ROYAL CIVIL SERVICE COMMISSION
BHUTAN CIVIL SERVICE EXAMINATION (BCSE) 2025
EXAMINATION CATEGORY: TECHNICAL

PAPER III: SUBJECT SPECIALISATION PAPER FOR AERONAUTICAL/AVIONIC ENGINEERING

Date	:	October 11, 2025
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 **10 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. In computer architecture, a byte is defined as a collection of how many bits?
   a) 2^n where n = 1
   b) Equivalent to one hexadecimal digit
   c) 8
   d) Half of a word in a 16-bit system

2. Which one of the following engines should be used by a subsonic passenger transport airplane for minimum specific fuel consumption?
   a) Turbojet engine with afterburner
   b) Turbofan engine
   c) Ramjet engine
   d) Scramjet engine

3. Total pressure at a point is defined as the pressure when the flow is brought to rest
   a) Isobarically
   b) Isothermally
   c) Isentropically
   d) adiabatically

4. On which one of the following thermodynamic cycles does an ideal ramjet operate?
   a) The Rankine cycle
   b) The Brayton cycle
   c) The Carnot cycle
   d) The Otto cycle

5. In steady, level turning flight of an aircraft at a load factor 'n', the ratio of the horizontal component of lift and aircraft weight is
   a) $\sqrt{n} - 1$
   b) $\sqrt{n} + 1$
   c) $\sqrt{n^2} - 1$
   d) $\sqrt{n^2} + 1$

6. Which one of the following high lift device results in higher stalling angle?
   a) Leading-edge flap
   b) Plain flap
   c) Fowler flap
   d) Split flap

7. A turbofan engine has a bypass ratio of 5 and a total mass flow rate of 120 kg/s. The mass flow rate through the bypass duct is
   a) 600 kg/s
   b) 120 kg/s
   c) 100 kg/s
   d) 20 kg/s

8. Sam is going to assemble a computer by himself. He has the choice of chips from two brands, a hard drive from four, memory from three, and an accessory bundle from five local stores. How many different ways can Sam order the parts?
   a) 100
   b) 120
   c) 125
   d) 130

9. At a certain point in a horizontal pipeline, the water's speed is 2.50 m/s and the gauge pressure is 1.80×10^4 Pa. Find the gauge pressure at a second point in the line if the cross-sectional area at the second point is twice that at the first. (Take $\rho = 1000$ kg/m^3)
   a) 1.95×10^4 Pa
   b) 1.80×10^4 Pa
   c) 2.20×10^4 Pa
   d) 2.03×10^4 Pa

10. During reentry, the space shuttle creates a shock-wave cone that makes an angle of 58.0° with its direction of motion. If the speed of sound at this altitude is 331 m/s, what is the Mach number of the shuttle at this instant?
    a) 1.18
    b) 0.85
    c) 1.50
    d) 1.75

11. Which of the following statements correctly distinguishes the Otto cycle from the Brayton cycle?
    a) The Otto cycle is used for gas turbines with constant-pressure heat addition, while the Brayton cycle is used for spark-ignition engines with constant-volume heat addition.
    b) Both the Otto and Brayton cycles operate with isothermal compression and expansion, but the Otto cycle has constant-pressure heat addition.
    c) The Otto cycle is typically used in spark-ignition engines with constant-volume heat addition, whereas the Brayton cycle is used in gas turbines with constant-pressure heat addition.
    d) The Brayton cycle is a practical cycle for internal combustion engines with adiabatic heat rejection, while the Otto cycle is idealized with isobaric processes.

