SIDI PhD Written Test – Syllabus & Format

The written test consists of two parts (A & B)

Part-A will have questions related to the following topics:

1. Visualization and spatial ability: Pictorial and diagrammatic questions to test the understanding of transformation and/or manipulation of 2D shapes and 3D objects and their spatial relationships.
2. Environmental and social awareness: General awareness of environmental factors (such as climate, population, water, vegetation, pollution, weather, natural resources) and their implications on the design of products, images, infrastructure and environment. Awareness of design terminologies, social and cultural connection with design, history of the designed artefact, and socially responsible and environmentally sustainable design responses. History of art, sculpture and literature.
3. Analytical and logical reasoning: Ability to analyse given information logically and select the most appropriate solutions; ability to weigh opinions, arguments or solutions against appropriate criteria; ability to use logic and structured thinking to deduce from a short passage, which of a number of statements is the most accurate response to a posed question.
4. Language and creativity: Ability to understand passages in commonly used English language; ability to think creatively in terms of alternatives; ability to distinguish innovative options and think out-of-the-box.
5. Design thinking and problem solving: Ability to understand the context, the users and the constraints and select the most appropriate solution for a given design problem.
6. Observation and design sensitivity: Ability to detect concealed properties in day-to-day life and think critically about them. Ability to discern subtle differences in visual properties and aesthetic outcomes.
7. Drawing: Ability to draw products, people or scenes in proportion with good line quality, composition, proportion, perspective, and shading.
8. Creativity: Ability to think out-of-the-box and come-up with unique as well as diverse solutions.
9. Communication skills: Ability to communicate concepts and ideas clearly with the help of text and visuals.
10. Problem identification skills: Ability to understand the user and the context, knowledge of properties of materials and their appropriate use in design.

Part-B will have questions related to the following topics:

1. Robotics and automation:
    a. Basic concepts: Definition and origin of robotics – different types of robotics – various generations of robots – degrees of freedom – Asimov's laws of robotics – dynamic stabilization of robots.
    b. Power sources and sensors: Hydraulic, pneumatic and electric drives – determination of HP of motor and gearing ratio – variable speed arrangements – path determination – micro machines in robotics – machine vision – ranging – laser – acoustic – magnetic, fibre optic and tactile sensors.
    c. Manipulators, actuators and grippers: Construction of manipulators – manipulator dynamics and force control – electronic and pneumatic manipulator control circuits – end effectors – u various types of grippers – design considerations.

d. Kinematics and path planning: Solution of inverse kinematics problem – multiple solution Jacobian work envelope – hill climbing techniques – robot programming languages.
e. Basic understanding of various applications: Aerial robots, Underwater robots, Medical robots, etc.

