DSSSB AE/JE 2026

COMPLETE ENGINEERING CHEMISTRY & ENVIRONMENTAL SCIENCE

Complete Theory • Detailed Hinglish Explanation • Chemical Reactions
Formula Sheets • Important Derivations • Practice Questions

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Table of Contents

How to use this book: Read Complete Theory, reinforce it with the Hinglish Explanation, review every equation and reaction row, then attempt all ten questions without viewing the solutions. Questions are original DSSSB-style practice, not claimed verbatim previous-year questions.

Useful Constants and Conversions

1. $F = 96485\ C\ mol^{-1}$
2. $R = 8.314\ J\ mol^{-1}\ K^{-1}$
3. $1\ L = 10^{-3}\ m^3$
4. 1 mg/L is approximately 1 ppm only for dilute water of density near 1 kg/L
5. 1 kWh = 3.6 MJ
6. $g = 9.81\ m\ s^{-2}$
7. logarithmic quantities such as pH and decibels must not be averaged arithmetically without conversion.

How to Study This Book

Exam Method: Reactions, Units, Assumptions and Checks

Begin every topic by identifying the engineering problem: unsafe water, inefficient energy conversion, metal deterioration, pollutant exposure or unstable biological treatment. Then connect the problem to the controlling mechanism. In Chemistry and Environmental Science, a memorized process name is not enough; the exam may change pH, oxygen, surface area, residence time or microbial state and ask for the consequence.

For numericals, write the balanced reaction or mass balance first, define every symbol and unit, convert the data, substitute only after the basis is consistent, and interpret the result. Keep an error log for CaCO3-equivalent conversion, air-fuel basis, anodic and cathodic signs, logarithmic sound levels, HRT versus SRT, and BOD or COD test conditions. Formulae are printed one per row to avoid visual crowding.

Use each Hinglish Explanation to build intuition, then return to the technical paragraph and explain it aloud. Trace every process from input through operation, reaction or biological transformation, separation, final product and residual. Attempt the MCQs without viewing the answer; the solution explains only the correct option.

Verify current legal limits from the latest official source before operational use.

CHAPTER 1 — WATER CHEMISTRY AND WATER TREATMENT

1. Introduction

Water treatment begins with source characterization and ends with stable water suitable for the intended use. Surface water commonly carries turbidity and pathogens; groundwater commonly carries dissolved minerals. No single unit removes all contaminants, so engineers combine physical separation, chemical reaction, biological control and residual management as a treatment train.

2. Complete Theory

Sources, impurities and water-quality parameters

Sources, impurities and water-quality parameters is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Suspended, colloidal, dissolved, organic, inorganic and biological impurities differ in size and removal route.

Colour, odour, turbidity, pH, conductivity, TDS, TSS, acidity, alkalinity, hardness, chloride, sulfate, fluoride, nitrate, iron, manganese, DO, BOD, COD, TOC and coliform results must be interpreted with test principle and unit. Current drinking-water limits must be verified from official standards.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

River ka muddy water aur borewell ka clear hard water same treatment nahi maangte. Test ka number tab useful hai jab source, unit aur removal mechanism clear ho.

Hardness, alkalinity and acidity

Hardness, alkalinity and acidity is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Calcium and magnesium hardness is reported as $CaCO_3$ equivalent.

Temporary or carbonate hardness is associated with bicarbonate alkalinity; permanent or non-carbonate hardness is associated with strong-acid anions. Phenolphthalein P and total T alkalinity identify OH^-, CO_3^{2-} and HCO_3^- combinations through standard titration relationships.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Salt concentrations direct add mat karo; pehle $CaCO_3$ equivalent mein convert karo. P aur T ka relation alkalinity species batata hai.

Screening, aeration, coagulation and flocculation

Screening, aeration, coagulation and flocculation is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Screens remove large matter; aeration transfers gases and can oxidize iron and manganese.

Coagulation destabilizes charged colloids through alum, ferric salts or polymers; rapid mixing disperses chemical, while gentle flocculation creates collisions and larger floc. Jar tests identify a practical dose and pH window.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Coagulation charge problem solve karta hai; flocculation collision and growth problem. Rapid mix aur slow mix ko interchange mat karo.

Sedimentation and filtration

Sedimentation and filtration is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Discrete, flocculent, hindered and compression settling describe different concentration regimes.

Ideal discrete settling is governed primarily by surface overflow rate. Slow sand filtration uses low rate and biological surface action; rapid gravity filtration uses pretreatment, higher rate and backwashing.

Effective size is D_{10} and uniformity coefficient is D_{60}/D_{10}. A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling.

Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact. In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude.

In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Clarifier ka plan area important hai. Slow sand ko scrape karte hain; rapid filter ko backwash.

Filter simple sieve nahi, adsorption and interception bhi karta hai.

Disinfection

Disinfection is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Disinfection reduces pathogens but is not complete sterilization.

Chlorine forms HOCl and OCl^-; HOCl is generally more effective. Demand equals dose minus residual after stated contact.

Breakpoint chlorination passes through demand, combined residual destruction and free-residual rise. Ozone is a strong oxidant; UV gives no lasting distribution residual.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Breakpoint ke baad free chlorine residual rise karta hai. UV aur ozone useful hain but chlorine jaisa lasting network residual generally nahi dete.

