



Detailed Solutions & Final Answer Key

PAPER CODE 51

TIME
60 minutes

QUESTIONS
32

MAX. MARKS
120

PAPER CODE 51

Questions 11 and 12 are dropped. Question 9 accepts either (a) or (b), and Question 26 accepts either of two listed response sets.

FINAL ANSWER KEY

DROPPED means that the question is not evaluated.

QUESTION	ANSWER
1	B
2	C
3	B
4	A
5	B
6	A
7	A
8	B
9	A OR B
10	B
11	DROP
12	DROP
13	A
14	C
15	D
16	B

QUESTION	ANSWER
17	C
18	B
19	C
20	C
21	C
22	B
23	A
24	D
25	A, B, C
26	A, B, C OR A, B, D
27	A, B
28	B, C
29	A, B
30	B, D
31	A, B, C, D
32	B, C, D

Key notes: Question 9 accepts either option (a) or option (b). Questions 11 and 12 are DROPPED. For Question 26, the final key accepts either (a),(b),(c) or (a),(b),(d) because the wording does not state clearly whether signed specific charge or its magnitude is being compared.

PHYSICS

Detailed explanations, calculations and option-wise reasoning.

Question 1 Answer: B

Gravitation - Surface Gravity

Use $g = GM/R^2$. Here $M = 1.5 \times 2 \times 10^{30} = 3.0 \times 10^{30}$ kg and $R = 10$ km = 10^4 m.
 $g = (6.67 \times 10^{-11})(3.0 \times 10^{30})/(10^4)^2 \approx 2.0 \times 10^{12} \text{ m s}^{-2}$.
 Therefore the correct answer is (b).

Question 2 Answer: C

Mechanical Properties of Fluids - Pressure

The pressure difference at depth h is $P = \rho gh$. The force on the ear drum is $F = PA = \rho ghA$.
 The drum radius is 0.5 cm = 5×10^{-3} m, so $A = \pi r^2 \approx 7.85 \times 10^{-5} \text{ m}^2$.
 $h = F/(\rho gA) = 2.5/[(1.05 \times 10^3)(9.8)(7.85 \times 10^{-5})] \approx 3.1$ m.
 Hence (c) 3 m.

Question 3 Answer: B

Ray Optics - Thin Lens

Let the lens be x cm from O_1 ; it is then $(24 - x)$ cm from O_2 . Applying the lens formula from the two sides for a common image position gives
 $1/9 - 1/x = 1/(24 - x) - 1/9$.
 Thus $2/9 = 1/x + 1/(24 - x)$, so $x(24 - x) = 108$.
 $x^2 - 24x + 108 = 0$, giving $x = 18$ cm or 6 cm. The distances are therefore 18 cm and 6 cm, option (b).

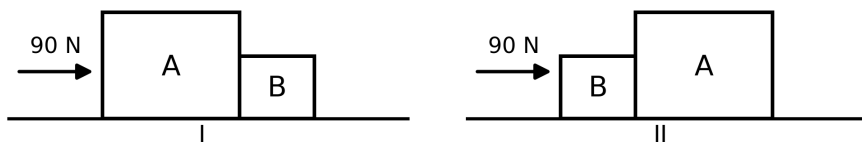
Question 4 Answer: A

Nuclear Energy and Power

Electrical output $P_{\text{out}} = 1000$ kW = 1.0×10^6 W. Since efficiency is 0.30 , nuclear power input is $P_{\text{in}} = P_{\text{out}}/0.30 = 3.33 \times 10^6 \text{ J s}^{-1}$.
 Energy per fission = $200 \times 10^6 \text{ eV} \times 1.6 \times 10^{-19} \text{ J/eV} = 3.2 \times 10^{-11} \text{ J}$.
 Number per second = $3.33 \times 10^6 / (3.2 \times 10^{-11}) \approx 1.04 \times 10^{17}$.
 Correct answer: (a).

