ROYAL CIVIL SERVICE COMMISSION
BHUTAN CIVIL SERVICE EXAMINATION (BCSE) 2024
EXAMINATION CATEGORY: TECHNICAL

PAPER III: SUBJECT SPECIALISATION PAPER FOR AERONAUTICAL/AVIONIC ENGINEERING

Date	: October 5, 2024
Total Marks	: 100
Writing Time	: 150 minutes (2.5 hours)
Reading Time	: 15 minutes (prior to writing time)

GENERAL INSTRUCTIONS:

1. Write your Registration Number clearly and correctly on the Answer Booklet.
2. The first 15 minutes is to check the number of pages of Question Paper, printing errors, clarify doubts and to read the instructions. You are NOT permitted to write during this time.
3. This paper consists of **TWO SECTIONS**, namely SECTION A & SECTION B:
   - **SECTION A** has two parts: Part I - 30 Multiple Choice Questions
     Part II - 4 Short Answer Questions

     All questions under SECTION A are COMPULSORY.
   - **SECTION B** consists of two Case Studies. Choose only **ONE** case study and answer the questions of your choice.
4. All answers should be written on the Answer Booklet provided to you. Candidates are not allowed to write anything on the question paper. If required, ask for additional Answer Booklet.
5. **All answers should be written with correct numbering of Section, Part and Question Number in the Answer Booklet provided to you. Note that any answer written without indicating the Section, Part and Question Number will NOT be evaluated and no marks will be awarded.**
6. Begin each Section and Part in a fresh page of the Answer Booklet.
7. You are not permitted to tear off any sheet(s) of the Answer Booklet as well as the Question Paper.
8. Use of any other paper including paper for rough work is not permitted.
9. **You are required to hand over the Answer Booklet to the Invigilator before leaving the examination hall.**
10. This paper has **11 printed pages**, including this instruction page.

GOOD LUCK

SECTION A

PART I: Multiple Choice Questions (30 marks)

Choose the correct answer and write down the letter of your chosen answer in the Answer Booklet against the question number e.g. 31 (d). Each question carries ONE mark. Any double writing, smudgy answers or writing more than one choice shall not be evaluated.

1. Which certification confirms that an aircraft's design adheres to all regulatory safety and performance standards?
   a) Production Certificate
   b) Certificate of Airworthiness
   c) Supplemental Type Certificate
   d) Type Certificate

2. As per International Civil Aviation Organization (ICAO) standards, which common mark or nationality mark is designated for aircraft registered in Bhutan?
   a) A4-
   b) A5-
   c) A6-
   d) A7-

3. Which organization is responsible for being the custodian of all civil aviation regulatory matters in Bhutan?
   a) Bhutan Civil Aviation Authority
   b) Department of Air Transport
   c) Bhutan Construction and Transport Authority
   d) Drukair Corporation Limited

4. If $x^2 + 2xy = y^2$, then $\frac{dy}{dx}$ is
   a) $\frac{x+y}{y-x}$
   b) $2x + 2y$
   c) $\frac{x+1}{y}$
   d) $-x$

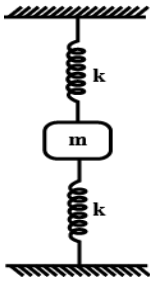
5. The equation of the straight line representing the tangent to the curve $y = x^2$ at the point (1,1) is
   a) $y = 2x - 1$
   b) $x = 2y - 1$
   c) $y - 1 = 2(x - 1)$
   d) $x - 1 = 2(y - 1)$

6. In isometric projection, how are the principal edges of an object oriented with respect to the projection plane?
   a) They form 90° angles with the projection plane
   b) They form equal angles of 120° with each other and are equally foreshortened
   c) They vary in length based on the object's orientation
   d) They are aligned parallel to the projection plane

7. The barrier potential across a P-N junction
   a) Decreases with increasing doping concentration
   b) Increases with decreasing band gap
   c) Does not depend on the doping concentration
   d) Increases with increase in doping concentration

8. Transform the hexadecimal value D5 into its corresponding binary form
   a) 10100101
   b) 11010010
   c) 11010101
   d) 10101011

9. A system consists of two springs and a mass $m = 1\ kg$ as shown in figure. If mass *m* is displaced slightly along vertical and released. The system oscillates with a period of 2 sec. Then the spring constant *k* is?



   a) $\frac{\pi 2}{2}$
   b) $\frac{\pi 2}{4}$
   c) $\frac{\pi 2}{6}$
   d) $\frac{\pi 2}{8}$