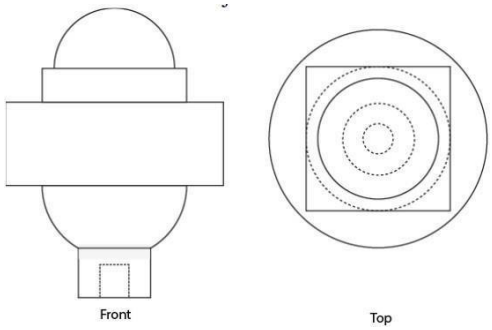
2. Medical devices:
   Implantable devices, minimally invasive surgery and robotic-assisted surgery, assistive rehabilitation platforms & exoskeletons.
3. Biosensors:
   Surface functionalization in biosensors, Optical Colorimetry and fluorescence, Electrochemical: Amperometric, Impedimetric and Voltametric, Nanobiosensors, Biofunctionalization of nanomaterials, Nanomaterials for signal amplification and transducer fabrication, Microfluidics (Lab on Chip) integrated point of care biosensors.
4. Photonics and Laser Characteristics:
   Coherence, directionality. Power, monochromaticity, intensity, and Phase; Laser Properties & Processes- spontaneous emission, stimulated emission, and population inversion; Laser types: solid-state lasers, gas lasers, diode lasers, pulsed lasers, and continuous lasers. Photonics: Absorption, emission and reflection, Si detectors, photomultiplier tubes.
5. Bio-inspired Design:
   a. Mechanical design – hierarchical construction, Bio-inspired impact resistance, self-healing. Materials and surfaces - Muscles and artificial muscles, lotus effect, gecko adhesion, desert beetle, pitcher plants, bio-fouling, coatings. Silver ant and heat dissipation, Biological and bio-inspired sensors;
   b. Bio-optics – structural colors, compound eyes, antireflection, stealth, imaging;
6. Additive manufacturing technologies and its applications:
   Fused Deposition Modeling (FDM), Selective Laser Sintering (SLS), Stereolithography (SLA), Selection Laser Melting (SLM), Jetting, 3D Printing, Laser Engineering Net Shaping (LENS), Laminated Object Manufacturing (LOM), Electron Beam Melting (EBM) Capabilities, materials, costs, advantages and limitations of different systems. AM applications in Battery thermal management, Desalination, Defense, Bio-reactors, Aerospace, Automobile, Medical implants.
7. CAD Modelling for 3D printing:
   3D Scanning and digitization, data handling & reduction Methods, AM Software: data formats and standardization, slicing algorithms: uniform flat layer slicing, adaptive slicing, Process-path generation: Process-path algorithms, rasterization, part Orientation and support generation.
8. Design of thermal systems:
   Conduction, convection and Radiation- design of heat exchangers- optimization of multicomponent thermal energy system-cogeneration and waste heat recovery- triply periodic minimal surface-Gyroid Structures-Lattice structures with AM.
9. Bio-microfluidics devices:
   Introduction and Fundamentals – Biofluid Mechanics – Microfabrication and Materials – Electrokinetic and Droplet Microfluidics – Micro Total Analysis Systems (μTAS) and Bioapplications – Biosensors and Lab-on-a-Chip Devices – Cell Sorting and Organ-on-Chip Technologies – Computational Modeling and Simulation – Paper and Wearable Microfluidics – AI and Data-Driven Microfluidic Design – Thermal and Mass Transport in Bio-MEMS – Emerging Trends and Future Healthcare Applications.
10. Quality control and reliability:
    Defects in FDM, SLS and SLM, Critical process parameters: geometry, temperature, composition, phase transformation, Numerical and experimental evaluation: roles of process parameter combination, process optimization.

