Engineering Chemistry (DI01000071)

Summer 2025 Exam Solutions

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Exam Overview

Exam Details

Subject:	Engineering Chemistry
Code:	DI01000071
Date:	06-06-2025
Time:	10:30 AM – 01:00 PM
Marks:	70

Topics at a Glance

Q.2	Atomic structure, pH, H-bond
Q.3	Corrosion, Fuels, Cells
Q.4	Fuels, Polymers, Lubricants
Q.5	Semiconductors, Cells, Rubber

Paper Structure

Q.1	14 MCQs (1 mark each $= 14$)
Q.2–5	(A) any 2×3 marks $= 6$ each
	(B) any 2×4 marks $= 8$ each

Q.1 — MCQ Answers (1–7) [14 marks]

#	Key word	Ans	Option
1	Sub-atomic particle in orbit	**C**	Electron
2	BCC crystal arrangement	**A**	Fe
3	ppm stands for	**A**	Parts per million
4	pH of acidic solution	**D**	Less than 7
5	Losing electron process	**B**	Oxidation
6	1 kilocalorie = ? calorie	**D**	1000
7	Highest CV coal	**C**	Anthracite

Quick Recall

- **Electrons** orbit the nucleus; protons & neutrons in nucleus
- **Fe** (iron) has BCC structure; Cu, Al have FCC
- **ppm** = parts per million (10^{-6})
- Acid: pH $<$ 7; Base: pH $>$ 7; Neutral: pH $=$ 7
- **Oxidation** = loss of electrons; Reduction = gain
- 1 kcal = **1000 cal** = 4186 J
- **Anthracite**: 90–95% C, highest CV (≈8500 kcal/kg)

#	Key word	Ans	Option
8	Example of primary fuel	**A**	Crude oil
9	Measures viscosity of lube oil	**D**	Viscometer
10	Grease type of lubricant	**C**	Semi-solid
11	Monomer of PVC	**A**	Vinyl chloride
12	Condensation polymer	**C**	Bakelite
13	Property of insulating material	**D**	All of these
14	Potential of dry cell	**B**	1.5 V

Quick Recall

- **Crude oil** is a natural/primary fuel; LPG is derived
- **Redwood viscometer** measures kinematic viscosity
- Grease = oil + soap = **semi-solid** lubricant
- PVC monomer: **vinyl chloride** ($CH_2{=}CHCl$)
- **Bakelite** = condensation of phenol + formaldehyde
- Insulator: high resistance, low conductivity, non-flammable
- Dry cell (Leclanché): EMF = **1.5 V**

Q.2(A)(1) — Pauli's Exclusion Principle [3 marks]

Statement

No two electrons in an atom can have all **four quantum numbers identical**.

If two electrons share the same orbital, they must have **opposite spins** ($+\frac{1}{2}$ and $-\frac{1}{2}$).

Significance

- Limits **max 2 electrons per orbital**
- Explains the filling order of atomic orbitals
- Basis for the periodic table structure
- Determines electron configuration of elements

Example: He ($Z = 2$)

e^-	n	l	m	s
1st	1	0	0	$+\frac{1}{2}$
2nd	1	0	0	$-\frac{1}{2}$

Only spin (s) differs $\rightarrow$ principle satisfied.

Both electrons in 1s orbital have same n, l, m but **opposite spins**.

Pauli (1925): Max 2 electrons per orbital, always with paired (opposite) spins.

Q.2(A)(2) — Ionic Bond [3 marks]

Definition

An **ionic bond** is formed by the **complete transfer** of one or more electrons from a metal to a non-metal atom. Oppositely charged ions are held together by **electrostatic attraction**.

Formation in NaCl

$$\text{Na (2,8,1)} \rightarrow \text{Na}^+ \text{ (2,8)} + e^- \quad \text{(loses 1 } e^-\text{)}$$

$$\text{Cl (2,8,7)} + e^- \rightarrow \text{Cl}^- \text{ (2,8,8)} \quad \text{(gains 1 } e^-\text{)}$$

$$\text{Na}^+ + \text{Cl}^- \longrightarrow \text{NaCl (ionic compound)}$$

Properties of Ionic Compounds

- **High melting & boiling point** — strong electrostatic forces
- **Solid** at room temperature (rigid lattice)
- **Conduct electricity** only in molten or aqueous state
- **Soluble** in polar solvents (water)
- **Hard but brittle** — fracture on stress

Condition: Formed between metals (low IE) and non-metals (high EA).

