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1122 Diploma in Fire Technology and Safety

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FS31010 Fire Engineering

Question Bank and Learning Material

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UNIT - I
UNIT 1 ANATOMY OF FIRE AND CASE STUDIES

PART A: MULTIPLE-CHOICE QUESTIONS (UNIT 1)

1. **Which phase must a solid fuel transition to before flaming combustion occurs?**

- A. Liquid phase
- B. Solid plasma
- C. Vapor phase
- D. Char residue

Answer: Option C

Justification: Solid fuels undergo pyrolysis to evolve flammable vapors that burn in the gas phase.

2. **Which property determines the rate of thermal heat conduction inside a solid fuel?**

- A. Thermal inertia
- B. Surface emissivity
- C. Mass density
- D. Latent heat

Answer: Option A

Justification: Thermal inertia ($krhoc$) governs surface heating and internal conduction rate.

3. **What process causes a solid material to chemically decompose under thermal energy?**

- A. Sublimation
- B. Vaporization
- C. Liquefaction
- D. Pyrolysis

Answer: Option D

Justification: Pyrolysis is thermal degradation producing combustible volatile gases.

4. **The flash point of a liquid fuel is defined as the lowest temperature to emit what?**

- A. Sustained flames
- B. Ignitable vapor
- C. Glowing embers
- D. Boiling bubbles

Answer: Option B

Justification: Flash point yields enough vapor for a momentary flash upon spark application.

5. **How does the fire point temperature compare to the flash point for flammable liquids?**

- A. Slightly lower
- B. Exactly equal
- C. Slightly higher
- D. Much lower

Answer: Option C

Justification: Fire point is a few degrees higher than flash point to sustain burning for >5s.

6. **Which physical form of liquid fuel ignites most rapidly in ambient air?**

- A. Dispersed mist
- B. Bulk pool
- C. Thick film
- D. Stagnant layer

Answer: Option A

Justification: Mists have high surface-to-volume ratio, facilitating rapid evaporation and ignition.

7. **What is the primary mode of fire spread across a flat ceiling surface in a compartment?**

- A. Conduction
- B. Radiation
- C. Advection
- D. Convection

Answer: Option D

Justification: Hot buoyant gas plumes flow along ceilings via convective transport.

8. **Which heat transfer mode governs distant ignitions across large compartment distances?**

- A. Fluid convection
- B. Thermal radiation
- C. Direct conduction
- D. Mass diffusion

Answer: Option B

Justification: Radiation travels as electromagnetic waves across open spaces without media.

9. Which gas parameter describes the minimum concentration required for flame propagation?

- A. Upper limit
- B. Flash threshold
- C. Lower limit
- D. Stoichiometric point

Answer: Option C

Justification: Lower Explosive Limit (LEL) is the minimum lean fuel concentration to burn.

10. What property dictates whether a spilled gas accumulates at floor level or rises?

- A. Vapor density
- B. Dynamic viscosity
- C. Surface tension
- D. Specific heat

Answer: Option A

Justification: Vapor density relative to air (air=1) determines sinking or rising behavior.

11. Which toxic gas produced in fires binds to blood hemoglobin and blocks oxygen?

- A. Hydrogen cyanide
- B. Phosgene gas
- C. Sulfur dioxide
- D. Carbon monoxide

Answer: Option D

Justification: CO forms carboxyhemoglobin, preventing oxygen transportation in blood.

12. Which combustion gas causes rapid cellular asphyxiation by inhibiting cytochrome oxidase?

- A. Carbon dioxide
- B. Hydrogen cyanide
- C. Nitrogen dioxide
- D. Acrolein vapor

Answer: Option B

Justification: HCN stops cellular respiration by binding to cytochrome enzymes.

13. What chemical phenomenon sustains the rapid propagation of a combustion wave?

- A. Acid neutralization
- B. Physical phase
- C. Radical chain
- D. Ionic pairing

Answer: Option C

Justification: Combustion relies on active free radical chain reactions (H^* , OH^*).

14. How does a deflagration differ fundamentally from a detonation combustion wave?

- A. Subsonic velocity
- B. Supersonic speed
- C. Zero pressure
- D. High vacuum

Answer: Option A

Justification: Deflagration flame fronts travel at subsonic speeds relative to unburnt gas.

15. What defines a detonation wave in gas explosion dynamics?

- A. Subsonic burn
- B. Thermal conduction
- C. Smoldering shift
- D. Supersonic shock

Answer: Option D

Justification: Detonations propagate via supersonic shock waves driven by energy release.

16. What is the primary asphyxiating mechanism of elevated Carbon Dioxide in fires?

- A. Blood destruction
- B. Oxygen displacement
- C. Skin corrosion
- D. Nerve paralysis

Answer: Option B

Justification: CO_2 acts primarily as a simple asphyxiant by displacing atmospheric oxygen.

17. Which element in synthetic polymers produces toxic Hydrogen Chloride gas upon burning?

- A. Polyurethane
- B. Polystyrene
- C. Polyvinyl chloride
- D. Polyethylene

Answer: Option C

Justification: PVC contains chlorine, emitting toxic corrosive HCl gas during combustion.

18. What parameter represents the minimum thermal energy required to ignite a flammable gas?

- A. Ignition energy
- B. Activation heat
- C. Flame enthalpy
- D. Combustion yield

Answer: Option A

Justification: Minimum Ignition Energy (MIE) is the smallest spark energy to trigger fire.

19. Which gas product causes extreme eye lachrimation and upper respiratory irritation at low ppm?

- A. Carbon monoxide
- B. Nitrogen gas
- C. Methane vapor
- D. Acrolein

Answer: Option D

Justification: Acrolein is a potent irritant aldehyde produced in incomplete combustion.

20. What condition causes incomplete combustion and excessive toxic smoke production?

- A. Excess oxygen
- B. Ventilation control
- C. Fuel deficiency
- D. High turbulence

Answer: Option B

Justification: Ventilation-controlled fires lack adequate oxygen, forming high CO and soot.

21. What type of fire results when a pressurized gas leak is ignited at the escape orifice?

- A. Pool fire
- B. Flash fire
- C. Jet fire
- D. BLEVE blast

Answer: Option C

Justification: Jet fires are high-velocity momentum-driven turbulent flames from pressurized leaks.

22. Which fire hazard occurs when a liquid fuel spills onto horizontal ground and ignites?

- A. Pool fire
- B. Jet fire
- C. Flash fire
- D. Explosive wave

Answer: Option A

Justification: Pool fires are gravity-driven burning fuel layers on horizontal surfaces.

23. What characterizes a flash fire when an unconfined flammable gas cloud ignites?

- A. High overpressure
- B. Deep cratering
- C. Supersonic wave
- D. Rapid flame front

Answer: Option D

Justification: Flash fires feature rapid flame spread through a vapor cloud without destructive overpressure.

24. What does UVCE stand for in industrial hazard evaluation?

- A. Ultra-Violent Chemical Explosion
- B. Unconfined Vapour Cloud Explosion
- C. Underground Vapor Control Element
- D. Unified Valve Cutoff Exemption

Answer: Option B

Justification: UVCE refers to Unconfined Vapour Cloud Explosion in open industrial plant spaces.

25. What physical feature distinguishes a shock wave produced by an explosion?

- A. Continuous flow
- B. Slow expansion
- C. Steep pressure jump
- D. Zero amplitude

Answer: Option C

Justification: Shock waves exhibit a near-instantaneous jump in pressure and density across the front.

26. Which mechanism creates high overpressure during an Unconfined Vapour Cloud Explosion?

- A. Congestion turbulence
- B. Quiet burning
- C. Cooling ambient
- D. Vacuum formation

Answer: Option A

Justification: Obstacles and congestion accelerate flame speed, building high blast overpressures.

27. What happens during auto-ignition of a combustible vapor-air mixture?

- A. Spark required
- B. Water addition
- C. Pressure drop
- D. No external spark

Answer: Option D

Justification: Auto-ignition occurs purely from thermal heating without an external spark/flame.

28. What does the acronym BLEVE stand for in loss prevention engineering?

- A. Basic Liquid Emergency Vapor Evacuation
- B. Boiling Liquid Expanding Vapour Explosion
- C. Bulk Liquid Engine Venting Explosion
- D. Buffered Liquid Expansion Valve Effect

Answer: Option B

Justification: BLEVE stands for Boiling Liquid Expanding Vapour Explosion.

29. What primary event triggers a BLEVE in a pressurized liquid storage tank?

- A. Minor valve leak
- B. Internal cooling
- C. Catastrophic vessel failure
- D. Submerged piping

Answer: Option C

Justification: BLEVE occurs when a pressurized vessel fails catastrophically under superheated conditions.

30. What is the principal hazard to personnel outside the immediate blast zone of a BLEVE?

- A. Fireball radiation
- B. Toxic acid rain
- C. Sonic vibration
- D. Cold gas cloud

Answer: Option A

Justification: Massive thermal radiation from the expanding fireball is the major hazard.

31. Which chemical substance was released during the 1974 Flixborough disaster in the UK?

- A. LPG gas
- B. Methyl isocyanate
- C. Nitroglycerin
- D. Cyclohexane

Answer: Option D

Justification: A temporary bypass pipe ruptured releasing 40 tons of hot cyclohexane vapor.

32. What structural component failed and initiated the Flixborough chemical disaster?

- A. Main reactor
- B. Bypass pipe
- C. Flare stack
- D. Storage tank

Answer: Option B

Justification: The temporary 20-inch bypass pipe bellows between reactors ruptured.

33. Which fuel was primarily involved in the 1984 San Juanico disaster in Mexico City?

- A. Benzene
- B. LNG
- C. LPG
- D. Gasoline

Answer: Option C

Justification: The disaster involved massive BLEVEs and pool fires at an LPG storage facility.

34. **What initial event caused the cascading BLEVE explosions in the Mexico City LPG disaster?**

- A. Pipeline leak
- B. Earthquake shock
- C. Terrorist attack
- D. Lightning strike

Answer: Option A

Justification: A liquid LPG pipe rupture created a vapor cloud that ignited, triggering cascading BLEVEs.

35. **In the 1989 Pasadena Texas disaster, which chemical gas cloud exploded at the polyethylene plant?**

- A. Methane
- B. Propane
- C. Chlorine
- D. Ethylene

Answer: Option D

Justification: Settling valve maintenance released flammable ethylene and isobutane gases.

36. **What safety procedure failure directly caused the gas release in the Pasadena Texas plant?**

- A. Water pump cut
- B. Lockout failure
- C. Power outage
- D. Vent blockage

Answer: Option B

Justification: Air hoses were improperly connected, opening a valve without lockout/tagout.

37. **Which offshore oil platform suffered a catastrophic explosion and collapse in 1988?**

- A. Deepwater Horizon
- B. Alexander Kielland
- C. Piper Alpha
- D. Ocean Ranger

Answer: Option C

Justification: Piper Alpha in the North Sea was destroyed by fire and explosions in July 1988.

38. **What breakdown in work management led to the initial condensate pump leak on Piper Alpha?**

- A. Permit to work
- B. Shift delay
- C. Supply transport
- D. Radio comms

Answer: Option A

Justification: An unused condensate pump missing a safety valve was turned on due to permit communication failure.

39. **In the 1990 Peterborough explosion in the UK, what hazardous cargo exploded inside a vehicle?**

- A. LPG cylinders
- B. Ammonium nitrate
- C. Sodium metal
- D. Commercial explosives

Answer: Option D

Justification: A van carrying 800 kg of commercial explosives exploded after a vehicle fire.

40. **What initial event led to the explosion of the explosives van in Peterborough?**

- A. Tire puncture
- B. Vehicle fire
- C. Brake failure
- D. Engine crash

Answer: Option B

Justification: An unattended fire in the engine/cab of the van heated the explosives cargo.

41. **Which ship exploded in the Bombay Victoria Dock in 1944 causing massive devastation?**

- A. SS Mont-Blanc
- B. RMS Lusitania
- C. SS Fort Stikine
- D. SS Grandcamp

Answer: Option C

Justification: SS Fort Stikine caught fire and exploded with a cargo of munitions and cotton.

42. **What mixed cargo combination on SS Fort Stikine drastically escalated the Bombay Dock fire?**

- A. Cotton and explosives
- B. Oil and grain
- C. Coal and timber
- D. Sulfur and sugar

Answer: Option A

Justification: Combustible cotton bales stored below high explosives created an uncontrollable fire.

43. **What key lesson was learned regarding modification control after the Flixborough explosion?**

- A. Color coding
- B. Shift timing
- C. Noise control
- D. Management of Change

Answer: Option D

Justification: Management of Change (MOC) procedures were instituted to review plant modifications.

44. **What layout recommendation arose from the Mexico City LPG disaster regarding tank spacing?**

- A. Underground burial
- B. Increased separation
- C. Vertical stacking
- D. Glass enclosures

Answer: Option B

Justification: Tank spacing and secondary containment dikes were increased to prevent domino effects.

45. **Which safety system modification was mandated for offshore platforms after Piper Alpha?**

- A. Canvas escape chutes
- B. Wooden blast walls
- C. Subsea isolation valves
- D. Manual water buckets

Answer: Option C

Justification: Subsea isolation valves (SSIVs) were installed to isolate gas pipeline inventories.

46. **What type of explosion occurred when the unconfined cyclohexane cloud ignited at Flixborough?**

- A. Vapour cloud explosion
- B. Dust explosion
- C. Nuclear explosion
- D. Boiler rupture

Answer: Option A

Justification: The massive cloud ignited resulting in a major Unconfined Vapour Cloud Explosion (UVCE).

47. **How many secondary ship fires were triggered by burning debris in the 1944 Bombay Dock disaster?**

- A. Zero ship fires
- B. Single tug fire
- C. Only onshore fires
- D. Multiple vessel fires

Answer: Option D

Justification: Burning debris and blast shock ignited and destroyed multiple surrounding ships.

48. **What hazard was highlighted by the Peterborough explosion regarding hazardous transport?**

- A. Speed limits
- B. Fire proximity risks
- C. Driver age
- D. Road paving

Answer: Option B

Justification: Transporting explosives in vehicles vulnerable to engine fires poses severe blast risks.

49. **Which disaster emphasized the extreme hazard of domino-effect BLEVEs in gas tank farms?**

- A. Flixborough UK
- B. Peterborough UK
- C. Mexico City LPG
- D. Bombay Dock

Answer: Option C

Justification: San Juanico (Mexico City) demonstrated cascading BLEVEs destroying an entire tank farm.

50. What major human factor contributed directly to the Piper Alpha disaster escalation?

- A. Inadequate shift handover
- B. Lack of food
- C. Poor lighting
- D. Extreme cold

Answer: Option A

Justification: Failure to communicate out-of-service equipment during shift handover led to pump restart.

PART B: DESCRIPTIVE QUESTIONS (UNIT 1) — 3 MARKS (3 IMPORTANT POINTS)

1. Define the flash point of a liquid.

○ **3 Important Points:**

1. Minimum temperature at which a liquid gives off sufficient vapor to form an ignitable mixture with air.
2. Requires an external ignition source to cause momentary flashing of the vapor.
3. Serves as a primary technical index for classifying flammable and combustible liquid hazards.

2. What are the four elements of the Fire Tetrahedron?

○ **3 Important Points:**

1. Comprises Fuel, Heat, Oxygen, and the Uninhibited Chemical Chain Reaction.
2. Extends the traditional fire triangle by incorporating free radical chain propagation.
3. Removing any single interdependent element results in fire extinction.

3. State the primary hazard of Carbon Monoxide (CO) in building fires.

○ **3 Important Points:**

1. Acts as a chemical asphyxiant by binding strongly to blood hemoglobin.
2. Possesses an affinity for hemoglobin approximately 200 to 250 times greater than oxygen.
3. Causes rapid incapacitation and loss of consciousness by starving vital tissues of oxygen.

4. Define a flash fire.

○ **3 Important Points:**

1. Rapid combustion reaction of a pre-mixed flammable vapor or dust cloud.
2. Characterized by high flame propagation speed with minimal destructive overpressure.