12. For an airplane to be statically stable, its centre of gravity must always be
    a) ahead of neutral point
    b) aft of neutral point
    c) ahead of wing aerodynamic centre
    d) aft of the wing aerodynamic centre

13. A main objective of by-pass in a turbo-fan engine is to increase
    a) mass flow rate through engine inlet
    b) turbine inlet temperature
    c) mass flow rate through exhaust nozzle
    d) compressor pressure ratio

14. Thermodynamic cycle on which the jet engine operates can be
    a) either open or closed Brayton cycle
    b) open Brayton cycle only
    c) either open or closed Rankine cycle
    d) open Rankine cycle only

15. Propulsion efficiency of a jet engine is
    a) inversely proportional to both the thrust power and the air mass flow rate
    b) directly proportional to both the thrust power and the air mass flow rate
    c) inversely proportional to the thrust power and directly proportional to the air mass flow rate
    d) directly proportional to the thrust power and inversely proportional to the air mass flow rate

16. In an un-powered glide of an aircraft having weight *W*, lift *L* and drag *D*, the equilibrium glide angle is defined as
    a) $\tan^{-1}$ (L/D)
    b) $\tan^{-1}$ (D/L)
    c) $\tan^{-1}$ (L/W)
    d) $\tan^{-1}$ (W/L)

17. Lift on an aircraft climbing vertically up is
    a) equal to its weight
    b) zero
    c) equal to the drag
    d) equal to the thrust

18. In the context of Prandtl's lifting line theory for a finite wing, which of the following combinations of statements is **TRUE**?
    P: The bound vortex is responsible for the lift force
    Q: The trailing vortices are responsible for the induced drag
    R: The bound vortex is responsible for the induced drag
    S: The trailing vortices are responsible for the lift force
    a) P,Q
    b) Q,R
    c) R,S
    d) P,S

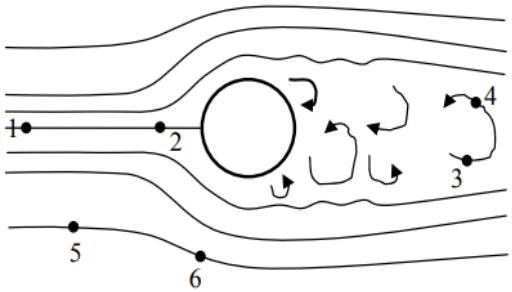
19. The general solution of the differential equation $\frac{dy}{dx} - 2\sqrt{y} = 0$ is
    a) $y - \sqrt{x} + C = 0$
    b) $y - x + C = 0$
    c) $\sqrt{y} - \sqrt{x} + C = 0$
    d) $\sqrt{y} - x + C = 0$

20. Bernoulli's equation is valid under steady state
    a) between any two points in both inviscid flow and potential flow.
    b) between any two points in inviscid flow, and only along a streamline in potential flow.
    c) only along a streamline in inviscid flow, and between any two points in potential flow.
    d) only along a streamline in both inviscid flow and potential flow.

21. The Mach angle for a flow at Mach 2.0 is
    a) 30°
    b) 45°
    c) 60°
    d) 90°

22. Which one of the following is the most stable configuration of an airplane in roll?
    a) Sweep back, anhedral and low wing
    b) Sweep forward, dihedral and low wing
    c) Sweep forward, anhedral and high wing
    d) Sweep back, dihedral and high wing

23. Streamline pattern of flow past a cylinder is shown in the figure below. The oncoming flow is steady, irrotational and incompressible. The flow is from left to right. Bernoulli's equation CANNOT be applied between the points



    a) 5 and 6
    b) 3 and 4
    c) 1 and 5
    d) 1 and 2

24. For a NACA 4415 airfoil, the location of maximum camber, as a fraction of the chord length from the leading edge, is
    a) 0.40
    b) 0.04
    c) 0.44
    d) 0.15

25. At what bank angle must an aircraft fly to maintain a coordinated turn on a circular path of radius 120 m at a velocity of 53 m/s?
    a) 45°
    b) 60°
    c) 67°
    d) 75°

26. A significant limitation of carbon-fibre-reinforced plastics (CFRP) that must be considered in aircraft design is:
    a) Brittleness and susceptibility to invisible impact damage
    b) Low stiffness compared to glass-reinforced plastic (GRP)
    c) Plastic yielding under stress concentrations
    d) High resistance to fatigue failure

27. Which one of the following systems is most suitable for short range navigation of airplanes?
    a) Distance Measuring Equipment (DME)
    b) Instrument Landing System (ILS)
    c) VHF Omni-directional Range (VOR)
    d) Global Positioning System (GPS)