Softening and demineralization

Softening and demineralization is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Lime-soda precipitates $CaCO_3$ and $Mg(OH)_2$; hot treatment is faster and gives denser precipitate.

Sodium zeolite exchanges Na^+ for hardness ions. Cation and anion exchangers together demineralize water and require regeneration, rinsing and waste management.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Softening ka target hardness hai, demineralization ka target almost all ions. Zeolite hardness kam karta hai but total dissolved salts zero nahi karta.

Membranes and advanced treatment

Membranes and advanced treatment is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Microfiltration and ultrafiltration retain particles and macromolecules; nanofiltration rejects many multivalent ions; RO applies pressure greater than osmotic pressure.

Electrodialysis moves ions electrically. Activated carbon adsorbs many organics; advanced oxidation generates reactive oxidants.

Pretreatment and concentrate disposal are essential. A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling.

Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact. In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude.

In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

RO contaminant destroy nahi karta; permeate ke saath concentrate bhi banata hai. Fouling and scaling ko pretreatment se control karo.

Boiler-water problems

Boiler-water problems is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Scale is hard and adherent; sludge is soft and loose.

Priming carries droplets, foaming stabilizes bubbles, and dissolved gases promote corrosion. External treatment, phosphate or Calgon conditioning, deaeration and controlled blowdown reduce risk, but excessive blowdown wastes heat and water.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Scale aur sludge synonyms nahi. Boiler evaporation salts concentrate karta hai; controlled blowdown concentrated water nikalta hai.

4. Chemical Equations, Formulae and Mathematical Expressions

Key Equations and Reactions
1. $CaCO_3$ equivalent = concentration x 50/equivalent mass
2. carbonate hardness = minimum(total hardness,total alkalinity)
3. non-carbonate hardness = total hardness - carbonate hardness
4. surface overflow rate = Q/A
5. detention time = V/Q
6. chlorine demand = dose - residual
7. uniformity coefficient = D_{60}/D_{10}
8. osmotic pressure $\pi = iCRT$
9. $Ca^{2+}+CO_3^{2-} \rightarrow CaCO_3(s)$
10. $Mg^{2+}+2OH^{-} \rightarrow Mg(OH)_2(s)$
11. $Cl_2+H_2O \rightleftharpoons HOCl+H^{+}+Cl^{-}$
12. $HOCl \rightleftharpoons H^{+}+OCl^{-}$

5. Important Derivations and Numerical Concepts

For 100 mg/L $CaSO_4$, equivalent mass is 68, so hardness = 100 x 50/68 = 73.5 mg/L as $CaCO_3$. A clarifier receiving 12,000 m^3/d at 30 $m^3m^{-2}d^{-1}$ needs $A = Q/v_o$ = 400 m^2. A chlorine dose of 2.5 mg/L leaving 0.6 mg/L residual gives 1.9 mg/L demand.

6. Practical Applications

- Municipal treatment uses multiple barriers.
- Ion exchange and RO prepare industrial process water.
- Boiler treatment protects heat-transfer surfaces.
- BOD, COD and coliform tests support pollution control.

7. Concept Diagram

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Raw water -> Screen -> Aeration -> Rapid mix -> Flocculation -> Clarifier -> Filter -> Disinfection -> Storage
                         coagulant |                 | sludge        | backwash

RO: pressurized feed -> selective membrane -> permeate
                                      |-> concentrate
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8. Comparison Table

Feature	Slow sand	Rapid gravity
Rate	Low	High
Key action	Biological surface layer	Pretreatment plus depth capture
Cleaning	Scraping	Backwash

9. Important DSSSB Exam Points

- Express hardness on one $CaCO_3$ basis.
- Coagulation destabilizes; flocculation enlarges.
- HOCl is generally more effective than OCl^-.
- RO produces permeate and concentrate.

10. Practice Questions with Solutions

Attempt each question first. The explanation discusses only the correct answer.

Q1. Which statement correctly describes hardness?

(A) It is commonly reported as $CaCO_3$ equivalent.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It is commonly reported as $CaCO_3$ equivalent.

Q2. Which statement correctly describes coagulation?

(A) It destabilizes colloids.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It destabilizes colloids.

Q3. Which statement correctly describes surface overflow rate?

(A) It is Q/A.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It is Q/A.

Q4. Which statement correctly describes uniformity coefficient?

(A) It is D_{60}/D_{10}.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It is D_{60}/D_{10}.

Q5. Which statement correctly describes chlorine demand?

(A) It is dose minus residual.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It is dose minus residual.

Q6. Which statement correctly describes HOCl?

(A) It is generally the stronger free-chlorine disinfectant.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It is generally the stronger free-chlorine disinfectant.

Q7. Which statement correctly describes zeolite softening?

(A) It exchanges sodium for hardness ions.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It exchanges sodium for hardness ions.

Q8. Which statement correctly describes reverse osmosis?

(A) It requires pressure greater than osmotic pressure.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It requires pressure greater than osmotic pressure.

Q9. Which statement correctly describes boiler scale?

(A) It is hard and adherent.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It is hard and adherent.

Q10. Which statement correctly describes BOD?