10. The maximum thickness to chord ratio for the NACA 24012 airfoil is
    a) 0.01
    b) 0.12
    c) 0.24
    d) 0.40

11. Laminar flow airfoils are used to reduce
    a) wave drag
    b) trim drag
    c) induced drag
    d) skin friction drag

12. An aircraft is cruising at a true air speed (TAS) of 100 m/s under ISA conditions, at which the air density of free stream is 0.526 kg/m^3. What will be the equivalent air speed (EAS)?
(ISA conditions: $\rho_0 = 1.225$ kg/m^3, $p_0 = 1$ atm $= 1.0132 * 10^5$ N/m^2, $T_0 = 288.16$ K)
    a) 65.5 m/s
    b) 72.5 m/s
    c) 110.5 m/s
    d) 152.7 m/s

13. The primary function of the fin in the vertical tail of an aircraft is to provide
    a) roll stability
    b) roll damping
    c) yaw stability
    d) yaw control

14. Which of the following statements is TRUE as the altitude increases in stratosphere of lnternational Standard Atmosphere?
    a) Temperature increases and dynamic viscosity decreases
    b) Temperature remains constant and pressure increases
    c) Temperature decreases and sound speed decreases
    d) Temperature remains constant and density decreases

15. A turbojet engine is operating with afterburner off. If the afterburner is switched on, then
    a) both thrust and *sfc* increase
    b) both thrust and *sfc* decrease
    c) thrust increases and *sfc* decreases
    d) thrust decreases and *sfc* increases

16. How does regeneration affect the efficiency of a Brayton cycle, and what is the primary mechanism by which it accomplishes this improvement?
    a) Regeneration increases the thermal efficiency by increasing the pressure of the air entering the combustion chamber.
    b) Regeneration has no effect on the thermal efficiency and only serves to reduce fuel consumption.
    c) Regeneration increases the thermal efficiency by using exhaust heat to preheat the air before it enters the combustion chamber.
    d) Regeneration decreases the thermal efficiency by cooling the exhaust gases before they leave the cycle.

17. Which of the following gases is commonly used to charge the accumulator in an aircraft hydraulic system?
    a) Nitrogen
    b) Oxygen
    c) Carbon dioxide
    d) Helium

18. Winglets are used on wings to minimize
    a) wave drag
    b) skin friction drag
    c) induced drag
    d) profile drag

19. In a semi-monocoque construction of an aircraft wing, the skin and spar webs are the primary carriers of
    a) shear stresses due to an aerodynamic moment component alone.
    b) normal (bending) stresses due to aerodynamic forces.
    c) shear stresses due to aerodynamic forces alone.
    d) shear stresses due to aerodynamic forces and a moment component.

20. Which one of the following flight instruments is used on an aircraft to determine its attitude in flight?
    a) Vertical speed indicator
    b) Altimeter
    c) Artificial Horizon
    d) Turn-bank indicator

21. In the structural design of an aircraft wing, which primary component serves as the main load-bearing element, running spanwise and providing essential support against bending forces?
    a) Spar
    b) Longerons
    c) Stringer
    d) Skin

22. The critical Mach number (M_{cr}) of an airfoil is defined as:
    a) The Mach number at which the flow remains entirely subsonic over the surface of the airfoil.
    b) The Mach number at which the entire flow field over the airfoil surface becomes sonic.
    c) The free-stream Mach number at which sonic conditions are first reached at any point on the airfoil surface.
    d) The Mach number at which aerodynamic drag on the airfoil is at its minimum.

23. If an aircraft is in pitching, rolling, and yawing moment equilibrium, then its flight is said to be in:
    a) Trim
    b) Equilibrium
    c) Steady state flight
    d) Neutral flight

24. If an aircraft battery is rated at 24V and has a capacity of 40Ah, what is the maximum power it can supply for 1 hour?
    a) 24 W
    b) 1200 W
    c) 28 W
    d) 960 W

25. Which of the following best describes the primary influence of the wheel base (B) on an aircraft with a tricycle landing gear?
    a) The wheel base primarily affects the aircraft's aerodynamic stability.
    b) The wheel base impacts the load distribution between the main and nose gear, as well as ground controllability and stability.
    c) The wheel base is most critical for determining the aircraft's take-off speed.
    d) The wheel base only affects the structural integrity of the landing gear.