28. Which of the following engines has no moving parts like compressors or turbines?
    a) Ramjet only
    b) Scramjet only
    c) Both Ramjet and Scramjet
    d) Neither Ramjet nor Scramjet

29. Which of the following statements about adverse yaw of an airplane is/are correct?
    P. It is caused by flow separation resulting from large rudder deflection.
    Q. It is caused by dissimilar drag forces acting on the two halves of the wing resulting from aileron deflections of same magnitude.
    R. It can be eliminated by ensuring that the upward deflection of one aileron is greater than the downward deflection of the opposite aileron.

    a) Q and R
    b) P and R
    c) P only
    d) Q only

30. Consider an airfoil in a flow of air, where far ahead (upstream) of the airfoil, the pressure, velocity, and density are 2116 lb/ft^2, 146.7 *ft/s*, and 0.002377 $slug/ft^3$, respectively. At a given point A on the airfoil, the pressure is 2070 lb/ft^2. What is the velocity at point A ?
    a) 242.0 *ft/s*
    b) 245.4 *ft/s*
    c) 248.0 *ft/s*
    d) 250.5 *ft/s*

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) A high-speed aircraft is cruising in still air. How will the temperature of air at the nose of the aircraft differ from the temperature of air at some distance from the aircraft? **(2 Marks)**

b) What four processes make up the simple ideal Brayton cycle? **(2 Marks)**

c) What is Reynolds number? Explain briefly why it is important in determining the type of flow over a wing? **(1 Marks)**

Question 2

a) Explain why flow separation occurs more easily in a laminar boundary layer compared to a turbulent boundary layer, and discuss its impact on lift and drag characteristics of an airfoil at high angles of attack. **(3 Marks)**

b) Explain the engineering principles and design strategies used in modern aircraft to ensure protection against lightning strikes. **(2 Marks)**

Question 3

a) An aircraft is cruising at an altitude of 9 km. The free-stream static pressure and density at this altitude are 3.08×10^4 N/m^2 and 0.467 kg/m^3 respectively. A Pitot tube mounted on the wing senses a pressure of 3.31×10^4 N/m^2. Ignoring compressibility effects, calculate the cruising speed of the aircraft. **(3 Marks)**

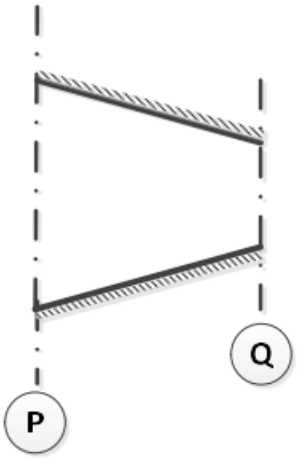
b) Air enters an aircraft engine at a velocity of 180 *m/s* with a flow rate of 94 *kg/s*. The engine combustor requires 9.2 *kg/s* of air to burn 1 *kg/s* of fuel. The velocity of gas exiting from the engine is 640 *m/s*. Calculate the momentum thrust (in *N*) developed by the engine. **(2 Marks)**

Question 4

a) In a converging duct given below, area and velocity at section P are 1 m^2 and 15 *m/s*, respectively. The temperature of the fluid is 300 *K*.

Air flow through the nozzle can be assumed to be inviscid and isothermal. Characteristic gas constant is 287 *J/(kg-K)* and ratio of specific heats is 1.4 for air.

To ensure that the air flow remains incompressible (Mach number, $M \leq 0.3$) in the duct, calculate the minimum area required at section Q. **(3 Marks)**



b) A Drukair Airbus A320 aircraft is cruising at a standard altitude of 30,000 *ft* with a velocity of 550 *mi/h*. Calcute its Mach number. **(2 Marks)**

At this altitude, the standard temperature is 411.86°R. Take the gas constant for air as 1716 *ft · lb/(slug)(°R)* and the ratio of specific heats as 1.4.

(Use 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.

CASE I

Certification and Airworthiness Challenges of eVTOL Aircraft

The Civil Aviation Authority (CAA) of Bhutan has received an application from an operator proposing to introduce electric vertical take-off and landing (eVTOL) capable powered-lift aircraft for short-range urban air mobility (UAM). These aircrafts are intended for passenger transport between key urban and semi-urban areas. The proposed design is a fully electric, tilt-rotor eVTOL capable of carrying 4 passengers with a range of 100 km per charge.