Q.2(A)(3) — pH of 0.01 M HCl [3 marks]

Given

Concentration of HCl $= 0.01\,\text{M} = 10^{-2}\,\text{M}$

Theory

pH $= -\log[H^+]$

HCl is a **strong acid** — fully ionized:
$HCl \longrightarrow H^+ + Cl^-$
$\therefore [H^+] = [HCl] = 10^{-2}\,\text{M}$

Solution

Step 1: Find $[H^+]$

$$[H^+] = 0.01\,\text{M} = 10^{-2}\,\text{M}$$

Step 2: Calculate pH

$$\text{pH} = -\log(10^{-2}) = -(-2)$$

$$\boxed{\text{pH} = 2}$$

Step 3: Find pOH

$$\text{pOH} = 14 - 2 = \boxed{12}$$

Since pH $= 2 < 7$, solution is **strongly acidic**.

Q.2(B)(1) — Hydrogen Bond: Types [4 marks]

Definition

A **hydrogen bond** is a weak electrostatic attraction between a H atom covalently bonded to a highly electronegative atom (F, O, N) and another electronegative atom.

Represented as: $X\text{–}H\cdots Y \quad (X, Y = F, O, \text{or } N)$

Type 1 — Intermolecular

Formed **between different molecules**.

Examples:

- Water: O–H···O–H (between H_2O molecules)
- HF: F–H···F (between HF molecules)
- Alcohols, carboxylic acids

Effect: Raises boiling point, increases viscosity.

Type 2 — Intramolecular

Formed **within the same molecule**.

Examples:

- *o*-nitrophenol: O–H···O=N within molecule
- *o*-chlorophenol
- Salicylaldehyde

Effect: Does NOT raise boiling point; lower BP than isomers.

Q.2(B)(1) — Hydrogen Bond: Importance [4 marks]

Physical Importance

1. **High BP of water (100°C)** — H-bonds require extra energy to break; without H-bonding, water would boil at $-80°$C.
2. **Ice less dense than water** — H-bonds form an open hexagonal lattice in ice.
3. **High surface tension** of water — H-bond network resists breaking at surface.

Biological Importance

4. **Protein structure** — H-bonds stabilize α-helix and β-sheet conformations.
5. **DNA double helix** — Base pairs (A–T, G–C) held by H-bonds; enables replication.
6. **Solubility** — Polar solutes (glucose, alcohol) dissolve in water via H-bonding.

Given

Mass of KOH $= 5.6\,\text{g}$
Molar mass of KOH $= 56\,\text{g/mol}$
Volume of solution $= 1000\,\text{mL} = 1\,\text{L}$

Formula

$$M = \frac{W \times 1000}{M.W. \times V_{mL}}$$

where $W =$ mass (g), $V_{mL} =$ volume (mL)

Solution

Step 1: Calculate moles of KOH

$$n = \frac{\text{mass}}{M.W.} = \frac{5.6}{56} = 0.1\,\text{mol}$$

Step 2: Apply molarity formula

$$M = \frac{n}{V(\text{L})} = \frac{0.1}{1}$$

$$\boxed{M = 0.1\,\text{mol/L}}$$

This is a **0.1 M KOH solution** — a moderately alkaline solution.

Q.2(B)(3) — Factors Affecting Degree of Ionization [4 marks]

Factors 1–3

1. **Nature of electrolyte** — Strong electrolytes (HCl, NaOH) ionize completely ($\alpha \approx 1$); weak electrolytes ionize partially.
2. **Nature of solvent** — Polar solvents (high dielectric constant ε) promote greater ionization by weakening inter-ionic attraction.
3. **Temperature** — Higher temperature increases ionization (endothermic; more kinetic energy).

Factors 4–5

4. **Concentration (Dilution)** — Greater dilution $\Rightarrow$ higher degree of ionization. Ostwald's law: $\alpha = \sqrt{K_a/C}$.
5. **Common ion effect** — Adding a common ion **suppresses** ionization (Le Chatelier's principle), reducing α.

Ostwald's Dilution Law

$K_a = \frac{C\alpha^2}{1-\alpha} \approx C\alpha^2$ (for weak acids, $\alpha \ll 1$)

Q.3(A)(1) — Electroplating [3 marks]

Definition & Setup

Electroplating deposits a thin adherent layer of one metal on another using **electrolysis**.