(A) It measures biological oxygen use under specified conditions.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It measures biological oxygen use under specified conditions.

Quick Revision: Re-read the formula box, cover the answers, and explain each exam point aloud. A formula is ready for the exam only when its symbols, SI units, assumptions and sign convention are clear.

CHAPTER 2 — CONVENTIONAL AND RENEWABLE ENERGY RESOURCES

1. Introduction

Energy engineering compares complete conversion chains rather than labels. Primary and secondary, commercial and non-commercial, renewable and non-renewable, conventional and non-conventional categories answer different questions. A useful comparison includes efficiency, availability, dispatchability, storage, emissions, land, water, safety and lifecycle cost.

2. Complete Theory

Energy classification and conservation

Energy classification and conservation is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Primary energy occurs in nature; secondary energy such as electricity or hydrogen follows conversion.

Efficiency is useful output divided by input, while conservation reduces avoidable demand. Energy security depends on diversity, infrastructure, affordability and resilience.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation
Resource se converter, storage and end-use tak losses trace karo. Renewable ka matlab zero environmental impact nahi.

Coal, petroleum and natural gas

Coal, petroleum and natural gas is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Coal proximate analysis gives moisture, volatile matter, ash and fixed carbon; ultimate analysis gives elemental composition.

Petroleum fractions are separated by boiling range; cracking breaks large molecules and reforming improves structure. Octane rates petrol knock resistance; cetane rates diesel ignition quality.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Petrol ke liye octane aur diesel ke liye cetane yaad rakho. Ash heat nahi deta and equipment load badhata hai.

Combustion and calorific value

Combustion and calorific value is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Balanced reactions give theoretical oxygen and air.

Controlled excess air improves completion but too much increases stack loss. GCV includes possible recovery of product-water condensation heat; NCV excludes it.

Bomb calorimetry requires calorimeter water equivalent and fuse-wire, acid and cooling corrections. A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling.

Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact. In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude.

In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Air calculation mein 21 percent volume aur 23 percent mass basis mix mat karo. GCV normally NCV se greater hota hai.

Nuclear energy

Nuclear energy is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Fission splits heavy nuclei and can sustain a chain reaction; fusion joins light nuclei.

Reactor fuel supplies fissile material, moderator slows neutrons in thermal reactors, control rods absorb neutrons, coolant removes heat, and shielding plus containment provide barriers. Waste and safety require lifecycle control.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Moderator neutron slow karta hai; control rod absorb karta hai. Critical state steady self-sustaining reaction ho sakta hai, explosion ka synonym nahi.

Solar and wind energy

Solar and wind energy is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Solar thermal devices produce heat; photovoltaic junctions convert photons to electricity.

PV output depends on irradiance, temperature, orientation and shading. Wind power varies with air density, swept area and cube of speed; Betz limit prevents extraction of all kinetic energy.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Solar collector aur solar cell different. Wind speed double hone par ideal available power eight-fold trend karta hai because v^3.

Hydro, biomass and biogas

Hydro, biomass and biogas is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Hydropower uses head and discharge.

Biomass may undergo combustion, gasification, pyrolysis or anaerobic digestion. Gasification uses limited oxidant; pyrolysis heats without sufficient oxidant; digestion biologically forms methane-rich gas through hydrolysis, acidogenesis, acetogenesis and methanogenesis.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Biogas plant oxygen-free biological reactor hai. Hydro ke liye Q aur H dono required hain.

Hydrogen, fuel cells and batteries

Hydrogen, fuel cells and batteries is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Hydrogen is an energy carrier whose impact depends on production.

Fuel cells receive reactants continuously and electrochemically produce power; batteries store active materials internally. Lead-acid is robust but heavy; lithium-ion has high specific energy but needs protection and thermal management.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Green hydrogen tabhi meaningful jab production electricity low-carbon ho. Battery and fuel cell same device nahi.

Energy storage and comparison

Energy storage and comparison is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Pumped hydro stores elevation energy, batteries electrochemical energy, thermal stores heat, supercapacitors charge and hydrogen chemical energy.

Power rating controls instantaneous output; energy rating controls duration; round-trip efficiency, cycle life, response, site and recycling control selection. A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling.

Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact. In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude.

In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Frequency support aur overnight shifting ki storage requirement different hoti hai. Sirf energy density dekhkar technology choose mat karo.

4. Chemical Equations, Formulae and Mathematical Expressions

Key Equations and Reactions
1. efficiency η = useful output/input
2. 1 kWh = 3.6 MJ
3. excess air percent = (actual-theoretical)/theoretical x 100
4. $P_{wind}=0.5\rho A v^3 C_p \eta$
5. $P_{hydro}=\rho g Q H \eta$
6. capacity factor = actual energy/(rated power x time)
7. round-trip efficiency = discharged/charged energy
8. $C+O_2 \rightarrow CO_2$
9. $CH_4+2O_2 \rightarrow CO_2+2H_2O$
10. $2H_2+O_2 \rightarrow 2H_2O$

5. Important Derivations and Numerical Concepts

One mole CH_4 requires two moles O_2; 20 percent excess gives an oxygen-equivalent supply of 2.4 mol with accompanying nitrogen. A hydro plant with Q=5 m^3/s, H=20 m and efficiency 0.85 gives about 0.834 MW from ρgQη.

