ROYAL CIVIL SERVICE COMMISSION
BHUTAN CIVIL SERVICE EXAMINATION (BCSE) 2023
EXAMINATION CATEGORY: TECHNICAL

PAPER III: SUBJECT SPECIALISATION PAPER FOR AERONAUTICAL/AVIONIC ENGINEERING

Date	: October 7, 2023
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 **9 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 agency is responsible for the registration of all civil aircrafts in Bhutan?
   a) Ministry of Infrastructure and Transport
   b) Bhutan Construction and Transport Authority
   c) Department of Air Transport
   d) Bhutan Civil Aviation Authority

2. Which of the following statements is **TRUE** regarding International Civil Aviation Organization (ICAO) and International Air Transport Association (IATA)?
   a) ICAO is a trade organization representing airlines, while IATA is a United Nations specialized agency.
   b) ICAO sets global standards and regulations for civil aviation, while IATA is an industry association representing airlines.
   c) ICAO focuses on lobbying for airline interests, while IATA is responsible for air traffic control.
   d) ICAO primarily deals with passenger ticketing and cargo logistics, while IATA develops air navigation systems.

3. Which of the following statements best characterizes circadian rhythms in the context of human factors?
   a) Circadian rhythms are biological processes that follow a strict 24-hour cycle, primarily driven by genetics.
   b) Circadian rhythms are solely influenced by external factors, such as light and temperature
   c) Circadian rhythms are highly adaptable and not affected by disruptions caused by shift work or travel across time zones
   d) Circadian rhythms do not affect sleep-wake patterns and hormone secretion

4. In a reciprocating engine, what is the term for the minimum volume formed in the cylinder when the piston is at Top Dead Center (TDC)?
   a) Compression volume
   b) Stroke volume
   c) Clearance volume
   d) Displacement volume

5. The Otto cycle is the ideal cycle for the spark-ignition reciprocating engines, and it consists of four internally reversible processes namely
   a) isentropic compression, constant-pressure heat addition, isentropic expansion, and constant-pressure heat rejection.
   b) isentropic compression, constant-volume heat addition, isentropic expansion, and constant-volume heat rejection.
   c) isentropic compression, constant-pressure heat subtraction, isentropic expansion, and constant-pressure heat acceptance.
   d) Isentropic compression, Isobaric heat addition, isentropic expansion, and Isobaric heat rejection.

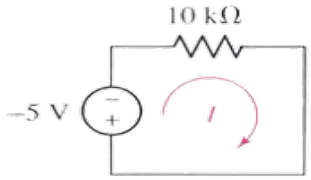
6. Which Law of Thermodynamics asserts that energy has quality as well as quantity, and actual processes occur in the direction of decreasing quality of energy?
   a) The Zeroth Law of Thermodynamics
   b) The First Law of Thermodynamics
   c) The Second Law of Thermodynamics
   d) The Third Law of Thermodynamics

7. In a closed-cycle gas-turbine engine, which of the following stages occurs at approximately constant pressure, as described by the Brayton cycle?
   a) Combustion and exhaust
   b) Combustion and intake
   c) Compression and exhaust
   d) Compression and combustion

8. In an adiabatic process, there is no transfer of:
   a) Heat
   b) Mass
   c) Energy
   d) Pressure

9. What is the main function of a transistor in an electronic circuit?
   a) To amplify signals
   b) To store charge
   c) To convert AC to DC
   d) To filter noise

10. In the circuit given below, what is the power absorbed by the resistor?



   a) 2.2 mW
   b) 2.3 mW
   c) 2.4 mW
   d) 2.5 Mw

11. An Inertial Navigation System (INS) works by
   a) using computers to keep a record of the aircraft's movement from a known starting point.
   b) frequent checks on position from satellites.
   c) using computers to continually work out the error in the magnetic readings and compensate accordingly.
   d) frequent checks on position using ground based radar stations.

12. In which layer of the atmosphere does most civilian aviation take place?
   a) Mesosphere
   b) Stratosphere
   c) Troposphere
   d) All of the above

13. The Maximum Zero Fuel Mass (MZFM) of an aircraft is
    a) the maximum permissible take off mas$ of the aircraft.
    b) the maximum permissible mass of an aircraft with no useable fuel.
    c) the maximum permissible mass of an aircraft with zero payload.
    d) the maximum permissible landing mass.