Cathode:	Object to be plated
Anode:	Metal to be deposited (Cu)
Electrolyte:	$CuSO_4$ solution

Reactions (Copper plating)

Anode: $Cu \longrightarrow Cu^{2+} + 2\,e^-$
Cathode: $Cu^{2+} + 2\,e^- \longrightarrow Cu$ (deposited)

Applications

- **Corrosion protection** — Zn/Cr/Ni plating on steel
- **Decorative purposes** — Gold/silver plating on jewellery
- **Electrical contacts** — Silver/gold on connectors
- **Automobile parts** — Chrome plating for shine
- **Tin cans** — Food containers (non-toxic)

Current control: Low current density gives uniform, adherent deposit.

Q.3(A)(2) — Pitting Corrosion [3 marks]

Definition & Mechanism

Pitting corrosion — localized form of corrosion producing small deep **pits** on the metal surface while the rest remains unaffected.

Mechanism:

1. Protective oxide film breaks at a **local weak spot** (becomes anode).
2. Small anode + large cathode $\Rightarrow$ high current density at pit.
3. Pit grows **deeper rapidly**; surface appears intact.

Why is it Dangerous?

- **Difficult to detect visually** — surface looks undamaged
- Can **perforate** the metal completely
- Causes sudden **unexpected failure** of pipes/tanks
- Common in **stainless steel** in chloride (seawater) environments
- Higher risk than uniform corrosion

Prevention: Use Cl^--free environments, protective coatings, or more resistant alloys.

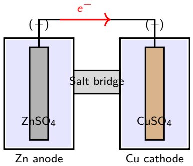
Q.3(A)(3) — Galvanizing vs Tinning [3 marks]

Property	Galvanizing	Tinning
Metal used	**Zinc (Zn)**	**Tin (Sn)**
Protection type	**Anodic** — Zn is more active than Fe	**Cathodic** — Sn is less active than Fe
Coating scratched	Zn still **sacrificially protects** Fe	Fe **corrodes rapidly** (exposed Fe is anode)
Method	Hot-dip in molten Zn or electro-plating	Hot-dip in molten Sn
Applications	Iron pipes, GI sheets, fences, car bodies	Food cans, containers, dairy equipment
Toxicity	Safe for structural use	**Non-toxic to food** (food-safe)

Key Difference

Galvanizing provides **sacrificial protection**; tinning provides only **barrier protection** (fails if coating is broken).

Q.3(B)(1) — Electrochemical Cell: Construction [4 marks]



Daniel Cell Setup

Anode (−):	Zinc rod in $ZnSO_4$
Cathode (+):	Copper rod in $CuSO_4$
Salt bridge:	KCl/KNO_3 in agar
EMF:	1.1 V

Cell Reactions

Anode (oxidation):
$Zn \longrightarrow Zn^{2+} + 2e^-$

Cathode (reduction):
$Cu^{2+} + 2e^- \longrightarrow Cu$

Overall:
$Zn + Cu^{2+} \longrightarrow Zn^{2+} + Cu$

$\text{EMF} = E^\circ_{Cu} - E^\circ_{Zn} = 0.34 - (-0.76) = 1.10$ V

Working Principle

1. **Anode (Zn):** Zinc dissolves → Zn^{2+} into solution; electrons released into wire.
2. **External circuit:** Electrons travel from anode (Zn) to cathode (Cu) through the wire.
3. **Cathode (Cu):** Cu^{2+} ions from $CuSO_4$ gain electrons → deposit as Cu metal.
4. **Salt bridge:** Maintains electrical neutrality by allowing ion flow (K^+/Cl^- migrate to balance charge).

Net Result

Chemical energy → Electrical energy

Zn electrode **loses mass** (dissolves)
Cu electrode **gains mass** (deposits)

Key Points

- **Oxidation** at anode (−)
- **Reduction** at cathode (+)
- Salt bridge prevents mixing but allows ionic flow

Q.3(B)(2) — Factors Affecting Rate of Corrosion [4 marks]

Physical/Environmental Factors

1. **Temperature** — Higher temperature increases ionic mobility and reaction rate, accelerating corrosion.
2. **Humidity/Moisture** — Water acts as electrolyte. No moisture = no corrosion. Higher humidity = faster corrosion.
3. **Presence of electrolytes** — NaCl in water greatly increases conductivity and corrosion rate (marine environments).

