ForumIAS

Prelims Marathon

4th week May, 2026

HISTORY
ECONOMICS
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SCIENCE AND TECHNOLOGY
GEOGRAPHY AND ENVIRONMENT

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Conventional and Alternative Energy-II

1. Consider the following statements regarding energy conversion devices:

1. In a fuel cell, fuel undergoes reduction at the anode to release free electrons, while an oxidant combines with protons at the cathode to generate water.
2. During the charging cycle of a standard storage battery, external electrical energy forces active ions to migrate from the cathode back to the anode.
3. Unlike standard batteries, fuel cells convert chemical energy directly into electrical energy without relying on a distinct internal electrolyte barrier.

Which of the statements given above is/are correct?

(a) 1 and 2 only
(b) 2 only
(c) 1 and 3 only
(d) 1, 2 and 3

Correct Answer: (b)

Explanation:

- **Statement 1 is incorrect:** In a fuel cell, the fuel (typically hydrogen) undergoes oxidation at the anode, not reduction, to release electrons and protons. Reduction happens at the cathode, where electrons and protons combine with oxygen to form water.
- **Statement 2 is correct:** During the discharge cycle of a battery, ions move from the anode to the cathode to generate a current. When charging, this chemical process is reversed by an external voltage, driving ions from the cathode back to the anode.
- **Statement 3 is incorrect:** Fuel cells, like batteries, require an electrolyte barrier to separate the anode and cathode. This electrolyte selectively allows protons to pass through while forcing electrons to travel along an external circuit to generate electricity.

2. Consider the following statements regarding India's energy storage infrastructure:

1. Advanced Chemistry Cells (ACCs) are designed to store electric energy using mechanical potential configurations to completely eliminate chemical degradation.
2. The National Programme on Advanced Chemistry Cell (ACC) Battery Storage mandates a 100% export target.
3. Under the associated Production-Linked Incentive (PLI) scheme, the government offers financial incentives exclusively to foreign sovereign entities to build battery manufacturing plants in India.

Which of the statements given above is/are correct?

(a) 1 and 2 only
(b) 2 and 3 only
(c) 1, 2 and 3
(d) None of the statements

Correct Answer: (d)

Explanation

- **All statements are incorrect:**
    - **Statement 1 is incorrect:** ACCs store electric energy through advanced chemical processes, not mechanical potential configurations. They are electrochemical systems, such as advanced lithium-ion chemistries.

- **Statement 2 is incorrect:** The primary goal of the National Programme on ACC Battery Storage is to satisfy domestic demand for electric vehicles and renewable energy storage, thereby decreasing India's reliance on imports.
- **Statement 3 is incorrect:** The PLI scheme is structured to encourage domestic manufacturing by domestic, foreign, or joint-venture corporate companies. It aims to develop local supply chains, attract private capital, and scale up domestic production capacities.

3. Which one of the following combinations correctly identifies the standard architectural components used in a Sodium-Ion battery cell?

(a) Anode: Graphite; Cathode: Pure Metallic Lithium; Electrolyte: Aqueous Zinc Sulfate
(b) Anode: Hard Carbons; Cathode: Layered Oxides; Electrolyte: Sodium Salt in an Organic Solvent
(c) Anode: Silicon Nanowires; Cathode: Polyborate Crystals; Electrolyte: Liquid Hydrogen Fuel
(d) Anode: Cadmium Compounds; Cathode: Carbon Composites; Electrolyte: Sulfuric Acid Solution

Correct Answer: (b)

Explanation

- Sodium-ion batteries are a promising alternative to lithium-ion systems due to the high abundance and lower cost of sodium raw materials. They operate on a similar intercalation mechanism where sodium ions shuttle between electrodes.
- Their specific chemistry requires hard carbons at the anode (since standard graphite cannot easily hold larger sodium ions), layered transition-metal oxides or polyanionic compounds at the cathode, and a specialized sodium salt dissolved in a non-aqueous organic solvent as the electrolyte.

4. Consider the following statements regarding Lithium-Ion battery cells:

1. During the charging cycle, lithium ions move through the internal electrolyte from the positive cathode to the negative anode.
2. Cobalt, lithium, and nickel are the primary metallic elements used to construct the anode, determining the overall safety and cost of the battery cell.
3. Graphite is a highly versatile carbon material that is used exclusively in the anode structure of electric vehicle lithium-ion batteries.
4. The porous separator membrane inside the cell is designed to enable the continuous flow of electrons while completely blocking ion transport to maximize power.

Which of the statements given above are correct?

(a) 1 and 3 only
(b) 2 and 4 only
(c) 1, 2 and 4
(d) 1 and 4 only

Correct Answer: (a)

Explanation

- **Statement 1 is correct:** When charging a lithium-ion battery, lithium ions are de-intercalated from the cathode and travel through the electrolyte to embed themselves into the anode structure.
- **Statement 2 is incorrect:** Cobalt, lithium, and nickel are utilized to form the cathode (positive electrode), not the anode. The cathode composition determines the energy density, lifespan, and cost of electric vehicle batteries.
- **Statement 3 is correct:** Graphite is used exclusively in the anode (negative electrode) due to its layered structure, which safely stores and releases lithium ions during cycling.

- **Statement 4 is incorrect:** The porous separator does the exact opposite: it is an electronic insulator that blocks electron flow to prevent short circuits, while allowing the smooth transport of ions.

5. Consider the following statements regarding mechanical energy storage devices:

1. Gravity batteries capture and store energy by lowering heavy masses during peak generation and elevating them during low production periods.
2. These energy storage systems utilize heavy masses, mechanical cranes or elevators, and a generator-linked release mechanism to convert gravitational potential energy into electricity.

Which of the statements given above is/are correct?

(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Correct Answer: (b)
Detailed Explanation

- **Statement 1 is incorrect:** Gravity batteries work by elevating heavy masses (using surplus power from wind or solar grids) to store energy as gravitational potential energy. They lower these masses to spin a generator and release electricity when the grid experiences high power demand.
- **Statement 2 is correct:** The core infrastructure requires heavy weights, a mechanical structure like cranes, shafts, or elevators to raise them, and a generator/motor assembly that converts kinetic energy back into grid electricity during descent.

6. Consider the following statements regarding the real-world deployment of Hydrogen Fuel Cells:

1. At the anode of a hydrogen fuel cell, hydrogen molecules split into protons and electrons, creating a usable electric current through an external circuit.
2. Hydrogen fuel cells are limited to low-power portable electronics and cannot be deployed in heavy-duty commercial transport or stationary building grids.
3. These fuel cell networks can be integrated with variable renewable systems like solar or wind power to balance fluctuating grid supplies.

Which of the statements given above are correct?

(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

Correct Answer: (c)
Detailed Explanation

- **Statements 1 and 3 are correct:** Hydrogen splitting at the anode provides the electrons that drive the electric circuit. Because hydrogen can be stored long-term as a compressed gas, it serves as an excellent balancing medium. It can store excess energy from solar or wind farms and convert it back into electricity when generation drops.
- **Statement 2 is incorrect:** Hydrogen fuel cells are highly scalable. They are well-suited for heavy-duty, long-range transportation (such as commercial trucks, trains, and maritime ships) and stationary backup power grids, making them a versatile alternative to fossil fuels.

7. Consider the following statements regarding advanced bio-energy systems:

1. Microbial Fuel Cells (MFCs) leverage inorganic chemical catalysts rather than living microorganisms to convert chemical bonds into electricity.
2. In an MFC, specialized bacteria colonize the anode and oxidize organic compounds, generating free electrons and protons in the process.
3. Due to their high-power output density, MFC arrays serve as the primary source of propulsion energy for commercial supersonic aircraft.

Which of the statements given above are correct?

(a) 1 and 2 only
(b) 2 only
(c) 1 and 3 only
(d) 1, 2 and 3

Correct Answer: (b)

Detailed Explanation

- **Statement 1 is incorrect:** MFCs rely on living microorganisms (bacteria) as biocatalysts to break down organic substrate materials, eliminating the need for expensive precious metal catalysts.
- **Statement 2 is correct:** The biological action takes place at the anode, where electrochemically active bacteria digest organic matter, transferring electrons to the electrode surface and releasing protons into the solution.
- **Statement 3 is incorrect:** MFCs typically produce a low power density. They are not suitable for high-power industrial propulsion like aircraft. Instead, they are used for wastewater treatment (cleaning organic pollutants while generating localized power), low-power environmental biosensors, and remote monitoring equipment.