Question 5 Answer: B

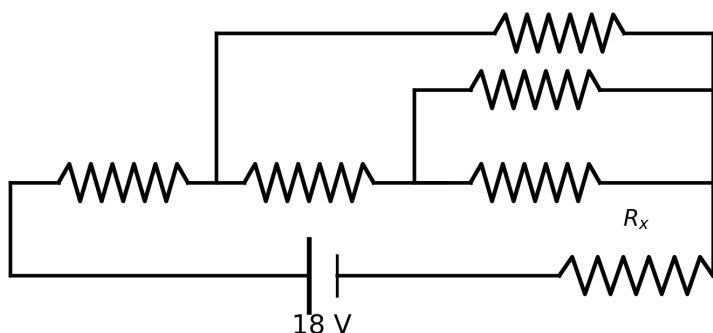
Laws of Motion - Contact Force



The two blocks move together, so their common acceleration is $a = 90/(20 + 10) = 3 \text{ m s}^{-2}$.
 Situation I: the contact force must accelerate block B, so $F_{AB} = 10 \times 3 = 30$ N.
 Situation II: the contact force must accelerate block A, so $F_{BA} = 20 \times 3 = 60$ N.
 Therefore (b) is correct.

Question 6 Answer: A

Current Electricity - Resistor Networks



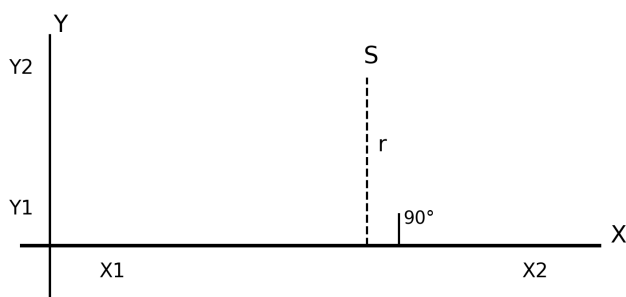
First reduce the fixed resistor network. The two right-hand $5\ \Omega$ resistors are in parallel, giving $2.5\ \Omega$. This is in series with the middle $5\ \Omega$, giving $7.5\ \Omega$. That $7.5\ \Omega$ path is in parallel with the top $5\ \Omega$ resistor, so its equivalent is $(5 \times 7.5)/(5 + 7.5) = 3\ \Omega$. Including the left $5\ \Omega$ resistor, the fixed part is $8\ \Omega$.

Now R_x is in series with $8\ \Omega$ across $18\ \text{V}$. By voltage division, $6/18 = R_x/(8 + R_x)$.

Hence $3R_x = 8 + R_x$, so $R_x = 4\ \Omega$, option (a).

Question 25 Answer: A, B, C

Moving Charges and Magnetism



$B = 2 \times 10^{-7} I/r$. With $B = 2 \times 10^{-4}\ \text{T}$ and $r = 0.01\ \text{m}$, $I = 10\ \text{A}$, so (a) is true. In $1\ \text{s}$, charge $Q = It = 10\ \text{C}$, giving $N = Q/e = 10/(1.6 \times 10^{-19}) = 6.25 \times 10^{19}$ electrons, so (b) is true.

Using the right-hand thumb rule, a field into the page at a point above the wire requires conventional current from $X2$ to $X1$, so (c) is true. Electrons move opposite to current, making (d) false. Correct options: (a), (b), (c).

Question 26 Answer: A, B, C OR A, B, D

Charge-to-Mass Ratio

(a) $\text{C kg}^{-1} = \text{A} \cdot \text{s kg}^{-1}$, so it is correct. (b) All singly ionised hydrogen isotopes have charge $+e$, and tritium has the greatest mass, so it has the least $|q/m|$; correct. (d) $|e|/m_e = 1.6 \times 10^{-19}/9.1 \times 10^{-31} \approx 1.76 \times 10^{11}\ \text{C kg}^{-1}$; correct.

For (c), the alpha particle has positive q/m while the electron has negative q/m . If algebraic sign is compared, the positive value is greater; if the usual magnitude is compared, the alpha value is much smaller. Because of this wording ambiguity, the final key accepts (a),(b),(c) or (a),(b),(d).