14. An airfoil has the root chord of 1.8 m and tip chord of 0.9 m. What is the taper ratio?
    a) 2
    b) 1
    c) 0.25
    d) 0.5

15. If an aeroplane of mass 950 kg has a wing area of 20 m^2, what is the wing loading in N/m^2?
    a) 465.7 N/m^2
    b) 475 N/m^2
    c) 47.5 N/m^2
    d) 237.9 N/m2

16. The portion of an Instrument Landing System (ILS) that provides guidance down the center line of the instrument runway is the_____.
    a) Marker Beacon
    b) Glideslope
    c) Localizer
    d) Inner Marker

17. What is the wavelength of a radio signal with a frequency of 150 MHz?
    a) 200 m
    b) 0.0002 m
    c) 2000 m
    d) 2 m

18. Fuel is prevented from surging back and forth in a fuel tank of the aircraft by the installation of what type of component inside the tank?
    a) Baffles
    b) Vents
    c) Filters
    d) Valves

19. In the context of aircraft structural design, what is the primary objective of implementing redundancy in critical structural components?
    a) To optimize the overall weight of the aircraft
    b) To fine-tune the overall balance of the aircraft
    c) To enhance fail-safety by providing backup structural support
    d) To minimize maintenance complexity

20. An aircraft climbs from sea level to 16,000 ft at 1,000ft per min, the cabin pressurisation is set to climb at 500ft per min to a cabin altitude of 8,000ft. The time taken for the cabin to reach 8,000ft is
    a) twice the time it takes the aircraft to reach 16,000ft.
    b) half the time it takes the aircraft to reach 16,000ft.
    c) the same time as it takes the aircraft to reach 16,000ft.
    d) three times the time it takes the aircraft to reach 16,000ft.

21. A specific measured distance from the datum or some other point identified by the manufacturer, to a point in or on the aircraft is called a
    a) zone number
    b) reference number
    c) arm measurement
    d) station number

22. What is the indication of last two digits in an early NACA 2412 airfoil series?
    a) maximum camber number
    b) maximum thickness
    c) maximum chord
    d) maximum diameter

23. Consider the following statements regarding the forces acting on an airplane in flight:
    I. Thrust, drag, lift and weight are the forces on an airplane in flight.
    II. The airplane is said to be in state of equilibrium, when thrust and drag are equal and opposite.
    III. If weight is greater than lift, the airplane will sink.
    IV. If thrust is greater than drag, the airplane will decelerate.

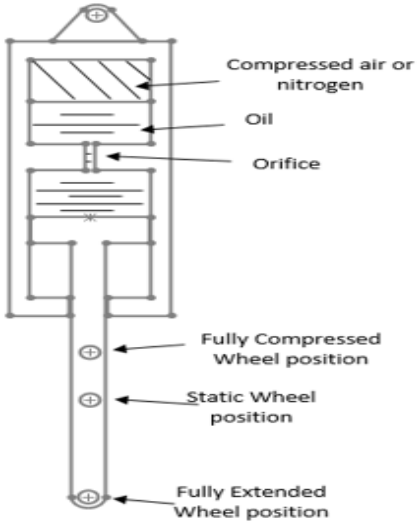
    Which of the above statements are correct?

    a) I, II and III only
    b) I, II and IV only
    c) I, III and IV only
    d) I, II, III and IV only

24. Consider the Lockheed Martin F-16 fighter airplane, which has a wing area of 15.79 m^2. The wing is generating 80,000 N of lift. For a flight velocity of 402.34 km/h at standard sea level, what is the lift coefficient? (Take density as 1.225 kg m^{-3})
    a) 0.66
    b) 0.45
    c) 0.24
    d) 0.16

25. In the Nose-gear shock strut, the link used to connect the strut cylinder to the piston and axle is called
    a) Overcenter Link
    b) Side Brace Link
    c) Torque Link
    d) Drag Link

26. Following structural components diagram of the landing gear system represents_____



a) Drag strut schematic
b) Simple oleo schematic
c) Downlock actuator schematic
d) Uplock actuator schematic

27. Engine Pressure Ratio (EPR) is defined as
a) the ratio of the compressor inlet pressure to the turbine exit pressure.
b) the ratio of the turbine exit pressure to the compressor inlet pressure.
c) the ratio of the turbine exit pressure to the ambient pressure.
d) the ratio of the compressor inlet pressure to the ambient pressure.