6. Practical Applications

- Combustion balance controls furnaces and emissions.
- Solar and wind supply distributed and grid power.
- Biogas stabilizes wet organic residues and recovers energy.
- Storage supports renewable integration and backup.

7. Concept Diagram

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Primary resource -> Converter -> Electricity/heat/fuel -> Storage/network -> End use
                    | losses         | losses

Wet biomass -> Hydrolysis -> Acidogenesis -> Acetogenesis -> Methanogenesis -> CH4+CO2
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8. Comparison Table

Feature	Solar PV	Wind
Input	Irradiance	Moving air
Key dependence	Area and irradiance	Area and speed cubed
Rotor	No	Yes

9. Important DSSSB Exam Points

- Octane is for petrol; cetane for diesel.
- NCV is lower than GCV on the same basis.
- Hydrogen is an energy carrier.
- Power and energy ratings differ.

10. Practice Questions with Solutions

Attempt each question first. The explanation discusses only the correct answer.

Q1. Which statement correctly describes octane number?

(A) It measures petrol knock resistance.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It measures petrol knock resistance.

Q2. Which statement correctly describes NCV?

(A) It excludes latent heat recovery of product water.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It excludes latent heat recovery of product water.

Q3. Which statement correctly describes reactor moderator?

(A) It slows neutrons in a thermal reactor.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It slows neutrons in a thermal reactor.

Q4. Which statement correctly describes wind power?

(A) It varies with v^3 before conversion limits.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It varies with v^3 before conversion limits.

Q5. Which statement correctly describes hydraulic power?

(A) It contains ρgQH.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It contains ρgQH.

Q6. Which statement correctly describes methanogenesis?

(A) It produces methane in anaerobic digestion.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It produces methane in anaerobic digestion.

Q7. Which statement correctly describes hydrogen?

(A) It is an energy carrier.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It is an energy carrier.

Q8. Which statement correctly describes fuel cell?

(A) It needs continuing reactant supply.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It needs continuing reactant supply.

Q9. Which statement correctly describes capacity factor?

(A) It compares actual energy with rated power times time.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It compares actual energy with rated power times time.

Q10. Which statement correctly describes round-trip efficiency?

(A) It is discharged energy divided by charging energy.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It is discharged energy divided by charging energy.

Quick Revision: Re-read the formula box, cover the answers, and explain each exam point aloud. A formula is ready for the exam only when its symbols, SI units, assumptions and sign convention are clear.

CHAPTER 3 — CORROSION MECHANISMS AND CORROSION PROTECTION

1. Introduction

Corrosion is deterioration by chemical or electrochemical interaction. It causes section loss, leakage, contamination, reinforcement spalling and failure. Correct control requires identification of the anodic and cathodic reactions, electrolyte, geometry and service environment rather than a generic coating prescription.

2. Complete Theory

Dry corrosion and oxide films

Dry corrosion and oxide films is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Direct gas attack often occurs at elevated temperature.

Further scale growth requires ion or electron movement through oxide. Pilling-Bedworth ratio compares oxide volume with metal consumed; coherent nonporous films may protect, while porous, volatile, cracked or spalling films do not.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation
Dry corrosion mein liquid electrolyte compulsory nahi. Oxide compact ho to diffusion slow; cracked film fresh metal expose karti hai.

Wet electrochemical corrosion

Wet electrochemical corrosion is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Anodic metal dissolution supplies electrons; cathodic hydrogen evolution or oxygen reduction consumes them.

Metal carries electrons and electrolyte carries ionic current. Iron forms Fe^{2+}, hydroxides and porous hydrated ferric rust.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

AN OX, RED CAT. Metal loss anode par hota hai; rust generally compact protective layer nahi.

Galvanic and differential-aeration corrosion

Galvanic and differential-aeration corrosion is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Dissimilar connected metals can form a galvanic couple.

The more active metal is anodic in that environment. A small anode coupled to a large cathode is severe.

Less-aerated crevices commonly become anodic, causing water-line, deposit, crevice and pitting attack. A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling.

Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact. In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude.

In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Small anode-large cathode dangerous hai. Low-oxygen crevice hidden anode ban sakta hai.

Localized forms and factors

Localized forms and factors is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Uniform, pitting, crevice, intergranular, stress-corrosion, corrosion fatigue, erosion-corrosion, fretting, selective leaching and microbiologically influenced attack have different morphology and cause.

Metal purity, film, stress and area ratio interact with pH, oxygen, temperature, conductivity, salts, flow and microbes. A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling.

Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact. In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude.

In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Shape ke saath cause identify karo. Average mass loss pitting risk ko hide kar sakta hai.

Corrosion rate

Corrosion rate is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Coupon mass loss normalized by area, time and density gives penetration rate.

Faraday law links charge to ideal dissolved mass, $m=ItM/(nF)$. Current density is more informative than total current when areas differ.

Localized penetration must be reported separately. A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling.

Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact. In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude.

In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Faraday numerical mein n electrons and units check karo. Uniform rate se pit depth assume mat karo.

Reinforcement corrosion

Reinforcement corrosion is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Alkaline concrete passivates steel.

