

Section - B

- Q.5) Derive the fundamental equation of thin airfoil theory and solve it for symmetric airfoil. 20
 Show the typical distribution of pressure coefficient on the upper and the lower surfaces of an airfoil for a zero and non-zero angle of attack. 09
 (c) Explain with appropriate sketches how stall occurs in an airfoil at a high angle of attack. 06
- Q.6(a) What is Magnus effect? A cylinder with 300 mm diameter with a circulation Γ is placed in free stream with uniform velocity of 5 m/s. Calculate the value of Γ when both the stagnation points coincide on the body. Also calculate the lift acting on the cylinder. Take $\rho_{air} = 1.2 \text{ kg/m}^3$. 15
 (b) A Rankine oval of 2 m long and 1 m high is immersed in a stream of 10 m/s, as in Fig. 6(b). Determine (i) the velocity at point A and (ii) the location of point B where a particle approaching the stagnation point achieves its maximum deceleration. 20

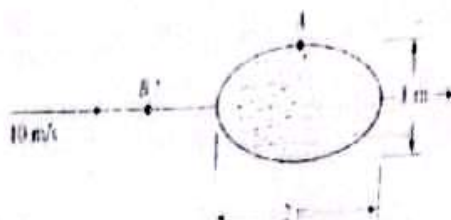


Fig. 6(b)

- Q.7) Find the velocity distribution and shear stress for the following cases by the exact solution of Navier-Stokes equations. (i) Plane Poiseuille flow and (ii) Plane Couette flow. The x-momentum equation is given as $\rho \left[\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} + w \frac{\partial u}{\partial z} \right] = -\frac{\partial p}{\partial x} + \mu \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} \right) + \rho b_x$. 20
- (b) The viscous, incompressible flow between the parallel plates shown in Fig 7(b) is caused by both the motion of the top plate and a pressure gradient $\frac{dp}{dx}$. Find the required pressure $\frac{dp}{dx}$ to achieve zero net volume flow rate across a cross-section. 15

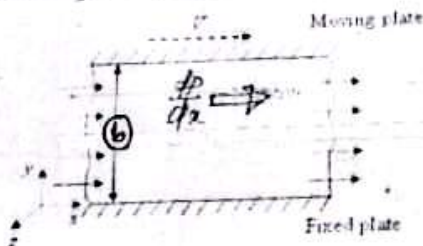


Fig. 7(b)

- Q.8(a) Define stability of an aircraft. Explain positive dynamic stability with necessary sketches. 10
 (b) What are the purposes of flaps in an aircraft? Name with neat sketches different types of flaps used in airplane. 10
 (c) In a tornado as shown in Fig.8(c), the circulation is $8500 \text{ m}^2/\text{s}$ and that the pressure at $r = 40 \text{ m}$ is 2200 Pa which is less than the far-field pressure. Assuming sea-level density of air, calculate (i) the sink strength, (ii) the pressure at $r = 15 \text{ m}$, and (iii) the angle β at which the streamlines cross the circle at $r = 40 \text{ m}$. 15

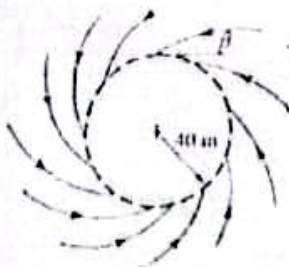


Fig. 8(c)

***** The End *****

Department of Mechanical Engineering
Chittagong University of Engineering and Technology (CUET)
Level 4, Term-II, Examination 2022

Course: ME 423	Full Marks: 210	Time: 3 hours
Course Title: Aerodynamics	Date: 27/02/2024	

The figures in the right margin indicate full marks. The questions are of equal value. There are 04 questions in each section. Answer any 03 questions from each section. Use separate script for each section.