3. Occurs typically in open or semi-confined spaces without forming shock waves.
5. **What is a jet fire?**
 - **3 Important Points:**
 1. A turbulent diffusion flame resulting from a continuous high-pressure fuel release.
 2. Emits intense, highly directional convective and radiative thermal flux.
 3. Capable of causing rapid structural failure upon direct impingement on equipment.
6. **What is a pool fire?**
 - **3 Important Points:**
 1. A diffusion flame sustained by vapors evaporating from a horizontal liquid fuel surface.
 2. Burning rate is heavily dictated by radiative heat feedback from the flame to the pool.
 3. Commonly encountered in industrial tank farms and bunded spill areas.
7. **What does BLEVE stand for?**
 - **3 Important Points:**
 1. Stands for Boiling Liquid Expanding Vapour Explosion.
 2. Triggered by sudden structural tank failure under high pressure and external fire exposure.
 3. Results in a devastating blast wave, fireball, and high-velocity shrapnel projection.
8. **What is an Unconfined Vapour Cloud Explosion (UVCE)?**
 - **3 Important Points:**
 1. Explosion resulting from the ignition of a large dispersed flammable vapor cloud.
 2. Flame acceleration through obstacles generates destructive blast overpressures.
 3. Poses severe catastrophic hazards across large process plant footprints.
9. **Define auto-ignition temperature.**
 - **3 Important Points:**
 1. The minimum temperature required to ignite a substance spontaneously in air.
 2. Occurs without requiring any external spark, flame, or pilot ignition source.
 3. Decreases as ambient system pressure or oxygen concentration increases.

10. Differentiate between a deflagration and a detonation.

○ **3 Important Points:**

1. Deflagration propagates at subsonic speeds via thermal conduction and molecular diffusion.
2. Detonation propagates at supersonic speeds driven by a powerful shock wave.
3. Detonations generate severe destructive overpressures compared to standard deflagrations.



UNIT - II
UNIT 2 BASIC CHEMISTRY AND PHYSICS OF FIRE

PART A: MULTIPLE-CHOICE QUESTIONS (UNIT 2)

1. **What type of chemical reaction occurs when an acid reacts with a base to form salt and water?**
 - A. Neutralization process
 - B. Endothermic cracking
 - C. Sublimation transition
 - D. Exothermic oxidation
 - **Answer:** Option A
 - **Justification:** Acid-base neutralization produces neutral salt and water.
2. **Which physical phase change involves a solid turning directly into vapor without melting?**
 - A. Melting transition
 - B. Sublimation process
 - C. Vapor condensation
 - D. Pyrolytic cracking
 - **Answer:** Option B
 - **Justification:** Sublimation is the direct phase shift from solid to gas.
3. **What term describes the thermal energy required to break chemical bonds during thermal breakdown?**
 - A. Sensible enthalpy
 - B. Latent vaporization
 - C. Decomposition heat
 - D. Activation energy
 - **Answer:** Option C
 - **Justification:** Heat of decomposition is absorbed during endothermic thermal breakdown.
4. **What chemical phenomenon involves the rearrangement of molecular bonds to form new substances?**
 - A. Physical mixing
 - B. Phase condensation
 - C. Mechanical shifting
 - D. Chemical reaction
 - **Answer:** Option D
 - **Justification:** Chemical reactions convert reactants into distinct products.

5. Which type of reaction releases net thermal energy to the surrounding environment?
- A. Exothermic reaction
 - B. Endothermic reaction
 - C. Isothermal process
 - D. Adiabatic shift
 - **Answer:** Option A
 - **Justification:** Exothermic reactions release heat, increasing ambient temperature.
6. What type of thermal process absorbs heat from its surroundings during a reaction?
- A. Oxidation process
 - B. Endothermic reaction
 - C. Exothermic reaction
 - D. Combustion event
 - **Answer:** Option B
 - **Justification:** Endothermic reactions absorb thermal energy from the environment.
7. Which mode of heat transfer involves the movement of fluid or gas currents?
- A. Thermal radiation
 - B. Solid conduction
 - C. Convection current
 - D. Molecular diffusion
 - **Answer:** Option C
 - **Justification:** Convection transfers heat through bulk fluid or gas motion.
8. What heat transfer mode travels across empty space via electromagnetic waves?
- A. Fluid convection
 - B. Solid conduction
 - C. Direct advection
 - D. Thermal radiation
 - **Answer:** Option D
 - **Justification:** Radiation propagates as electromagnetic waves without needing a medium.
9. Which heat transfer mechanism occurs through direct physical contact within solid materials?
- A. Solid conduction
 - B. Fluid convection
 - C. Radiant emission
 - D. Vapor transport

- **Answer:** Option A
 - **Justification:** Conduction transfers thermal energy through direct molecular contact.
10. **What is the lowest temperature at which a liquid gives off enough vapor to form an ignitable mixture?**
- **A.** Fire point
 - **B.** Flash point
 - **C.** Auto-ignition point
 - **D.** Boiling threshold
 - **Answer:** Option B
 - **Justification:** Flash point is the minimum temperature for a momentary flash.
11. **What temperature threshold ensures that a liquid fuel continues to burn for at least 5 seconds after ignition?**
- **A.** Flash point
 - **B.** Melting point
 - **C.** Fire point
 - **D.** Ambient baseline
 - **Answer:** Option C
 - **Justification:** Fire point requires sustained burning following ignition.
12. **What is the minimum temperature required to initiate self-sustained combustion without an external spark?**
- **A.** Flash point baseline
 - **B.** Cooling threshold
 - **C.** Melting point
 - **D.** Ignition temperature
 - **Answer:** Option D
 - **Justification:** Ignition temperature (auto-ignition) triggers combustion without external sparks.
13. **During an endothermic decomposition process, what happens to the surrounding temperature?**
- **A.** Temperature drops
 - **B.** Temperature rises
 - **C.** Remains constant
 - **D.** Pressure spikes
 - **Answer:** Option A
 - **Justification:** Endothermic processes absorb heat, causing ambient temperature to drop.

14. Which chemical process neutralizes corrosive acid spills safely in an industrial shop?
- A. Exothermic oxidation
 - B. Neutralization process
 - C. Sublimation shift
 - D. Endothermic cracking
 - **Answer:** Option B
 - **Justification:** Neutralization neutralizes acid hazards using chemical bases.
15. What chemical transformation occurs when dry ice (solid CO₂) turns directly into gas?
- A. Melting transition
 - B. Boiling vaporization
 - C. Sublimation process
 - D. Chemical reduction
 - **Answer:** Option C
 - **Justification:** Dry ice exhibits sublimation under normal atmospheric pressure.
16. What parameter measures the heat absorbed when complex molecules break apart?
- A. Sensible enthalpy
 - B. Latent heat
 - C. Thermal capacity
 - D. Decomposition heat
 - **Answer:** Option D
 - **Justification:** Heat of decomposition quantifies the energy absorbed during bond breaking.
17. When two reactive chemical substances combine to alter their molecular structure, it is called a:
- A. Chemical reaction
 - B. Physical mixture
 - C. Phase transition
 - D. Mechanical blend
 - **Answer:** Option A
 - **Justification:** Chemical reactions create new substances with different properties.
18. Which type of chemical fire reaction rapidly generates heat and increases flame propagation speed?
- A. Endothermic reaction
 - B. Exothermic reaction
 - C. Neutralization phase
 - D. Isothermal shift
 - **Answer:** Option B
 - **Justification:** Exothermic reactions release heat and accelerate fire spread.

19. What type of chemical reaction absorbs heat, thereby cooling down the immediate surroundings?
- A. Exothermic reaction
 - B. Oxidation process
 - C. Endothermic reaction
 - D. Combustion event
 - **Answer:** Option C
 - **Justification:** Endothermic reactions absorb thermal energy from the environment.
20. How is thermal energy transmitted through circulating liquid or gas media within an enclosure?
- A. Thermal radiation
 - B. Solid conduction
 - C. Molecular diffusion
 - D. Convection current
 - **Answer:** Option D
 - **Justification:** Convection transfers heat via fluid movement.
21. Which heat transfer mechanism requires no physical medium and travels effectively across vacuums?
- A. Thermal radiation
 - B. Fluid convection
 - C. Solid conduction
 - D. Direct advection
 - **Answer:** Option A
 - **Justification:** Radiation transfers energy via electromagnetic waves.
22. What mode of heat transmission transfers thermal energy through stationary metal walls?
- A. Fluid convection
 - B. Solid conduction
 - C. Radiant emission
 - D. Vapor transport
 - **Answer:** Option B
 - **Justification:** Conduction operates through solid molecular vibration.

23. What temperature value represents the lowest point where a liquid fuel flashes momentarily?
- A. Fire point
 - B. Auto-ignition point
 - C. Flash point
 - D. Boiling threshold
 - **Answer:** Option C
 - **Justification:** Flash point is the lowest temperature for a transient flash.
24. What specific temperature ensures that a fuel vapor-air mixture continues burning steadily?
- A. Flash point
 - B. Melting point
 - C. Ambient baseline
 - D. Fire point
 - **Answer:** Option D
 - **Justification:** Fire point indicates sustained combustion capability.
25. What parameter defines the lowest temperature at which a substance ignites spontaneously without a spark?
- A. Ignition temperature
 - B. Flash point baseline
 - C. Cooling threshold
 - D. Melting point
 - **Answer:** Option A
 - **Justification:** Ignition temperature is the threshold for spontaneous auto-ignition.
26. Which chemical process neutralizes alkali spills using appropriate acidic agents?
- A. Endothermic cracking
 - B. Neutralization process
 - C. Sublimation transition
 - D. Exothermic oxidation
 - **Answer:** Option B
 - **Justification:** Neutralization balances pH levels safely.
27. Which phase change process is observed when mothballs evaporate directly into gas?
- A. Melting transition
 - B. Vapor condensation
 - C. Sublimation process
 - D. Pyrolytic cracking
 - **Answer:** Option C
 - **Justification:** Mothballs sublime directly from solid to gas.

28. What term denotes the specific heat absorbed during the thermal breakdown of wood polymers?
- A. Sensible enthalpy
 - B. Latent vaporization
 - C. Activation energy
 - D. Decomposition heat
 - **Answer:** Option D
 - **Justification:** Heat of decomposition governs thermal degradation energy.
29. What fundamental process involves breaking old chemical bonds and forming new ones?
- A. Chemical reaction
 - B. Physical mixing
 - C. Phase condensation
 - D. Mechanical shifting
 - **Answer:** Option A
 - **Justification:** Chemical reactions form new chemical species.
30. What classifies a chemical reaction that liberates thermal energy and raises fire intensity?
- A. Endothermic reaction
 - B. Exothermic reaction
 - C. Isothermal process
 - D. Adiabatic shift
 - **Answer:** Option B
 - **Justification:** Exothermic reactions release heat.
31. Which reaction type takes in heat from the surrounding air during chemical dissociation?
- A. Exothermic reaction
 - B. Oxidation process
 - C. Endothermic reaction
 - D. Combustion event
 - **Answer:** Option C
 - **Justification:** Endothermic reactions absorb ambient heat.
32. How is heat primarily transmitted upward through hot combustion smoke plumes?
- A. Thermal radiation
 - B. Solid conduction
 - C. Molecular diffusion
 - D. Convection current
 - **Answer:** Option D
 - **Justification:** Convection drives hot buoyant smoke upward.

33. Which heat transfer process is responsible for radiant heat feedback from flames to fuel beds?
- A. Thermal radiation
 - B. Fluid convection
 - C. Solid conduction
 - D. Direct advection
 - **Answer:** Option A
 - **Justification:** Radiation provides feedback heat to sustain pool and crib fires.
34. What mode of heat transmission dominates inside solid fire barrier walls?
- A. Fluid convection
 - B. Solid conduction
 - C. Radiant emission
 - D. Vapor transport
 - **Answer:** Option B
 - **Justification:** Conduction is the primary heat transfer mode through solid walls.
35. What key parameter represents the lowest liquid temperature producing flammable vapor flashes?
- A. Fire point
 - B. Auto-ignition point
 - C. Flash point
 - D. Boiling threshold
 - **Answer:** Option C
 - **Justification:** Flash point is the threshold for a transient vapor flash.
36. What temperature defines when a liquid fuel sustains continuous burning upon ignition?
- A. Flash point
 - B. Melting point
 - C. Ambient baseline
 - D. Fire point
 - **Answer:** Option D
 - **Justification:** Fire point ensures sustained burning.
37. What is the term for the lowest temperature at which spontaneous combustion occurs without a spark?
- A. Ignition temperature
 - B. Flash point baseline
 - C. Cooling threshold
 - D. Melting point
 - **Answer:** Option A
 - **Justification:** Ignition temperature triggers auto-ignition.

38. During an exothermic oxidation reaction, what happens to the surrounding temperature?
- A. Temperature drops
 - B. Temperature rises
 - C. Remains constant
 - D. Pressure drops
 - **Answer:** Option B
 - **Justification:** Exothermic reactions release heat, raising ambient temperature.
39. What chemical safety procedure is utilized to counteract hazardous acidic chemical spills?
- A. Sublimation shift
 - B. Endothermic cracking
 - C. Neutralization process
 - D. Exothermic oxidation
 - **Answer:** Option C
 - **Justification:** Neutralization renders acids safe using chemical bases.
40. Which phenomenon describes solid iodine converting directly into purple vapor?
- A. Melting transition
 - B. Vapor condensation
 - C. Pyrolytic cracking
 - D. Sublimation process / Sublimation process
 - **Answer:** Option D
 - **Justification:** Iodine readily undergoes sublimation.
41. What thermal metric calculates the energy absorbed during fuel decomposition reactions?
- A. Decomposition heat
 - B. Sensible enthalpy
 - C. Latent vaporization
 - D. Activation energy
 - **Answer:** Option A
 - **Justification:** Heat of decomposition measures bond-breaking thermal energy.
42. What chemical process alters reactant molecular structures into distinct combustion products?
- A. Physical mixing
 - B. Chemical reaction
 - C. Phase condensation
 - D. Mechanical shifting
 - **Answer:** Option B
 - **Justification:** Chemical reactions form new product molecules.

43. Which reaction classification describes combustion releasing large amounts of heat?
- A. Endothermic reaction
 - B. Isothermal process
 - C. Exothermic reaction
 - D. Adiabatic shift
 - **Answer:** Option C
 - **Justification:** Combustion is a strongly exothermic oxidation reaction.
44. What type of chemical reaction requires continuous external heat input to proceed?
- A. Exothermic reaction
 - B. Oxidation process
 - C. Combustion event
 - D. Endothermic reaction
 - **Answer:** Option D
 - **Justification:** Endothermic reactions require constant heat supply.
45. How is heat transferred through the movement of heated air masses in a room?
- A. Convection current
 - B. Thermal radiation
 - C. Solid conduction
 - D. Molecular diffusion
 - **Answer:** Option A
 - **Justification:** Convection transfers heat via bulk fluid motion.
46. Which heat transfer mode transmits energy via infrared electromagnetic waves?
- A. Fluid convection
 - B. Thermal radiation
 - C. Solid conduction
 - D. Direct advection
 - **Answer:** Option B
 - **Justification:** Radiation transfers energy across space via waves.
47. What heat transmission mode governs energy flow through a solid steel fire door?
- A. Fluid convection
 - B. Radiant emission
 - C. Solid conduction
 - D. Vapor transport
 - **Answer:** Option C
 - **Justification:** Conduction transfers heat through solid media.

48. What baseline temperature denotes the minimum point for a liquid to emit ignitable vapors?

- A. Fire point
- B. Auto-ignition point
- C. Boiling threshold
- D. Flash point
- **Answer:** Option D
- **Justification:** Flash point is the threshold for a transient vapor flash.

49. What temperature threshold ensures that a liquid fuel sustains burning after ignition?

- A. Fire point
- B. Flash point
- C. Melting point
- D. Ambient baseline
- **Answer:** Option A
- **Justification:** Fire point ensures sustained combustion.

50. What parameter specifies the minimum temperature for a vapor-air mixture to ignite spontaneously?

- A. Flash point baseline
- B. Ignition temperature
- C. Cooling threshold
- D. Melting point
- **Answer:** Option B
- **Justification:** Ignition temperature causes auto-ignition without external spark.