8. Consider the following statements regarding nuclear fusion research initiatives:

1. The International Thermonuclear Experimental Reactor (ITER) utilizes a tokamak configuration to confine superheated plasma using powerful magnetic fields.
2. India's domestic nuclear fusion research and experimental tokamak developments are spearheaded by the Institute for Plasma Research (IPR) in Gandhinagar, Gujarat.
3. ADITYA was India's first indigenously designed and built tokamak, which was later upgraded into the operational ADITYA-U system.
4. The Steady State Superconducting Tokamak (SST-1) at IPR utilizes advanced superconducting magnets to study steady-state plasma operations.

Which of the statements given above are correct?

(a) 1 and 3 only
(b) 2 and 4 only
(c) 1, 2 and 3
(d) 1, 2, 3 and 4

Correct Answer: (d)

Explanation

- All four statements are correct. The tokamak concept uses a torus-shaped magnetic field configuration to isolate high-temperature plasma from reactor walls, which is essential for sustaining a fusion reaction between deuterium and tritium.
- India is a full member state of the global ITER project. Locally, the IPR has successfully engineered and operated the ADITYA-U and SST-1 facilities, building the technological foundation for future fusion reactors like the planned SST-2.

9. Consider the following statements regarding low-energy nuclear reactions:

1. Cold fusion describes a hypothetical nuclear reaction that takes place at or close to ambient room temperatures, contrasting with the high-temperature fusion seen in stars.
2. There is currently a universally accepted, peer-reviewed theoretical model and widespread scientific replication verifying cold fusion energy production.

Which of the statements given above is/are correct?

(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Correct Answer: (a)

Detailed Explanation

- **Statement 1 is correct:** Cold fusion is a conceptual form of nuclear energy generation. Unlike hot fusion, which requires temperatures of millions of degrees to overcome the electrostatic repulsion between atomic nuclei, cold fusion aims to initiate reactions near room temperature.
- **Statement 2 is incorrect:** There is no accepted theoretical model or reproducible experimental evidence for cold fusion within the mainstream scientific community. Most initial claims have failed rigorous verification and peer-review trials, leaving the concept on the fringes of nuclear physics.

10. Consider the following statements regarding the structural components of a standard nuclear power reactor:

1. Control rods are constructed from neutron-absorbing materials like boron or cadmium to regulate the rate of the fission chain reaction.
2. The primary function of a nuclear moderator is to speed up fast-moving neutrons to ensure they escape the reactor core without splitting heavy fuel atoms.
3. Materials such as heavy water, helium gas, or ordinary water can serve as a coolant to transfer thermal energy away from the reactor core.
4. The steam generator acts as a safety barrier by turning liquid fuel directly into gaseous plasma to drive electrical turbines.

Which of the statements given above are correct?

(a) 1 and 3 only
(b) 2 and 4 only
(c) 1, 2 and 3
(d) 1 and 4 only

Correct Answer: (a)

Explanation

- **Statement 1 is correct:** Control rods manage the reactor's power output. By sliding into the core, they absorb excess neutrons, slowing or stopping the fission chain reaction as needed.
- **Statement 2 is incorrect:** The moderator is designed to slow down fast neutrons, turning them into thermal neutrons. Slower neutrons have a much higher probability of being captured by Uranium-235 nuclei to sustain steady fission.
- **Statement 3 is correct:** Coolants carry the intense heat generated by nuclear fission away from the fuel rods, preventing meltdowns and delivering thermal energy to power generation units.
- **Statement 4 is incorrect:** The steam generator does not process liquid fuel or create plasma. It is a heat exchanger that transfers heat from the isolated reactor coolant loop to a separate water loop, turning water into clean steam to drive electrical turbines.

Nuclear Energy

1. Consider the following statements regarding Pressurized Heavy Water Reactors (PHWRs):

1. They utilize heavy water (deuterium oxide, D_2O) to serve simultaneously as the core coolant and the neutron moderator.
2. PHWR blocks require highly enriched uranium fuel containing over 20% Uranium-235 to maintain steady fission chain reactions.
3. Boron-based control rods are mechanically adjusted within the reactor core to regulate total power output by absorbing excess neutrons.

Which of the statements given above are correct?

(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

Correct Answer: (c)

Explanation

- **Statements 1 and 3 are correct:** PHWRs use heavy water (D_2O) as both a coolant to carry away heat and a moderator to slow down fast neutrons. Control rods made of neutron-absorbing materials like Boron or Cadmium regulate or halt the fission chain reaction.
- **Statement 2 is incorrect:** A defining feature of PHWR design is its ability to run on natural, unenriched uranium (which consists mostly of Uranium-238 with only about 0.7% fissile Uranium-235). The excellent neutron economy of heavy water moderators makes expensive enrichment facilities unnecessary.

2. Consider the following statements regarding Small Modular Reactors (SMRs):

1. SMRs are defined as advanced commercial nuclear reactors maintaining a maximum electrical power generation capacity profile of up to 300 MW(e) per unit.
2. Their compact design allows for complete structural fabrication inside a factory before being transported to a site for rapid deployment.

Which of the statements given above is/are correct?

(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Correct Answer: (c)

Explanation

- Both statements are correct. SMRs represent a major innovation in nuclear energy. They address the high capital costs and long construction timelines of traditional, large-scale nuclear facilities by providing a smaller footprint, easier scaling, and modular construction.

3. Consider the following statements regarding Gas-Cooled Reactors (GCRs):

1. GCRs use high-velocity gases, such as helium or carbon dioxide, as a coolant to transfer thermal energy from the reactor core.
2. Because gas coolants are prone to chemical breakdown at high temperatures, GCR thermal efficiencies are strictly capped at 15%.

Which of the statements given above is/are correct?

(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Correct Answer: (a)
Explanation

- **Statement 1 is correct:** GCR architectures use inert or stable gases like helium or carbon dioxide to absorb and move heat from the reactor core to the steam turbines.
- **Statement 2 is incorrect:** GCRs operate at high temperatures, which allows them to achieve high thermal efficiencies of up to 50%. Because they generate high temperatures safely, these reactors can also support secondary industrial applications, such as high-efficiency water desalination and thermochemical hydrogen production.

4. Consider the following statements regarding Light Water Reactors (LWRs):

1. LWRs rely on ordinary water (H_2O) to function as both the core coolant fluid and the primary neutron moderator.
2. In a Boiling Water Reactor (BWR), high-pressure water is kept from boiling in a primary loop, transferring its heat to a separate secondary loop to generate steam.

Which of the statements given above is/are correct?
(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Correct Answer: (a)
Explanation

- **Statement 1 is correct:** LWRs use ordinary, highly purified water as both a coolant and a moderator. This distinguishes them from reactors that use heavy water (D_2O) or liquid metals.
- **Statement 2 is incorrect:** The statement describes a Pressurized Water Reactor (PWR), not a Boiling Water Reactor (BWR). In a BWR, water boils directly inside the reactor core to produce steam that drives the turbine. A PWR keeps the primary coolant under high pressure to prevent boiling, using a steam generator to pass heat to a secondary water circuit.

5. Consider the following statements regarding Fast Reactors:

1. Fast reactors utilize high-energy, unmoderated fast neutrons to convert non-fissile Uranium-238 into fissile Plutonium-239 through a process called fuel breeding.
2. These systems require large amounts of heavy water moderators to increase the velocity of fast neutrons for efficient interactions with Uranium-238.

Which of the statements given above is/are correct?
(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Correct Answer: (a)
Explanation

- **Statement 1 is correct:** Fast reactors do not slow down neutrons. Instead, they use fast neutrons to sustain fission and transmute abundant, non-fissile Uranium-238 into fissile Plutonium-239, breeding more fuel than they consume.
- **Statement 2 is incorrect:** Fast reactors operate without any neutron moderators. Adding a moderator like heavy water or ordinary water would slow down the neutrons into the thermal spectrum, preventing the breeding reactions with Uranium-238.

6. Consider the following statements regarding Radioisotope Thermoelectric Generators (RTGs):

1. RTGs convert the thermal energy released by the natural decay of radioactive isotopes directly into electricity without using moving parts.
2. The operational generation of electrical current in an RTG relies on creating a temperature difference across thermoelectric materials, leveraging the Seebeck effect.
3. Liquid Hydrogen is the most commonly used radioisotope heat source in space-bound RTGs due to its long, multi-century radioactive decay half-life.

Which of the statements given above are correct?