Metal/Chemical Factors

4. **Nature of metal** — More active metals corrode faster; impurities create local galvanic cells.
5. **pH of environment** — Acidic conditions ($pH < 7$) dissolve protective oxide films and accelerate corrosion.
6. **Galvanic series position** — Larger EMF difference between metals in contact $\rightarrow$ faster corrosion of the anodic metal.

Feature	LPG (Liquefied Petroleum Gas)	CNG (Compressed Natural Gas)
Composition	Propane (C_3H_8) + Butane (C_4H_{10})	Mainly Methane (CH_4, ≈90%)
Physical state	Liquid (under moderate pressure)	Gas (compressed to ≈200 bar)
Calorific value	≈11000 kcal/kg	≈12400 kcal/kg
Properties	Colourless, odourless (odorant added); heavier than air	Colourless; lighter than air; non-toxic
Applications	Domestic cooking, industrial heating	Vehicle fuel, domestic/industrial use
Advantage	Easy to store and transport in cylinders	Cleaner burning, less pollution than LPG

Safety Note

LPG is heavier than air → accumulates at floor level (explosion risk). CNG is lighter → disperses upward (safer indoors).

Definition of Fuel

A **fuel** is any combustible substance that releases **heat energy** on burning and can be used economically.

Properties 1–4

1. **High calorific value** — large heat per unit mass
2. **Low ignition temperature** — easy to ignite
3. **Moderate rate of combustion** — controllable burn
4. **Burns without smoke/residue** — no pollution

Properties 5–7

5. **Easy to store and transport** — safe handling
6. **Cheap and readily available** — economical
7. **Non-toxic combustion products** — environment-friendly

Examples

Solid: Coal, wood **Liquid:** Petrol, diesel
Gaseous: LPG, CNG, hydrogen (nearest to ideal)

Q.4(A)(2) — Classification of Polymer: Molecular Structure [3 marks]

1. Linear Polymers

Monomers linked end-to-end in a straight chain.

Properties:

- High tensile strength
- High melting point
- Can be crystalline

Examples:
HDPE, PVC, Nylon

2. Branched Chain

Side branches on main chain reduce packing.

Properties:

- Lower density than linear
- More flexible
- Lower MP and strength

Examples:
LDPE, Glycogen, Amylopectin

3. Cross-linked (Network)

Chains linked by covalent bonds in 3D network.

Properties:

- Rigid and hard
- Infusible (thermosetting)
- Chemically resistant

Examples:
Bakelite, Vulcanized rubber

Q.4(A)(3) — Biodegradable Polymers [3 marks]

Definition

Biodegradable polymers are polymers that can be broken down by **microorganisms** (bacteria, fungi) into CO_2, H_2O, and biomass under natural environmental conditions.

Examples

PLA (Polylactic acid)	Medical sutures, packaging
PHB (Polyhydroxybutyrate)	Films, bottles
PHBV	Packaging, coatings
Nylon-2-nylon-6	Biodegradable fibre

Advantages

- **Reduce plastic pollution** — decompose naturally without landfill
- **Eco-friendly** — no toxic residues left in environment
- **Sustainable** — many derived from renewable resources
- **Safe disposal** — compostable under right conditions

Conventional plastics (PVC, PE) take **100s of years** to degrade; biodegradable ones degrade in months.

Q.4(B)(1) — Power Alcohol (Gasohol) [4 marks]

Definition & Composition

Power alcohol (Gasohol) is a blend of **petrol (80%) + ethyl alcohol (20%)** used as a motor fuel in petrol engines.

Ethanol source: Fermentation of sugarcane, maize, or starchy crops.

Advantages

1. **Higher octane number** than petrol alone → better anti-knock property.
2. **Renewable** — ethanol regenerated from crops annually.
3. **Cleaner combustion** — lower CO and HC emissions.
4. **Reduces fossil fuel dependence** — extends petrol supply.

Disadvantages

- **Absorbs moisture** — phase separation in wet conditions
- **Corrodes rubber parts** — swells rubber gaskets/seals
- **Lower energy density** than pure petrol
- **Large agricultural land** needed for ethanol crops
- **Food vs fuel** dilemma — competes with food crops

Q.4(B)(2) — Lubricant: Definition & Functions [4 marks]

Definition

A **lubricant** is a substance (solid, liquid, or semi-solid) applied between two **moving surfaces** to reduce friction, heat, and wear.