PART B: DESCRIPTIVE QUESTIONS (UNIT 2) — 3 MARKS (3 IMPORTANT POINTS)

1. Differentiate between a physical change and a chemical change.

○ **3 Important Points:**

1. Physical changes alter state or appearance without producing new chemical substances.
2. Chemical changes form one or more new substances with entirely different molecular properties.
3. Chemical changes involve breaking and forming chemical bonds, whereas physical changes do not.

2. State the primary effect of heat on the physical state and volume of matter.

○ **3 Important Points:**

1. Increases the thermal kinetic energy of particles within matter.
2. Drives phase transitions from solid to liquid and liquid to gas.
3. Causes thermal expansion, increasing the overall volume of substances.

3. Define combustion and list its key components.

○ **3 Important Points:**

1. Defined as a rapid, exothermic oxidation-reduction reaction between fuel and oxidant.
2. Releases significant thermal energy (heat) and luminous radiation (light).
3. Requires fuel, heat, oxygen, and uninhibited chemical chain reactions.

4. Define specific heat capacity and explain its importance in fire protection.

○ **3 Important Points:**

1. Amount of heat required to raise unit mass of a substance by 1 deg c.
2. Determines how effectively a cooling agent absorbs thermal energy from fires.
3. Water has a uniquely high specific heat, making it an exceptional cooling medium.

5. Explain the function of a catalyst in a chemical reaction.

○ **3 Important Points:**

1. Alters reaction rate by lowering activation energy barriers.
2. Remains chemically unconsumed and unaltered at the end of the reaction.
3. Used in chemical processes to accelerate or direct specific reaction pathways.

6. What is a neutralization reaction? Give an example.

○ **3 Important Points:**

1. Reaction between an acid and a base yielding salt and water.
2. Typically highly exothermic, releasing neutralization heat.
3. Example: $HCl + NaOH \rightarrow NaCl + H_2O$.

7. Define sublimation and provide a common example.

○ **3 Important Points:**

1. Direct phase transition from solid state to gaseous state.
2. Does not pass through an intermediate liquid phase.
3. Example: Dry ice (solid carbon dioxide) subliming at room pressure.

8. What is meant by the heat of decomposition?

○ **3 Important Points:**

1. Thermal energy absorbed or released during chemical bond dissociation.
2. Measures the stability of chemical compounds under thermal stress.
3. Critical for evaluating runaway reaction hazards in chemical plants.

9. Differentiate between exothermic and endothermic reactions.

○ **3 Important Points:**

1. Exothermic reactions release thermal energy to the surrounding environment.
2. Endothermic reactions absorb thermal energy from their surroundings.
3. Combustion is exothermic, whereas thermal decomposition or melting is often endothermic.

10. Distinguish between the flash point and fire point of a liquid fuel.

○ **3 Important Points:**

1. Flash point is the lowest temperature for momentary vapor flash with an ignitor.
2. Fire point requires slightly higher temperature to sustain continuous burning for ≥ 5 seconds.
3. Both indicate liquid flammability hazards but measure transient vs. sustained combustion.

UNIT - III
UNIT 3 FIRE PREVENTION AND PROTECTION

PART A: MULTIPLE-CHOICE QUESTIONS (UNIT 3)

Q.1: What primary element represents the heat component in the classical fire triangle?

Choices: A) Thermal energy | B) Chemical spark | C) Oxygen supply | D) Fuel vapor

Answer: A

Justification: Heat is the thermal energy required to ignite and sustain combustion.

Q.2: Which ignition source is generated by high electrical resistance across loose terminals?

Choices: A) Static spark | B) Electrical arc | C) Frictional heat | D) Open flame

Answer: B

Justification: Loose terminals cause localized high resistance heating and arcing.

Q.3: What three elements constitute the basic fire triangle?

Choices: A) Gas, spark, wind | B) Carbon, water, ash | C) Fuel, heat, oxygen | D) Fuel, foam, heat

Answer: C

Justification: The fire triangle consists of fuel, heat, and oxygen.

Q.4: Which extinguishing principle removes the fuel source from an active fire zone?

Choices: A) Smothering blanket | B) Cooling water | C) Inhibition spray | D) Starvation method

Answer: D

Justification: Starvation involves removing unburnt fuel to stop the fire.

Q.5: What type of fire protection system includes structural fire-rated walls and compartmentation?

Choices: A) Passive protection | B) Active protection | C) Manual suppression | D) Emergency alarms

Emergency alarms

Answer: A

Justification: Passive systems like fire walls prevent fire spread without human action.

Q.6: Which class of fire involves ordinary combustible solids like wood, paper, and cloth?

Choices: A) Class B fire | B) Class A fire | C) Class C fire | D) Class D fire

Answer: B

Justification: Class A involves solid carbonaceous combustible materials.

Q.7: What class of fire specifically designates flammable and combustible liquid fires?

Choices: A) Class A fire | B) Class D fire | C) Class B fire | D) Class E fire

Answer: C

Justification: Class B covers flammable liquids like petrol, oil, and solvents.

Q.8: Which fire class involves flammable gases such as propane, methane, and acetylene?

Choices: A) Class B fire | B) Class A fire | C) Class D fire | D) Class C fire

Answer: D

Justification: Class C represents flammable pressurized gas fires.

Q.9: What class of fire involves combustible reactive metals like sodium, potassium, and magnesium?

Choices: A) Class D fire | B) Class C fire | C) Class B fire | D) Class E fire

Answer: A

Justification: Class D designates combustible metal fires requiring specialized powders.

Q.10: Which fire category traditionally designates energized electrical equipment and live circuits?

Choices: A) Class A fire | B) Class E fire | C) Class C fire | D) Class B fire

Answer: B

Justification: Class E (or electrical) involves energized electrical hazards.

Q.11: What portable fire extinguisher type uses pressurized water suitable for Class A fires?

Choices: A) CO₂ type | B) Foam unit | C) Water type | D) Dry powder

Answer: C

Justification: Water extinguishers cool Class A solid fires effectively.

Q.12: Which fire suppression agent is ideal for electrical fires because it leaves no residue?

Choices: A) Plain water | B) Foam liquid | C) Wet chemical | D) Carbon dioxide

Answer: D

Justification: CO₂ is a clean gaseous agent safe for electrical equipment.

Q.13: What device is permanently installed in building walls to supply pressurized water for fire hoses?

Choices: A) Standpipe system | B) Foam generator | C) Air duct | D) Water basin

Answer: A

Justification: Standpipes supply water lines across multi-story buildings.

Q.14: What high-capacity water dispensing nozzle is mounted on fixed towers for major industrial fires?

Choices: A) Garden sprinkler | B) Fire monitor | C) Smoke vent | D) Drain valve

Answer: B

Justification: Monitors deliver high-volume water jets over long distances.

Q.15: What is the primary operational role of designated plant 'fire watchers' during hot work?

Choices: A) Control traffic | B) Operate boilers | C) Monitor sparks | D) Check payroll

Answer: C

Justification: Fire watchers oversee hot work to extinguish stray sparks immediately.

Q.16: Where should a central plant fire station be located within a master facility layout?

Choices: A) Basement corner | B) Boiler room | C) Cafeteria roof | D) Main entrance

Answer: D

Justification: Entrance location ensures rapid unhindered dispatch of fire trucks.

Q.17: What auditory warning device is activated across a plant to signal an immediate evacuation?

Choices: A) Plant siren | B) Exhaust fan | C) Cooling buzzer | D) Door chime

Answer: A

Justification: Sirens alert all occupants to evacuate during emergencies.

Q.18: What routine maintenance check is essential for industrial fire pump trucks and engines?

Choices: A) Tire painting | B) Engine test run | C) Seat washing | D) Window polishing

Answer: B

Justification: Regular test running ensures fire trucks start reliably during emergencies.

Q.19: What equipment is utilized in petrochemical plants to produce large volumes of fire-fighting foam?

Choices: A) Water pump | B) Air compressor | C) Foam generator | D) Steam boiler

Answer: C

Justification: Foam generators mix concentrate, water, and air to blanket liquid fires.

Q.20: What is the primary objective of conducting regular scheduled plant fire drills?

Choices: A) Check stationery | B) Test cafeteria food | C) Audit accounts | D) Practice evacuation

Answer: D

Justification: Fire drills train staff on speedy and orderly evacuation routes.

Q.21: What immediate first-aid action is required for minor thermal skin burns?

Choices: A) Cool running water | B) Apply heavy grease | C) Tie tight bandage | D) Expose to sun

Answer: A

Justification: Cooling with clean running water relieves pain and tissue damage.

Q.22: What active fire protection system detects smoke or heat and automatically discharges water?

Choices: A) Security fence | B) Sprinkler system | C) Drainage sump | D) Lighting grid

Answer: B

Justification: Automatic sprinklers activate upon detecting heat from fires.

Q.23: Which ignition source involves open flames from welding torches or cutting operations?

Choices: A) Static charge | B) Short circuit | C) Hot work flame | D) Solar glare

Answer: C

Justification: Welding torches are direct open flame ignition sources.

Q.24: What extinguishing principle is achieved when smothering a fire with a fire blanket?

Choices: A) Fuel removal | B) Cooling liquid | C) Chain breaking | D) Oxygen exclusion

Answer: D

Justification: Blankets block oxygen access, smothering the fire.

Q.25: What flexible conveyance line is used by firefighters to carry pressurized water from hydrants?

Choices: A) Fire hose line | B) Suction cable | C) Air duct pipe | D) Hydraulic tube

Answer: A

Justification: Fire hoses transport water from supply sources to fire nozzles.

Q.26: What automatic fire detection device responds to invisible combustion gas products?

Choices: A) Heat sensor | B) Smoke detector | C) Water meter | D) Pressure gauge

Answer: B

Justification: Smoke detectors provide early warning by sensing combustion particles.

Q.27: What rescue operation priority must be established first during building fire emergencies?

Choices: A) Asset salvage | B) Machine shutdown | C) Human evacuation | D) Record backup

Answer: C

Justification: Life safety and human evacuation take absolute priority.

Q.28: Which fire extinguishing agent interrupts the chemical chain reaction of flames effectively?

Choices: A) Plain water stream | B) Sand bucket fill | C) Heavy air stream | D) Dry chemical powder

Answer: D

Justification: Dry powders inhibit the chemical chain reaction of combustion.

Q.29: What layout feature provides safe vertical exit pathways during multi-story building fires?

Choices: A) Fire escape stairwell | B) Passenger elevator | C) Freight conveyor | D) Exhaust chimney

Answer: A

Justification: Protected stairwells ensure safe downward evacuation.

Q.30: What manual fire-stopping tool consists of a bucket filled with dry sand for small fuel spills?

Choices: A) Water barrel | B) Sand bucket | C) Foam canister | D) CO2 cylinder

Answer: B

Justification: Sand buckets smother small liquid pool spills.

Q.31: What maintenance test verifies the leak-proof pressure integrity of plant fire hydrant lines?

Choices: A) Visual color check | B) Weight measurement | C) Hydrostatic pressure test | D) Temperature scan

Answer: C

Justification: Hydrostatic testing proves piping can withstand high emergency pressures.

Q.32: Which fire hazard is created by improper storage of oily rags and waste materials?

Choices: A) Electrical shock | B) Chemical freezing | C) Structural frost | D) Spontaneous ignition

Answer: D

Justification: Oily rags undergo slow oxidation, leading to spontaneous heating and fire.

Q.33: What is the primary function of fire door assemblies in compartmentalized walls?

Choices: A) Prevent fire spread | B) Enhance airflow | C) Reduce room noise | D) Support roof weight

Answer: A

Justification: Fire doors compartmentalize buildings to block fire and smoke spread.

Q.34: What emergency communication system links manual break-glass call points to the security desk?

Choices: A) Intercom phone | B) Fire alarm system | C) Public radio | D) Megaphone horn

Answer: B

Justification: Manual call points trigger building-wide fire alarms instantly.

Q.35: What protective action should be taken if clothing catches fire during an accident?

Choices: A) Run toward wind | B) Jump into elevator | C) Stop, drop, and roll | D) Fan flames fast

Answer: C

Justification: Stop, drop, and roll extinguishes clothing flames by smothering.

Q.36: What specialized extinguishing agent is required for burning lithium or titanium metal fires?

Choices: A) Standard water jet | B) Light foam spray | C) Carbon dioxide gas | D) Special metal powder

Answer: D

Justification: Metal fires react violently with water; dry metal powders are required.

Q.37: What device connects fire brigade hoses to an external building water supply network?

Choices: A) Fire department connection | B) Sprinkler head | C) Smoke damper | D) Drain valve

Answer: A

Justification: FDC allows fire engines to pump water into internal building standpipes.

Q.38: What safety principle governs the minimum clearance distance between storage racks and sprinkler heads?

Choices: A) Maximum floor loading | B) Unobstructed spray pattern | C) Aesthetic alignment | D) Easy cleaning access

Answer: B

Justification: Clearance ensures water discharge patterns cover storage properly.

Q.39: What portable fire suppression tool is rated for multiple fire classes (ABC dry powder)?

Choices: A) Water bucket | B) CO2 horn | C) Multi-class extinguisher | D) Foam blanket

Answer: C

Justification: ABC powder handles solid, liquid, and gas fires effectively.

Q.40: What emergency procedure must follow the activation of a CO2 total flooding system in a room?

Choices: A) Open all doors | B) Turn on heaters | C) Start welding work | D) Complete evacuation

Answer: D

Justification: CO2 displaces oxygen, requiring immediate room evacuation.

Q.41: What is the primary purpose of painting fire hydrants and emergency equipment bright red?

Choices: A) High visual visibility | B) Prevent rust corrosion | C) Absorb solar heat | D) Reduce paint cost

Answer: A

Justification: Red coloring ensures equipment is easily located during emergencies.

Q.42: Which ignition hazard is produced by ungrounded rotating belts generating high charge?

Choices: A) Frictional spark | B) Static electricity | C) Magnetic flux | D) Thermal radiation

Answer: B

Justification: Belt friction accumulates electrostatic charges capable of sparking.

Q.43: What active fire protection component detects temperature rate-of-rise in boiler rooms?

Choices: A) Smoke sensor | B) Water gauge | C) Heat detector | D) Air flow meter

Answer: C

Justification: Heat detectors activate when ambient temperature rises rapidly.

Q.44: What hazard is associated with applying water directly onto burning cooking oil (Class F/K)?

Choices: A) Instant freezing | B) Toxic gas release | C) Electrical short | D) Splattering fireball

Answer: D

Justification: Water boils instantly beneath hot oil, causing violent splattering.

Q.45: What training exercise simulates realistic fire response using uncharged extinguishers?

Choices: A) Live fire drill | B) Tabletop review | C) Written exam | D) Video screening

Answer: A

Justification: Live drills build practical competence in handling extinguishers.

Q.46: What is the primary function of smoke control ventilation systems in corridor escape routes?

Choices: A) Warm up corridors | B) Keep escape paths clear | C) Dry wet flooring | D) Increase oxygen feed

Answer: B

Justification: Smoke exhaust systems maintain visibility and breathable air in exits.

Q.47: What maintenance check must be performed monthly on portable fire extinguishers?

Choices: A) Hydraulic bursting | B) Chemical refilling | C) Visual inspection | D) Valve replacement

Answer: C

Justification: Monthly visual checks verify extinguishers are charged and undamaged.

Q.48: What safety equipment protects rescue personnel entering toxic smoke-filled buildings?

Choices: A) Cotton face mask | B) Sunglasses | C) Ear muffs | D) Self-contained breathing apparatus

Answer: D

Justification: SCBA supplies independent breathable air in hazardous smoke environments.

Q.49: What emergency notice instruction must be followed regarding chemical burn first aid?

Choices: A) Flush with copious water | B) Apply strong acid | C) Rub with wool | D) Heat with torch

Answer: A

Justification: Washing with abundant running water dilutes and removes chemicals.

Q.50: What is the ultimate goal of combining fire prevention, active protection, and emergency drills?

Choices: A) Reduce building taxes | B) Life and property safety | C) Increase production | D) Lower insurance fees

Answer: B

Justification: Comprehensive fire safety protects human lives and facility assets.



