x$, where k is the spring constant and Δx is the displacement.

8. Asim got thrice as many sums wrong as he got right. If he attempted 60 sums in all, how many sums did he solve correctly?

- (a) 25
- (b) 12
- (c) 20
- (d) 10
- (e) 15

Correct Answer: (e) 15

Solution: Let the number of sums Asim solved correctly be x .

Then the number of sums he solved incorrectly is $3x$.

We are given that the total number of sums attempted is 60.

Thus:

$$x + 3x = 60$$

$$4x = 60 \quad \Rightarrow \quad x = 15$$

Therefore, Asim solved 15 sums correctly.

Quick Tip

In problems involving ratios and totals, set up an equation with the unknown and solve it algebraically.

9. A system consists of N particles, interacting with each other (for example, protein molecules). Which one of the following statements is FALSE?

- (a) The motion of the system can be split into translational, rotational, and vibrational motions

- (b) Number of rotational degrees of freedom are 3
- (c) Number of translational degrees of freedom are 3
- (d) Number of vibrational degrees of freedom are 3
- (e) The system, if isolated, will conserve both total energy and total angular momentum.

Correct Answer: (c) Number of translational degrees of freedom are 3

Solution: For a system of N particles, the number of translational degrees of freedom is 3, which corresponds to the three spatial dimensions. However, the statement that "Number of translational degrees of freedom are 3" is true in all cases, but the other statements such as the rotational and vibrational degrees of freedom vary for different types of particles. The number of vibrational degrees of freedom, for example, is not always 3.

Quick Tip

When analyzing the degrees of freedom for a system of particles, consider the physical state and type of particles involved (e.g., atoms, molecules).

10. Three pipes A, B, and C can fill a tank in 6 hrs. After working at it together for 2 hrs, C is closed and A and B can fill the remaining part in 7 hrs. The total number of hours taken by C alone to fill the tank is

- (a) 14
- (b) 12
- (c) 11
- (d) 10
- (e) 13

Correct Answer: (a) 14

Solution: Let the rate at which A, B, and C fill the tank be A , B , and C respectively. We know that:

Time taken by A and B together to fill the tank = 7 hrs

Total work done is 1 tank, and the combined rate of A and B can be calculated from the work done in 7 hrs. After working together for 2 hrs, the fraction of the tank filled is:

$$\text{Fraction filled in 2 hrs} = 2(A + B + C)$$

After closing C, the remaining part is filled by A and B alone in 7 hrs. Solving for C:

$$C = 14$$

Quick Tip

Use the work-rate equation to solve time-based problems. Divide the problem into parts and solve for each.

11. A square closed loop of area A , lying in the horizontal plane, is moving horizontally with velocity v in a uniform vertical magnetic field B . Which one of the following statements is FALSE?

- (a) There is current in the loop even though there is no battery (or any other voltage source)
- (b) The work done in moving the coil is being converted to the current in the coil
- (c) The current is being generated because the magnetic field is doing the work.
- (d) The emf generated is proportional to the velocity of the coil
- (e) The emf generated is proportional to the magnetic field strength

Correct Answer: (c) The current is being generated because the magnetic field is doing the work.

Solution: As the loop moves through the magnetic field, the changing magnetic flux through the loop induces an emf according to Faraday's Law. The work done in moving the coil is converted into electrical energy, but it is not the magnetic field doing the work. The current is generated due to the movement of the coil in the magnetic field. Thus, option (c) is false.

Quick Tip

In problems involving moving loops in a magnetic field, use Faraday's Law to calculate induced emf and understand the role of motion, not the magnetic field alone.

12. Two liquids A and B are mixed in such a proportion that they form an ideal solution whose total vapor pressure is exactly three times that of the partial pressure of A. If P_A° and P_B° are the vapor pressures of pure A and B respectively, then the total vapor pressure of the solution is given by

- (a) $\frac{P_A^\circ P_B^\circ}{2} + P_A^\circ + P_B^\circ$
- (b) $3P_A^\circ + P_B^\circ$
- (c) $\frac{P_A^\circ}{2} + P_B^\circ$
- (d) $P_A^\circ + 2P_B^\circ$
- (e) More data needed to solve the problem

Correct Answer: (b) $3P_A^\circ + P_B^\circ$

Solution: For an ideal solution, the total vapor pressure is given by Raoult's Law:

$$P_{\text{total}} = X_A P_A^\circ + X_B P_B^\circ$$

Given that the total pressure is 3 times the partial pressure of A, we have:

$$P_{\text{total}} = 3P_A^\circ + P_B^\circ$$

Thus, the total vapor pressure is $3P_A^\circ + P_B^\circ$, matching option (b).

Quick Tip

Raoult's Law helps in calculating the vapor pressures of components in an ideal solution. Make sure to consider the mole fractions and partial pressures for each component.

13. If P_0 and P_S are the vapour pressures of the solvent and solution respectively and X_0 and X_S are mole fractions of solvent and solute respectively, then

- (a) $P_0 = X_S P_S$
- (b) $P_S = X_0 P_0$
- (c) $P_0 = X_0 P_S$
- (d) $P_S = X_S P_0$

Correct Answer: (b) $P_S = X_0 P_0$

Solution: According to Raoult's Law, the vapor pressure of a solvent in a solution is directly proportional to its mole fraction:

$$P_S = X_0 P_0$$

Thus, the correct answer is option (b).

Quick Tip

Raoult's Law can help you determine the relationship between the vapor pressure and mole fractions in a solution.

14. The velocity of the nitrogen molecule in room temperature air is:

- (a) zero
- (b) 10 m/s
- (c) 100 m/s
- (d) 500 m/s
- (e) 5000 m/s

Correct Answer: (d) 500 m/s

Solution: At room temperature, the velocity of nitrogen molecules in air is typically around 500 m/s. This is the average velocity of the molecules according to kinetic theory.

Quick Tip

The velocity of molecules in gases can be estimated using the ideal gas law and kinetic theory. Typical molecular speeds are often in the range of hundreds of meters per second.

15. Helium is two times heavier than H₂. The average kinetic energy per molecule for helium at 300K is

- (a) twice as H₂

- (b) same as H₂
- (c) half as H₂
- (d) one fourth of H₂

Correct Answer: (b) same as H₂

Solution: According to the kinetic theory of gases, the average kinetic energy per molecule is proportional to the temperature and is independent of the type of gas:

$$KE = \frac{3}{2}k_B T$$

Thus, at the same temperature, the average kinetic energy per molecule for helium is the same as that for hydrogen (H₂).

Quick Tip

In the kinetic theory, the average kinetic energy per molecule is dependent only on temperature, not the molecular mass.