國立成功大學
115學年度碩士班招生考試試題

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系　所：能源工程國際碩士學位學程

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節　次：第 2 節

注　意：1.不可使用計算機
2.請於答案卷(卡)作答，於試題上作答，不予計分。

Part 1 (30 points) Fill in each blank with 1 correct answer. Each question is worth 3 points.

Aeronautical engineering is the primary branch of engineering focused on the design, construction, and study of aircraft. A crucial discipline within this field is ____1_____, which involves the motion of air and the forces it generates on solid objects, such as lift and drag. Another core area is ____2____, relating to the systems that generate thrust, most commonly jet engines or turboprops. Modern aircraft development also heavily relies on ____3_____ methods, including Computational Fluid Dynamics (CFD) for simulating airflow. Furthermore, selecting the right ____4_____, such as lightweight composites, is ____5_____ to achieving structural integrity and maximizing fuel efficiency in the final assembly of the airframe.

1. (A) hydraulics (B) thermodynamics (C) aerodynamics (D) aeronautics
2. (A) navigation (B) propulsion (C) avionics (D) hydraulics
3. (A) analytical (B) physical (C) theoretical (D) computational
4. (A) alloys (B) designs (C) materials (D) components
5. (A) irrelevant (B) secondary (C) optional (D) paramount

Propulsion engineering focuses on the design and operation of systems that generate _____6____ for vehicles. In jet engines, the core process involves compressing incoming air, mixing it with ____7_____ in the combustor, and igniting the mixture to produce high-velocity exhaust gases. The resulting expansion drives the ___8______, which in turn powers the ____8_____, maintaining the cycle. A critical performance measure is the ___9______ ratio, which dictates a vehicle's acceleration capability. Engineers must also manage the extreme thermal loads through advanced cooling techniques and utilize lightweight, heat-resistant superalloys for components like turbine blades. Future research is exploring alternative methods, such as electric and ____10_____ propulsion, particularly for deep space missions where maximizing specific impulse is essential.

6. (A) drag (B) thrust (C) torque (D) lift
7. (A) coolant (B) fuel (C) oxygen (D) lubricant
8. (A) compressor; turbine (B) turbine; compressor (C) combustor; nozzle (D) nozzle; combustor
9. (A) fuel-to-air ratio (B) thrust-to-weight ratio (C) specific impulse (D) thermal efficiency
10. (A) physical (B) plasma (C) nuclear (D) hydraulic

Part 2 (30 points) Choose only 1 correct answer for each question. Each question is worth 3 points.

11. Structural engineering involves designing buildings and bridges that _______ loads and environmental forces. (A) withstand (B) absorb (C) dissipate (D) succumb
12. What does "FEM" stand for in technical fields like materials and structural engineering? (A) Fatigue Endurance Matrix (B) Fiber-Enhanced Module (C) Finite Element Method (D) Force Equilibrium Mapping
13. What does "CFD" stand for in technical fields like flow analysis, propulsion, and material interactions? (A) Coupled Fluid Dynamics (B) Computational Fluid Dynamics (C) Critical Flow Dynamics (D) Conjugate Fluid Diffusion
14. Concepts like __________ and friction are fundamental to understanding rotational motion and energy transfer in gears and bearings. (A) velocity (B) torque (C) amplitude (D) density
15. Innovations in __________ manufacturing, or 3D printing, enable rapid prototyping with complex geometries and reduced material waste. (A) subtractive (B) additive (C) destructive (D) conductive
16. In heat transfer, __________ refers to the process where thermal energy moves through a solid material without fluid motion. (A) convection (B) radiation (C) conduction (D) evaporation
17. In materials engineering, __________ is a measure of a material's resistance to elastic deformation when subjected to an applied load, often quantified by Young's modulus. (A) plasticity (B) liquidity (C) stiffness (D) brittleness
18. Furthermore, all claims must be supported by credible evidence, requiring meticulous use of __________ to avoid plagiarism and to allow readers to verify the sources. (A) formatting (B) citation (C) rhetoric (D) analysis
19. A key technical challenge is extending the operational __________ (flight time), often limited by battery size and power consumption. (A) agility (B) speed (C) capacity (D) endurance
20. In a turbofan engine, the high-pressure compressor __________ incoming air to increase its density, enabling more efficient combustion and higher thrust output. (A) expands (B) compresses (C) exhausts (D) diffuses

Part 3 (40 points) Read the following paragraphs and choose 1 correct answer to each question. Each question is worth 4 points.