PART B: DESCRIPTIVE QUESTIONS (UNIT 3) — 3 MARKS (3 IMPORTANT POINTS)

1. Give three common industrial sources of ignition.

○ **3 Important Points:**

1. Electrical short circuits and arcing faults.
2. Open flames from hot work operations like welding and cutting.
3. Mechanical friction sparks generated by unlubricated moving machinery.

2. List the various classes of fires from A to E.

○ **3 Important Points:**

1. Class A: Ordinary combustible solids (wood, paper, textiles).
2. Class B: Flammable liquids; Class C: Flammable gases; Class D: Combustible metals; Class E: Energized electrical equipment.
3. Correct classification ensures appropriate extinguishing agent selection.

3. Differentiate between active and passive fire protection systems with examples.

○ **3 Important Points:**

1. Active systems require manual or automatic activation (e.g., automatic sprinklers, alarms).
2. Passive systems rely on built-in structural design without activation (e.g., fire-rated walls, doors).
3. Both systems integrate to provide comprehensive life safety and property protection.

4. State the three main principles of fire extinguishing.

○ **3 Important Points:**

1. Cooling (removing heat energy).
2. Smothering (excluding oxygen supply).
3. Starvation (removing the fuel source).

5. What are the primary types of portable fire extinguishers based on agent?

○ **3 Important Points:**

1. Water and Foam extinguishers.
2. Carbon Dioxide (CO_2) and Clean Agent extinguishers.
3. Dry Chemical Powder (DCP) and Wet Chemical extinguishers.

6. Explain the purpose of hydrant pipes and ring mains in industrial facilities.

○ **3 Important Points:**

1. Provide a reliable, looped, high-pressure continuous water supply network.
2. Ensure adequate water flow and redundancy to firefighting hydrants and monitors.
3. Guarantee dedicated suppression capacity independent of municipal water fluctuations.

7. What is the function of fire monitors in high-hazard areas like tank farms?

○ **3 Important Points:**

1. Deliver high-volume, high-velocity directional streams of water or foam.
2. Operated remotely or manually from safe distances during major emergencies.
3. Protect large storage tanks and process units against radiant heat and fire escalation.

8. State the role of a fire watcher during hot work operations.

○ **3 Important Points:**

1. Continuously monitor sparks, slag, and ignition sources during welding or cutting.
2. Remain on site for a mandatory period post-work to extinguish hidden smoldering embers.
3. Equipped with immediate fire suppression gear and alarm activation authority.

9. What is the purpose of fire alarms and sirens in an industrial or commercial building?

○ **3 Important Points:**

1. Provide early audible and visual warning to all building occupants.
2. Prompt immediate evacuation and initiation of emergency response protocols.
3. Interconnect with suppression systems to streamline facility safety.

10. What is the correct immediate first-aid procedure specified in notices for minor thermal burns?

○ **3 Important Points:**

1. Cool the burn immediately under clean, running cool water for at least 10 to 20 minutes.
2. Avoid applying ice directly to prevent frostbite and further tissue damage.
3. Cover loosely with a sterile, non-adherent dressing and do not puncture blisters.

UNIT - IV
UNIT 4 INDUSTRIAL FIRE PROTECTION SYSTEMS
PART A: MULTIPLE-CHOICE QUESTIONS (UNIT 4)

Q.1: What automatic water suppression system discharges through open nozzles simultaneously over an entire hazard area?

Choices: A) Deluge system | B) Wet pipe system | C) Dry pipe system | D) Pre-action system

Answer: A

Justification: Deluge systems use open nozzles to flood a high-hazard area rapidly with water.

Q.2: Which special fire suppression system uses high-velocity water spray to extinguish flammable liquid fires via emulsification?

Choices: A) Halon 1301 unit | B) Emulsifier system | C) Dry chemical powder | D) Gas flooding system

Answer: B

Justification: Emulsifier spray systems mix water and oil film to form a non-flammable emulsion.

Q.3: What factor primarily dictates the selection criteria for installing an automatic sprinkler system?

Choices: A) Building paint color | B) Room ceiling height | C) Hazard classification | D) Door width size

Answer: C

Justification: Hazard category determines sprinkler head density and water supply flow requirements.

Q.4: What routine maintenance practice ensures high reliability of industrial fire pump systems?

Choices: A) Annual repainting | B) Daily oil wash | C) Monthly valve polish | D) Weekly test run

Answer: D

Justification: Weekly automatic and manual start tests verify pump readiness during power cuts.

Q.5: Which fire alarm initiating device activates when the room temperature exceeds a pre-set threshold?

Choices: A) Fixed temperature detector | B) Optical smoke sensor | C) Flow switch meter | D) Manual call button

Answer: A

Justification: Fixed temperature thermal detectors activate when ambient heat hits a designated level.

Q.6: What gaseous extinguishing agent suppresses fire primarily by displacing ambient oxygen in enclosed spaces?

Choices: A) Plain water mist | B) Carbon dioxide | C) AFFF foam solution | D) Potassium dry powder

Answer: B

Justification: CO₂ flooding reduces oxygen concentrations below the level required for combustion.

Q.7: Which firefighting foam type is most effective for blanketing hydrocarbon fuel spills in tank farms?

Choices: A) High expansion foam | B) Protein foam base | C) AFFF foam | D) Synthetic soap film

Answer: C

Justification: Aqueous Film Forming Foam (AFFF) forms a aqueous barrier film over hydrocarbon surfaces.

Q.8: What is the primary extinguishing mechanism of Dry Chemical Powder (DCP) on Class B and C fires?

- **Choices:** A) Cooling fuel surface | B) Oxygen displacement | C) Radiation shielding | D) Chain reaction inhibition
- **Answer:** D

- **Justification:** DCP chemical radicals combine with free radicals to interrupt combustion chain reactions.

Q.9: Why were traditional Halon fire suppression systems phased out under environmental regulations?

Choices: A) Ozone layer depletion | B) High electrical shock | C) Corrosive residue formation | D) Excessive water damage

Answer: A

Justification: Halon gases contain bromine which causes severe stratospheric ozone depletion.

Q.10: Which clean gaseous agent is widely deployed as an environmentally safe replacement for Halon 1301?

Choices: A) Carbon monoxide | B) FM-200 gas | C) Argon water mist | D) Nitrous oxide gas

Answer: B

Justification: FM-200 (HFC-227ea) provides effective clean agent suppression with zero ozone depletion.

Q.11: What is the primary function of roof-mounted smoke venting systems in industrial plants?

Choices: A) Increase airflow velocity | B) Lower room humidity | C) Exhaust hot smoke | D) Trap toxic vapors

Answer: C

Justification: Smoke vents release buoyant smoke and thermal gases, preserving low-level visibility.

Q.12: Which portable extinguisher is most suitable for small flammable liquid solvent fires in a workshop?

Choices: A) Soda acid cylinder | B) Water bucket unit | C) Chemical foam tank | D) DCP extinguisher

Answer: D

Justification: Dry Chemical Powder (DCP) rapidly smothers and knocks down Class B solvent fires.

Q.13: Which fixed fire protection layout is mandatory around flammable liquid tank farms?

Choices: A) Cooling water rings | B) Ceiling plaster boards | C) Portable sand buckets | D) Manual hand pumps

Answer: A

Justification: Water spray rings cool adjacent storage tanks to prevent BLEVE heat escalation.

Q.14: What safety parameter evaluates the relative ease of ignition and burning rate of liquid fuels?

Choices: A) Flash point variance | B) Index of inflammability | C) Latent heat rating | D) Viscosity coefficient

Answer: B

Justification: Inflammability indices categorize fuels by flash point and volatility risk.

Q.15: What primary objective governs the fire-safe design of commercial and industrial buildings?

Choices: A) Reducing tax liabilities | B) Maximizing floor space | C) Life safety preservation | D) Lowering build costs

Answer: C

Justification: Building safety codes prioritize life safety and occupant safe evacuation.

Q.16: What parameter represents the total combustible mass per unit floor area in building fire safety calculations?

Choices: A) Thermal conductivity rate | B) Floor mass ratio | C) Structural weight limit | D) Fire load density

Answer: D

Justification: Fire load quantifies the total heat energy released by all combustible materials in a space.

Q.17: Which material property allows concrete walls to withstand elevated temperatures during a fire?

Choices: A) High fire resistance | B) Low thermal capacity | C) High electrical flow | D) Rapid heat expansion

Answer: A

Justification: Concrete possesses strong fire resistance and slow thermal conductivity.

Q.18: How is the structural fire resistance rating of building components typically expressed in standards?

Choices: A) Maximum weight tons | B) Time duration hours | C) Pressure kilopascals | D) Surface area meters

Answer: B

Justification: Fire resistance ratings specify how long a component survives standard fire exposure in hours.

Q.19: What structural engineering concept ensures a building does not collapse prematurely during a fire?

Choices: A) Flexible joint movement | B) Lightweight beam support | C) Structural integrity maintenance | D) Open floor layout

Answer: C

Justification: Structural integrity maintains load-bearing capacity while exposed to fire heat.

Q.20: What fundamental safety concept dictates the arrangement and sizing of building emergency escape routes?

Choices: A) Interior decoration plans | B) Lighting brightness levels | C) Acoustic control limits | D) Egress design rules

Answer: D

Justification: Egress design provides continuous, unobstructed escape routes to safe areas.

Q.21: How is the total required exit width calculated for an assembly building compartment?

Choices: A) Occupant load factor | B) Floor tile length | C) Window glass size | D) Ceiling height metric

Answer: A

Justification: Exit width is calculated based on occupant capacity and exit discharge rates.

Q.22: Who issues the statutory Fire Safety Certificate after inspecting high-rise building installations?

Choices: A) Municipal tax officer | B) Fire service authority | C) Local water board | D) Electrical inspectorate

Answer: B

Justification: The state Fire and Rescue Services department inspects and issues fire safety clearance.

Q.23: What mandatory active fire protection system is required on all floors of high-rise commercial buildings?

Choices: A) Manual water buckets | B) Canvas escape chutes | C) Wet riser standpipes | D) Roof water tanks

Answer: C

Justification: Wet risers maintain pressurized water at all floor landings for firefighting.

Q.24: Which specialized aerial firefighting vehicle is deployed for high-rise building rescue operations?

Choices: A) Foam tender truck | B) Water bowser van | C) Chemical rescue unit | D) Snorkel hydraulic platform

Answer: D

Justification: Snorkel platforms elevate firefighters and rescue equipment to upper floors.

Q.25: What pipe network continuously holds water under pressure for immediate automatic sprinkler discharge?

Choices: A) Wet pipe system | B) Dry pipe system | C) Deluge line network | D) Pre-action pipe line

Answer: A

Justification: Wet pipe systems contain pressurized water right up to closed sprinkler heads.

Q.26: Which sprinkler pipe system is installed in unheated cold storage facilities to prevent freezing?

Choices: A) Wet pipe system | B) Dry pipe system | C) Deluge spray system | D) Foam water line

Answer: B

Justification: Dry pipe systems hold pressurized air in pipes until a head opens.

Q.27: What mechanical component opens automatically when the glass bulb of a sprinkler head bursts from heat?

Choices: A) Water pressure gauge | B) Main alarm valve | C) Orifice plug seal | D) Flow control switch

Answer: C

Justification: Heat bursts the liquid bulb, releasing the seal plug to allow water spray.

Q.28: What standard testing method evaluates the fire door resistance against standard time-temperature curves?

Choices: A) Tensile pull test | B) Water drop test | C) Impact hammer test | D) Standard furnace test

Answer: D

Justification: Fire doors are tested in standardized fire furnaces following standard temperature curves.

Q.29: What device prevents the movement of smoke and hot gases through central air conditioning ducts?

Choices: A) Fire smoke damper | B) Air filter screen | C) Flow velocity fan | D) Duct volume damper

Answer: A

Justification: Fire dampers close automatically upon sensing heat or smoke to seal ducts.

Q.30: What type of fire detector utilizes radioactive Americium-241 to sense small smoke particles?

Choices: A) Photoelectric optical unit | B) Ionization smoke detector | C) Infrared flame sensor | D) Thermal heat cable

Answer: B

Justification: Ionization detectors sense invisible combustion particles disrupting ion currents.

Q.31: What optical smoke detector operates on the principle of light scattering by visible smoke particles?

Choices: A) Ionization sensor head | B) Rate of rise heat head | C) Photoelectric smoke detector | D) Thermal expansion bulb

Answer: C

Justification: Photoelectric sensors detect visible smoke that scatters an internal light beam.

Q.32: Which gas system requires a pre-discharge alarm delay to allow personnel to evacuate the room safely?

Choices: A) Local water spray | B) Wet chemical foam | C) Inert nitrogen gas | D) Total flooding CO₂

Answer: D

Justification: Pre-discharge alarms give occupants time to exit before lethal CO₂ concentration builds.

Q.33: What concentration of CO₂ gas is typically required in total flooding systems to extinguish hydrocarbon fires?

Choices: A) 30 to 40 percent | B) 5 to 10 percent | C) 75 to 90 percent | D) 1 to 2 percent

Answer: A

Justification: CO₂ flooding requires 30-40% concentration to reduce oxygen below 15%.

Q.34: Which firefighting foam expansion ratio is used to fill large basement volumes quickly during fires?

Choices: A) Low expansion foam | B) High expansion foam | C) Medium foam film | D) Aqueous liquid film

Answer: B

Justification: High expansion foam (200:1 to 1000:1 ratio) rapidly fills enclosed three-dimensional spaces.

Q.35: What dry powder agent is rated specifically for metal fires like sodium and magnesium?

Choices: A) Sodium bicarbonate powder | B) Monoammonium phosphate powder | C) Class D dry powder | D) Potassium chloride dust

Answer: C

Justification: Class D dry powders smother burning metals without reacting violently.

Q.36: What environmentally friendly inert gas mixture is used as a clean agent Halon replacement?

Choices: A) Pure chlorine gas | B) Sulfur hexafluoride | C) Carbon monoxide mix | D) Inergen gas mix

Answer: D

Justification: Inergen (Nitrogen, Argon, CO₂) extinguishes fire cleanly without ozone harm.

Q.37: What is the primary function of smoke curtains installed in large commercial shopping malls?

Choices: A) Contain smoke movement | B) Decorate roof ceiling | C) Improve room lighting | D) Block noise pollution

Answer: A

Justification: Smoke curtains channel buoyant smoke toward mechanical exhaust fans.

Q.38: Where must portable fire extinguishers be positioned along exit routes in industrial premises?

Choices: A) Inside locked cabinets | B) Conspicuous clear locations | C) Behind heavy machinery | D) Under stairwell landings

Answer: B

Justification: Extinguishers must be clearly visible and accessible along normal travel paths.

Q.39: What fixed water spray system is mandated on the outer shells of LPG storage bullet tanks?

Choices: A) Foam pourer system | B) Dry powder monitor | C) Deluge cooling spray | D) Hand hose line

Answer: C

Justification: Water deluge spray coats the shell, preventing shell weakening and BLEVE explosion.

Q.40: What term describes the maximum distance a worker must travel on a floor to reach an exit doorway?

Choices: A) Corridor length size | B) Egress width total | C) Stair step height | D) Travel distance limit

Answer: D

Justification: Building safety codes limit maximum travel distance to guarantee quick evacuation.

Q.41: What structural feature prevents vertical fire spread between floors through external glass curtain walls?

Choices: A) Spandrel wall barrier | B) Horizontal steel beam | C) Open floor grating | D) Plywood window frame

Answer: A

Justification: Fire-rated spandrel walls prevent external flame lap between adjacent floors.

Q.42: How many independent exit staircases are statutory for high-rise buildings above specified heights?

Choices: A) Single exit only | B) At least two | C) Minimum four exits | D) Optional single ramp

Answer: B

Justification: Safety codes mandate a minimum of two remote, independent exit staircases.

Q.43: What pressurization system prevents smoke entry into protected emergency escape stairwells?

Choices: A) Exhaust draft duct | B) Natural window vent | C) Stairwell pressurization fan | D) Ceiling cooling fan

Answer: C

Justification: Positive air pressure inside stairwells keeps toxic smoke out when doors open.

Q.44: What calculation metric dictates the minimum width per unit for emergency exit doorways?