Carbonation lowers pH; chloride can locally break passivity. Expansive corrosion products crack and spall cover.

Low permeability, adequate cover, curing, crack control, suitable reinforcement, repair and cathodic protection reduce risk. A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling.

Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact. In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude.

In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Carbonation pH girata hai; chloride local passive film break karta hai. Sirf surface patch root cause solve nahi karta.

Cathodic and anodic protection

Cathodic and anodic protection is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Cathodic protection supplies electrons through sacrificial anodes or impressed current.

It suits electrically continuous buried or immersed structures. Anodic protection holds suitable active-passive metals in a passive-potential range and requires precise control.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Sacrificial anode khud dissolve hota hai. Anodic protection controlled passivation hai, uncontrolled corrosion nahi.

Coatings, inhibitors and design

Coatings, inhibitors and design is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Good design drains water, avoids crevices, isolates dissimilar metals and permits inspection.

Galvanizing uses sacrificial zinc; tinning relies mainly on an intact noble barrier. Surface preparation controls coating life.

Anodic, cathodic, mixed and volatile inhibitors alter reaction kinetics but require controlled concentration and environmental review. A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling.

Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact. In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude.

In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Paint se pehle surface preparation. Zinc scratch par sacrificial protection de sakta hai; tin defect par exposed steel anodic ho sakta hai.

4. Chemical Equations, Formulae and Mathematical Expressions

Key Equations and Reactions
1. $m = ItM/(nF)$
2. corrosion current density $i = I/A$
3. penetration rate is proportional to mass loss/(area x time x density)
4. Pilling-Bedworth ratio = oxide volume/metal volume consumed
5. $Fe \rightarrow Fe^{2+} + 2e^-$
6. $2H^+ + 2e^- \rightarrow H_2$
7. $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$
8. $Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$
9. $4Fe(OH)_2 + O_2 + 2H_2O \rightarrow 4Fe(OH)_3$

5. Important Derivations and Numerical Concepts

For $Fe \rightarrow Fe^{2+} + 2e^-$, 0.10 A for 3600 s ideally dissolves m=0.10 x 3600 x 55.85/(2 x 96485)=0.104 g. Area, density and morphology are still needed for penetration and life assessment.

6. Practical Applications

- Cathodic protection serves pipelines, tanks and marine steel.
- Galvanizing protects structural steel.
- Concrete durability limits carbonation and chloride ingress.
- Inspection catches localized attack before leakage.

7. Concept Diagram

```
Oxygen-rich cathode: O2+2H2O+4e-->4OH-
Steel electron path <------------------------------
Low-oxygen crevice anode: Fe->Fe2++2e-

Mg/Zn sacrificial anode --wire-- steel pipeline cathode
        |_______________ moist soil electrolyte __|
```

8. Comparison Table

Feature	Cathodic protection	Anodic protection
State	Made cathodic	Held passive anodically
Use	Buried/immersed structures	Active-passive systems
Control	Sacrificial or impressed	Precise potential

9. Important DSSSB Exam Points

- Oxidation occurs at the anode.
- Small anode-large cathode is severe.
- Galvanizing uses zinc.
- Carbonation and chloride depassivate differently.

10. Practice Questions with Solutions

Attempt each question first. The explanation discusses only the correct answer.

Q1. Which statement correctly describes anode?

(A) It is the site of oxidation and metal dissolution.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It is the site of oxidation and metal dissolution.

Q2. Which statement correctly describes oxygen reduction?

(A) It is a common neutral-water cathodic reaction.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It is a common neutral-water cathodic reaction.

Q3. Which statement correctly describes small anode-large cathode?

(A) It produces high anodic current density.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It produces high anodic current density.

Q4. Which statement correctly describes galvanizing?

(A) It applies zinc.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It applies zinc.

Q5. Which statement correctly describes sacrificial protection?

(A) It uses a more active anode.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It uses a more active anode.

Q6. Which statement correctly describes carbonation?

(A) It lowers concrete alkalinity.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It lowers concrete alkalinity.

Q7. Which statement correctly describes pitting?

(A) It can deeply penetrate with small total mass loss.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It can deeply penetrate with small total mass loss.

Q8. Which statement correctly describes Faraday law?

(A) It relates electrochemical mass to charge.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It relates electrochemical mass to charge.

Q9. Which statement correctly describes tinning?

(A) It relies mainly on an intact barrier.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It relies mainly on an intact barrier.

Q10. Which statement correctly describes anodic protection?

(A) It maintains a suitable passive range.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It maintains a suitable passive range.

Quick Revision: Re-read the formula box, cover the answers, and explain each exam point aloud. A formula is ready for the exam only when its symbols, SI units, assumptions and sign convention are clear.

CHAPTER 4 — ENVIRONMENTAL CHEMISTRY AND POLLUTION CONTROL

1. Introduction

Environmental chemistry follows a pollutant from source through air, water or soil, through transformation and exposure, to receptor and effect. Hazard is intrinsic potential for harm; risk also depends on exposure. Current limits, laws and policies must be checked from authoritative official sources before publication.

2. Complete Theory

Compartments, cycles and pollutant fate

Compartments, cycles and pollutant fate is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Atmosphere, hydrosphere, lithosphere and biosphere exchange matter through natural cycles.