Article 1: Ali, Kabbir, et al. "H2–CO-Rich Syngas in HCCI Engines: Combustion Performance, Challenges, and Future Prospects–A Comprehensive Review." *Energy* (2025): 139658.

The transportation and power generation sectors remain heavily dependent on combustion-based systems, which account for nearly 80 % of global primary energy demand in the form of high-grade heat, propulsion work, and electricity. However, the reliance on fossil fuels in internal combustion (IC) engines continues to exacerbate greenhouse gas emissions and environmental degradation, accelerating the need for low-carbon alternatives. In response, international energy policies are increasingly prioritizing carbon-neutral propulsion technologies that can balance energy security with stringent emission reduction targets.

Among emerging concepts, homogeneous charge compression ignition (HCCI) engines have gained attention for their ability to deliver high thermal efficiency and ultra-low NOx and particulate matter (PM) emissions by operating in a low-temperature combustion regime. A promising approach to fuel these systems involves the use of H2–CO-rich syngas, produced via coal, biomass, and waste gasification or recovered from industrial off-gases. In this dual-component fuel, hydrogen offers high reactivity and wide flammability limits, enabling lean-burn operation and stable ignition, while carbon monoxide provides controllable combustion phasing.

Utilizing H2-CO-rich syngas as fuel in HCCI engines offers several advantages. Firstly, the high H2 content in the off-gas provides an opportunity to tap into the clean-burning characteristics of hydrogen fuel, which can significantly reduce emissions of greenhouse gases and pollutants. Secondly, the presence of CO allows for better regulation of combustion timing and improved stability in HCCI engines, leading to enhanced efficiency and lower nitrogen oxide (NOx) emissions. HCCI engines depend on the auto-ignition of a homogeneous fuel-air mixture without a spark plug. In this context, the H2-CO-rich off-gas/syngas can be directly utilized as the primary fuel due to its auto-ignition characteristics and controlled burning characteristics. The precise control of the air-to-fuel ratio and compression ratio enables efficient combustion and lower emissions in HCCI engines.

Overall, utilizing H2-CO-rich off-gas/syngas as a fuel in HCCI combustion engines represents a promising avenue for achieving clean and efficient powertrains. The combination of hydrogen's clean-burning properties and carbon monoxide's combustion control capabilities enables these engines to deliver improved performance while reducing environmental impact. As research and development efforts continue, these technologies have the potential to play a significant role in the transition toward a more durable and greener transportation sector.

21. According to the text, why are international energy policies shifting their focus toward carbon-neutral propulsion technologies?
    (A) To completely replace primary energy demand with electricity.
    (B) To eliminate the need for high-grade heat in industrial sectors.
    (C) To balance energy security with the necessity of meeting strict emission reduction targets.
    (D) To reduce the global primary energy demand by more than 80%.

22. What is the specific role of Carbon Monoxide (CO) when used as part of a H2–CO-rich syngas in HCCI engines?
    (A) It provides high reactivity and wider flammability limits.
    (B) It allows for better regulation of combustion timing and improved stability.
    (C) It is responsible for creating a low-temperature combustion regime.
    (D) It acts as a primary lubricant for the internal combustion components.
23. Which of the following best describes the operational characteristic of a Homogeneous Charge Compression Ignition (HCCI) engine as mentioned in the text?
    (A) It relies on a spark plug to ignite a rich fuel-air mixture.
    (B) It requires a heterogenous mixture to maintain thermal efficiency.
    (C) It achieves auto-ignition of a homogeneous fuel-air mixture without using a spark plug.
    (D) It can only operate using pure hydrogen recovered from industrial off-gases.

Article 2: Shahjalal, Mohammad, et al. "A review on second-life of Li-ion batteries: Prospects, challenges, and issues." *Energy* 241 (2022): 122881.