(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

Correct Answer: (a)

Explanation

- **Statements 1 and 2 are correct:** RTGs are highly reliable, solid-state power sources often used in deep-space missions. They use the Seebeck effect to convert the heat from natural radioactive decay directly into electricity across a specialized thermocouple framework, removing the need for mechanical turbines.
- **Statement 3 is incorrect:** Liquid hydrogen is a non-radioactive chemical rocket fuel, not a radioactive isotope. The most common isotope used in RTGs is Plutonium-238 because its high thermal energy output, safe alpha-radiation profile, and favorable 87.7-year half-life provide steady power for decades.

7. Consider the following statements regarding the developmental stages of India's domestic nuclear energy framework:

1. Stage I relies on Pressurized Heavy Water Reactors (PHWRs) fueled by natural uranium to generate electricity while producing Plutonium-239 as a spent-fuel byproduct.
2. Stage II utilizes Fast Breeder Reactors (FBRs) fueled by Plutonium-239 to breed additional plutonium from a blanketing layer of Uranium-238.
3. India's first commercial, domestic 500 MWe Fast Breeder Reactor (PFBR), constructed at Kalpakkam in Tamil Nadu, successfully commenced its core fuel loading phase on March 4, 2024.
4. Stage III is designed as a long-term strategy to utilize India's extensive domestic thorium reserves, using advanced reactors to breed fissile Uranium-233 from Thorium-232.

Which of the statements given above are correct?

(a) 1 and 3 only
(b) 2 and 4 only
(c) 1, 2 and 4 only
(d) 1, 2, 3 and 4

Correct Answer: (d)

Explanation

- All four statements are correct. India's three-stage nuclear strategy was designed by Homi J. Bhabha to maximize energy independence by making step-by-step use of the country's limited uranium and abundant thorium reserves. Stage I produces plutonium fuel, Stage II scales up plutonium breeding while producing Uranium-233, and Stage III deploys self-sustaining thorium-cycle reactors.

8. Consider the following statements regarding Stage III of India's nuclear program:

1. The primary goal of Stage III is to utilize Thorium-232 as a fertile blanket material, transmuting it into fissile Uranium-233 to tap into India's vast thorium reserves.
2. India holds a major global share of thorium resources, with large concentrations of monazite sands found along its coastal plains.
3. The public sector enterprise Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI), under the Department of Atomic Energy, was established explicitly to manage Stage I commercial light-water reactor imports.
4. Thorium-232 can sustain a commercial nuclear fission chain reaction directly inside a reactor without requiring any external fissile starter fuel.

Which of the statements given above are correct?

(a) 1 and 2 only
(b) 3 and 4 only
(c) 1, 2 and 4
(d) 1, 2 and 3

Correct Answer: (a)

Explanation

- **Statements 1 and 2 are correct:** India holds approximately 25% of global thorium reserves, mostly in monazite sands along coastal stretches like Kerala and Tamil Nadu. Converting fertile Thorium-232 into fissile Uranium-233 forms the core of India's long-term energy strategy.
- **Statement 3 is incorrect:** BHAVINI was set up specifically to guide Stage II of the nuclear program, focusing on building and operating fast breeder reactors (like the PFBR at Kalpakkam), not managing Stage I light-water reactor imports.
- **Statement 4 is incorrect:** Thorium-232 is fertile, not fissile. It cannot sustain a nuclear chain reaction on its own. It must first be placed inside a reactor alongside a fissile driver fuel (like Plutonium-239 or Uranium-235) to absorb neutrons and transform into fissile Uranium-233.

9. Consider the following statements regarding nuclear safety systems:

1. The Atomic Energy Regulatory Board (AERB) operates as an independent body in India, responsible for enforcing safety standards and issuing licenses for nuclear facilities.
2. The International Atomic Energy Agency (IAEA) serves as a global governing body with direct legal authority to shut down domestic nuclear plants within sovereign member states.
3. The World Association of Nuclear Operators (WANO) is a non-governmental international body that promotes safety and collaboration among nuclear power plant operators worldwide.

Which of the statements given above are correct?

(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

Correct Answer: (c)

Explanation

- **Statements 1 and 3 are correct:** The AERB oversees nuclear and radiation safety regulations across India. WANO connects commercial operators globally to share best practices and conduct peer reviews to improve safety standards.
- **Statement 2 is incorrect:** The IAEA does not have sovereign legal authority to enforce laws or order the shutdown of domestic nuclear facilities within member states. It functions as an advisory and monitoring organization, providing safety guidelines and verification safeguards that countries adopt voluntarily through bilateral agreements.

10. Consider the following statements regarding nuclear fuel resources:

1. India ranks as the world's largest producer of uranium ore, mining over 85% of global reserves from domestic deposits.
2. Natural uranium consists of approximately 99.3% non-fissile Uranium-238 and only about 0.7% fissile Uranium-235.
3. Low-Enriched Uranium (LEU) features a Uranium-235 concentration increased above natural levels but kept below 20%, serving as fuel for commercial nuclear power plants.
4. Highly Enriched Uranium (HEU) contains a Uranium-235 concentration of 20% or higher, and has historically been used in military applications and nuclear weapons.

Which of the statements given above are correct?

(a) 1, 2 and 3
(b) 2, 3 and 4
(c) 1 and 4 only
(d) 1, 2 and 4

Correct Answer: (b)

Explanation

- **Statements 2, 3, and 4 are correct:** Natural uranium requires enrichment because standard light-water reactors need a higher concentration of fissile U-235 (3-5% LEU) to maintain fission. Concentrations of 20% or more are classified as HEU, which is used in specialized research reactors or military weapons.
- **Statement 1 is incorrect:** India is **not** the world's largest producer of uranium (ranking 15th in estimated reserves). India relies on imports from international partners like Kazakhstan, Russia, and Australia to fuel its growing commercial nuclear fleet.

Nuclear Energy-I

1. This heavy, naturally occurring radioactive element is predominantly found inside coastal monazite beach sands, zircon, and ilmenite placer deposits. While inland pegmatite reserves exist, its highest geographic concentrations are distributed along the coastal stretches of Andhra Pradesh (31%), Tamil Nadu (22%), and Odisha (20%). Identify this specific fuel resource:

(a) Actinates-225
(b) Thorium
(c) Highly Enriched Uranium
(d) Polonium-210

Correct Answer: (b)

Explanation:

- India holds some of the world's largest reserves of Thorium, which is a foundational component of the nation's long-term three-stage nuclear energy roadmap.
- Thorium is found in heavy mineral sand assemblages like monazite, zircon, and ilmenite. Geographically, its largest placer deposits are distributed along India's eastern and southern coasts. State-wise mapping data indicates that Andhra Pradesh holds the largest share (31%), followed by Tamil Nadu (22%), Odisha (20%), and Kerala (12%).

2. Consider the following comparative matrix between Thorium and Uranium systems:

Row	Aspect	Thorium	Uranium
1.	Nuclear Reactor Use	Specifically integrated into Advanced Heavy Water Reactors (AHWRs).	Widely deployed in Pressurized Water Reactors (PWRs) and Boiling Water Reactors (BWRs).
2.	Fertile Material	Thorium-232 transutes into fissile Uranium-233.	Uranium-238 transmutes into fissile Plutonium-239.
3.	Proliferation Risks	Lower weapon-grade extraction risks due to non-fissile natural states.	Higher proliferation concerns in traditional open/closed fuel cycles.
4.	Fuel Cycle Output	Produces alpha-emitting waste that requires high-velocity moderators.	Leaves a spent fuel stream containing diverse radioactive fission products.

How many of the rows presented above are correctly matched?

(a) Only one row
(b) Only two rows
(c) Only three rows
(d) All four rows

Correct Answer: (c)

Explanation:

· **Rows 1, 2, and 3 are correctly matched:** Thorium and Uranium are both fertile isotopes that require neutron absorption to yield fissile fuels (U-233 and Pu-239, respectively). Thorium is highly suited for India's domestic AHWR designs and offers lower nuclear proliferation risks compared to standard Uranium enrichment pathways.

· **Row 4 is incorrectly matched:** The fuel cycle output properties for Thorium do not involve alpha-emitting waste requiring high-velocity moderators. Instead, the Thorium fuel cycle operates by breeding fissile Uranium-233, which produces significantly lower volumes of long-lived transuranic nuclear waste compared to the conventional Uranium-Plutonium fuel cycle.

3. Consider the following statements regarding the evolution of India's nuclear energy program:

1. The Tata Institute of Fundamental Research (TIFR) was established in 1945 by Homi J. Bhabha to lay the scientific foundation for nuclear research.
2. The early structural milestone of connecting India's commercial nuclear power grid to the Tarapur Atomic Power Station was achieved in 1969.