CHEMISTRY

Detailed explanations, calculations and option-wise reasoning.

Question 7 Answer: A

Mole Concept, Density and Polymers

Total thickness = $300 \times 6 \text{ \AA} = 1800 \text{ \AA} = 1.8 \times 10^{-7} \text{ m}$.
Film volume = area $\times$ thickness = $2 \times 1.8 \times 10^{-7} = 3.6 \times 10^{-7} \text{ m}^3 = 0.36 \text{ cm}^3$.
At density 1.0 g cm^{-3} , film mass = 0.36 g .
Molar mass of repeat unit $(\text{CH}_3)_2\text{SiO} \approx 74 \text{ g mol}^{-1}$; molar mass of $(\text{CH}_3)_2\text{SiCl}_2 \approx 129 \text{ g mol}^{-1}$.
Required mass = $0.36 \times 129/74 \approx 0.63 \text{ g}$. Correct answer: (a).

Question 8 Answer: B

Chemical Equilibrium

For $\text{A} + \text{B} \rightleftharpoons 2\text{C}$, $K_c = [\text{C}]^2/([\text{A}][\text{B}])$. Using the stated data,
 $K_c = (0.1/1.5)^2/[(5/1.5)(7/1.5)] = 0.01/35 \approx 2.86 \times 10^{-4}$.
None of the printed values is exact. The official final key accepts (b) 2.31×10^{-4} , which is the nearest listed choice. Therefore the answer recorded for evaluation is (b).

Question 9 Answer: A OR B

Organic Chemistry - Alcohols and Alkenes

Two identical acetaldehyde molecules are formed when the alkene is but-2-ene, $\text{CH}_3\text{-CH=CH-CH}_3$. Dehydration of 2-butanol directly gives but-2-ene. Under strongly acidic high-temperature conditions, 1-butanol can also give/isomerise to but-2-ene. The final key therefore accepts either (a) or (b).

Question 10 Answer: B

Metals and Reactivity Series

The solution contains $0.100 \times 0.1 = 0.010 \text{ mol CuCl}_2$. The mixture contains 1.25 g calcium, about 0.031 mol Ca , which is more than enough to displace all Cu^{2+} ions because calcium is much more reactive than copper:
 $\text{Ca} + \text{CuCl}_2 \rightarrow \text{CaCl}_2 + \text{Cu}$.
Removal of blue Cu^{2+} ions decolourises the solution. Silver does not displace copper, and calcium is the main cause. Correct answer: (b).

Question 11 Answer: DROPPED

Mole Concept and Percentage Concentration

This question was DROPPED in the official final key and must not be evaluated.
A 0.2% w/v solution contains 0.2 g per 100 mL , so 200 mL contains 0.4 g triclosan. Its molar mass is about 289.5 g mol^{-1} . Thus molecules = $(0.4/289.5)N_A \approx 1.38 \times 10^{-3}N_A \approx 8.3 \times 10^{20}$.
None of the printed options matches this value, which explains the dropped status.

Question 12 Answer: DROPPED

Atomic Mass from Compound Formulae

This question was DROPPED in the official final key and must not be evaluated.
Molar mass of $\text{B}_2\text{A}_3 = 12/0.05 = 240$, so $2\text{B} + 3\text{A} = 240$.
Molar mass of $\text{B}_2\text{A} = 10/0.1 = 100$, so $2\text{B} + \text{A} = 100$.
Subtracting gives $2\text{A} = 140$, hence $\text{A} = 70$. Then $2\text{B} = 30$, so $\text{B} = 15$. The correct pair would be 70 and 15 , which is absent from the options. Therefore the question is dropped.

Question 27 Answer: A, B

**Applied Inorganic Chemistry
- Rare Earths**

Traditional didymium-type glass contains rare-earth oxides, especially those of neodymium and praseodymium, which absorb troublesome radiation from hot glass and flames. Didymium is a historical mixture, not a separate element. Hence the correct elements are (a) and (b).