26. Shock waves are very thin regions of the flow, across which some very severe changes in the flow properties take place. Specifically, as a fluid element flows through a shock wave, the:
    a) Mach number decreases
    b) static pressure decreases
    c) flow velocity increases
    d) Mach number remains same

27. The design aspect ratio for a conventional airplane is a compromise between:
    a) materials and structures
    b) thrust and lift
    c) aerodynamics and structures
    d) weight and lift

28. In a turbo jet engine, subsequent to heat addition to compressed air, to get the power output, the working substance is expanded in
    a) turbine blades, which is essentially an isentropic process
    b) turbine blades, which is a constant volume process
    c) exit nozzle, which is essentially an isentropic process
    d) exit nozzle, which is a constant volume process

29. For a wing-body combination, the aerodynamic center lies 0.05 chord length ahead of the center of gravity. The moment coefficient about the aerodynamic center is —0.016. If the lift coefficient is 0.45, calculate the moment coefficient about the center of gravity.
    a) −0.025
    b) −0.0065
    c) 0.0065
    d) 0.025

30. In a radar system, a modulator:
    a) separate two frequencies
    b) impress the information on to radar frequency carrier
    c) extract information from the carrier
    d) amplify the radar frequency signal

PART II – Short Answer Questions (20 marks)

This part has 4 Short Answer Questions. Answer ALL the questions. Each question carries 5 marks. Mark for each sub-question is indicated in the brackets.

Question 1

a) Explain the differences between monocoque and semi-monocoque structures in aircraft. **(2 Marks)**

b) Discuss the concepts of "safe life" and "fail-safe" structures in aircraft design. How do these approaches mitigate the risk of catastrophic fatigue failure? Provide examples of components that are typically designed with each approach. **(3 Marks)**.

Question 2

a) Calculate the slant range given by the distance measuring equipment for the following data:
Ground distance from the DME ground station is 10 NM (nautical miles) and the distance from the ground is 1 NM. Also, find the height of the aircraft from the ground if the value displayed by the DME is 6.1 NM and the ground distance of the aircraft from the DME ground station is 6 NM.
(3 Marks)

b) What do you understand by the following terms in the context of aircraft weight and balance? Explain briefly. **(2 Marks)**
(i) Datum
(ii) Basic Empty Weight
(iii) Mean Aerodynamic Chord
(iv) Useful load

Question 3

a) Describe the distinction between the Minimum Equipment List (MEL) and the Configuration Deviation List (CDL), and outline the different categories within the MEL. **(2 Marks)**

b) Distinguish between the centre of pressure and the aerodynamic centre of an airfoil. Explain why the pitching moment about the quarter chord point of an airfoil is nominally constant in subsonic flight. **(3 Marks)**

Question 4

a) Consider a hypersonic vehicle with a spherical nose flying at Mach 20 at a standard altitude of 150,000 ft, where the ambient temperature and pressure are 500°R and 3.06 lb/ft^2, respectively. At the point on the surface of the nose located 20° away from the stagnation point, estimate the:
(i) pressure, (ii) temperature, (iii) Mach number, and (iv) velocity of the flow. **(4 Marks)**
Given:
   i. *Specific heat ratio, $\gamma = 1.4$*

b) Consider the Northrop F-5 fighter airplane, which has a wing area of 170 ft^2. The wing is generating 18,000 lb of lift. For a flight velocity of 250 mi/h at standard sea level, calculate the lift coefficient. **(1 Mark)**

Given:

i. The air density at standard sea level, $\rho = 0.002377$ slugs/ft^3

ii. 1 mile = 5280 feet

SECTION B: Case Study (50 marks)

Choose either CASE I or CASE II from this section. Each case study carries 50 marks. Mark for each sub-question is indicated in the brackets.

The Impact of Emerging Technologies on Aviation Maintenance

CASE I

As an airworthiness officer or flight safety officer, you will be responsible for ensuring the safety, reliability, and efficiency of aircraft operations. With the rapid advancement of technology, new tools and methodologies are being introduced that significantly impact aviation maintenance practices. Your task is to analyze these emerging technologies and propose how they can be integrated into current aviation maintenance processes to enhance safety, efficiency, and cost-effectiveness.

Based on the above case study, answer the following questions in your own words:

1. Explain how the Internet of Things (IoT) can be used in aviation maintenance to improve real-time monitoring and predictive maintenance. Discuss the potential benefits and challenges of implementing IoT in the aviation industry. **(10 Marks)**

2. Augmented Reality (AR) is being increasingly adopted in aviation maintenance. Discuss how AR can assist technicians in their work and the impact it may have on training and operational efficiency. Provide examples of scenarios where AR could be most beneficial. **(10 Marks)**

3. Robotics and Artificial Intelligence (AI) are transforming how inspections and repairs are conducted in aviation. Propose a strategy for integrating these technologies into an existing aircraft maintenance organization. Your strategy should address:
   - The types of tasks that should be automated.
   - The potential risks and how to mitigate them.
   - Training requirements for personnel.