3. India's historic first peaceful nuclear explosive test, code-named "Smiling Buddha," was conducted in the year 1954.
4. The Nuclear Power Corporation of India Limited (NPCIL), which manages the operations of commercial nuclear power reactors, was created during the pre-independence phase in 1940.

Which of the statements given above are correct?

(a) 1 and 2 only
(b) 2 and 4 only
(c) 1, 3 and 4
(d) 1 and 4 only

Correct Answer: (a)

Explanation:

- **Statements 1 and 2 are correct:** TIFR (1945), the Atomic Energy Commission (1948), and the Department of Atomic Energy (1954) formed the early institutional framework of India's nuclear program. The commissioning of the Tarapur plant in 1969 marked the official beginning of commercial nuclear power generation in the country.
- **Statement 3 is incorrect:** The Smiling Buddha nuclear test at Pokhran was conducted in **1974**, not 1954.
- **Statement 4 is incorrect:** NPCIL was established as a public sector enterprise under the Department of Atomic Energy in 1987, not 1940.

4. Match the following scientific organizations with their core institutional mandates:

Column I (Institution)	**Column II (Primary Functional Mandate)**
A. DAE	1. Premier multidisciplinary facility executing peaceful applications of nuclear science.
B. BARC	2. Apex administrative department overseeing nuclear energy programs and policy.
C. GCNEP	3. Field agency responsible for exploration, resource assessment, and mapping of atomic minerals.
D. AMD	4. Global facility facilitating international collaboration, expert exchanges, and advanced training.

Which of the following options represents the correct matching pairs?

(a) A-1, B-2, C-3, D-4
(b) A-2, B-1, C-4, D-3
(c) A-2, B-4, C-1, D-3
(d) A-3, B-1, C-4, D-2

Correct Answer: (b)

Explanation:

1. **DAE (Department of Atomic Energy - Pair 2):** Functions directly under the Prime Minister of India as the executive department managing all nuclear operations, safety regulations, and corporate entities.

2. **BARC (Bhabha Atomic Research Centre - Pair 1):** Based in Trombay, it serves as India's premier multi-disciplinary nuclear research facility, working on areas from reactor design to nuclear medicine.
3. **GCNEP (Global Centre for Nuclear Energy Partnership - Pair 4):** Located in Haryana, it promotes international cooperation through safety research, training programs, and professional exchanges.
4. **AMD (Atomic Minerals Directorate for Exploration and Research - Pair 3):** Headquartered in Hyderabad, it focuses on surveying, exploring, and mapping commercial-grade atomic mineral deposits like uranium and thorium across India.

5. Consider the following statements regarding the command and control architecture of India's strategic deterrent:

1. The Nuclear Command Authority (NCA) is an elite dual-council structure comprising an Executive Council chaired by the Prime Minister and a Political Council chaired by the National Security Advisor.
2. The Strategic Forces Command (SFC) serves as the operational military custodian responsible for executing nuclear policy decisions under direct command authorization.

Which of the statements given above is/are correct?

(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Correct Answer: (b)

Explanation:

- **Statement 1 is incorrect:** The leadership of the two councils within the NCA is reversed in the statement. The Political Council is chaired by the Prime Minister (and is the sole body authorized to greenlight nuclear weapons use), while the Executive Council is chaired by the National Security Advisor to provide strategic input and execute instructions from the Political Council.
- **Statement 2 is correct:** The Strategic Forces Command (SFC) is part of India's Tri-Services Command framework. It manages, maintains, and exercises operational control over the country's nuclear delivery systems and stockpiles.

6. Consider the following statements regarding global nuclear non-proliferation treaties:

1. The Comprehensive Nuclear-Test-Ban Treaty (CTBT) aims to ban all nuclear explosions globally, but it has not entered into legal force because several key nations have failed to ratify it.
2. The International Atomic Energy Agency (IAEA) uses localized verification safeguards to monitor civil nuclear facilities and enforce compliance with Non-Proliferation Treaty (NPT) agreements.
3. The Convention on Nuclear Safety (CNS) is a legally binding international treaty designed to regulate and maintain high safety benchmarks at civilian, land-based nuclear power plants.
4. India signed and ratified the Non-Proliferation Treaty (NPT) during its initial drafting phase to secure access to global enriched uranium supply chains.

Which of the statements given above are correct?

(a) 1 and 3 only
(b) 2 and 4 only
(c) 1, 2 and 3 only
(d) 1, 2, 3 and 4

Correct Answer: (c)

Explanation:

- **Statements 1, 2, and 3 are correct:** The CTBT requires ratification by specific nuclear-capable states listed in its Annex 2 before it can enter into force. The IAEA monitors civilian facilities through safeguards to confirm they are used for peaceful purposes, and the CNS sets international safety benchmarks for civilian power reactors.
- **Statement 4 is incorrect: India is not a signatory to the NPT**. India has consistently declined to sign the treaty, arguing that it creates a discriminatory division between recognized nuclear-weapon states and non-nuclear-weapon states.

7. Consider the following statements regarding the Sustainable Harnessing and Advancement of Nuclear Energy for Transforming India (SHANTI) Act, 2025:

1. The SHANTI Act consolidates India's nuclear regulatory framework by completely repealing the Atomic Energy Act of 1962 and the Civil Liability for Nuclear Damage Act of 2010.
2. The Act maintains a strict public monopoly, completely banning private entities and joint ventures from fuel fabrication, refining, or enrichment activities.
3. Under this act, the Atomic Energy Regulatory Board (AERB) is stripped of its statutory authority and placed entirely under the administrative control of private operators.
4. The new civil liability framework removes all operator liability caps, shifting financial responsibility for nuclear incidents entirely onto equipment suppliers.

Which of the statements given above is/are correct?

(a) 1 only
(b) 2 and 3 only
(c) 1, 3 and 4
(d) 1 and 4 only

Correct Answer: (a)

Explanation:

- **Statement 1 is correct:** The SHANTI Act of 2025 creates a single, unified legal framework by consolidating past laws and repealing both the Atomic Energy Act (1962) and the Civil Liability for Nuclear Damage Act (2010).
- **Statement 2 is incorrect:** The Act allows for private sector participation. Private companies and joint ventures can participate in plant operations, power generation, and activities like fuel fabrication and uranium enrichment up to approved thresholds.
- **Statement 3 is incorrect:** The Act strengthens the AERB by granting it explicit statutory status and making it answerable directly to Parliament rather than solely to the executive branch.
- **Statement 4 is incorrect:** The Act sets graded liability caps for operators (e.g., ₹3,000 crore for large facilities, ₹100 crore for SMRs), with the government covering any liabilities above those limits via a dedicated fund. Notably, it completely removes supplier liability, preventing claims against suppliers for equipment defects.

8. Consider the following statements regarding Proton Exchange Membrane (PEM) fuel cells:

1. India's first indigenous hydrogen fuel cell passenger vessel utilizes a Low-Temperature Proton Exchange Membrane (LT-PEM) fuel cell system for zero-emission marine propulsion.
2. Inside a PEM fuel cell system, hydrogen fuel enters the cathode terminal where a catalyst splits it into protons and electrons to generate power.

Which of the statements given above is/are correct?

(a) 1 only
(b) 2 only
(c) Both 1 and 2

(d) Neither 1 nor 2

Correct Answer: (a)
Explanation:

- **Statement 1 is correct:** India's first domestic hydrogen-powered passenger vessel, deployed in Varanasi, features a custom marine LT-PEM fuel cell system that produces electricity cleanly without combustion.
- **Statement 2 is incorrect:** Hydrogen fuel enters the anode terminal, not the cathode. At the anode, a catalyst (typically platinum) splits the hydrogen molecule into protons and electrons. The electrons flow through an external circuit to generate an electric current, while the protons pass through the membrane to the cathode to combine with oxygen and form water.

9. This landmark bilateral arms control treaty, which entered into force in 2011, caps the deployed strategic nuclear warheads of its two superpower signatories at 1,550 units each while placing strict verifiable limits on intercontinental ballistic missiles (ICBMs), submarine-launched ballistic missiles (SLBMs), and heavy bombers. Identify this agreement:
(a) The INF Accord
(b) The START Treaty
(c) The New START Treaty
(d) The Salt-II Framework

Correct Answer: (c)
Explanation:

- The New Strategic Arms Reduction Treaty (New START) is a critical bilateral arms control agreement between the United States and the Russian Federation. It limits deployed strategic nuclear arsenals and establishes verification mechanisms, such as on-site inspections and data exchanges, to maintain strategic stability.