Due to environmental and emerging energy concerns, the transportation industry is rapidly electrifying. For example, by 2030 Volvo cars will no longer provide vehicles powered exclusively by internal combustion engines, since electric vehicles (EVs) are proving to be a viable alternative to internal combustion engine-powered vehicles. Lithium-ion battery (LIB) is commonly used in transportation because of their high energy capacity (200–250 W h/kg), high columbic performance (nearly 100%), and lack of memory effect. In the automotive industry, a LIB is commonly determined to be no longer suitable if its output falls below 80% of its nominal capacity. In the coming years, a considerable number of batteries in EVs will be retired. For instance, 250,000 metric tons of EV lithium-ion batteries (LIBs) are predicted to hit end-of-life (EOL) by 2025. Again, even under the most optimistic estimates, 3.4 million kg of Li-ion EV battery cells might end up in the waste stream by 2040. As a result, a large number of retired batteries will be produced in future. In addition, in response to global climate change, the loss of fossil fuels has increased power production through the use of renewable energy sources such as solar or wind. The created power fluctuates due to the intermittent and time-varying existence of renewable energy sources. These are difficult to process into the grid, which has an effect on grid performance, voltage stability, and reliability. This can be effectively mitigated if the generated energy from a renewable source is first deposited in a battery, and then converted by an appropriate power electronic converter topology to achieve the necessary grid voltage, frequency, and permissible total harmonic distortion. Energy storage systems (ESS) will be in high demand in the coming years as more renewable energy systems are incorporated into the power grid. As a consequence, there will be a big number of retired batteries. These numerous retired batteries containing volatile chemical elements would be released into the atmosphere if reusing or recycling is not performed which will undergo both environmental and economic harm. Giving such retired batteries a second-life, which is the application of batteries after they have reached the end of their useable life would not only support the economy, but it will also help to minimize total battery demand, resulting in a substantial reduction in the use of extracted chemical materials and significantly benefit the transport-grid applications.

Second-life is a phenomenon with positive aspects such as lowering manufacturing costs and mitigating waste produced by direct disposal, as well as negative aspects such as battery collection, storage, handling, and recycling. However, because of its high energy potential, using this retied battery has attracted interest. According to Bloomberg New Energy Finance, the combined capacity of used EV batteries could exceed 185 GWh/year by 2025, with around three-quarters of used EV batteries being reused. The second-life battery (SLB) has the potential to generate more than 200 GWh by 2030, with a global value of more than $30 billion, according to another report. In order to optimize their economic and environmental benefits, batteries with available residual values can be reused rather than recycled or disposed of. LIBs that have been retired due to low performance may be recycled to recover valuable materials or discarded during the reuse process.

24. According to the automotive industry standards mentioned in the text, when is a lithium-ion battery (LIB) typically considered retired from an electric vehicle (EV)?
(A) When its energy capacity reaches 250 W h/kg.

(B) When its output falls below 80% of its nominal capacity.

(C) When the vehicle has been driven for more than 10 years.

(D) When the battery begins to exhibit a "memory effect".

25. How can retired EV batteries help address the challenges associated with renewable energy sources like solar and wind?

(A) By replacing renewable sources to provide a more constant power supply.

(B) By acting as energy storage systems (ESS) to mitigate power fluctuations before the energy enters the grid.

(C) By increasing the total harmonic distortion to match grid voltage.

(D) By extracting fossil fuels from the atmosphere to improve voltage stability.

26. What are the primary economic and environmental benefits of giving retired batteries a "second-life" instead of immediate recycling or disposal?

(A) It increases the demand for extracted chemical materials to support the economy.

(B) It eliminates the need for battery collection, storage, and handling.

(C) It lowers manufacturing costs, mitigates waste, and reduces the overall demand for new batteries.

(D) It guarantees that the combined capacity of batteries will stay below 185 GWh/year.

Article 3: Tian, Weiyong, et al. "Review of energy management technologies for unmanned aerial vehicles powered by hydrogen fuel cell." *Energy* 323 (2025): 135751.