Choices: A) Door panel thickness | B) Hinge weight rating | C) Frame height size | D) Units of exit width

Answer: D

Justification: Exit capacity is calculated in standard units of exit width (usually 500 mm per unit).

Q.45: Which certificate confirms that building fire protection systems comply fully with national building codes?

Choices: A) Fire clearance certificate | B) Land ownership title | C) Water supply connection | D) Electrical energy bill

Answer: A

Justification: Fire Clearance / NOC certifies full compliance of building safety installations.

Q.46: What hydraulic equipment on a Snorkel fire truck enables high-elevation water monitor discharge?

Choices: A) Submersible water pump | B) Articulated boom arm | C) Heavy winch cable | D) Telescopic ladder rung

Answer: B

Justification: Snorkel trucks use articulated hydraulic booms to position water monitors high up.

Q.47: What visual inspection check verifies that a portable stored-pressure extinguisher is ready for service?

Choices: A) Cylinder paint shade | B) Hose nozzle length | C) Pressure gauge needle | D) Wall bracket height

Answer: C

Justification: The pressure gauge needle must lie within the green operable zone.

Q.48: Which building element is classified as a passive fire barrier to divide large floor areas?

Choices: A) Glass partition screen | B) Gypsum board ceiling | C) Wooden sliding door | D) Fire-rated compartment wall

Answer: D

Justification: Compartment walls restrict horizontal fire and smoke spread across large floor spaces.

Q.49: What is the function of a refuge area in high-rise building emergency evacuation plans?

Choices: A) Temporary safe holding | B) Helicopter landing pad | C) Storage room floor | D) Equipment maintenance area

Answer: A

Justification: Refuge areas offer temporary fire-protected holding zones for occupants during evacuation.

Q.50: Which alarm system component triggers building fire alarms automatically when sprinkler water flows?

Choices: A) Manual break glass | B) Water motor gong switch | C) Thermal fuse plug | D) Gas pressure gauge

Answer: B

Justification: Water flow through alarm valves activates mechanical gongs and pressure switches.



PART B: DESCRIPTIVE QUESTIONS (UNIT 4) — 3 MARKS (3 IMPORTANT POINTS)

1. **Why was the use of Halon extinguishing agents phased out internationally?**
 - **3 Important Points:**
 1. Halons contain active bromine atoms that catalytically destroy stratospheric ozone molecules.
 2. Ozone depletion increases harmful ultraviolet radiation reaching the earth's surface.
 3. Phased out globally under international environmental agreements like the Montreal Protocol.
2. **What is the primary fire suppression system used for large-scale flammable liquid storage tank farms?**
 - **3 Important Points:**
 1. Fixed foam systems (such as AFFF pourers) to blanket liquid surfaces.
 2. Peripheral water spray deluge cooling rings to protect tank shells from radiant heat.
 3. Remote fire monitors capable of high-volume long-range stream application.
3. **How does a Dry Chemical Powder (DCP) fire suppression system extinguish flames?**
 - **3 Important Points:**
 1. Interrupting combustion chain reactions via free radical scavenging ($H^\bullet$ and $OH^\bullet$).
 2. Forming a temporary smothering crust over solid and liquid fuel surfaces.
 3. Providing rapid knockdown capability on Class B and Class C fires.
4. **State the main objectives of smoke venting systems in industrial buildings.**
 - **3 Important Points:**
 1. Remove hot toxic smoke and gases to maintain tenable conditions along escape paths.
 2. Maintain visibility for occupants and firefighting personnel.
 3. Prevent high-temperature upper-layer radiant heat buildup and structural thermal collapse.
5. **Define "Fire Load" in building fire safety engineering.**
 - **3 Important Points:**
 1. Total potential thermal energy (calorific value) released by burning all contents and structures in a space.
 2. Expressed standardly in megajoules per square meter (MJ/m^2).
 3. Used to calculate structural fire resistance ratings and sprinkler design densities.

6. **What is the purpose of standardized fire resistance tests on building structural elements?**
- **3 Important Points:**
 1. Evaluate how long structural components withstand standard furnace temperature curves.
 2. Verify maintenance of structural integrity, insulation, and stability under fire.
 3. Ensure compliance with building codes for fire compartmentalization.
7. **Explain the concept of structural integrity during a building fire.**
- **3 Important Points:**
 1. Ability of load-bearing structural elements to support imposed loads without collapsing.
 2. Resistance of steel or concrete to thermal weakening and deformation during fire exposure.
 3. Prevents premature building collapse during firefighting operations.
8. **State key fire safety requirements mandated for high-rise buildings.**
- **3 Important Points:**
 1. Provision of dedicated fire refuge floors and wet/dry riser standpipe systems.
 2. Emergency backup power generators for fire pumps, smoke extraction, and lifts.
 3. Automatic smoke management and compartmentalized fire escape stairwells.
9. **What is the regulatory purpose of a Fire Safety Certificate (NOC)?**
- **3 Important Points:**
 1. Officially certifies building compliance with statutory fire prevention and life safety bylaws.
 2. Verified by fire authorities prior to issuing occupancy permits.
 3. Ensures active and passive protection systems are fully operational.
10. **What is an emulsifier (water spray) system and where is it applied?**
- **3 Important Points:**
 1. Fixed system discharging fine water droplets through specialized spray nozzles.
 2. Forms a non-flammable oil-water emulsion layer over immiscible heavy liquid fuels.
 3. Applied primarily on high-flash-point flammable liquid equipment, transformers, and oil pumps.

UNIT - V
UNIT 5 COMMON AND SPECIAL HAZARDS

PART A: MULTIPLE-CHOICE QUESTIONS (UNIT 5)

Q.1: What dangerous electrical phenomenon occurs when insulation fails between two conductors?

Choices: A) Short circuit arc | B) Static discharge | C) Magnetic flux drop | D) Ground current leak

Answer: A

Justification: Insulation failure causes direct short-circuit arcing and intense thermal sparks.

Q.2: Which national code classifies hazardous electrical locations into specific classes and divisions?

Choices: A) Boiler pressure standard | B) National Electric Code | C) Building civil code | D) Mechanical piping rule

Answer: B

Justification: NEC defines hazardous electrical locations based on flammable gas/dust presence.

Q.3: What design feature prevents electrical equipment sparks from igniting surrounding explosive atmospheres?

Choices: A) Open wire mesh | B) Thin plastic casing | C) Explosion-proof housing | D) Water-cooled jacket

Answer: C

Justification: Explosion-proof enclosures contain internal sparks so they cannot ignite external vapors.

Q.4: What organization performs independent safety testing and listing of electrical equipment?

Choices: A) Municipal tax office | B) Civil police station | C) Trade export board | D) Testing laboratory

Answer: D

Justification: Nationally recognized testing laboratories certify electrical equipment safety compliance.

Q.5: What classification distinguishes flammable liquids from combustible liquids based on flash point?

Choices: A) Flash point threshold | B) Boiling water limit | C) Freezing ice point | D) Vapor density ratio

Answer: A

Justification: Flammable liquids have flash points below 37.8°C; combustible liquids are higher.

Q.6: What term defines the leanest gas concentration in air that can support a flame?

Choices: A) Upper explosive limit | B) Lower explosive limit | C) Flash point line | D) Boiling threshold

Answer: B

Justification: LEL is the minimum fuel concentration required for flame propagation.

Q.7: What term describes the richest fuel-air concentration above which a mixture is too dense to burn?

Choices: A) Lower explosive limit | B) Flash point baseline | C) Upper explosive limit | D) Minimum spark point

Answer: C

Justification: UEL is the maximum fuel concentration above which mixtures are too rich to burn.

Q.8: What approved container type is used for safely storing small quantities of flammable liquids?

Choices: A) Open metal bucket | B) Glass beverage jar | C) Cardboard box bin | D) Safety storage can

Answer: D

Justification: Approved safety cans feature spring-loaded lids and flame arresters for safe storage.

Q.9: What critical precaution must be observed when transferring flammable liquids between containers?

Choices: A) Bonding and grounding | B) High-speed pouring | C) Open air splashing | D) Plastic hose use

Answer: A

Justification: Bonding and grounding prevents static electricity spark buildup during liquid transfer.

Q.10: What fire-rated safety feature is built into metal storage cabinets storing flammable liquid containers?

Choices: A) Glass observation pane | B) Self-closing doors | C) Exhaust fan motor | D) Wooden outer frame

Answer: B

Justification: Approved flammable storage cabinets feature self-closing doors and thermal latches.

Q.11: What type of storage tank sits entirely above ground level for bulk petroleum products?

Choices: A) Underground vault | B) Submerged basin | C) Above ground tank | D) Sealed dry pit

Answer: C

Justification: Above ground tanks hold bulk flammable liquids with dyke containment.

Q.12: What corrosion-protection method is mandatory for underground flammable liquid storage tanks?

Choices: A) Bright red painting | B) Outer rubber wrap | C) Direct soil burial | D) Cathodic protection

Answer: D

Justification: Cathodic protection prevents electrochemical corrosion of buried steel tanks.

Q.13: What safety procedure is required before loading or unloading fuel tank trucks at terminal racks?

Choices: A) Static bonding hookup | B) Engine full throttle | C) Tire pressure check | D) Driver lunch break

Answer: A

Justification: Static bonding drains electrostatic charges before flammable liquid transfer begins.

Q.14: What primary fire hazard is associated with compressed Hydrogen gas storage?

Choices: A) Toxic gas release | B) Extreme flammability | C) Heavy liquid spill | D) Radioactive decay

Answer: B

Justification: Hydrogen has a wide explosive range and extremely low ignition energy.

Q.15: What chemical property makes Acetylene gas exceptionally hazardous in industrial welding?

Choices: A) Heavy vapor weight | B) Cold freezing point | C) High instability | D) Water solubility

Answer: C

Justification: Acetylene decomposes violently under pressure or shock without requiring oxygen.

Q.16: How does pure Oxygen gas affect combustible materials in industrial workplaces?

Choices: A) Extinguishes fires | B) Cools hot surfaces | C) Absorbs moisture | D) Accelerates combustion

Answer: D

Justification: Oxygen strongly accelerates combustion, making organic materials highly flammable.

Q.17: What physical characteristic of Liquefied Petroleum Gas (LPG) vapor makes it accumulate in low areas?

Choices: A) Heavier than air | B) Lighter than air | C) Dissolves in water | D) Evaporates upward

Answer: A

Justification: LPG vapor density is greater than air, causing it to pool in low floor trenches.

Q.18: What electrical ignition hazard is created by frayed lamp cords in industrial work areas?

Choices: A) Magnetic field pull | B) Exposed wire spark | C) Voltage drop surge | D) Battery acid leak

Answer: B

Justification: Frayed insulation exposes live copper conductors, creating direct arcing hazards.

Q.19: What classification zone in the National Electric Code represents continuous explosive gas atmospheres?

Choices: A) Zone 2 location | B) Safe general area | C) Zone 0 location | D) Outdoor open yard

Answer: C

Justification: Zone 0 represents locations where explosive gas atmospheres are present continuously.

Q.20: What safety standard feature is required on electric motors operating in flammable gas areas?

Choices: A) High-speed turbine | B) Open cooling fan | C) Wooden rotor base | D) Non-sparking enclosure

Answer: D

Justification: Motors in hazardous zones must prevent internal electrical sparks from escaping.

Q.21: Why do testing laboratories subject electrical control panels to rigorous thermal aging tests?

Choices: A) Verify fire safety | B) Check paint color | C) Measure metal weight | D) Test acoustic sound

Answer: A

Justification: Laboratory testing ensures electrical panels withstand thermal stress without catching fire.

Q.22: What is the primary distinction between Class I and Class II hazardous locations in electrical codes?

Choices: A) Indoor versus outdoor | B) Gases versus dusts | C) High versus low voltage | D) AC versus DC power

Answer: B

Justification: Class I covers flammable gases/vapors, while Class II covers combustible dusts.

Q.23: What physical property determines whether a liquid fuel floats or sinks when mixed with water?

Choices: A) Kinetic viscosity | B) Surface tension | C) Specific gravity | D) Thermal capacity

Answer: C

Justification: Specific gravity less than water causes flammable liquids to float and spread on water.

Q.24: What safety device prevents flame flashback inside Acetylene supply gas lines?

Choices: A) Pressure regulator | B) Water trap valve | C) Flow check meter | D) Flashback arrestor

Answer: D

Justification: Flashback arrestors stop flame propagation back into acetylene cylinders.

Q.25: What protective barrier is constructed around above-ground flammable liquid storage tanks?

Choices: A) Secondary containment dyke | B) Wooden acoustic fence | C) Glass viewing screen | D) Steel security roof

Answer: A

Justification: Dykes retain 100% of tank volume if a major rupture or spill occurs.

Q.26: What hazard is presented by underground fuel storage tanks leaking undetected into surrounding soil?

Choices: A) Surface frost buildup | B) Groundwater pollution | C) Electrical grounding | D) Boiler pressure loss

Answer: B

Justification: Leaking underground tanks contaminate soil and groundwater tables.

Q.27: Why must oxygen cylinder valves never be touched with oily or greasy hands?

Choices: A) Cylinder freezing | B) Valve thread lock | C) Spontaneous ignition | D) Rust formation

Answer: C

Justification: Grease reacts violently with high-pressure oxygen, causing spontaneous ignition.

Q.28: What explosive range width characterizes Hydrogen gas mixed with atmospheric air?

Choices: A) Extremely narrow | B) Zero flammability | C) Strictly constant | D) Very wide range

Answer: D

Justification: Hydrogen has an extremely broad explosive limit range (4% to 75% in air).

Q.29: What color-coding is universally applied to Acetylene high-pressure gas cylinders?

Choices: A) Maroon red body | B) Black steel finish | C) Dark green shade | D) Bright yellow coat

Answer: A

Justification: Acetylene gas cylinders are painted maroon red for clear visual identification.

Q.30: What safety fitting on LPG storage vessels relieves excess internal pressure during external fires?

Choices: A) Manual drain cock | B) Spring relief valve | C) Water inlet nozzle | D) Glass sight gauge

Answer: B

Justification: Relief valves discharge excess vapor pressure to prevent vessel bursting.

Q.31: What electrical ignition source is produced by static electricity discharge during belt drives?

Choices: A) Induction current | B) Resistance heat | C) Electrostatic spark | D) Magnetic surge

Answer: C

Justification: Moving belts accumulate static charge that discharges as incendiary sparks.

Q.32: What laboratory test determines the exact flash point temperature of a flammable liquid sample?

Choices: A) Boiling tube trial | B) Weight loss scale | C) Viscosity funnel | D) Closed cup test

Answer: D

Justification: Closed-cup testers measure the minimum temperature where vapors flash above liquid.

Q.33: What is the primary fire hazard of combustible metal powders like finely divided Aluminum?

Choices: A) Dust explosion risk | B) Radioactive emission | C) Acidic fume cloud | D) Water freezing effect

Answer: A

Justification: Fine metal powders suspended in air form highly explosive dust clouds.

Q.34: What safety measure is mandatory inside flammable liquid storage cabinet interiors?

Choices: A) Electric heater coils | B) Vapor vent bungs | C) Carpet flooring mats | D) Open shelving wood

Answer: B

Justification: Cabinets include threaded vent bungs for optional vapor exhaust connection.

Q.35: Why are electrical switches in hazardous paint-spraying booths required to be remotely located?

Choices: A) Save wiring costs | B) Improve room lighting | C) Prevent vapor ignition | D) Reduce fan noise

Answer: C

Justification: Isolating switches outside spray booths prevents ignition of flammable paint mists.

Q.36: What term describes liquids with a flash point at or above 37.8°C (100°F) but below 93.3°C?

Choices: A) Flammable solvent | B) Cryogenic fluid | C) Compressed gas | D) Combustible liquid

Answer: D

Justification: Combustible liquids require higher temperatures to ignite than flammable liquids.

Q.37: What safety hazard occurs when water is added to a burning tank of heavy hot asphalt or oil?

Choices: A) Frothover eruption | B) Instant freezing | C) Chemical neutralization | D) Electric short circuit

Answer: A

Justification: Water boiling beneath hot oil causes violent frothover and burning liquid expulsion.