10. Consider the following statements regarding India's strategic maritime infrastructure:
1. INS Aridaman is an advanced, indigenously built nuclear-powered ballistic missile submarine (SSBN) developed as part of the Arihant-class fleet under the Advanced Technology Vessel (ATV) program.
2. The development of India's SSBN capability relies on a collaborative framework involving the Defence Research & Development Organisation (DRDO), private sector firms, and strategic technical assistance from Russia.

Which of the statements given above is/are correct?
(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Correct Answer: (c)
Explanation:

- Both statements are correct. The ATV program is a successful model of public-private cooperation and international technical partnership. Inducting advanced nuclear-powered ballistic missile submarines like INS Arihant, INS Arighaat, and INS Aridaman strengthens India's naval capabilities and completes its nuclear triad, providing a secure second-strike deterrent.

Miscellaneous Applications

1. Consider the following statements regarding Project UNNATI:

1. It is a dedicated capacity-building initiative launched by the Indian Space Research Organisation (ISRO) with a focus on deep-space exploration and lunar orbiter assembly.
2. The program's main objective is to enhance the skills of international participants, particularly from developing nations, in assembly, integration, and testing of nanosatellites.
3. The initiative was conceptualized to commemorate the 50th anniversary of the United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE+50).

Which of the statements given above is/are correct?

(a) 1 and 2 only
(b) 2 and 3 only
(c) 3 only
(d) 1, 2 and 3

Correct Answer: (b)

Explanation:

- **Statement 1 is incorrect:** Project UNNATI (Unispace Nanosatellite Assembly & Training by ISRO) is specific to nanosatellite development, not deep-space exploration or lunar orbiters.
- **Statement 2 is correct:** The initiative provides comprehensive hands-on training to scientists, engineers, and official representatives from developing nations, improving their capabilities in building, integrating, and analyzing small-scale nanosatellites.
- **Statement 3 is correct:** India announced this program at Vienna during the UNISPACE+50 symposium to promote international cooperation and peaceful uses of outer space by sharing its technical facilities.

2. Consider the following statements regarding Metal-Organic Frameworks (MOFs), for which the 2025 Nobel Prize in Chemistry was recognized:

1. MOFs are synthetic materials constructed by linking metal ions with organic (carbon-based) molecules to form highly porous, three-dimensional structures.
2. Unlike traditional hard materials, such as zeolites, MOFs are structurally dynamic and can flexibly expand or contract based on their surrounding environment.
3. Due to their customizable design, MOFs are actively being tested for environmental applications like capturing Carbon Dioxide and harvesting water from desert air.

Which of the statements given above is/are correct?

(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2, and 3

Correct Answer: (d)

Explanation:

- **Statements 1, 2, and 3 are all correct:** Metal-Organic Frameworks (MOFs) are highly advanced crystalline materials composed of metallic nodes linked together by organic struts. Their high internal surface area and structural flexibility set them apart from rigid, naturally occurring mineral structures like zeolites.
- Because researchers can customize their pore size and chemical functionality down to the molecular level, they are highly effective for environmental engineering applications. These include storing gases,

selectively capturing carbon from industrial emissions, and collecting clean drinking water from low-humidity desert air.

3. Consider the following statements regarding the 2025 Nobel Prize in Physics:

1. It was awarded for demonstrating macroscopic quantum tunnelling and energy quantisation in electric circuits.
2. The experiments proved that bizarre quantum behaviours can be scaled up to systems observable on a human scale.
3. The research forms the foundational basis for developing modern superconducting quantum computers and sensors.

Which of the statements given above is/are correct?

(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2, and 3

Correct Answer: (d)

Explanation:

- **Statements 1, 2, and 3 are all correct:** Historically, quantum mechanics was thought to apply only to subatomic particles like electrons and atoms. The breakthrough experiments honored by the 2025 Nobel Prize in Physics proved that quantum states, such as quantized energy levels and macroscopic quantum tunneling, can manifest in larger, human-engineered superconducting electronic circuits.
- Demonstrating that macro-scale currents can obey quantum rules laid the groundwork for constructing Josephson junctions, SQUID sensors, and the superconducting qubits used to process information in modern quantum computers.

4. Consider the following statements regarding Superconductivity:

1. Superconductivity is a physical phenomenon where certain materials exhibit zero electrical resistance and completely expel internal magnetic fields when cooled below a specific critical temperature.
2. In this state, materials conduct electrical currents with a steady, fractional thermal energy loss, making them moderately more efficient than conventional copper cabling.

Which of the statements given above is/are correct?

(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Correct Answer: (a)

Explanation:

- **Statement 1 is correct:** Superconductivity is defined by two key characteristics: the complete absence of electrical resistance and the active expulsion of magnetic fields, known as the Meissner effect. Both occur when a material drops below its critical threshold temperature.
- **Statement 2 is incorrect:** In a true superconducting state, electrical current flows with absolutely zero energy loss or thermal dissipation. It does not exhibit fractional loss. This makes these materials highly efficient channels for electricity transmission, high-field electromagnets, and advanced scientific sensors.

5. Consider the following statements regarding Electrostatic Precipitators (ESPs):

1. ESPs are filtration devices that use high-voltage electrostatic charges to charge, attract, and remove fine particulate matter from industrial exhaust gases.
2. The operational physics of an ESP relies primarily on high-intensity sound wave vibration patterns to break down and shatter ash particles.

Which of the statements given above is/are correct?

(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Correct Answer: (a)

Explanation:

- **Statement 1 is correct:** ESPs are highly efficient air pollution control devices used in industrial facilities like thermal power plants. They pass dirty exhaust gases through an electric field, imparting a negative charge to fly ash and particulate matter. These charged particles are then pulled out of the gas stream by positively charged collection plates.
- **Statement 2 is incorrect:** The system operates on the principles of electrostatics and electromagnetism, not sound waves or acoustic vibrations. It extracts particulates by utilizing electric fields and charge differentials, leaving the exhaust gas clean.

6. This device, integrated into vehicle exhaust systems, converts hazardous automotive pollutants like carbon monoxide and nitrogen oxides into less harmful emissions like carbon dioxide, nitrogen and water by accelerating chemical reactions without consuming its own internal precious metal components. Identify this technology:

(a) Centrifugal Scrubber
(b) Electrostatic Precipitator
(c) Catalytic Converter
(d) Cyclone Separator

Correct Answer: (c)

Explanation:

- Catalytic converters are essential for managing vehicle emissions. They pass hot exhaust gases over a honeycomb structure coated with precious metal catalysts, such as platinum, palladium, and rhodium.
- This structure triggers simultaneous reduction and oxidation reactions. It breaks down toxic nitrogen oxides into harmless nitrogen gas, while converting poisonous carbon monoxide and unburnt hydrocarbons into carbon dioxide and water vapor before they leave the tailpipe.

7. Consider the following statements regarding high-speed transportation systems:

1. Maglev systems utilize powerful electromagnetic forces to levitate and propel trains above a guide track, significantly increasing speeds by eliminating physical track friction.
2. Hyperloop technology involves launching passenger pods through low-pressure, near-vacuum tubes to drastically reduce aerodynamic drag.
3. Asia's longest vacuum-sealed Hyperloop test track facility, measuring 422 meters, was developed indigenously at the IIT Madras Discovery Campus.
4. Gujarat's Deendayal Port (Kandla) has adopted linear induction motor (LIM) technology to explore cargo maglev systems for automated freight logistics.

Which of the statements given above are correct?

(a) 1 and 3 only

(b) 2 and 4 only
(c) 1, 2 and 4 only
(d) 1, 2, 3 and 4

Correct Answer: (d)
Explanation:

- All four statements are correct. Maglev and Hyperloop systems represent the next generation of high-speed mass transit. Maglev eliminates ground friction, while Hyperloop cuts down on air resistance by operating inside a low-pressure tube network.
- India is actively testing these technologies. Examples include the 422-meter test facility built by Avishkar Hyperloop and TuTr Hyperloop at IIT Madras, alongside projects evaluating the feasibility of using linear induction motor configurations for cargo transport at major ports.