11. Product Design, Ergonomics, Design Research, User Experience, Immersive Technologies (VR/AR/XR), and AI in Design: Product design and development, ergonomics including physical and cognitive, and Human/user-centered design; design research methods, UI/UX, usability, immersive technologies (VR/AR/XR), and the application of AI tools in design.
12. Electronics and Instrumentation:
    Analog and digital electronics, operational amplifiers, filters, oscillators, microcontrollers and embedded systems, sensors and transducers, signal conditioning and data acquisition, measurement principles and calibration, control systems and automation, error analysis, PLC and SCADA, IoT-based instrumentation, and AI applications in sensor data.
13. Biomedical Instrumentation and Signal Processing:
    Human physiology for engineers, biopotential measurement (ECG, EEG, EMG), biomedical sensors and electrodes, patient monitoring and diagnostic instruments, medical imaging basics (X-ray, CT, MRI, ultrasound), safety and regulatory standards, digital and biomedical signal processing, feature extraction and filtering, AI/ML for health monitoring, wearable and assistive device design.
14. Mechatronic system design:
    BLDC motors, position sensors, IMUs, force and torque sensors, PID control, Finite state machine, Microcontrollers.
15. Biomechanics and motor control:
    Application of the principles of biomechanics and motor control to rehabilitation and the development assistive devices, Mechanics and energetics of walking, muscle mechanics, basic principles of neural control of movement.
16. Lightweighting, Sustainable design, Finite Element Analysis, computer-aided engineering in product design, Impact and crashworthiness.
17. Materials selection:
    Fundamental understanding of metals, non-metals, alloys, and composites; basic concepts of material properties, their testing, and validation including mechanical, magnetic, thermal, electrical, and optical properties, along with corresponding testing methodologies.
18. Affordable Healthcare Devices, Rehabilitation, Assistive and Therapeutic Technologies, Socially Innovative Product Design & Development, and Automation & IoT-based Solutions:
    Introduction to Human-Centered & Empathy-Driven Design, Design Thinking, TRIZ, User Centered Design, Ergonomics, Anthropometry, and Biomechanics in Product Design, Concept Generation, Evaluation, and Prototyping, Sustainable & Frugal Design Approaches for Low-Cost Healthcare Solutions, Case Studies in Medical and Assistive Device Design, Integration of Aesthetics, Functionality, and Manufacturability, Fundamentals of IoT and Sensor Integration, Smart Rehabilitation and Therapeutic Devices using Microcontrollers (Arduino, Raspberry Pi), Grassroots Innovation and Contextual Design, Intellectual Property Rights (IPR), Patents, and Technology Transfer, CAD/CAM/CAE Tools for Product Design (SolidWorks, CATIA), Rapid Prototyping using 3D Printing and Laser Cutting, Design Validation using User Testing and Feedback Analysis.
19. AI in Design:
    1. Linear Algebra: Eigenvalues and eigenvectors, optimization, BFGS
    2. Minima and maxima
    3. PDEs and it's classification
    4. Softmax and regression analysis, predictive analytics
    5. Machine learning algorithms for forecasting
    6. Dynamical systems

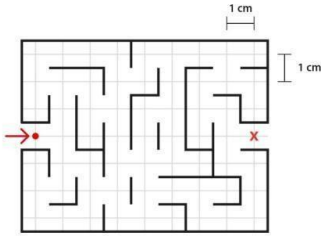
Sample Questions

Part A

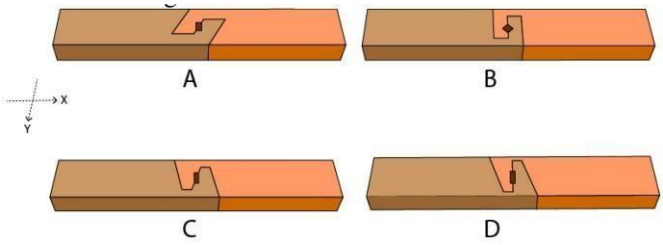
1. Two views of a solid object are shown. Count the number of surfaces.



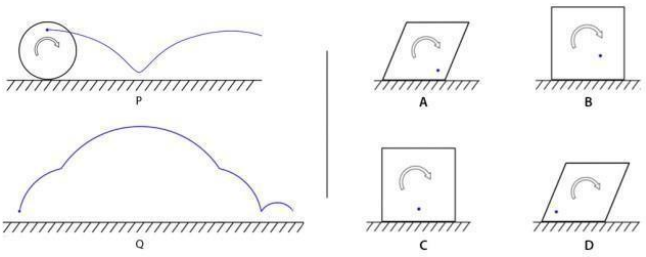
2. What is the shortest distance (in cm) for the red dot to reach the position x? The dotcan travel only along the grid lines shown.



3. The given options show wooden joints, each made of 2 wooden blocks of different colors with a wooden pin at the center. All joints can be released along the Z axis. Which of the joints can be released along the Y axis?



4. Figure P shows how a point on a circle traces a path when it is rolled on the ground. The point in which of the polygons shown in the options creates the path in Figure Q?



Part B

1. What are the different configurations (robot structure) that are commonly used for industrial robots? With free hand sketches show the workspace of different robot configurations.
2. With respect to an industrial robotic arm explain the following in brief. Use a normal distribution curve for explanations.
    i). Spatial resolution
    ii). Accuracy
    iii). Repeatability
3. With a neat sketch explain the working of a tactile sensor.