Question 28 Answer: B, C

Acids and Metals

HCl and HNO_3 are strong acids and provide a much higher effective concentration of H^+ than 1 M acetic acid, which is weak. Magnesium reacts vigorously in the strong-acid test tubes; nitric acid may produce nitrogen oxides rather than only hydrogen. Magnesium does not show the same vigorous reaction with ordinary NaOH under these conditions. Correct options: (b) and (c).

BIOLOGY

Detailed explanations, calculations and option-wise reasoning.

Question 13 Answer: A

Molecular Basis of Inheritance - DNA Structure

The extra length is $6.7 - 5.0 = 1.7 \mu\text{m} = 1700 \text{ nm}$. In double-stranded DNA, adjacent base pairs are separated by about 0.34 nm .

Additional base pairs = $1700/0.34 = 5000 = 0.5 \times 10^4$.

Correct answer: (a).

Question 14 Answer: C

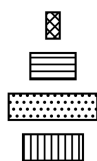
Principles of Inheritance - Sex Linkage

A recessive gene on the X chromosome is expressed easily in males because they have only one X chromosome. A carrier mother passes the affected X to about half of her sons, while an affected daughter usually needs an affected father and a carrier or affected mother. These are the signs of X-linked (sex-linked) recessive inheritance. Correct answer: (c).

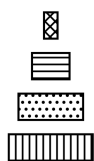
Question 15 Answer: D

Ecology - Ecological Pyramids

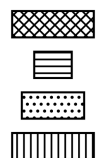
(a)



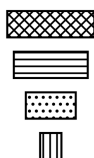
(b)



(c)



(d)



In many aquatic ecosystems, tiny phytoplankton have a small standing biomass because they reproduce and are eaten very rapidly. At a given instant, the consumer biomass may be greater than the producer biomass. The biomass pyramid is therefore often inverted. Among the diagrams, this is shown by (d).

Question 16 Answer: B

Plant Physiology - Transpiration

Open stomata allow water vapour to leave. Dry air creates a steep water-vapour gradient from the leaf to the atmosphere, and moist soil keeps supplying water to the roots. Together these conditions produce the greatest transpiration and pull. Correct answer: (b).

Question 17 Answer: C

Biodiversity and Conservation - Biopiracy

These Indian biological resources and traditional uses have been involved in disputes over patents or commercial claims by outside organisations. Unfair use or patenting of biological resources and traditional knowledge without proper permission or benefit-sharing is called biopiracy. Correct answer: (c).

Question 18 Answer: B

Evolution - Living Fossils

An organism or lineage that survives today with many ancient features and closely resembles fossil ancestors is called a living fossil. The clues in the question describe this idea directly. Correct answer: (b).

Question 29 Answer: A, B

Human Health and Disease - Vaccines

Live attenuated vaccines imitate natural infection closely and often create a strong, lasting response, so (a) is correct. Killed or inactivated vaccines are safer but may be less immunogenic and often need boosters, so (b) is correct. Conjugation and multivalent design are used to improve or broaden protection, not always reduce it. Alum and other adjuvants are included to increase immune response. Thus (a) and (b) are correct.

Question 30 Answer: B, D

Human Physiology - Metabolism and Hormones

Thyroid hormone generally raises metabolic rate, so (a) is false. Growth hormone promotes growth and metabolism, so (b) is true. Fever raises the rate of biochemical reactions and therefore increases metabolic rate, so (c) is false. Long-term malnutrition lowers BMR as the body conserves energy, so (d) is true. Correct options: (b) and (d).

MATHEMATICS

Detailed explanations, calculations and option-wise reasoning.