8. Consider the following statements regarding autonomous and connected vehicle technologies:
1. Autonomous navigation systems rely on LiDAR and RADAR sensor arrays, which emit and capture light and radio waves respectively to map environments and detect obstacles.
2. Connected vehicle technology uses radio frequency communication and wireless networking to enable real-time Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) data exchange.
3. LiDAR systems operate by projecting high-frequency acoustic ultrasound waves, making them highly effective in zero-visibility deep mud environments.
4. Vehicle-to-Infrastructure (V2I) communication pathways are strictly analog, prohibiting any digital data interactions with smart traffic grid systems.
Which of the statements given above are correct?
(a) 1 and 2 only
(b) 2 and 4 only
(c) 1, 3 and 4
(d) 1 and 4 only

Correct Answer: (a)
Explanation:

- **Statements 1 and 2 are correct:** Autonomous driving requires a combination of sensors and connectivity. LiDAR uses pulsed laser light to generate precise 3D maps of the vehicle's surroundings, while RADAR uses radio waves to track the speed and distance of objects. Connected vehicle protocols use cellular or dedicated short-range radio frequencies to coordinate movements with nearby cars (V2V) and traffic signals (V2I).
- **Statement 3 is incorrect:** LiDAR stands for Light Detection and Ranging; it uses light waves (laser beams), not acoustic ultrasound waves.
- **Statement 4 is incorrect:** V2I networks are fully digital, allowing vehicles to exchange high-speed data with digital traffic systems to optimize city traffic flow and improve safety.

9. Consider the following statements regarding alternative powertrain vehicle platforms:
1. Full Battery Electric Vehicles (BEVs) operate without an internal combustion engine, relying solely on rechargeable battery packs to achieve zero tailpipe emissions.
2. Hydrogen Fuel Cell Vehicles (FCEVs) generate electricity onboard through an electrochemical reaction between hydrogen and oxygen, releasing only water vapor and heat.
3. Fuel Cell Electric Hybrid Vehicles (FCE-HVs) integrate both an onboard fuel cell stack and a secondary energy storage battery pack to maximize driving range and efficiency.

4. Regenerative braking systems improve efficiency by reversing the electric propulsion motor process, turning kinetic energy back into storable electricity during deceleration.
5. India's alternative powertrain initiatives are designed to support the National Electric Mobility Mission Plan (NEMMP) and the National Green Hydrogen Mission.

Which of the statements given above are correct?

(a) 1, 2 and 4 only
(b) 3, 4 and 5 only
(c) 1, 2, 3 and 5 only
(d) 1, 2, 3, 4 and 5

Correct Answer: (d)

Explanation:

- All five statements are correct. Shifting away from conventional petroleum internal combustion engines requires a variety of technologies. BEVs remove emissions from the tailpipe entirely, while FCEVs provide long range and fast refueling for heavy-duty shipping and transit. Hybrid models and regenerative braking systems capture energy that would otherwise be lost as heat during braking, storing it to maximize overall vehicle efficiency. These advancements align with India's national sustainability initiatives.

10. Consider the following statements regarding the Agnite propulsion engine:

1. Designed by an Indian private space startup, Agnite is the world's largest single-piece, 3D-printed booster engine.
2. Both the Agnite and Agnilet systems are engineered as high-performance, 3D-printed semi-cryogenic engines.
3. The structural body of the Agnite engine is fabricated using Inconel, a specialized superalloy designed to withstand extreme temperatures and high pressures.

Which of the statements given above are correct?

(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

Correct Answer: (d)

Explanation:

- **Statements 1, 2, and 3 are all correct:** Developed by Agnikul Cosmos, the Agnite engine is a major milestone for India's private space sector. Fabricating a rocket engine as a single, 3D-printed piece removes the need for complex welds and joins, reducing the risk of structural failure.
- It uses Inconel, an oxidation- and corrosion-resistant nickel-chromium superalloy that maintains its structural strength under the extreme heat and pressure of semi-cryogenic rocket combustion. These engines are designed to power the booster stage of the company's Agnibaan launch vehicle.

Miscellaneous Applications-II

1. Match Column I (Name of the Treaty/Convention/Agreement) with Column II (Description):

Treaty/Convention/Agreement	Description

A. TRIPS Agreement	1. Establishes a global framework for protecting industrial property, including patents and trademarks.
B. Lisbon Agreement	2. Administered by the WTO, it establishes enforceable minimum standards for IPR, including compulsory licensing.
C. Berne Convention	3. Provides a specialized international registration framework for the protection of appellations of origin.
D. Paris Convention	4. Ensures automatic, worldwide copyright protection for literary and artistic works without requiring formal registration.

Which of the following options represents the correct matching pairs?

(a) A-2, B-3, C-4, D-1
(b) A-1, B-4, C-3, D-2
(c) A-2, B-4, C-3, D-1
(d) A-3, B-2, C-4, D-1

Correct Answer: (a)

Explanation:

- **TRIPS Agreement (Pair 2):** Administered by the World Trade Organization (WTO), it ties intellectual property protection to international trade rules and establishes mandatory minimum enforcement standards for member states.
- **Lisbon Agreement (Pair 3):** Administered by the World Intellectual Property Organization (WIPO), it focuses specifically on protecting appellations of origin and their geographical indications across borders.
- **Berne Convention (Pair 4):** Deals with copyright protection. Its core principle is "automatic protection," meaning creative works are protected internationally from the moment of creation without mandatory copyright registration.
- **Paris Convention (Pair 1):** One of the oldest IPR treaties, it handles industrial property in its broadest sense, covering inventions, utilities, designs, trademarks, and trade names.

2. Consider the following statements regarding Small Language Models (SLMs) in artificial intelligence:

1. SLMs are built on fundamentally different non-neural network architectures to avoid the use of Transformer attention mechanisms.
2. The primary technical metric separating SLMs from Large Language Models (LLMs) is parameter count, with SLMs typically configured under 30 billion parameters.
3. SLMs can be systematically optimized from larger pre-trained architectures using compression techniques like knowledge distillation, pruning, and quantization.
4. Due to their low memory footprint, SLMs are incapable of on-device (edge) deployment and must rely entirely on external, high-bandwidth cloud servers.

Which of the statements given above are correct?

(a) 1 and 3
(b) 2 and 3 only
(c) 1, 2 and 4
(d) 1 and 4 only

Correct Answer: (b)

Explanation:

- **Statements 2 and 3 are correct:** SLMs maintain a smaller footprint (typically under 10–30 billion parameters compared to the hundreds of billions or trillions in frontier models like GPT-4). They are often optimized using knowledge distillation (training a compact student model to replicate a larger teacher model), pruning (removing redundant neural weights), and quantization (reducing numerical precision to save memory).
- **Statement 1 is incorrect:** SLMs share the exact same underlying neural architecture as LLMs, relying heavily on modern Transformer networks.
- **Statement 4 is incorrect:** A key advantage of SLMs is their ability to run locally on edge devices (smartphones, laptops, and IoT hardware) without an active internet connection, which keeps user data private.

3. Consider the following statements regarding the National Supercomputing Mission (NSM):

1. The mission connects national academic and research institutions into a single high-performance computing grid.
2. The supercomputing assets under the NSM are networked on a dedicated grid built over the infrastructure of the National Knowledge Network (NKN).
3. The mission is executed as a standalone corporate initiative managed exclusively by private tech consortia without Central Government oversight.

Which of the statements given above are correct?

(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 only
(d) 1, 2 and 3

Correct Answer: (a)

Explanation:

- **Statements 1 and 2 are correct:** The NSM establishes a secure, high-speed supercomputing grid across India's premier academic and R&D centers, leveraging the high-bandwidth backbone of the National Knowledge Network (NKN).
- **Statement 3 is incorrect:** The NSM is jointly steered by two government bodies: the Department of Science and Technology (DST) and the Ministry of Electronics and Information Technology (MeitY). It is implemented by the Center for Development of Advanced Computing (C-DAC), Pune, and the Indian Institute of Science (IISc), Bengaluru.

4. Consider the following statements regarding Food Irradiation technology:

1. It is a physical preservation technique where packed or bulk food commodities are exposed to controlled amounts of ionizing radiant energy.
2. The primary process relies on radiolysis, which splits water molecules inside pathogens and insects to disrupt their biological functions.
3. To protect the public from residual radioactive contamination, the process strictly forbids using gamma rays emitted by Cobalt-60 sources.

Which of the statements given above is/are correct?

(a) 1 and 2 only
(b) 2 and 3 only
(c) 3 only
(d) 1, 2 and 3

Correct Answer: (a)
Explanation:

- **Statements 1 and 2 are correct:** Food irradiation uses ionizing radiation to extend shelf life and control pests. A key mechanism is the radiolysis of water, where radiant energy splits water molecules inside the cells of insects or micro-organisms, producing reactive components that neutralize them without altering the food's quality.
- **Statement 3 is incorrect:** Approved methods for food irradiation include gamma rays from radioactive Cobalt-60, alongside high-energy X-rays and electron beams generated by electrical accelerators. None of these methods make the food itself radioactive.