Q.38: What specialized fittings connect portable flammable liquid containers during gravity transfer?

Choices: A) Plastic hose cuffs | B) Bonding wire clamps | C) Cotton rope ties | D) Rubber suction pads

Answer: B

Justification: Bonding clamps ensure electrical continuity between containers to drain static.

Q.39: What structural design standard governs the venting capacity of above-ground fuel storage tanks?

Choices: A) Roof tile thickness | B) Foundation depth rule | C) Emergency vent sizing | D) Door swing clearance

Answer: C

Justification: Tanks require emergency relief vents to prevent rupture during external fires.

Q.40: What color designation is standard for compressed Hydrogen gas cylinder bodies?

Choices: A) Bright yellow shell | B) Signal green tube | C) French grey body | D) Dark red cylinder

Answer: D

Justification: Hydrogen and flammable gas cylinders are traditionally painted red.

Q.41: What ignition source is generated by mechanical friction in unlubricated machinery bearings?

Choices: A) Frictional heat spark | B) Static electrical arc | C) Magnetic coil surge | D) Chemical reaction

Answer: A

Justification: Unlubricated bearings generate intense frictional heat capable of igniting lubricants.

Q.42: What National Electric Code division represents abnormal or occasional hazardous gas conditions?

Choices: A) Division 1 location | B) Division 2 location | C) General safe zone | D) Office control room

Answer: B

Justification: Division 2 covers areas where hazardous gases are handled under abnormal conditions.

Q.43: What safety testing ensures underground fuel tanks do not leak prior to backfilling?

Choices: A) Visual dirt scan | B) Weight scale check | C) Air pressure test | D) Temperature scan

Answer: C

Justification: Underground tanks undergo pneumatic pressure testing to verify weld integrity.

Q.44: What is the primary danger of storing Acetylene cylinders in a horizontal laying position?

Choices: A) Cylinder rolling off | B) Valve freezing up | C) Metal rusting fast | D) Acetone liquid leak

Answer: D

Justification: Laying acetylene flat causes acetone solvent to discharge, creating extreme explosion hazards.

Q.45: What active system protects tanker truck loading gantries against sudden static fuel fires?

Choices: A) Deluge water spray | B) Manual sand bucket | C) Foam fire blanket | D) CO2 handheld horn

Answer: A

Justification: Loading gantries feature automatic deluge spray systems for rapid fire knockdown.

Q.46: What chemical behavior makes Oxygen gas containers dangerous when exposed to high heat?

Choices: A) Spontaneous freezing | B) Pressure increase risk | C) Liquid evaporation | D) Vapor condensation

Answer: B

Justification: Heating compressed oxygen cylinders increases internal pressure, risking rupture.

Q.47: What safety device is installed on fuel tanker truck unloading lines to prevent backflow?

Choices: A) Open drainage pipe | B) Manual shutoff lever | C) Non-return check valve | D) Air pressure pump

Answer: C

Justification: Check valves prevent reverse flow of flammable liquids during transfer operations.

Q.48: What ventilation requirement is mandatory for indoor storage rooms housing LPG cylinders?

Choices: A) High ceiling fans | B) Sealed glass walls | C) Air conditioning units | D) Low-level floor vents

Answer: D

Justification: Since LPG vapor is heavier than air, low-level floor vents prevent hazardous pooling.

Q.49: What testing standard verifies the dielectric breakdown strength of electrical insulating equipment?

Choices: A) High-voltage proof test | B) Thermal overload scan | C) Mechanical drop test | D) Chemical acid dip

Answer: A

Justification: Dielectric proof testing ensures electrical protective gear blocks high voltages safely.

Q.50: What is the ultimate engineering goal of classifying electrical hazards and storing flammable liquids safely?

Choices: A) Lower insurance taxes | B) Prevent fire disasters | C) Speed up production | D) Increase warehouse space

Answer: B

Justification: Proper hazard classification and storage prevent catastrophic industrial fire explosions.

PART B: DESCRIPTIVE QUESTIONS (UNIT 5) — 3 MARKS (3 IMPORTANT POINTS)

1. **How does the National Electric Code (NEC) classify hazardous locations involving flammable gases and vapors?**
 - **3 Important Points:**
 1. Classified specifically under **Class I** hazardous locations.
 2. Subdivided into Division 1 (normal operating hazard) and Division 2 (abnormal/failure hazard).
 3. Governs strict electrical equipment selection to prevent vapor ignition.
2. **Define Upper and Lower Explosive Limits (UEL and LEL).**
 - **3 Important Points:**
 1. LEL is the minimum concentration of vapor in air below which flame propagation cannot occur ("too lean").
 2. UEL is the maximum concentration above which flame propagation cannot occur ("too rich").
 3. The range between LEL and UEL defines the explosive flammability envelope.
3. **Why are bonding and grounding critical during the transfer of flammable and combustible liquids?**
 - **3 Important Points:**
 1. Prevents the accumulation of dangerous static electric charges during liquid flow.
 2. Eliminates electrostatic spark discharges that can ignite flammable vapor clouds.
 3. Ensures continuous electrical continuity between transfer containers and piping.
4. **What is a key advantage of Above Ground Storage Tanks (ASTs) over Underground Storage Tanks (USTs) regarding maintenance?**
 - **3 Important Points:**
 1. ASTs permit direct visual inspection of tank shells, piping, and foundation pads.
 2. External leaks, corrosion, or structural damage can be spotted and repaired immediately.
 3. Avoids complex underground soil excavation and environmental testing costs.
5. **How are Underground Storage Tanks (USTs) typically protected against structural corrosion and leaks?**
 - **3 Important Points:**
 1. Utilizing double-walled fiberglass or coated steel construction.
 2. Installing cathodic protection systems (sacrificial anodes or impressed current).

3. Implementing continuous interstitial leak detection monitoring sensors.
6. **What mandatory safety step must be performed before loading or unloading a fuel tanker truck?**
- **3 Important Points:**
 1. Establishing continuous electrical bonding and grounding between the tanker and rack.
 2. Engaging vehicle wheel chocks to prevent accidental roll-away movement.
 3. Securing emergency spill containment equipment and checking vapor recovery lines.
7. **Why is Hydrogen gas explosion safety exceptionally challenging compared to standard hydrocarbons?**
- **3 Important Points:**
 1. Possesses an extremely wide flammability range (4% to 75% in air).
 2. Requires exceptionally low minimum ignition energy (highly sensitive to static).
 3. Hydrogen flames burn nearly invisibly, making flame detection difficult without sensors.
8. **How is Acetylene gas safely stored in steel cylinders under pressure?**
- **3 Important Points:**
 1. Dissolved in liquid acetone under moderate pressure.
 2. Absorbed within a porous monolithic solid mass matrix inside the cylinder.
 3. Prevents dangerous free acetylene self-decomposition and explosive polymerization.
9. **What is the primary fire hazard associated with enriched Oxygen atmospheres or oxygen equipment?**
- **3 Important Points:**
 1. Drastically lowers the activation energy and ignition thresholds of materials.
 2. Causes rapid, violent, and spontaneous combustion of oils, greases, and organic plastics.
 3. Accelerates flame spread rates exponentially compared to normal air.
10. **What physical state is Liquefied Petroleum Gas (LPG) maintained in inside a standard pressurized cylinder?**
- **3 Important Points:**
 1. Maintained as a balanced two-phase equilibrium mixture of liquid and gas.
 2. Kept under moderate vapor pressure inside sealed steel pressure vessels.
 3. Vaporizes rapidly upon release, producing heavy vapor clouds that settle in low points.

FIRE ENGINEERING — 10-MARK QUESTION BANK (PART C)

UNIT 1: ANATOMY OF FIRE AND CASE STUDIES

Q1. Analyze the major products of combustion in building and industrial fires, with specific emphasis on toxic asphyxiants (CO and HCN) and their physiological impacts.

10 Important Points:

1. **Definition of Combustion Products:** Combustion generates gases, heat, smoke, and flame; gases and smoke cause the majority of fire fatalities rather than burns.
2. **Carbon Monoxide (CO):** A colorless, odorless, and tasteless gas formed during incomplete combustion of carbon-based materials.
3. **Affinity for Hemoglobin:** CO binds to blood hemoglobin with an affinity 200 to 250 times greater than oxygen, forming carboxyhemoglobin (*COHb*).
4. **Physiological Impact of CO:** It starves the brain and vital tissues of oxygen, leading to rapid dizziness, confusion, unconsciousness, and death.
5. **Hydrogen Cyanide (HCN):** A highly toxic asphyxiant gas released during the burning of nitrogen-containing polymers like wool, silk, polyurethane, and plastics.
6. **Cellular Respiration Blockage:** HCN inhibits the cellular cytochrome oxidase enzyme, preventing cells from utilizing oxygen even when blood oxygen levels are normal.
7. **Combined Asphyxiant Effect:** Simultaneous exposure to CO and HCN accelerates physical incapacitation dramatically, preventing victims from escaping.
8. **Irritant Gases:** Other products like Hydrogen Chloride (*HCl*) and sulfur dioxide irritate the eyes, nose, and respiratory tract.
9. **Reduced Visibility:** Suspended soot particles and smoke obscure exit routes, compounding panic and entrapment risks.
10. **Preventive Measures:** Use of self-contained breathing apparatus (SCBA) by firefighters and installation of smoke/toxic gas extraction systems.

Q2. Describe the phenomenon of Unconfined Vapour Cloud Explosions (UVCE) and flash fires, detailing how flame acceleration and blast overpressure are generated.

10 Important Points:

1. **Accidental Release:** UVCE occurs when a large volume of volatile flammable liquid or gas escapes into the atmosphere and mixes with air.
2. **Vapor Cloud Formation:** The vapor forms an unconfined or semi-confined drifting cloud before encountering an ignition source.
3. **Flash Fire vs. UVCE:** If the cloud burns smoothly without significant turbulence or confinement, it forms a low-pressure **flash fire**.
4. **Transition to UVCE:** If the flame encounters obstacles, congestion, or confinement, flame speed increases rapidly, creating a destructive **UVCE**.
5. **Flame Acceleration:** Obstacles (like pipes, equipment structures, and walls) generate turbulence that wrinkles and expands the flame front surface area.

6. **Deflagration to Detonation:** Rapid flame acceleration can cause transition from subsonic deflagration to supersonic detonation waves.
7. **Blast Overpressure:** The rapid expansion of hot combustion gases creates a high-pressure shock wave (blast wave) capable of collapsing buildings.
8. **Thermal Radiation:** Intense radiant heat is emitted during the combustion of the vapor cloud.
9. **Contributing Factors:** Weather conditions (wind speed, atmospheric stability) and the reactivity of the chemical substance.
10. **Mitigation Controls:** Water spray curtains, vapor cloud detection sensors, emergency isolation valves, and plant layout spacing.

Q3. Explain the mechanics of a Boiling Liquid Expanding Vapour Explosion (BLEVE). What are the primary contributing factors and consequences associated with a flammable BLEVE?

10 Important Points:

1. **Definition of BLEVE:** A BLEVE is an explosion resulting from the catastrophic failure of a pressure vessel containing a liquid stored above its atmospheric boiling point.
2. **External Fire Exposure:** Typically triggered when an external pool or jet fire impinges on the vapor space of a pressurized tank (e.g., LPG or propane tank).
3. **Wall Weakening:** Flames heat the tank wall above the liquid level where cooling is absent, causing steel to lose tensile strength.
4. **Catastrophic Rupture:** Internal vapor pressure exceeds the weakened steel's yield strength, resulting in sudden, violent vessel splitting.
5. **Superheated Liquid Flash:** The sudden depressurization causes the superheated liquid to flash instantly into a massive volume of vapor.
6. **Fireball Formation:** If the released gas is flammable, the vapor mixes with air and ignites immediately, creating a giant thermal fireball.
7. **Blast Wave:** The rapid physical expansion of vapor generates a destructive shock wave.
8. **Projectile Shrapnel:** Steel tank fragments are hurled at high velocities over long distances like missiles.
9. **Consequences:** Severe thermal radiation burns, structural demolition from blast waves, and impact damage from flying shrapnel.
10. **Prevention:** Application of water spray cooling systems, pressure relief valves (PRVs), and fire-resistant insulation coatings.

Q4. Differentiate between auto-ignition, flash point, and fire point, and explain the theoretical concept of deflagration versus detonation wave propagation.

10 Important Points:

1. **Flash Point:** The minimum temperature at which a liquid gives off enough vapor to form an ignitable mixture that flashes momentarily when exposed to a spark.

2. **Fire Point:** The temperature slightly higher than the flash point where continuous burning is sustained for at least 5 seconds after ignition.
3. **Auto-Ignition Temperature:** The lowest temperature at which a substance ignites spontaneously in air without any external spark or flame.
4. **Combustion Wave Concept:** Flames propagate through explosive mixtures via thermal conduction and radical diffusion (deflagration) or shock compression (detonation).
5. **Deflagration Characteristics:** A subsonic combustion wave where heat transfers forward to ignite unburned gases; creates lower overpressures.
6. **Detonation Characteristics:** A supersonic combustion wave driven by a powerful leading shock wave that compresses and instantaneously ignites the fuel-air mixture.
7. **Pressure Profiles:** Deflagrations produce gentle pressure rises; detonations produce sharp, devastating high-pressure spikes.
8. **Flame Speeds:** Deflagration speeds range from meters per second up to hundreds of meters/sec; detonations exceed thousands of meters per second (supersonic).
9. **Engineering Significance:** Understanding these limits prevents accidental explosions in chemical reactors and fuel pipelines.
10. **Safety Devices:** Flashback arrestors and explosion-relief vents are designed to arrest deflagration waves before transitioning to detonations.

Q5. Review the 1988 Piper Alpha offshore disaster, analyzing the operational failures, communication breakdowns, and regulatory reforms that transformed offshore safety.

10 Important Points:

1. **Disaster Overview:** In July 1988, a series of massive gas explosions and fires destroyed the Piper Alpha oil production platform in the North Sea, killing 167 workers.
2. **Initial Gas Leak:** Condensate leaked from a high-pressure pump that had its safety pressure safety valve removed for routine maintenance.
3. **Shift Handover Failure:** Written logs and verbal communication failed during shift change, leading operators to restart the pump unaware that maintenance was incomplete.
4. **Ignition Source:** Escaping condensate vapor ignited, causing the first major explosion and disabling control rooms.
5. **Vulnerability of Risers:** Unprotected gas riser pipes from subsea wells ruptured under fire exposure, feeding massive high-pressure gas into the fire.
6. **Evacuation Bottlenecks:** Personnel retreated to the accommodation block, but smoke and blocked pathways prevented safe helicopter evacuation.
7. **Lack of Subsea Isolation:** Surface workers could not isolate subsea wells due to lack of remote isolation systems.
8. **Lord Cullen Inquiry:** An official judicial inquiry exposed severe flaws in operator self-regulation and safety management.
9. **Regulatory Reform:** Shifted from prescriptive rules to goal-setting safety cases requiring formal Safety Management Systems (SMS) and quantitative risk assessment.

10.Engineering Improvements: Installation of blast-resistant control rooms, subsea emergency shutdown valves (SESVs), and improved evacuation routing.



UNIT 2: BASIC CHEMISTRY AND PHYSICS OF FIRE

Q1. Analyze the primary effects of heat on matter, including thermal expansion, phase transitions, and how these phenomena impact structural integrity and pressure containment during fire exposure.

10 Important Points:

1. **Thermal Kinetic Energy:** Heating matter increases particle vibration and kinetic energy, leading to macroscopic physical changes.
2. **Thermal Expansion:** Most solids, liquids, and gases expand when heated, increasing volume and stressing structural connections.
3. **Phase Transitions:** Heat drives phase changes from solid to liquid (melting) and liquid to gas (vaporization/boiling).
4. **Structural Steel Weakening:** Structural steel maintains load capacity up to 500°C , but loses nearly 50% of its strength at 600°C , causing sagging and collapse.
5. **Concrete Spalling:** Moisture trapped in concrete turns to steam under fire heat, generating internal pressure that cracks and fractures the concrete.
6. **Pressure Vessel Stress:** Heating closed containers increases internal gas/vapor pressure, risking tank rupture or BLEVE.
7. **Thermal Shock:** Rapid cooling of hot materials (e.g., applying water to hot metal) induces thermal shock and cracking.
8. **Volume Expansion Ratio:** Water expands over 1,700 times when converted to steam, generating extreme volumetric displacement.
9. **Mitigation via Insulation:** Fire-resistive coatings (SFRM) and expansion joints protect structural frames from thermal stress.
10. **Engineering Design:** Fire safety design incorporates thermal expansion allowances in piping networks and structural steel frames.