   (10 Marks)

4. Identify and analyze the key ethical and regulatory challenges associated with the adoption of AI and robotics in aviation maintenance. How would you address these challenges in your role as an airworthiness officer or flight safety officer? **(10 Marks)**

5. You are presented with a scenario where an AI system has predicted a potential failure in an aircraft component, but the traditional inspection methods do not confirm this finding. As an airworthiness officer, how would you approach this situation? Discuss the steps you would take to ensure safety while also considering the reliability of emerging technologies. **(10 Marks)**

CASE II

Mitigating Aircraft Noise and Emissions

The XYZ Airline operates a diverse fleet of mid-sized commercial jets, serving both regional and intercontinental routes. The airline has a strong market presence, but its environmental impact has come under scrutiny due to growing concerns about noise pollution near airports and the contribution of aircraft emissions to climate change.

Aircraft noise, particularly during takeoff and landing, is a significant source of community disturbance, leading to stricter noise regulations around airports. Emissions, including carbon dioxide (CO_2) and nitrogen oxides (NOx), contribute to global warming and local air quality issues, prompting regulatory agencies to impose stringent emission limits.

In response to these challenges, the airline has embarked on a comprehensive environmental initiative that includes both technological upgrades to its aircraft, the adoption of Sustainable Aviation Fuels (SAFs) and changes to its operational practices. This initiative is not only driven by regulatory requirements but also by the airline's commitment to corporate social responsibility, commitment to sustainability, and its desire to improve public perception.

- ***Technological Upgrades:***

The airline is investing heavily in new technologies that promise to reduce noise and emissions. Key areas of focus include:

a) *Engine Redesign:*
   Introduction of quieter, more fuel-efficient engines, incorporating advanced materials and aerodynamics to reduce noise and emissions.
b) *Noise-Reducing Technologies:*
   Implementation of technologies such as chevron nozzles, acoustic liners, and modified wing and landing gear designs to minimize noise impact.
c) *Emissions Control:*
   Adoption of cleaner fuels and advanced exhaust systems to reduce greenhouse gas emissions, alongside the exploration of Sustainable Aviation Fuels (SAFs).

- ***Operational Changes:***

To complement these technological upgrades, the airline is implementing several operational strategies aimed at minimizing its environmental impact:

a) *Optimized Flight Paths:*
   Redesign of flight paths to reduce noise impact on residential areas, including the use of continuous descent approaches.
b) *Efficient Scheduling:*
   Adjustment of flight schedules to limit operations during night-time hours in noise-sensitive regions.

c) *Regulatory Compliance:*
Commitment to exceeding current environmental regulations, positioning the airline as a leader in environmental stewardship.

Based on the above case study, answer the following questions in your own words:

1. Analyze the engineering principles behind the redesign of aircraft engines aimed at reducing noise and emissions. Discuss the potential benefits, challenges, and overall environmental impact of implementing these engines in the airline's fleet. **(10 Marks)**

2. Given specific engine parameters, calculate the thrust generated by the redesigned engine. Use the provided data below to determine how the new engine design impacts thrust-to-weight ratio, fuel efficiency, and emissions. Explain how these calculations influence the overall performance and environmental footprint of the aircraft. **(5 Marks)**
   Data for Thrust Calculation:
   - Engine bypass ratio: 10:1
   - Inlet air velocity: 300 m/s
   - Exhaust gas velocity: 600 m/s
   - Mass flow rate of air through the engine: 500 kg/s
   - Mass flow rate of fuel: 10 kg/s

3. Evaluate the effectiveness of advanced noise-reducing materials and design principles used in aircraft, considering factors such as cost, weight, maintenance, and compliance with noise regulations in real-world scenarios. **(10 Marks)**

4. Discuss the impact of optimizing flight paths on noise pollution and fuel efficiency, and analyze the challenges associated with implementing these changes, including potential conflicts with air traffic control and their implications for the airline's environmental performance and public perception. **(10 Marks)**

5. Analyze the potential of Sustainable Aviation Fuels (SAFs) to reduce the airline's carbon footprint. Discuss the benefits and challenges associated with SAFs and their impact on overall emissions and long-term sustainability. **(10 Marks)**

6. Based on your analysis, propose areas for further research or technological development that could help the airline achieve greater environmental sustainability, and discuss how future innovations in aeronautical engineering could influence the industry's approach to noise and emissions reduction. **(5 Marks)**