5. This material consists of a single layer of carbon atoms arranged in a two-dimensional hexagonal honeycomb lattice. Known for its performance metrics, it can stretch by up to 20-25% of its length, conducts electricity better than copper, and exhibits mechanical tensile strength roughly 200 times stronger than steel by weight. Identify this material:
(a) Fullerene
(b) Graphene
(c) Boron Nitride Nanotubes
(d) Carbonatite Intrusions

Correct Answer: (b)
Explanation:

- Graphene is a versatile nanomaterial. Its unique single-atom-thick 2D structure gives it exceptional electrical conductivity, thermal performance, elasticity, and mechanical strength.
- These properties make it useful for an array of advanced applications, from high-sensitivity environmental sensors and high-density electric vehicle batteries to water desalination filters.

6. Consider the following statements regarding Project Glasswing:
1. Project Glasswing is a multi-company AI coalition aimed at securing critical global software infrastructure by autonomously detecting and patching software vulnerabilities.
2. The framework utilizes specialized, unreleased frontier AI models to autonomously discover zero-day vulnerabilities and generate fixed code to patch them.

Which of the statements given above is/are correct?
(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Correct Answer: (c)
Explanation:

- Both statements are correct. Project Glasswing brings together major technology firms (including Anthropic, AWS, Apple, Google, and Microsoft) to address cybersecurity challenges using advanced AI.
- By using next-generation models like Claude Mythos Preview, the project aims to identify zero-day software vulnerabilities—flaws unknown to the developers—and write clean patch code to secure systems faster than human teams can.

7. Consider the following statements regarding the Phenome India National Biobank:

1. The repository is designed to store high-resolution genomic, lifestyle, and clinical data from diverse populations to assist in early diagnosis and gene-guided therapies.
2. The facility was established under the Phenome India-CSIR Health Cohort Knowledgebase (PI-Check) project.
3. An organism's phenome represents its complete internal genetic sequence, which remains unaffected by environmental factors or lifestyle variables.

Which of the statements given above are correct?

(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

Correct Answer: (a)

Explanation:

- **Statements 1 and 2 are correct:** The National Biobank at CSIR-IGIB collects genetic, lifestyle, and medical histories to build a high-resolution data pool tailored to Indian genetic diversity. This data helps fuel AI diagnostics and personalized precision medicine.
- **Statement 3 is incorrect:** A phenome is the complete set of phenotypes (observable physical traits, developmental processes, and behaviors) of an organism. An organism's phenotype is shaped by both its underlying genotype and the environmental conditions it experiences over time.

8. Consider the following statements regarding the National Biofoundry Network:

1. A biofoundry operates as an automated facility that designs, constructs, and optimizes engineered organisms by integrating gene-editing workflows with high-throughput biomanufacturing.
2. The National Biofoundry Network was established as a core component to support India's BioE3 (Biotechnology for Economy, Environment and Employment) Policy.

Which of the statements given above is/are correct?

(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Correct Answer: (c)

Explanation:

- Both statements are correct. Launched under the Department of Biotechnology's (DBT) BioE3 Policy, the National Biofoundry Network serves as a key infrastructure driver.
- By automating DNA synthesis and testing, it helps scale lab discoveries into commercial technologies across sectors like precision biothreat therapeutics, carbon capture utilization, and alternative proteins.

9. Consider the following statements regarding the Diverse Epigenetic Epidemiology Partnership (DEEP) project:

1. Epigenetics focuses on studying how behaviors and environmental factors trigger changes that alter the underlying core DNA sequence of an individual.
2. The DEEP project is a multi-year international research collaboration designed to explore how genomic and environmental diversity influence disease risks across different global populations.

Which of the statements given above is/are correct?

(a) 1 only

(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Correct Answer: (b)
Explanation:

- **Statement 1 is incorrect:** Epigenetic changes do not alter the underlying DNA sequence. Instead, they add or remove chemical tags on the DNA that change how the cell reads the sequence, meaning these modifications are often reversible.
- **Statement 2 is correct:** The DEEP project brings together international bodies (including the University of Bristol and CSIR-CCMB) to study how genetic and environmental diversity affect health and disease risks worldwide.

10. Which of the following statements about the Vikram3201 processor is/are correct?

1. It is an advanced version of the indigenously designed 16-bit VIKRAM1601 microprocessor, which is integrated into the avionics systems of ISRO's launch vehicles.
2. It is a fully "Make-in-India" 32-bit microprocessor qualified to operate reliably under the harsh environmental conditions of spaceflight.

Select the answer using the code given below:
(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Correct Answer: (c)
Explanation:

- Both statements are correct. Unveiled at Semicon India, the Vikram3201 microprocessor represents a major step forward for India's space hardware.
- Developed by the Vikram Sarabhai Space Centre (VSSC) alongside the Semiconductor Laboratory (SCL) in Chandigarh, this 32-bit upgrade builds on the proven 16-bit VIKRAM1601 architecture. It is built to withstand extreme vibration, thermal shifts, and radiation during launch and spaceflight.

Miscellaneous Applications-III

1. Consider the following statements regarding Neutrinos and Dark Matter:

1. Neutrinos are subatomic particles that carry a net positive electrical charge and are heavily diverted by interstellar magnetic fields.
2. Unlike dark matter, ordinary baryonic matter actively interacts with electromagnetic radiation, making it visible across the cosmos.
3. Both dark matter and ordinary matter possess mass and exert a measurable gravitational force on surrounding celestial bodies.

Which of the statements given above are correct?
(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

Correct Answer: (b)
Explanation:

- **Statement 1 is incorrect:** Neutrinos are often referred to as ghost particles because they have zero electrical charge, zero size, and a tiny mass. Because they are electrically neutral, they travel in completely straight lines from their source and are completely undisturbed by even the strongest magnetic fields.
- **Statement 2 is correct:** Ordinary matter (baryonic matter) includes gas, dust, stars, and planets. It interacts with electromagnetic radiation (light), whereas dark matter constitutes roughly 27% of the cosmos but remains completely invisible because it does not absorb, reflect, or emit light.
- **Statement 3 is correct:** Despite their compositional differences, both ordinary matter and dark matter share the basic properties of matter: they possess mass, take up space, and exert a gravitational pull on one another.

2. Consider the following statements regarding Fast Radio Bursts (FRBs):

1. Fast Radio Bursts (FRBs) are high-energy blasts of electromagnetic radiation in the form of radio waves that typically originate from galaxies far beyond the Milky Way.
2. As FRBs travel through space, their signal compresses into a single unified wavelength, hiding the distribution of matter along their cosmic trajectory.

Which of the statements given above is/are correct?
(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Correct Answer: (a)
Explanation:

- **Statement 1 is correct:** FRBs are brief, intense pulses of radio waves lasting from a fraction of a millisecond to a few seconds, mostly originating from deep extragalactic space.
- **Statement 2 is incorrect:** Instead of compressing, FRBs disperse into different wavelengths as they travel through the universe, similar to how a prism splits sunlight into a spectrum. The degree of this dispersion tells scientists exactly how much matter the signal encountered along its path. This makes FRBs reliable cosmic flashlights for mapping the matter distribution of the cosmic web.

3. The World Health Organization (WHO) launched a targeted initiative to combat non-communicable diseases (NCDs) and obesity by encouraging member states to implement specialized health taxes that would raise retail prices by at least 50% by the year 2035. This initiative targets three specific unhealthy consumer commodities: tobacco, alcohol, and sugary drinks. Identify this initiative:
(a) The 50-by-35 Accord
(b) The NCD Fiscal Pact
(c) The 3 By 35 Initiative
(d) The Global Health Tax Framework

Correct Answer: (c)
Explanation:

- The 3 By 35 Initiative was developed by the WHO to tackle population-level obesity, diabetes, cardiovascular conditions, and other non-communicable diseases (NCDs).

- By raising the prices of tobacco, alcohol, and sugar-sweetened beverages by at least 50% through health taxes by 2035, the WHO aims to curb consumption of these products. This strategy is recognized as one of the most cost-effective fiscal tools available for public health intervention.

4. Consider the following statements regarding Step-and-Shoot Proton Arc Therapy (SPArc):

1. SPArc is an advanced radiation therapy technique that destroys cancer cells or halts their growth by directly damaging their cellular DNA structures.
2. The primary operational benefit of SPArc is its ability to deliver precise proton arcs that target tumor volumes while minimizing radiation exposure to the surrounding healthy tissue.