Q2. Provide a detailed technical analysis of combustion as an exothermic oxidation-reduction reaction, contrasting it with endothermic processes and energy absorption mechanics.

10 Important Points:

1. **Oxidation-Reduction (Redox):** Combustion is fundamentally a redox reaction where fuel acts as the reducing agent and oxygen acts as the oxidizing agent.
2. **Exothermic Nature:** The reaction releases net thermal energy because the chemical bond energy of the products (CO_2 , H_2O) is lower than that of the reactants.
3. **Activation Energy:** An initial spark or heat source is required to overcome the activation energy barrier and start bond breaking.
4. **Endothermic Processes:** Unlike combustion, endothermic processes (like thermal decomposition or melting) absorb heat from their surroundings.

5. **Heat of Combustion:** Quantifies the thermal energy released per unit mass during complete combustion of a substance.
6. **Chain Reaction:** Free radicals ($H^\bullet$, $OH^\bullet$) propagate the exothermic oxidation cycle rapidly.
7. **Flame Temperature:** The balance between heat release and radiative/convective heat losses dictates actual flame temperature.
8. **Fire Suppression Role:** Water application absorbs heat endothermically (latent heat of vaporization), dropping flame zone temperatures.
9. **Incomplete Combustion:** Insufficient oxygen results in partial oxidation, producing toxic carbon monoxide and soot instead of complete CO_2 .
10. **Thermodynamic Laws:** Governed by the First Law of Thermodynamics (energy conservation) and Second Law (entropy increase).

Q3. Explain the concepts of temperature and specific heat capacity, and evaluate how conduction, convection, and radiation govern heat transmission across industrial settings.

10 Important Points:

1. **Temperature:** A measure of the average kinetic energy of particles within a substance, determining the direction of heat flow.
2. **Specific Heat Capacity:** The amount of thermal energy required to raise the temperature of unit mass of a substance by 1°C .
3. **Role of Water:** Water possesses an exceptionally high specific heat capacity, making it the supreme cooling agent in firefighting.
4. **Conduction:** Heat transfer through direct molecular contact and lattice vibration within solid materials (e.g., heat traveling along a steel beam).
5. **Convection:** Heat transfer through bulk fluid and gas motion (e.g., hot buoyant smoke rising toward a ceiling).
6. **Radiation:** Heat transfer via electromagnetic infrared waves without requiring an intervening medium (e.g., radiant heat from a flame touching adjacent buildings).
7. **Industrial Conduction Risk:** Heat conducting through uninsulated metal partition walls can ignite combustibles on the opposite side.
8. **Industrial Convection Risk:** Convective hot gases travel through HVAC ductwork, spreading smoke and fire across building compartments.
9. **Industrial Radiation Risk:** Radiation is the primary mode driving room flashover and tank-to-tank fire spread in refineries.
10. **Thermal Barriers:** Insulation, fire doors, and water spray curtains are engineered to block conduction, convection, and radiation.

Q4. Examine the role of catalysts in chemical reactions and combustion processes, detailing how they alter activation energy barriers and reaction rates without being consumed.

10 Important Points:

1. **Definition of Catalyst:** A substance that alters the rate of a chemical reaction without being permanently consumed or altered itself.
2. **Activation Energy Reduction:** Catalysts provide an alternative reaction pathway with a lower activation energy barrier.
3. **Homogeneous vs. Heterogeneous:** Catalysts can be in the same phase as reactants (homogeneous) or in a different phase (heterogeneous).
4. **Combustion Inhibition:** Chemical fire suppressants act as negative catalysts (inhibitors) by scavenging active free radicals ($H^\bullet$, $OH^\bullet$).
5. **Halon Action:** Halon clean agents release bromine atoms that catalytically destroy combustion chain radicals.
6. **Dry Chemical Powders:** Fine powders (like monoammonium phosphate) interrupt chain branching via catalytic surface reactions.
7. **Industrial Process Hazards:** Contaminants or metal surfaces can act as unexpected catalysts, triggering runaway exothermic polymerization or decomposition.
8. **Enzymatic Reactions:** Biological systems use enzyme catalysts that operate under specific thermal limits.
9. **Exhaust Catalytic Converters:** Used in vehicles to catalyze incomplete combustion gases (CO , unburned hydrocarbons) into harmless CO_2 and water.
10. **Reaction Kinetics:** Catalyzed reactions proceed much faster at lower temperatures compared to uncatalyzed pathways.

Q5. Describe the phenomenon of sublimation and the concept of heat of decomposition, explaining their significance in evaluating the thermal stability of solid fuels and hazardous substances.

10 Important Points:

1. **Sublimation Definition:** The direct phase transition of a substance from solid state to gaseous state without passing through an intermediate liquid phase.
2. **Common Example:** Dry ice (solid carbon dioxide) sublimates directly at atmospheric pressure.
3. **Endothermic Sublimation:** Sublimation absorbs latent heat, creating cooling blankets of inert gas (utilized in specialized extinguishing applications).
4. **Heat of Decomposition:** The thermal energy absorbed or released when a chemical compound breaks down into simpler substances or elements.
5. **Thermal Stability Evaluation:** Heat of decomposition indicates whether a solid chemical or polymer is stable or prone to exothermic self-heating.

6. **Endothermic Decomposition:** Fire retardants like aluminum hydroxide undergo endothermic decomposition, releasing water vapor to cool flames.
7. **Exothermic Decomposition Hazards:** Unstable compounds (like organic peroxides or nitrates) undergo exothermic decomposition, leading to thermal runaway and explosions.
8. **Solid Fuel Pyrolysis:** Solid wood and plastics undergo thermal decomposition (pyrolysis) before flaming combustion.
9. **Testing Standards:** Differential Scanning Calorimetry (DSC) and Thermogravimetric Analysis (TGA) measure decomposition kinetics.
10. **Safe Storage Design:** Materials with high heat of decomposition risks require refrigerated storage and strict temperature controls.



UNIT 3: FIRE PREVENTION AND PROTECTION

Q1. Compare and contrast active and passive fire protection systems, evaluating their respective roles, structural integration requirements, and collective effectiveness in mitigating structural collapse and life safety risks.

10 Important Points:

1. **Active Systems Definition:** Systems requiring manual or automatic activation to detect, signal, or suppress a fire (e.g., sprinklers, alarms, extinguishers).
2. **Passive Systems Definition:** Built-in structural elements and materials designed to contain fire and smoke without requiring human or mechanical activation.
3. **Synergistic Role:** Active systems provide early detection and rapid suppression; passive systems buy crucial evacuation time and prevent fire spread.
4. **Structural Integration:** Passive systems include fire-rated walls, floors, structural fireproofing (SFRM), and fire doors.
5. **Compartmentation:** Passive fire walls divide buildings into compartments to restrict fire growth to a single zone.
6. **Active Suppression Variety:** Includes wet pipe sprinklers, deluge systems, and gas clean agent flooding systems.
7. **Reliability Factor:** Passive systems are always "on" and require zero electrical power or moving parts to function.
8. **Mitigating Collapse:** Spray-applied fireproofing protects steel columns from losing strength during intense fires.
9. **Life Safety Egress:** Passive corridor fire doors protect escape routes, while active smoke extraction systems keep air tenable.
10. **Building Codes:** National building codes mandate the integration of both active and passive protection for regulatory compliance (Fire NOC).

Q2. Classify fires into categories A through E, detailing the specific fuel characteristics, associated hazards, and the scientific rationale behind selecting appropriate extinguishing agents and portable extinguishers for each class.

10 Important Points:

1. **Class A Fires:** Involve ordinary solid combustible materials such as wood, paper, textiles, rubber, and plastics.
2. **Class B Fires:** Involve flammable and combustible liquids, petroleum oils, greases, paints, and solvents.
3. **Class C Fires:** Involve flammable gases under pressure, such as liquefied petroleum gas (LPG), methane, and acetylene.

4. **Class D Fires:** Involve reactive combustible metals such as magnesium, titanium, sodium, and potassium.
5. **Class E (Electrical) Fires:** Involve energized electrical equipment where non-conductive extinguishing agents are mandatory.
6. **Class A Extinction:** Requires water or foam for deep cooling and saturation of solid embers.
7. **Class B Extinction:** Requires foam, CO_2 , or Dry Chemical Powder (DCP) to blanket and smother fuel vapors.
8. **Class C Extinction:** Requires gas shutoff combined with DCP or CO_2 ; extinguishing flames without stopping gas leaks risks unburned vapor cloud explosions.
9. **Class D Extinction:** Requires specialized dry powder agents (graphite or sodium chloride-based) that smother metal fires without reacting.
10. **Class E Extinction:** Requires non-conductive agents (CO_2 , clean agents, DCP) to prevent fatal electrical shock hazards.

Q3. Describe the engineering layout and hydraulic design of industrial fire water networks, including hydrant ring mains, building standpipe system layouts, and high-capacity directional fire monitors.

10 Important Points:

1. **Fire Water Network Purpose:** Supplies high-volume, reliable water pressure dedicated exclusively to firefighting infrastructure.
2. **Hydrant Ring Main:** A looped underground piping network encircling the industrial plant, providing redundant flow paths.
3. **Redundancy & Reliability:** Looped ring mains ensure that if one pipe section is damaged, water feeds from the opposite direction.
4. **Fire Water Pumps:** Comprises main electric pumps, diesel backup pumps, and a small jockey pump to maintain system pressure.
5. **Standpipe Systems:** Vertical piping risers in multi-story buildings fitted with hose valve outlets on each floor for firefighter connection.
6. **Wet vs. Dry Standpipes:** Wet standpipes are permanently charged with pressurized water; dry standpipes remain empty until fire engines pump water into ground inlets.
7. **Fire Monitors:** High-capacity, long-range directional water/foam cannons mounted on towers to protect large tank farms.
8. **Hydraulic Design Criteria:** Pipe diameters, friction losses, and residual pressures must meet NFPA standards at the most remote hydrant.
9. **Water Storage Tanks:** Dedicated fire water reservoirs sized to supply maximum demand for a specified duration (e.g., 2 to 4 hours).
10. **Isolation Valves:** Sectional gate valves allow isolating damaged pipe segments without shutting down the entire plant network.

Q4. Evaluate the design, operation, and integration of industrial fire detection systems, manual call points, alarm networks, and sirens in orchestrating prompt facility-wide emergency communication and evacuation.

10 Important Points:

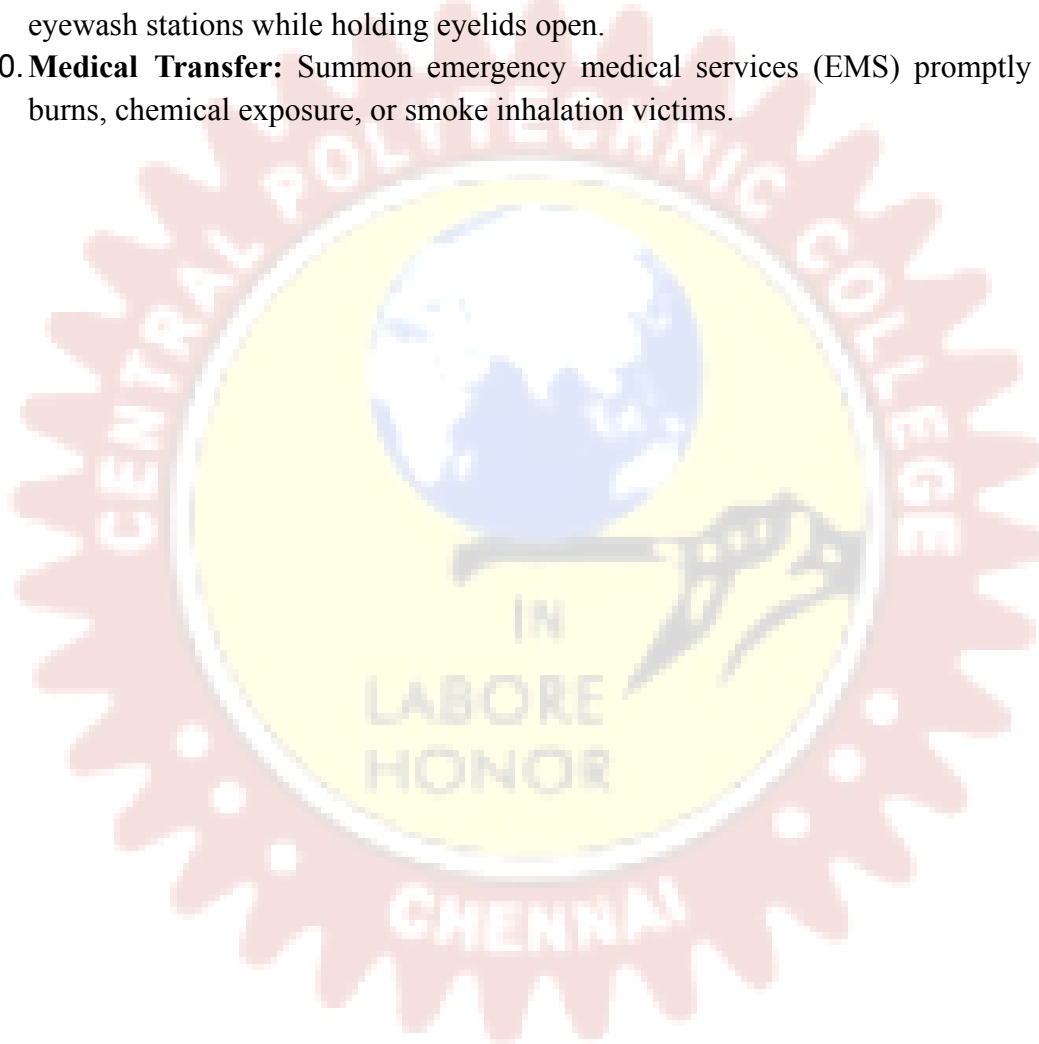
1. **Detection System Purpose:** Senses fire signatures (smoke, heat, flame) early to trigger automated alarms and suppression interlocks.
2. **Smoke Detectors:** Optical (photoelectric) and ionization sensors detect smoke particles in corridors and clean spaces.
3. **Heat Detectors:** Rate-of-rise and fixed-temperature thermal sensors operate in areas prone to dust or steam (e.g., kitchens, boiler rooms).
4. **Flame Detectors:** Optical sensors reacting to ultraviolet (UV) or infrared (IR) radiation from flames in hazardous tank yards.
5. **Manual Call Points (MCPs):** Break-glass call stations allowing building occupants to manually trigger alarms during emergencies.
6. **Alarm Control Panel (FACP):** The "brain" of the system that receives detector signals and initiates pre-programmed response actions.
7. **Addressable Systems:** Advanced FACPs pinpoint the exact detector address and location activated.
8. **Audible & Visual Alarms:** Sirens, horns, and flashing strobe lights alert all personnel across noisy industrial environments.
9. **Interlocks:** Automatic shutdown of HVAC air handlers, closing of fire dampers, and elevator homing to ground floors.
10. **Emergency Power:** Battery backups and emergency generators ensure detection and alarm systems operate during total power failure.

Q5. Discuss the planning, execution, and evaluative objectives of industrial fire drills, paired with standard first-aid protocols and emergency medical notices for handling thermal and chemical burn injuries.

10 Important Points:

1. **Fire Drill Objectives:** Train occupants on safe evacuation routes, assembly procedures, and familiarization with alarm sounds.
2. **Pre-Planning:** Establishing written evacuation procedures, assigning floor wardens, and identifying safe assembly points.
3. **Execution Phase:** Triggering unannounced alarms, initiating orderly single-file evacuation, and verifying headcount.
4. **Post-Drill Evaluation:** Analyzing evacuation times, bottlenecks, and warden performance to refine emergency plans.