The operator claims the aircraft is safe, sustainable, and compliant with international standards. However, eVTOL technology introduces unique challenges in terms of airworthiness certification, battery reliability, maintenance, continuing airworthiness management, and integration into existing airspace.

As an Airworthiness Officer/Flight Safety Officer in the CAA, you are required to evaluate the application and assess the potential risks, compliance aspects, and regulatory requirements.

Based on this case study, answer the following questions:

Question 1: Design and Propulsion Fundamentals

a) Explain how lift, thrust-to-weight ratio, and stability requirements differ between a conventional fixed-wing aircraft and a tilt-rotor eVTOL design. **(10 Marks)**

Question 2: Certification and Compliance Challenges

a) List and explain five key airworthiness requirements that should be considered during the certification of an eVTOL aircraft. **(10 Marks)**

Question 3: Continuing Airworthiness & Maintenance

a) Define the Aircraft Maintenance Programme (AMP) and formulate a structured framework for the approval of a Maintenance Programme specific to eVTOL aircraft, with focused considerations on battery systems, electric propulsion units, the airframe, associated systems, and software update management. **(10 Marks)**

Question 4: Safety & Risk Assessment

a) Analyze how system redundancy and fail-safe architecture in eVTOL designs influence certification decisions. Provide two practical examples. **(10 Marks)**

Question 5: Personnel Licensing

a) Considering that eVTOL aircraft may operate in piloted, remotely piloted, or autonomous modes, and that they also require routine maintenance and inspection, how should the CAA define the licensing and training requirements for both pilots and maintenance engineers? **(10 Marks)**

CASE II

Airworthiness and Technical Challenges of Heavy-Payload UAS (Cargo Drones)

A private operator in Bhutan has proposed the use of a large Unmanned Aircraft System (UAS) for cargo transportation in remote and mountainous regions. The system is designed with a maximum take-off weight of 250 kg, a payload capacity of 100 kg, and is powered by twin electric motors supported by swappable lithium battery packs. It has a composite airframe with fixed landing gear, can operate autonomously with ground station override, and offers an endurance of 2.5 hours with a range of up to 200 km, including beyond visual line of sight (BVLOS) capability.

The operator highlights that this UAS could reduce costs and environmental impacts compared to short-haul manned cargo flights. However, introducing such heavy-payload drones presents significant engineering, airworthiness and operational challenges. Key concerns include structural integrity of the airframe, reliability of the propulsion and power systems, handling of loss-of-link scenarios, and ensuring safe integration into controlled civil airspace.

Question 1: Structural & Aerodynamic Considerations

a) What do you understand by the term 'Drones'? **(2 Marks)**

b) Analyze the aerodynamic challenges associated with mounting heavy payloads on large UAS. In your answer, discuss effects on stability, control authority, center of gravity shifts, induced drag, and potential flow disturbances, and how these factors influence the overall airworthiness of the drone. **(8 Marks)**

Question 2: Propulsion Systems

a) Propose two alternative propulsion or energy solutions to improve endurance or payload capacity of the drone. For each solution, analyze its feasibility, engineering trade-offs, and integration challenges with the existing airframe and autonomous systems. **(10 Marks)**

Question 3: Flight Control & Autonomy

a) Discuss the role of redundancy in sensors, communication links, and actuators in ensuring flight safety. **(10 Marks)**

Question 4: Safety & Risk Mitigation

a) Assess the consequences of in-flight propulsion failure and discuss various mitigation strategies. **(10 Marks)**

Question 5: Continuing Airworthiness & Operational Safety

a) Recommend six critical inspection, maintenance, or monitoring tasks for ensuring continuing airworthiness of heavy-payload UAS. Include both structural and system-level checks. **(6 Marks)**

b) Explain how engineering and operational data such as flight logs, battery cycle life, structural fatigue monitoring, etc. can support decisions regarding continuing airworthiness. **(4 Marks)**

TASHI DELEK