Pollutants undergo transport, dispersion, volatilization, sorption, hydrolysis, photolysis, reaction and biodegradation. Persistence controls residence; bioaccumulation is buildup within an organism and biomagnification is increase across trophic levels.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation
Source-pathway-receptor chain follow karo. Bioaccumulation organism ke andar, biomagnification food-chain levels par.

Atmosphere, pollutants and inversion

Atmosphere, pollutants and inversion is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. The troposphere contains weather and most emissions; stratospheric ozone shields ultraviolet radiation.

Primary pollutants are emitted directly; secondary pollutants form in air. PM, SO_x, NO_x, CO, VOCs, ozone and metals affect health and materials.

Temperature inversion suppresses vertical mixing. A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling.

Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact. In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude.

In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation
Inversion polluted surface air ke upar lid jaisa kaam karta hai. Ground ozone harmful, stratospheric ozone protective.

Smog and acid deposition

Smog and acid deposition is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Classical smog combines sulfurous pollution, smoke and fog in cool humid conditions.

Photochemical smog uses NO_x, VOCs and sunlight to form ozone, PAN and oxidants. Oxidation of SO_2 and NO_x produces acidic wet and dry deposition.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation
Classical sulfur-smoke-fog type; photochemical sunny oxidant type. Best acid-rain control precursor emissions reduce karna hai.

Ozone depletion and climate change

Ozone depletion and climate change is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. CFC-derived chlorine radicals catalytically destroy stratospheric ozone.

Greenhouse gases absorb and re-emit terrestrial infrared radiation; enhanced forcing changes climate. Ozone depletion and greenhouse warming are different mechanisms.

Mitigation reduces causes; adaptation manages impacts. A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling.

Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact. In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude.

In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation
Ozone depletion UV problem hai; greenhouse effect infrared heat-balance problem. Dono ko mix mat karo.

Water pollution, BOD and COD

Water pollution, BOD and COD is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Point and non-point sources release organics, nutrients, metals, pesticides, oil, pathogens and heat.

BOD measures biological oxygen use under specified incubation; COD uses chemical oxidation and is faster; TOC measures carbon. Nutrient enrichment can drive eutrophication and oxygen depletion.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

BOD microbes ka demand, COD chemical oxidant ka demand. COD often BOD se high, but test conditions mention karo.

Soil pollution and remediation

Soil pollution and remediation is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Pesticides, fertilizers, industrial waste, metals and leachate interact with soil pH, clay, organic matter, cation exchange and redox condition.

Sorption delays transport but does not destroy mass. Excavation, containment, washing, stabilization, thermal, biological and plant-based remediation suit different contaminants.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Metal biodegrade nahi hota; immobilize, extract ya recover ho sakta hai. Soil mein adsorbed mass vanish nahi hota.

Noise, thermal pollution and wastes

Noise, thermal pollution and wastes is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Decibels are logarithmic and cannot be added arithmetically.

Thermal discharge changes oxygen solubility and aquatic metabolism. Waste hierarchy prioritizes prevention, reduction, reuse and recycling.

Composting, controlled incineration and sanitary landfill require feed segregation, emission, leachate, gas and residual control. A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling.

Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact. In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude.

In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Do 60 dB sources 120 dB nahi bante. Sanitary landfill open dump nahi; engineered liner, leachate and gas systems hote hain.

Green chemistry and monitoring

Green chemistry and monitoring is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Green chemistry prevents hazard and waste using atom economy, safer solvents, catalysis, energy efficiency and renewable feedstocks.

Grab samples are snapshots; composites integrate time or flow. QA/QC uses blanks, standards, duplicates, calibration checks and traceable records.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

High yield aur high atom economy same nahi. Best instrument bhi biased sample ko correct nahi bana sakta.

4. Chemical Equations, Formulae and Mathematical Expressions

Key Equations and Reactions
1. $BOD=(D_1-D_2)/P$ for the stated unseeded dilution method
2. percent removal$=(C_{in}-C_{out})/C_{in}$ x 100
3. $L=10\log_{10}(I/I_0)$
4. $L_T=10\log_{10}(\Sigma 10^{L_i/10})$
5. atom economy=desired-product molar mass/Σ reactant molar masses x 100
6. $NO_2+h\nu \rightarrow NO+O$
7. $O+O_2 \rightarrow O_3$
8. SO_2+oxidants$\rightarrow H_2SO_4$ (representative pathway)

5. Important Derivations and Numerical Concepts

If diluted-bottle DO falls from 8.8 to 3.2 mg/L and sample fraction P=0.02, unseeded BOD=(8.8-3.2)/0.02=280 mg/L, subject to blank and method validity. Two independent 60 dB sources combine as $10\log_{10}(10^6+10^6)=63$ dB.

6. Practical Applications

- Air control links precursors to atmospheric products.
- BOD and COD monitor wastewater.
- Landfill systems contain leachate and gas.
- QA/QC makes environmental data defensible.