28. As the Angle of Attack (AoA) of an aircraft's wing reaches a specific threshold, what happens to the airflow over the wing and its lift characteristics?
a) The airflow becomes laminar, and the lift is significantly increased.
b) The airflow becomes turbulent, and the lift is significantly increased.
c) The airflow becomes turbulent, and the lift is significantly increased.
d) The airflow becomes turbulent, and the lift is significantly reduced.

29. Which of the following best describes the purpose of ACARS in aviation?
a) Aircraft Collision Avoidance and Resolution System
b) Aircraft Cabin Audio Recording System
c) Aircraft Communication Addressing and Reporting System
d) Aircraft Cargo Arrangement and Routing System

30. An aircraft should always take off into wind to
a) increase the length of take off run.
b) decrease the length of take off run.
c) increase ground speed at take off.
d) reduce air speed at take off.

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) Aircraft design engineers need to consider both Centre of Gravity (CG) and Centre of Pressure (CP) when designing an airplane. Explain why it is important to manage the positions of CG and CP in aircraft design for stability and control. **(2 marks)**

b) Discuss the concept of 'dynamic stability' in the context of CG and CP in aeronautics. How does dynamic stability differ from static stability, and why is it important? **(3 marks)**.

Question 2

a) How do laminar and turbulent flows differ in aerodynamics, and what are the implications for aircraft design and performance under these flow regimes? **(2.5 marks)**

b) How does VOR (VHF Omni-Directional Range) navigation work, and what are its advantages and limitations in modern aviation? **(2.5 marks)**

Question 3

a) What do you understand by the following terms? Explain briefly. **(3 marks)**
   (i) Airworthiness Directive (AD)
   (ii) Advisory Circular (AC)
   (iii)Service Bulletin (SB)
   (iv)Type Certificate (TC)

b) Explain the terms 'Sideslip' and 'Propeller Feathering' in your own words. **(2 marks)**

Question 4

a) Consider a convergent duct with an inlet area $A_1 = 3$ ft^2 and an exit area $A_2 = 2.57$ ft^2. Air enters this duct with a velocity $V_1 = 700$ ft/s and a density $\rho_1 = 0.002$ slug/ft^3, and air leaves with an exit velocity $V_2 = 1070$ ft/s. Calculate the density of the air ρ_2 at the exit. Is the flow compressible or incompressible? **(1 mark)**

b) Consider a turbojet powered airplane flying at a standard altitude of 30,000 ft at a velocity of 500 mi/h. The turbojet engine itself has inlet and exit areas of 7 ft^2 and 4.5 ft^2, respectively. The velocity and pressure of the exhaust gas at the exit are 1600 ft/s and 640 lb/ft^2, respectively. Calculate the thrust of the turbojet. **(2 marks)**
   *i. At standard altitude of 30,000 ft, pressure = 629.66 lb/ft^2, density = 8.9068 * 10^{-4} slug/ft^3*
   ii. 1 mile = 5280 feet

c) The fighter aircraft F-15 has a mass of 30,845 kg and a wing area of 56.5 m^2. If this fighter is cruising at 15,000 m altitude with the lift coefficient of 0.1, determine its true airspeed. (Take air density at 15,000 m altitude, $\rho = 0.1935$ kg/m^3). **(2 marks)**

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.

CASE I

In recent years, Bhutan has experienced a significant growth in air transportation. The government has made substantial investments in expanding and upgrading its airports to accommodate the increasing demand for both domestic and international flights as Bhutan's aviation industry has been expanding rapidly with the introduction of new international routes, modernization and expansion of domestic airports, increased number of fleets and growth of helicopter operations. However, the country's mountainous terrain and unpredictable weather conditions pose unique challenges for aviation safety and operations.