With the serious environmental pollution and energy crisis, the continuous development of aircraft presents new challenges for carbon emissions reduction. Hydrogen energy is an important implementation method to decrease carbon emissions in the aviation field. In recent years, UAVs are widely used in various fields such as communication, power inspection, express delivery, environmental monitoring, urban firefighting, battlefield reconnaissance, and so on. They have become an indispensable part of our society production and daily life. These UAVs are powered by oil engines have some limitations in terms of noise pollution, vibration, and pollutant emissions. On the contrary, UAVs powered by hydrogen fuel cell are pollution-free, and they have excellent flight endurance, due to high energy density and high thermal efficiency of fuel cell. Proton exchange membrane fuel cells (PEMFC) use high-purity hydrogen as fuel, which can efficiently convert the chemical energy of hydrogen into electrical energy. Therefore, PEMFC is one of the most promising energy system solutions for small and medium-sized UAVs.

UAVs with PEMFC as the core energy system have attracted widespread attention. Because hydrogen does not undergo high-temperature combustion for PEMFC, its energy conversion efficiency is relatively high. Additionally, hybrid energy systems without engines take electricity as their only form of output energy, so that noise pollution is significantly reduced without high-speed rotation of engine rotors. Hybrid electric UAVs have more comprehensive advantages. Therefore, this work focuses on the research progress in energy management technologies for hybrid electric UAVs. Since the world's first fuel cell UAV is born in the "Helios UAV" modification project, various types of fuel cell UAVs have emerged rapidly.

The related designers and developers have continuously pursued the performance enhancement of fuel cell UAVs, and strove to improve the energy efficiency. From the initial flight endurance of only a few tens of minutes to the long-duration flights lasting several tens of hours, their flight endurance has significantly increasing with constantly breaking through the flight record. However, hydrogen fuel cells have a relatively high energy density, their power density is relatively low. If hydrogen fuel cell is taken as the only energy source, it is difficult to ensure UAV maneuverability and meet power requirements for the entire flight mission profile. This approach may result in significant redundancy in the power and weight scales of fuel cell, thus reducing energy utilization efficiency. Additionally, due to the time delay for hydrogen to diffuse and react within fuel cell, the response speed is relatively slow, and voltage characteristics are relatively weak. Instantaneous high-power output can easily lead to a significant voltage drop. Therefore, in order to meet the energy density requirements and power density requirements in flight process, fuel cell usually needs to be combined with other energy sources to compose hybrid energy systems. Lithium battery is the most commonly used energy source in UAVs, with a relatively high power density but a relatively low energy density. Solar cell can continuously harvest energy from flight environment, and convert it into electricity. However, the energy density and power density of solar cell are weak. Its output power is significantly affected by environmental conditions and UAV flight motion. Therefore, it is necessary to combine various energy sources based on their characteristics and flight mission requirements, which is to fully leverage the advantages of different energy sources.

27. Based on the text, what is a primary disadvantage of UAVs powered by traditional oil engines?
    (A) They have excessively high thermal efficiency.
    (B) They are limited by noise pollution, vibration, and pollutant emissions.
    (C) They lack the high-speed rotation required for engine rotors.
    (D) They cannot be used for battlefield reconnaissance or express delivery.
28. Why is the Proton Exchange Membrane Fuel Cell (PEMFC) considered a promising solution for small and medium-sized UAVs?
    (A) It converts electrical energy into high-purity hydrogen chemical energy.
    (B) It relies on high-temperature combustion to increase power density.
    (C) It offers high energy conversion efficiency and pollution-free operation.
    (D) It provides the highest power density among all known energy sources.
29. According to the passage, what technical limitation occurs when using a hydrogen fuel cell as the *only* energy source for a UAV?
    (A) The energy density is too low to sustain long-duration flights.
    (B) The response speed is slow due to the time delay for hydrogen diffusion and reaction.
    (C) It creates excessive voltage increases during instantaneous high-power output.
    (D) It eliminates the need for any cabin space arrangement.
30. How does a "hybrid energy system" optimize the performance of a UAV?
    (A) By using solar cells as the primary source to ensure high power density.
    (B) By combining sources like fuel cells (high energy density) and lithium batteries (high power density) to leverage their respective advantages.
    (C) By reducing the flight endurance from several tens of hours to only a few minutes.
    (D) By ensuring that the output power is never affected by environmental conditions.