Types

Solid: Graphite, MoS_2
Semi-solid: Grease (soap + oil)
Liquid: Mineral oils, synthetic oils

Six Functions of a Lubricant

1. **Reduce friction and wear** between moving parts
2. **Reduce heat** generated by friction (acts as coolant)
3. **Prevent corrosion** — forms protective film on metal
4. **Act as sealant** — prevents gas/fluid leakage in engines
5. **Carry away contaminants** (metal particles, dust)
6. **Reduce noise** from machine operation

Q.4(B)(3) — Lubricant for Cutting Tools [4 marks]

Properties 1–3

1. **High viscosity index (VI)** — viscosity must remain stable over a wide temperature range; low VI means drastic viscosity change with temp.
2. **Extreme pressure (EP) properties** — must withstand very high loads at gear-tooth contact points without squeezing out.
3. **Good thermal stability** — must not decompose or oxidize at high cutting temperatures.

Properties 4–6

4. **Anti-wear & anti-scoring** — prevents welding and seizure of metal surfaces under load.
5. **Good cooling ability** — dissipates heat generated during cutting operations efficiently.
6. **Non-corrosive** — should not corrode the tool material, workpiece, or machine parts.

Q.5(A)(1) — n-type and p-type Semiconductors [3 marks]

n-type Semiconductor

Doping: Pentavalent impurity (P, As, Sb) added to Si/Ge.

Extra (5th) electron from impurity $\rightarrow$ free electron for conduction.

Majority carriers: Electrons (e^-)
Minority carriers: Holes (h^+)
Overall charge: Neutral

Example: Si + Phosphorus (P)

p-type Semiconductor

Doping: Trivalent impurity (B, Al, Ga) added to Si/Ge.

Electron **deficiency** creates a **hole** that acts as a positive charge carrier.

Majority carriers: Holes (h^+)
Minority carriers: Electrons (e^-)
Overall charge: Neutral

Example: Si + Boron (B)

Q.5(A)(2) — Primary Cell vs Secondary Cell [3 marks]

Property	Primary Cell	Secondary Cell
Recharging	**Cannot** be recharged; discarded after use	**Can be recharged** many times
Reactions	**Irreversible** electrode reactions	**Reversible** electrode reactions
Energy source	Chemical energy stored at manufacture	Energy stored by external charging
Life span	Short (single use)	Long (hundreds of cycles)
Cost	Cheap initially	More expensive initially
Maintenance	Not required	Requires periodic maintenance
Weight	Lighter	Heavier
Examples	Dry cell (Leclanché), Mercury cell	Lead-acid, Ni-Cd, Li-ion

Q.5(A)(3) — Solar Cell [3 marks]

Definition & Principle

A **solar cell** (photovoltaic cell) converts **solar energy directly into electrical energy** using the **photovoltaic effect** in a p-n junction semiconductor (silicon).

When photons hit the p-n junction, electron-hole pairs are created; the built-in field separates them, generating a potential difference.

Advantages

- Renewable & inexhaustible energy
- Zero pollution during operation
- No moving parts $\rightarrow$ low maintenance
- Long operational life (20–30 years)
- Suitable for remote/rural areas

Disadvantages

- High initial cost
- Depends on sunlight (ineffective at night/clouds)
- Low efficiency ($\approx$15–20%)
- Requires large surface area

Q.5(B)(1) — Vulcanization of Rubber [4 marks]

Definition & Process

Vulcanization is the process of heating natural rubber with **2–3% sulfur** at **140–160°C**.

Sulfur forms **cross-links** (–S–S– bridges) between adjacent polymer chains, converting soft sticky rubber into a strong elastic material.

Discovered by: Charles Goodyear (1839)
Hard rubber (Ebonite): 30% sulfur gives very hard material.

Properties Improved

Natural	**Vulcanized**
Low elasticity	High elasticity
Low strength	High strength
Sticky surface	Non-sticky
Solvent-soluble	Resistant
Narrow temp range	Wide range

Uses

Tyres, hoses, gaskets, shoe soles, conveyor belts, gloves.