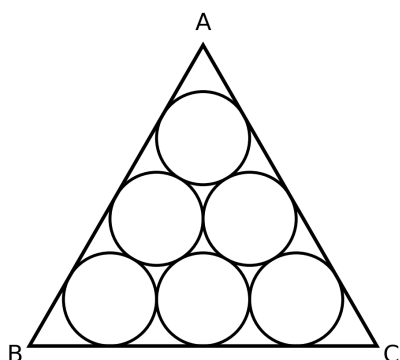
Question 19 Answer: C

Algebra - Quadratic Equations

Let r be the common root. Subtracting the two equations gives $(a - b)r + (b - a) = (a - b)(r - 1) = 0$. For two distinct quadratics having one common root, $a \neq b$, so $r = 1$. Substituting $r = 1$ into either equation gives $1 + a + b = 0$. Therefore $a + b = -1$, option (c).

Question 20 Answer: C

Geometry - Circle Packing



Let the circle radius be $r = 3$ cm. The centre of the bottom row is r above the base. The vertical separation between centres of two touching circles in adjacent rows is $r/\sqrt{3}$, and there are two such gaps. The top circle centre is therefore $r + 2r/\sqrt{3}$ above the base. From the top centre to the apex, the perpendicular distance to either side is r ; in a 60° angle this gives an axial distance $r/\sin 30^\circ = 2r$.

Height $= r + 2r/\sqrt{3} + 2r = 3r + 2r/\sqrt{3} = 9 + 6\sqrt{3} = 3(2\sqrt{3} + 3)$ cm. Correct answer: (c).

Question 21 Answer: C

Algebra - Polynomial Remainders

Since $x^2 - 3x + 2 = (x - 1)(x - 2)$, the remainder has the form $R(x) = px + q$. At $x = 1$, $R(1) = 1^{51} = 1$, so $p + q = 1$. At $x = 2$, $R(2) = 2^{51}$, so $2p + q = 2^{51}$. Subtracting gives $p = 2^{51} - 1$ and $q = 2 - 2^{51}$. Thus the remainder is $(2^{51} - 1)x + 2 - 2^{51}$, option (c).

Question 22 Answer: B

Algebra - Rational Inequalities

Bring everything to one side:

$$3/(x - 2) - 1 = (5 - x)/(x - 2) < 0.$$

The critical points are $x = 2$ (not allowed) and $x = 5$. The fraction is negative when numerator and denominator have opposite signs: $x < 2$ or $x > 5$. Therefore (b) is correct.

Question 23 Answer: A

Number Sense - Powers of Ten

$100^{25} = 10^{50}$. Therefore $10^{50} - 25$ is a 50-digit number consisting of 48 nines followed by 75. Its digit sum is $48 \times 9 + 7 + 5 = 432 + 12 = 444$. Correct answer: (a).

Question 24 Answer: D

Geometry - Angle Bisector

Let $AB = c$, $AC = b$ and $BC = a$. The internal angle-bisector length satisfies $AD^2 = bc[1 - a^2/(b + c)^2]$.

Since $a > 0$, the bracket is less than 1. Hence $AD^2 < bc = AB \cdot AC$, so $AD < \sqrt{(AB \cdot AC)}$. Correct answer: (d).

Question 31 Answer: A, B, C, D

Algebra and Trigonometry - Exponential Equation

Let $y = 81^{\sin^2 x}$. Since $\sin^2 x + \cos^2 x = 1$, the other term is $81/y$. Therefore $y + 81/y = 30$, so $y^2 - 30y + 81 = 0$. This gives $y = 3$ or 27 .

Because $81 = 3^4$, $y = 3$ means $\sin^2 x = 1/4$, and $y = 27$ means $\sin^2 x = 3/4$. In $0 \leq x \leq \pi$, these give $x = \pi/6, \pi/3, 2\pi/3$ and $5\pi/6$. Hence all four options are correct.

Question 32 Answer: B, C, D

Algebra - Identities and Factorisation

Expand and simplify:

$$(a - b)^2 + (a - c)^2 - (b - c)^2 = 2(a - b)(a - c).$$

The given equation is therefore equivalent to $(a - b)(a - c) = 0$. Hence it is valid when $a = b$ or $a = c$, making (b) and (c) true. If a, b and c are all distinct, neither factor is zero, so (d) is also true. If $b = c$ but $a \neq c$, it is not valid, so (a) is false. Correct options: (b), (c), (d).