Which of the statements given above is/are correct?

(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Correct Answer: (c)

Explanation:

- Both statements are correct. SPArc represents a significant leap forward in precision oncology. Recently used to treat a rare Adenoid Cystic Carcinoma (ACC), this approach improves dose-planning quality for complex tumor locations, such as head, neck, and brain cancers, by delivering a tightly focused radiation dose that spares nearby critical organs.

5. Consider the following statements regarding the GSAT-7R (CMS-03) satellite:

1. It is an advanced military communications satellite launched into Geostationary Orbit to provide secure, multi-band voice, video, and data transmission.
2. The satellite extends India's maritime domain awareness and secure communication networks across the Indian Ocean Region, reaching up to 2,000 kilometers from the nation's coastline.
3. Designed as a brand-new orbital capability, it operates independently without replacing any pre-existing naval communications infrastructure.

Which of the statements given above are correct?

(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

Correct Answer: (a)

Explanation:

- **Statements 1 and 2 are correct:** Launched by ISRO using the LVM3 rocket, GSAT-7R provides encrypted multi-band communications across the Indian landmass and the Indian Ocean Region. This network links naval ships, submarines, aircraft, and strategic Operations Centers.
- **Statement 3 is incorrect:** The satellite does not operate as an isolated addition; it is a direct replacement for the aging GSAT-7 (Rukmini) satellite, upgrading India's long-term maritime communications infrastructure with a 15-year operational lifespan.

6. Match the Directed Energy Weapon (DEW) systems in Column I with their respective country of origin in Column II:

Column I (DEW System)	Column II (Country of Origin)

A. DragonFire	1. United States of America
B. HELIOS	2. India
C. Silent Hunter	3. United Kingdom
D. IDD&IS Mk2A	4. China

Select the correct matching options using the codes given below:
(a) A-1, B-3, C-4, D-2
(b) A-3, B-1, C-4, D-2
(c) A-3, B-4, C-1, D-2
(d) A-2, B-1, C-4, D-3

Correct Answer: (b)
Explanation:

- **A-3 (DragonFire -> United Kingdom):** DragonFire is the UK's advanced laser directed energy weapon (LDEW) technology demonstrator. It is engineered to track, lock onto, and neutralize airborne and maritime threats with extreme precision at the speed of light.
- **B-1 (HELIOS -> United States of America):** Developed by Lockheed Martin for the US Navy, HELIOS (High Energy Laser with Integrated Optical-dazzler and Surveillance) is a weapon system that combines high-energy laser interception, tactical organic long-range intelligence, and an optical dazzler to blind adversarial sensors.
- **C-4 (Silent Hunter -> China):** Silent Hunter is a mobile, electrically powered, laser-based air defense system built by China. It is specialized for low-altitude tactical defense, particularly for seeking out and neutralizing low-flying, low-speed unmanned aerial vehicles (UAVs).
- **D-2 (IDD&IS Mk2A -> India):** Developed indigenously by the Defence Research and Development Organisation (DRDO), the Integrated Drone Detection and Interdiction System (IDD&IS) Mk2A serves as a strategic anti-drone asset. It integrates multiple sensory feeds for comprehensive detection and deploys both soft-kill (jamming/spoofing) and hard-kill (kinetic/laser countermeasure) options against hostile drone systems.

7. Consider the following statements regarding Thorium Molten Salt Reactors (TMSR):
1. TMSR technology is a fourth-generation nuclear energy design that utilizes high-temperature molten salt as its primary coolant, eliminating the need for high-pressure water cooling.
2. In its natural state, the sole naturally occurring isotope, Thorium-232, is a highly fissile material that can sustain a nuclear chain reaction without any initial transmutation.
3. MSRs feature passive safety systems, such as a solid salt plug that automatically melts to drain the liquid fuel and halt the reaction if temperatures exceed safe limits.
4. Thorium is roughly three times less abundant in nature than uranium, which makes it a rare and highly restricted fuel resource worldwide.

Which of the statements given above are correct?
(a) 1 and 2 only
(b) 2 and 4 only
(c) 1 and 3 only
(d) 3 and 4 only

Correct Answer: (c)

Explanation:

- **Statements 1 and 3 are correct:** TMSR systems operate at normal atmospheric pressure without the risk of high-pressure steam explosions. They rely on passive safety features, like a freeze plug that melts during a power loss or overheating event to drain the fuel salt into secure holding tanks, stopping the reaction automatically.
- **Statement 2 is incorrect:** Thorium-232 is fertile, not fissile. It cannot sustain a chain reaction on its own and must first absorb neutrons in a reactor to transmute into fissile Uranium-233 fuel.
- **Statement 4 is incorrect:** Thorium is actually three times more abundant in nature than uranium. However, its widespread adoption is currently limited by high extraction costs and the complex technology required to manage the thorium fuel cycle.

8. Consider the following statements regarding Black Mass Recovery technology:

1. Black Mass is a valuable, dark, powdery mixture of critical minerals—including lithium, cobalt, and nickel—extracted from recycled, end-of-life lithium-ion batteries.
2. The recovery process relies exclusively on dry mechanical crushing, making it chemically impossible to incorporate liquid-based wet processing modes.

Which of the statements given above is/are correct?

(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Correct Answer: (a)

Explanation:

- **Statement 1 is correct:** Black mass is the structural material left over after spent lithium-ion batteries are processed and shredded. It contains a high concentration of critical materials like lithium, nickel, and cobalt, which can be refined and reused to manufacture new clean energy products.
- **Statement 2 is incorrect:** The advanced indigenous technology supported by India's Technology Development Board (TDB) explicitly utilizes a dual-mode system that combines both wet and dry processing. This approach maximizes the extraction and recovery rate of pure elements while minimizing environmental pollution.

9. Consider the following statements regarding Sodium-Ion Batteries (SIBs) and Solid-State Batteries (SSBs):

1. SIBs function identically to lithium-ion configurations but transport charge using sodium ions, which generally results in a lower overall energy density than Lithium-Ion Batteries (LIBs).
2. Unlike liquid-electrolyte batteries, SIBs can be fully discharged and safely transported at zero voltage, significantly reducing transit fire risks.
3. Solid-state batteries replace volatile liquid electrolytes with solid alternatives, enabling faster recharging cycles and improved resistance to leakage or combustion.
4. Flow batteries are powered by redox reactions in which two liquid electrolytes pass ions through a porous membrane, allowing energy storage capacity to scale with the size of the external liquid tanks.

Which of the statements given above are correct?

(a) 1 and 3 only
(b) 2 and 4 only
(c) 1, 2 and 4 only
(d) 1, 2, 3 and 4

Correct Answer: (d)

Explanation:

- All four statements are correct. These next-generation energy storage options address the key limitations of standard lithium-ion systems. SIBs leverage widely available sodium resources and offer safer transit options because they can be completely discharged to zero volts.
- At the same time, solid-state batteries (SSBs) eliminate volatile liquids to deliver higher energy densities and faster charging speeds, while flow batteries offer a modular solution for grid-scale storage by scaling capacity based on electrolyte tank volume.

10. Consider the following statements regarding solid-state and liquid-electrolyte flow batteries:

1. Solid-state batteries utilize a porous, liquid-infused separator membrane to exchange ions between the cell terminals.
2. Flow batteries separate their energy storage medium from the power-generating components, allowing operators to scale storage capacity simply by resizing the liquid electrolyte tanks.
3. A key safety advantage of solid-state batteries is that solid electrolytes are far less prone to leak or catch fire than the volatile liquid chemistry used in conventional batteries.
4. Vanadium redox systems are a prominent category of flow battery technology used for long-duration grid energy storage.

Which of the statements given above are correct?

(a) 1 and 2 only
(b) 2, 3 and 4 only
(c) 1, 3 and 4 only
(d) 1 and 4 only

Correct Answer: (b)

Explanation:

- **Statements 2, 3, and 4 are correct:** Flow batteries (such as vanadium redox, iron-salt, and zinc-bromine systems) store energy in external liquid tanks, meaning their capacity scales with tank size. Solid-state configurations replace flammable liquid components with stable solid electrolytes, which prevents dangerous thermal runaway and leakage while allowing more energy to be packed into less space.
- **Statement 1 is incorrect:** Solid-state batteries do away with liquid components entirely. They use a solid electrolyte layer that serves as both the ion conductor and the physical separator, removing the need for liquid-infused membranes.