5. **First Aid for Thermal Burns:** Immediately cool the burn under clean, running cool water for at least 10 to 20 minutes.
6. **Prohibition of Ice:** Never apply ice directly to burns, as extreme cold causes vasoconstriction and deepens tissue injury.
7. **Blister Management:** Never pop or puncture burn blisters; unbroken skin acts as a natural sterile barrier against infection.
8. **Chemical Burn Protocol:** Flush chemical splashes continuously with large volumes of water for at least 20 minutes.
9. **Eye Splashing Care:** For chemical eye splashes, irrigate immediately using emergency eyewash stations while holding eyelids open.
10. **Medical Transfer:** Summon emergency medical services (EMS) promptly for severe burns, chemical exposure, or smoke inhalation victims.



UNIT 4: INDUSTRIAL FIRE PROTECTION SYSTEMS

Q1. Compare and contrast wet-pipe automatic sprinkler systems, deluge water spray systems, and water emulsifier installations, detailing their engineering design criteria and application suitability in industrial plants.

10 Important Points:

1. **Wet-Pipe Sprinkler Systems:** Pipes are permanently filled with pressurized water up to closed, heat-activated sprinkler heads.
2. **Wet-Pipe Operation:** Individual sprinkler heads open independently only when exposed to their rated fusing temperature, minimizing water damage.
3. **Deluge Sprinkler Systems:** All sprinkler heads remain open permanently; water supply valve is controlled by a quick-opening deluge valve linked to fire detectors.
4. **Deluge Application:** Used in high-hazard areas where rapid fire spread requires instantaneous flooding (e.g., aircraft hangars, chemical plants).
5. **Water Emulsifier Systems:** Discharges fine water spray through specialized nozzles to form a non-flammable emulsion over heavy oil surfaces.
6. **Emulsifier Mechanism:** Combines cooling and emulsification to extinguish heavy oil and transformer fires safely.
7. **Design Criteria:** Based on hydraulic calculations, design density ($L/min/m^2$), and operating area coverage per NFPA standards.
8. **Water Supply Reliability:** Requires dedicated fire pumps and storage tanks capable of sustaining design flow rates.
9. **Freezing Protection:** Wet-pipe systems cannot be installed in unheated freezing areas (where dry-pipe systems are used instead).
10. **Suitability Summary:** Wet-pipes suit offices/warehouses; deluge systems suit high-hazard process units; emulsifiers suit electrical transformers.

Q2. Analyze total-flooding carbon dioxide (CO₂) systems, Dry Chemical Powder (DCP) systems, and modern halon replacement clean agents, evaluating their suppression mechanisms, design constraints, and environmental compliance.

10 Important Points:

1. **Total-Flooding CO₂ Systems:** Discharge carbon dioxide gas into enclosed spaces, displacing oxygen below the 15% combustion threshold.
2. **CO₂ Safety Hazard:** Poses severe asphyxiation hazards to personnel in occupied rooms, requiring pre-discharge alarms and evacuation delays.
3. **Dry Chemical Powder (DCP) Systems:** Discharge fine powders (sodium bicarbonate or monoammonium phosphate) to interrupt combustion chain reactions.

4. **DCP Advantage & Mess:** Provides rapid knockdown on Class B/C fires, but leaves corrosive residues that damage electrical equipment.
5. **Clean Agents Definition:** Gaseous suppression agents (e.g., FM-200, Novec 1230, Inergen) that suppress fires cleanly without leaving residue.
6. **Clean Agent Mechanism:** Extinguishes fires primarily via heat absorption and chemical chain inhibition while remaining safe for human occupancy.
7. **Halon Phase-Out:** Traditional halons were banned globally under the Montreal Protocol due to extremely high stratospheric ozone depletion potential (ODP).
8. **Environmental Compliance:** Modern clean agents feature zero ODP and very low Global Warming Potential (GWP).
9. **Enclosure Integrity:** Gaseous systems require tight room enclosure integrity tests to ensure extinguishing concentration is retained during discharge.
10. **Application Suitability:** CO_2 suits un-manned generator rooms; clean agents suit data centers and telecommunication archives.

Q3. Define "fire load" and evaluate how fire-resistant construction materials, standardized fire testing procedures, and intumescent coatings contribute to structural fire protection.

10 Important Points:

1. **Fire Load Definition:** The total potential thermal energy (calorific value) released by the combustion of all contents and structural elements in a space, expressed in MJ/m^2 .
2. **Significance of Fire Load:** Determines required structural fire resistance ratings and sprinkler water design densities.
3. **Fire-Resistive Materials:** Materials like reinforced concrete, brick, and gypsum board that withstand high temperatures without collapsing.
4. **Standard Fire Testing:** Protocols like ASTM E119 / ISO 834 test building assemblies in gas furnaces subjected to standardized time-temperature curves.
5. **Furnace Curve:** Temperatures ramp up rapidly to over $1,000^{\circ}\text{C}$ over several hours to simulate severe compartment fires.
6. **Failure Criteria:** Assemblies are evaluated based on structural load-bearing collapse, temperature transmission limits, and flame penetration.
7. **Intumescent Coatings:** Specialized paints applied to structural steel that swell up to 50 times their thickness when heated.
8. **Intumescent Insulation:** The swollen char acts as a thick, insulating thermal barrier, delaying steel temperature rise for 1 to 2 hours.
9. **Spray-Applied Fire Resistive Materials (SFRM):** Cementitious or mineral fiber sprays applied directly to steel columns and beams.
10. **Composite Protection:** Combining fire load calculations with certified fire-resistant assemblies prevents premature structural collapse.

Q4. Analyze the concept of structural integrity during a severe industrial or building fire, detailing how load-bearing assemblies resist thermal degradation and prevent premature structural collapse.

10 Important Points:

1. **Structural Integrity Definition:** The ability of load-bearing building elements (beams, columns, floors) to support imposed gravity loads and resist collapse during fire exposure.
2. **Thermal Degradation of Steel:** Steel loses roughly 50% of its structural yield strength at 600°C , leading to plastic deformation and buckling.
3. **Thermal Expansion Stresses:** Uneven heating across structural frames induces internal thermal bending moments and shear stresses.
4. **Concrete Behavior:** Reinforced concrete retains strength longer than steel, but severe heat causes concrete spalling and rebar strength loss.
5. **Load Redistribution:** Intact structural bays redistribute loads around fire-weakened zones, preventing progressive collapse.
6. **Fireproofing Protection:** SFRM and board fireproofing delay heat penetration into primary structural framing.
7. **Compartmentation Support:** Maintaining wall and floor integrity prevents fire from breaching adjacent structural sectors.
8. **Failure Modes:** Floor sagging, column buckling, and beam-column connection pull-away are primary collapse mechanisms.
9. **Engineering Standards:** Designed using Eurocode or AISC structural fire engineering design guidelines.
10. **Post-Fire Assessment:** Structures exposed to severe fire require non-destructive testing (NDT) and metallurgical analysis before re-occupation.

Q5. Discuss the operational mechanics and benefits of natural versus mechanical smoke venting systems in large compartments, and explain how indices of inflammability govern chemical hazard assessment.

10 Important Points:

1. **Smoke Management Purpose:** Extracts hot toxic smoke and gases to maintain tenable visibility and temperature along escape routes.
2. **Natural Smoke Venting:** Uses buoyancy-driven thermal forces through roof vents or operable windows to exhaust smoke upward.
3. **Natural Vent Mechanics:** Hot smoke rises to the ceiling layer; pressure differentials push smoke outward through open roof hatches.
4. **Mechanical Smoke Venting:** Uses mechanical exhaust fans and ductwork to forcibly draw smoke out of large compartments (e.g., atriums, basements).
5. **Make-Up Air Supply:** Mechanical systems require filtered low-level fresh air intake to replace exhausted smoke and maintain neutral pressure planes.
6. **Combination Systems:** Many large facilities integrate both natural gravity roof vents and mechanical exhaust fans.
7. **Indices of Inflammability:** Quantitative metrics evaluating the relative ease of ignition and flammability severity of dusts, gases, or liquids.
8. **Dust Explosion Index (K_{st}):** Measures maximum rate of pressure rise for combustible dust clouds in industrial silos.
9. **Flammability Limits (LEL/UEL):** Defines compositional concentration ranges where vapor-air mixtures can ignite.
10. **Hazard Assessment Integration:** Combining smoke venting design with inflammability indices ensures comprehensive industrial explosion protection.

UNIT 5: COMMON AND SPECIAL HAZARDS

Q1. Analyze electricity as a primary industrial ignition source, detailing how resistive heating, short circuits, arcs, and sparks occur, and evaluate how the National Electric Code (NEC) classifies hazardous locations and divisions to prevent explosions.

10 Important Points:

1. **Electrical Ignition Hazards:** Electricity causes fires through Joule heating, overloads, loose connections, electrical arcs, and sparks.
2. **Joule Heating (I^2R):** Excessive current flow through undersized wiring generates high thermal resistance heat, melting insulation.
3. **Short Circuits:** Direct contact between live conductors bypasses electrical load resistance, creating massive current surges and sparks.
4. **Electrical Arcing:** High-temperature luminous electric arcs bridge gaps between damaged conductors, generating thousands of degrees.
5. **Static Sparks:** Electrostatic discharges ignite flammable vapors during unbonded liquid transfers.
6. **NEC Hazardous Classifications:** The National Electrical Code classifies explosive atmospheres into Classes, Divisions, and Groups.
7. **Class I Locations:** Areas containing flammable gases, vapors, or liquids in quantities sufficient to produce explosive atmospheres.
8. **Class II Locations:** Areas rendered hazardous by the presence of combustible dusts (e.g., grain elevators, flour mills).
9. **Division 1 vs. Division 2:** Division 1 indicates continuous/normal hazard presence; Division 2 indicates abnormal/failure hazard presence.
10. **Explosion-Proof Equipment:** Electrical enclosures designed to contain internal explosions and cool escaping gases below ignition temperatures.

Q2. Compare and contrast flammable and combustible liquids based on flash point criteria, and critically analyze the significance of Upper Explosive Limits (UEL) and Lower Explosive Limits (LEL) in evaluating vapor-air explosion risks and safe operating envelopes.

10 Important Points:

1. **Flammable Liquids (NFPA Criteria):** Liquids having a flash point below 37.8°C (100°F) and vapor pressures below 40psia.
2. **Combustible Liquids (NFPA Criteria):** Liquids having a flash point at or above 37.8°C (100°F).
3. **Volatility Difference:** Flammable liquids vaporize readily at ambient temperatures, presenting severe continuous fire hazards.
4. **Lower Explosive Limit (LEL):** The minimum fuel vapor concentration in air below which flame propagation cannot occur ("too lean to burn").

5. **Upper Explosive Limit (UEL):** The maximum fuel vapor concentration above which flame propagation cannot occur ("too rich to burn").
6. **Explosive Envelope:** The concentration range between LEL and UEL where vapor-air mixtures are explosive.
7. **Stoichiometric Mixture:** The ideal chemical balance of fuel and oxygen producing maximum explosion pressure.
8. **Temperature Effect on Limits:** Higher ambient temperatures lower LEL and raise UEL, widening the dangerous explosive envelope.
9. **Inerting Practice:** Purging vessels with nitrogen to keep oxygen levels below Minimum Oxygen Concentration (MOC) prevents explosions.
10. **Storage Rules:** Flammable liquids require strict bonding, grounding, flame arresters, and approved safety storage cabinets.

Q3. Contrast Above Ground Storage Tanks (ASTs) and Underground Storage Tanks (USTs) regarding structural design, corrosion protection (cathodic protection), leak detection capabilities, emergency venting devices, and containment bunds.

10 Important Points:

1. **Above Ground Storage Tanks (ASTs):** Tanks situated entirely above grade, used for bulk petroleum and chemical storage.
2. **Underground Storage Tanks (USTs):** Tanks buried beneath ground level, commonly used at retail service stations.
3. **AST Inspection & Containment:** ASTs permit direct visual inspection for leaks and require secondary containment dikes (bunds) holding 110% of tank volume.
4. **UST Hidden Risks:** UST leaks remain hidden, risking undetected soil and groundwater contamination and explosive vapor migration into basements.
5. **Corrosion Protection:** USTs require double-walled fiberglass/steel construction coupled with cathodic protection (sacrificial anodes).
6. **Emergency Venting (ASTs):** ASTs require emergency relief vents (ERVs) to relieve overpressure caused by external pool fires, preventing tank BLEVEs.
7. **Leak Detection Systems:** USTs utilize automated interstitial monitoring sensors to detect fluid leaks between double walls.
8. **Foundation Design:** ASTs require engineered concrete foundation ring walls; USTs require stable backfill and anchoring to prevent buoyancy uplift.
9. **Regulatory Standards:** Governed strictly by NFPA 30 and EPA underground storage environmental regulations.
10. **Maintenance Access:** ASTs offer easy access for maintenance painting and shell repairs compared to excavated USTs.

Q4. Analyze the unique fire and explosion hazards associated with Hydrogen gas—focusing on its wide flammability limits, high buoyancy, and low ignition energy—and discuss safe handling, leak detection, and ventilation practices.

10 Important Points:

1. **Hydrogen Properties:** Hydrogen is the lightest element, highly diffusive, odorless, colorless, and burns with a nearly invisible flame.
2. **Wide Flammability Range:** Flammability limits in air span from 4% to 75% by volume, making ignition extremely easy.
3. **Extremely Low Ignition Energy:** Requires only 0.017mJ of spark energy to ignite—nearly ten times less than hydrocarbon gases.
4. **High Buoyancy & Diffusion:** Hydrogen is 14 times lighter than air and diffuses rapidly upward at high velocities.
5. **Invisible Flame Hazard:** Hydrogen flames emit ultraviolet radiation with virtually no visible luminosity in daylight, risking severe unseen burns.
6. **Hydrogen Embrittlement:** Hydrogen penetrates metal crystal lattices, causing micro-cracking and catastrophic pipeline failures.
7. **Leak Detection Systems:** Requires specialized electrochemical or catalytic hydrogen leak detectors tied to emergency shutdown valves.
8. **Ventilation Requirements:** High-level roof ridge ventilation prevents hydrogen from pocketing under building ceilings.
9. **Electrical Classification:** Requires explosion-proof electrical fittings rated for Group B (Hydrogen) hazardous locations.
10. **Safe Handling Standards:** Managed via ISO/NFPA standards requiring seamless stainless steel piping and continuous nitrogen purging.

Q5. Examine the physical properties, storage behavior, and vapor density hazards of Liquefied Petroleum Gas (LPG), and synthesize a comprehensive hazard mitigation plan for facilities handling compressed and liquefied fuel gases.

10 Important Points:

1. **LPG Composition:** A mixture of hydrocarbon gases, primarily propane (C_3H_8) and butane (C_4H_{10}), stored as liquids under moderate pressure.
2. **Vapor Density Hazard:** LPG vapor is approximately 1.5 to 2 times heavier than air, causing it to flow along the ground and pool in low points, trenches, and drains.
3. **Odorization:** Ethyl mercaptan is added to odorless LPG to give it a distinctive rotten-egg smell for leak detection.
4. **Expansion Ratio:** Liquid LPG expands significantly upon vaporization, producing large volumes of flammable gas.
5. **BLEVE Risk:** Pressurized LPG tanks exposed to fire face catastrophic BLEVE hazards if shell cooling fails.

6. **Storage Regulations:** Stored in certified pressure vessels (bullets or spherical tanks) equipped with pressure relief valves (PRVs).
7. **Mitigation - Siting & Zoning:** Locate storage yards outdoors in well-ventilated areas away from ignition sources and property boundaries.
8. **Mitigation - Water Spray Systems:** Install fixed water deluge cooling rings around storage tanks to prevent vessel wall weakening during fires.
9. **Mitigation - Gas Detection & ESD:** Equip facilities with continuous LEL gas detectors linked to automated Emergency Shutdown (ESD) valves.
10. **Emergency Response Plan:** Coordinate with municipal fire brigades, enforce strict hot work permits, and maintain dry powder/water monitor defenses.