Therefore, as a Flight Safety Officer, you are responsible for overseeing the safety of all flight operations within Bhutan's airspace and must ensure that airlines, pilots, maintenance personnel, airports and all the aviation stakeholders adhere to strict safety standards to prevent accidents and incidents. With these tasks in your hand, answer the following questions in your own words:

1. Bhutan's mountainous terrain and challenging weather conditions can be a significant safety concern for aviation operations. How would you assess and mitigate the specific risks associated with these geographical and meteorological factors? **(10 marks)**

2. Describe the key safety regulations and procedures that need to be implemented to ensure the safe operation of international flights within Bhutan's airspace. **(12 marks)**

3. As a Flight Safety Officer, you need to oversee the safety practices of domestic airlines operating within Bhutan. What strategies would you employ to monitor and enforce safety standards consistently across all domestic carriers and its operations? **(10 marks)**

4. With the growth in air transportation, the workload of air traffic controllers have increased. How would you collaborate with the air traffic service providers to ensure that their operations align with flight safety best practices and standards? **(8 marks)**

5. Bhutan's mountainous terrain and challenging weather conditions make helicopter operations a crucial aspect of the country's aviation. Explain the critical safety considerations and protocols that should be integrated into the planning and conduct of helicopter operations to ensure the highest level of safety for passengers, crew, and the surrounding environment in Bhutan's unique operational environment. **(10 marks)**

CASE II

Back in the box: the importance of tool control for safety

Technology can assist, but not replace, human thoroughness in controlling this foreign object damage hazard.

"On 07 October 2010, ABC Airlines Airbus A320 was taking off from JFK airport when the crew reported feeling a vibration and hearing a 'popping' noise that rapidly increased in frequency and volume. At the same time, the aircraft veered to the right of the runway centreline despite the first officer applying full left rudder. The captain immediately selected reverse thrust and brought the aircraft to a stop. During the incident, passengers, an air traffic controller and the crew of the following aircraft saw a burst of flames coming from the right engine. An inspection immediately after found metallic debris in the tailpipe of the right engine. When it was dismantled, a screwdriver tip was found in the engine's combustion section. It had done significant damage to the high-pressure compressor. Based on the aircraft's maintenance records, the tip had been in the engine for 112 flights. It nicked and scratched stator vanes and compressor blades, one of which eventually detached, causing the engine failure".

Leaving tools or fasteners in the component or system being serviced comprises about 10 percent of maintenance error, leading to various incidents and accidents. These foreign object debris have become a major hazard causing costly damage to the aircrafts and its various components. Tendency of human beings to be forgetful due to the influence of various human factors have been a biggest safety challenges in the aviation world.

Therefore, proper system with the utilisation of technology (Radio-Frequency Identification or barcode system) to track the maintenance tools need to be always incorporated in aviation maintenance environment to better control tools so that maintenance personnel doesn't leave the tools behind after the maintenance.

In view of significance of systematic tool control culture in the aircraft maintenance environment, answer the following questions in your own words:

1. Explain the statement, "Technology can assist, but not replace, human thoroughness in controlling this foreign object damage hazard." What are the limitations of technology in addressing the issue of foreign object debris in aviation maintenance, and why is human vigilance still essential? **(8 marks)**
2. Analyze the incident involving ABC Airlines Airbus A320 and the screwdriver tip left in the engine. What were the root causes of this incident, and how could technology-based solutions, such as tool tracking systems, have prevented it? **(12 marks)**
3. Discuss the various human factors that contribute to maintenance personnel leaving tools or fasteners behind in aircraft components. How can human factors engineering principles be applied to reduce the occurrence of such errors? **(12 marks)**
4. Examine the role of maintenance procedures and checklists in preventing foreign object damage hazards. How can technology be integrated into these procedures to enhance tool accountability and prevent tool-related incidents? **(10 marks)**
5. Evaluate the benefits and challenges of implementing technology-based solutions, such as Radio-Frequency Identification (RFID) or digital tool tracking systems, to control maintenance tools in the aviation industry. What competencies and training would maintenance personnel require to effectively use these systems? **(8 marks)**