Q.5(B)(2) — Thermoplastic vs Thermosetting Plastic [4 marks]

Property	Thermoplastic	Thermosetting
On heating	**Softens** — can be reshaped repeatedly	**Decomposes/chars** on strong heating
Structure	Linear or branched chain	3D cross-linked network
Recyclability	**Can be recycled** and re-moulded	**Cannot be recycled**
Strength	Moderate; lower rigidity	**Higher**, hard and rigid
Solubility	Soluble in suitable solvents	**Insoluble** in all solvents
Moulding	Repeated moulding possible	Moulded only once
Cost	Generally cheaper	Generally costlier
Examples	PVC, Polyethylene, Polystyrene, Nylon	Bakelite, Epoxy resin, Melamine, Urea-formaldehyde

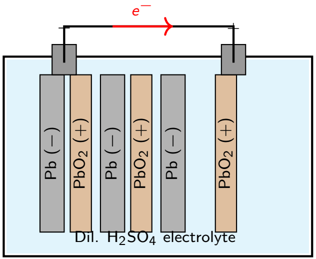
Q.5(B)(3) — Lead Acid Storage Cell: Construction [4 marks]

Construction

Anode (−): Spongy lead (Pb)
Cathode (+): Lead dioxide (PbO_2)
Electrolyte: Dil. H_2SO_4 (SG 1.25)
Cell EMF: 2.0 V per cell
Car battery: 6 cells = 12 V

Discharge Note

During discharge, both plates form $PbSO_4$; acid density decreases. Acid density indicates charge state.



Q.5(B)(3) — Lead Acid Cell: Working & Reactions [4 marks]

During Discharge (cell gives current)

Anode:

$$\mathrm{Pb} + \mathrm{SO_4}^{2-} \longrightarrow \mathrm{PbSO_4} + 2\,\mathrm{e}^-$$

Cathode:

$$\mathrm{PbO_2} + 4\,\mathrm{H}^+ + \mathrm{SO_4}^{2-} + 2\,\mathrm{e}^- \longrightarrow \mathrm{PbSO_4} + 2\,\mathrm{H_2O}$$

Overall:

$$\mathrm{Pb} + \mathrm{PbO_2} + 2\,\mathrm{H_2SO_4} \longrightarrow 2\,\mathrm{PbSO_4} + 2\,\mathrm{H_2O}$$

During Charging

Reverse reactions occur:

$PbSO_4 \rightarrow Pb$ (at negative plate)
$PbSO_4 \rightarrow PbO_2$ (at positive plate)
H_2SO_4 regenerated; acid density rises.

Applications

- Automobile ignition/starting
- Inverters and UPS systems
- Electric vehicles (EVs)
- Emergency backup power

Summary — Summer 2025 Solutions

Q	Topic	Marks
Q.1 (1–14)	MCQ Fill in the Blanks	14
Q.2(A)(1)	Pauli's Exclusion Principle	3
Q.2(A)(2)	Ionic Bond	3
Q.2(A)(3)	pH of 0.01 M HCl	3
Q.2(B)(1)	Hydrogen Bond types + importance	4
Q.2(B)(2)	Molarity of KOH	4
Q.2(B)(3)	Degree of Ionization factors	4
Q.3(A)(1)	Electroplating	3
Q.3(A)(2)	Pitting Corrosion	3
Q.3(A)(3)	Galvanizing vs Tinning	3
Q.3(B)(1)	Electrochemical Cell (Daniel)	4
Q.3(B)(2)	Factors affecting corrosion rate	4
Q.3(B)(3)	LPG and CNG	4

Q	Topic	Marks
Q.4(A)(1)	Fuel + Ideal Fuel characteristics	3
Q.4(A)(2)	Polymer: molecular structure	3
Q.4(A)(3)	Biodegradable Polymer	3
Q.4(B)(1)	Power Alcohol (Gasohol)	4
Q.4(B)(2)	Lubricant + 6 Functions	4
Q.4(B)(3)	Lubricant for cutting tools	4
Q.5(A)(1)	n-type and p-type Semiconductors	3
Q.5(A)(2)	Primary vs Secondary Cell	3
Q.5(A)(3)	Solar Cell	3
Q.5(B)(1)	Vulcanization of Rubber	4
Q.5(B)(2)	Thermoplastic vs Thermosetting	4
Q.5(B)(3)	Lead Acid Storage Cell	4