7. Concept Diagram

```
Source -> Release -> Air/water/soil -> Transformation -> Exposure -> Receptor -> Effect
          | source control     | pathway control     | protection

NO2 --sunlight--> NO+O ; O+O2->O3
VOCs help recycle NO to NO2, allowing ozone accumulation
```

8. Comparison Table

Feature	BOD	COD	TOC
Measures	Biological O_2 use	Chemical oxidant demand	Organic carbon
Time	Days	Hours	Rapid instrumentally
Typical value	Often below COD	Often above BOD	Matrix dependent

9. Important DSSSB Exam Points

- Primary is emitted; secondary forms later.

- Ozone effect depends on atmospheric layer.
- Decibels add logarithmically.
- Atom economy differs from yield.

10. Practice Questions with Solutions

Attempt each question first. The explanation discusses only the correct answer.

Q1. Which statement correctly describes secondary pollutant?

(A) It forms through environmental reactions.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It forms through environmental reactions.

Q2. Which statement correctly describes temperature inversion?

(A) It suppresses vertical mixing.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It suppresses vertical mixing.

Q3. Which statement correctly describes photochemical smog?

(A) It involves NO_x, VOCs and sunlight.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It involves NO_x, VOCs and sunlight.

Q4. Which statement correctly describes stratospheric ozone?

(A) It absorbs harmful UV.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It absorbs harmful UV.

Q5. Which statement correctly describes COD?

(A) It is commonly at least as large as BOD for one sample.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It is commonly at least as large as BOD for one sample.

Q6. Which statement correctly describes bioaccumulation?

(A) It is buildup within an organism.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It is buildup within an organism.

Q7. Which statement correctly describes sound levels?

(A) They combine logarithmically.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
They combine logarithmically.

Q8. Which statement correctly describes sanitary landfill?

(A) It uses engineered leachate and gas control.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It uses engineered leachate and gas control.

Q9. Which statement correctly describes atom economy?

(A) It measures reactant incorporation into desired product.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It measures reactant incorporation into desired product.

Q10. Which statement correctly describes grab sample?

(A) It represents a particular place and time.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It represents a particular place and time.

Quick Revision: Re-read the formula box, cover the answers, and explain each exam point aloud. A formula is ready for the exam only when its symbols, SI units, assumptions and sign convention are clear.

CHAPTER 5 — ENVIRONMENTAL BIOTECHNOLOGY AND BIOLOGICAL TREATMENT PROCESSES

1. Introduction

Environmental biotechnology uses microorganisms, plants, enzymes and mixed biological communities to transform biodegradable pollutants, recover resources and stabilize waste. Biological treatment succeeds only when habitat, electron acceptor, nutrients, retention and solids separation are controlled.

2. Complete Theory

Microorganisms and growth phases

Microorganisms and growth phases is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Bacteria, fungi, algae and protozoa perform distinct roles.

Prokaryotic and eukaryotic cells differ structurally. Heterotrophs use organic carbon; autotrophs use inorganic carbon.

Aerobic, anaerobic and facultative organisms differ in electron-acceptor use. Batch growth passes through lag, log, stationary and death phases.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Microbes ko food, nutrients, pH, temperature and electron acceptor chahiye. Lag adaptation, log rapid growth, stationary balance and death decline.

Growth kinetics and parameters

Growth kinetics and parameters is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Monod kinetics relates specific growth rate to substrate.

Yield links biomass formed with substrate used; decay accounts for endogenous loss. HRT describes water residence, SRT biomass residence, and F/M compares biodegradable loading with biomass inventory.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation
HRT water kitni der, SRT microbes kitni der. Return and waste sludge SRT control karte hain.

Activated sludge

Activated sludge is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Wastewater and RAS enter an aeration tank; oxygen and mixing support oxidation and floc.

A secondary clarifier separates solids, returning RAS and removing WAS. MLSS, MLVSS, DO, F/M, SRT, HRT and SVI support control.

Bulking and foaming require cause-specific diagnosis. A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling.

Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact. In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude.

In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation
Aeration tank biology, clarifier separation. RAS useful biomass wapas, WAS extra biomass bahar.

Trickling filter and attached growth

Trickling filter and attached growth is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Biofilm grows on media; distributor, ventilation, underdrain and recirculation maintain contact.

Thick biofilm sloughs and needs downstream clarification. RBC discs alternate between wastewater and air; MBBR retains moving biofilm carriers.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation
Trickling filter simple sieve nahi, biofilm reactor hai. Sloughed solids ko clarify karna padta hai.

Anaerobic treatment

Anaerobic treatment is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Hydrolysis, acidogenesis, acetogenesis and methanogenesis convert concentrated organics to methane-rich gas and digestate.

Methanogens are sensitive to pH, temperature, toxicants and rapid loading. Sealed gas collection, sulfur control, safety and digestate management are integral.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Acid formers aur methanogens ka balance bigda to digester sour ho sakta hai. Oxygen supply nahi karte.

Ponds, wetlands and nutrient removal

Ponds, wetlands and nutrient removal is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Facultative ponds combine aerobic upper and anaerobic lower zones; wetlands use plants, media and biofilms.

Aerobic nitrification converts ammonium to nitrate; anoxic denitrification converts nitrate to N_2. Biological phosphorus removal requires controlled anaerobic-aerobic cycling.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Nitrification nitrate banata hai; denitrification N_2 gas banakar nitrogen remove karta hai. Anoxic aur anaerobic same nahi.

Bioremediation and biosorption

Bioremediation and biosorption is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Biostimulation improves conditions for native microbes; bioaugmentation adds organisms.

In situ treatment avoids excavation; ex situ provides more control. Biosorption is commonly passive surface binding, while bioaccumulation involves cellular uptake.

Phytoremediation uses plants for extraction, stabilization or degradation. A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling.

Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact. In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude.

In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Oil biodegrade ho sakta hai; metal element biodegrade nahi. Biosorption surface, bioaccumulation cell ke andar.

Composting, bioenergy and tools

Composting, bioenergy and tools is needed because engineering decisions fail when the controlling chemical, physical or biological mechanism is not identified. Controlled aerobic composting passes through mesophilic, thermophilic and curing stages; moisture, aeration and C:N balance matter.

Vermicomposting works under milder conditions. Biosensors couple biological recognition to a transducer; bioindicators reveal environmental condition; immobilized cells and enzymes improve retention and reuse.

A correct treatment or control decision begins with a representative input description, follows mass and charge balance, identifies the rate-limiting step, and states operating conditions such as pH, temperature, contact time, loading and residual handling. Advantages must be weighed against energy, chemical consumption, sludge or concentrate production, reliability and environmental impact.

In numerical questions, write the governing relation, define every symbol and SI unit, convert the data before substitution, and check the sign and order of magnitude. In statement questions, distinguish definition, mechanism, design parameter and operational symptom; they are not interchangeable.

Hinglish Explanation

Composting uncontrolled rotting nahi. Excess water anaerobic odour, too little water activity stop karta hai.

4. Chemical Equations, Formulae and Mathematical Expressions

Key Equations and Reactions
1. $\mu=\mu_{max}S/(K_s+S)$
2. net growth $=(\mu-k_d)X$
3. Y=biomass formed/substrate consumed
4. HRT $\theta=V/Q$
5. SRT θ_c=solids mass in system/solids mass leaving per day
6. $F/M=QS_0/(VX)$
7. SVI=settled sludge volume/MLSS mass
8. $NH_4^++1.5O_2\rightarrow NO_2^-+2H^++H_2O$
9. $NO_2^-+0.5O_2\rightarrow NO_3^-$
10. $NO_3^-\rightarrow N_2$ (representative endpoint)
11. organic matter$\rightarrow CH_4+CO_2$ (representative overall)

5. Important Derivations and Numerical Concepts

A 3000 m^3 aeration tank receiving 12,000 m^3/d has HRT=V/Q=0.25 d=6 h. If MLSS is 3000 mg/L and 30-minute settled volume is 240 mL/L, SVI=240/3.0=80 mL/g.

6. Practical Applications

- Activated sludge treats biodegradable wastewater.
- Anaerobic digestion stabilizes sludge and recovers gas.
- Wetlands provide lower-energy polishing where land is available.
- Bioremediation treats suitable soil and groundwater contamination.

7. Concept Diagram

```
Influent -> Aeration tank + air -> Secondary clarifier -> Effluent
             ^                     |
             |--------- RAS ---------|
                                   +-> WAS

Organics -> Hydrolysis -> Acidogenesis -> Acetogenesis -> Methanogenesis -> CH4+CO2
```

8. Comparison Table

Feature	Activated sludge	Trickling filter
Biomass	Suspended floc	Attached biofilm
Reactor	Aeration tank	Media bed
Issue	Bulking/foaming	Ponding/sloughing

9. Important DSSSB Exam Points

- HRT and SRT differ.
- RAS returns biomass; WAS removes it.
- Anoxic denitrification uses nitrate.
- Metals cannot be biodegraded as elements.

10. Practice Questions with Solutions

Attempt each question first. The explanation discusses only the correct answer.

Q1. Which statement correctly describes log phase?

(A) It has rapid exponential growth.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It has rapid exponential growth.

Q2. Which statement correctly describes Monod model?

(A) It relates growth rate to substrate.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It relates growth rate to substrate.

Q3. Which statement correctly describes RAS?

(A) It returns settled biomass to aeration.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It returns settled biomass to aeration.

Q4. Which statement correctly describes SVI?

(A) It indicates sludge settleability.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It indicates sludge settleability.

Q5. Which statement correctly describes trickling filter?

(A) It is an attached-growth reactor.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It is an attached-growth reactor.

Q6. Which statement correctly describes methanogenesis?

(A) It forms methane.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It forms methane.

Q7. Which statement correctly describes nitrification?

(A) It oxidizes ammonium toward nitrate.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It oxidizes ammonium toward nitrate.

Q8. Which statement correctly describes denitrification?

(A) It reduces nitrate under anoxic conditions.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It reduces nitrate under anoxic conditions.

Q9. Which statement correctly describes biostimulation?

(A) It improves conditions for native microbes.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It improves conditions for native microbes.

Q10. Which statement correctly describes biosorption?

(A) It commonly binds species on biomass surfaces.
(B) It is unrelated to the stated process.
(C) It always removes every pollutant.
(D) It has no operating limitation.

Correct Answer: (A)
It commonly binds species on biomass surfaces.

Quick Revision: Re-read the formula box, cover the answers, and explain each exam point aloud. A formula is ready for the exam only when its symbols, SI units, assumptions and sign convention are clear.