Section - A

- Q1 (a) Define aerodynamics and identify the applications of aerodynamics. 08
 (b) What are the sources of the aerodynamic drag? Name them. 07
 (c) Consider a Boeing 747 airliner cruising at a velocity of 246 m/s at a standard altitude of 11 km, where the freestream pressure and temperature are 22.7 kPa and 216.77 K, respectively. A one-fiftieth scale model of the 747 is tested in a wind tunnel where the temperature is 238.88 K. determine the required velocity and pressure of the test airstream in the wind tunnel such that the lift and drag coefficients measured for the wind-tunnel model are the same as for free flight. Assume that both μ and velocity of sound are proportional to $T^{1/2}$. 20
- Q2 (a) Derive the fundamental thrust equation for jet propulsion and hence simplify it for a rocket engine. 15
 (b) Consider a rocket engine burning hydrogen and oxygen; the combustion chamber pressure and temperature are 25 atm and 3517 K, respectively. The area of the rocket nozzle throat is 0.1 m². The area of the exit is designed so that the exit pressure exactly equals ambient pressure at a standard altitude of 30 km. For the gas mixture, assume that $\gamma = 1.22$ and the molecular weight $M = 16$. At a standard altitude of 30 km, determine (i) specific impulse, (ii) thrust, (iii) area of the exit, and (iv) flow Mach number at exit. 20
- Q3 (a) What do understand by range and endurance for a jet airplane? 05
 (b) Derive the general equation of motion of airplane and hence show that during level and unaccelerated flight, lift force is balanced by weight of the airplane. 15
 (c) A jet powered aircraft, Airbus A-321 has the following characteristics: 15
 Wing span = 35.80 m, wing area = 122.4 m², normal gross weight = 93500 kg, power plant (thrust) = 147 × 2 kN, parasite drag co-efficient = 0.026 and Oswald efficiency factor = 0.746. AR = $\frac{b^2}{S}$
 Calculate the thrust required for the cruising velocity of 300 m/s in level and unaccelerated flight. TR
- Q4 (a) What is V-n diagram in context to flight operation? Draw a typical V-n diagram and explain. 08
 (b) Explain how sweepback makes aircraft directionally stable. 09
 (c) Boeing 787-8 Dreamliner have maximum takeoff weight of 2,27,930 kg, maximum lift co-efficient during takeoff, wing span 60.17 m, wing area 377 m², power plant (thrust) 2 × 280 kN, wing height (when the airplane is on the ground) = 5.94 m, parasite drag co-efficient 0.027 and Oswald efficiency factor 0.771. Assume a paved runway where $\mu_r = 0.02$. Determine minimum length of the runway required for takeoff Boeing 787-8 aircraft. 18

Section - B

- Q5 (a) Find the velocity distribution and shear stress for following cases by the exact solution of Navier-Stokes equations, (i) Plane Poiseuille flow and (ii) Plane coquette flow. The x-momentum equation is given as: 20

$$\rho \left[\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial v}{\partial y} + w \frac{\partial w}{\partial z} \right] = -\frac{\partial p}{\partial x} + \mu \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} \right) + \rho b_x$$

- (b) Deduce the velocity distribution equation by the approximate solution of flow through a circular pipe by applying of N-S equation or exact solution of N-S equation for pipe flow. The continuity and z-momentum equations are given as: 15

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$\frac{e^2}{2\pi R L}$

Continuity equation: $\frac{1}{r} \frac{\partial}{\partial r} (\rho r v_r) + \frac{1}{r} \frac{\partial}{\partial \theta} (\rho v_\theta) + \frac{\partial}{\partial z} (\rho v_z) = 0$

z - momentum equation:

$$\rho \left(\frac{\partial v_z}{\partial t} + v_r \frac{\partial v_z}{\partial r} + \frac{v_\theta}{r} \frac{\partial v_z}{\partial \theta} + v_z \frac{\partial v_z}{\partial z} \right) = -\frac{\partial p}{\partial z} + \mu \left[\frac{1}{r} \frac{\partial}{\partial r} \left(r \frac{\partial v_z}{\partial r} \right) + \frac{1}{r^2} \frac{\partial^2 v_z}{\partial \theta^2} + \frac{\partial^2 v_z}{\partial z^2} \right]$$

Q.6 (a) Prove that the surface pressure coefficient over a circular cylinder is $C_p = 1 - 4\sin^2\theta$. 12
Also draw the theoretical and experimental value of distribution C_p over a circular cylinder.

(b) Derive the expression for the Kutta-Joukowski theorem by superimposing stream functions of the elementary flows such as uniform flow, a doublet and a vortex flow. 13

(c) A cylinder 1.2 m in diameter and 8 m long rotates at 90 rpm with its axis perpendicular to an air stream with a wind velocity of 30 m/s. Assuming no slip condition between the cylinder and the circulatory flow, find (i) magnitude of circulation and (ii) the transverse or lift force. 10

Q.7 (a) Draw an asymmetric (cambered) airfoil and show its nomenclature. Also show the drag and lift forces when the airfoil is placed at an angle of attack greater than zero against a uniform system. 07

(b) Derive the fundamental equation of thin airfoil theory for symmetrical airfoil. 20

(c) Explain the Kutta condition for the flow is smoothly leaving from the trailing edge of the airfoil. 08

Q.8 (a) Prove that ideal propulsive efficiency of the propulsion system $\eta_p = \frac{V}{\frac{1}{2}(V_s + V)}$ 18

The symbols have usual meaning.

(b) An aircraft is propelled by a 4.472 m diameter propeller, which produces 35.6 kN thrust. The aircraft is flying at an altitude where the atmospheric conditions are such that the density of air is 1.03 kg/m^3 . Using momentum theory, determine: (i) the induced velocity, and (ii) the final velocity of the flow in the far wake. Assume the efficiency of the propeller is 90%. 17

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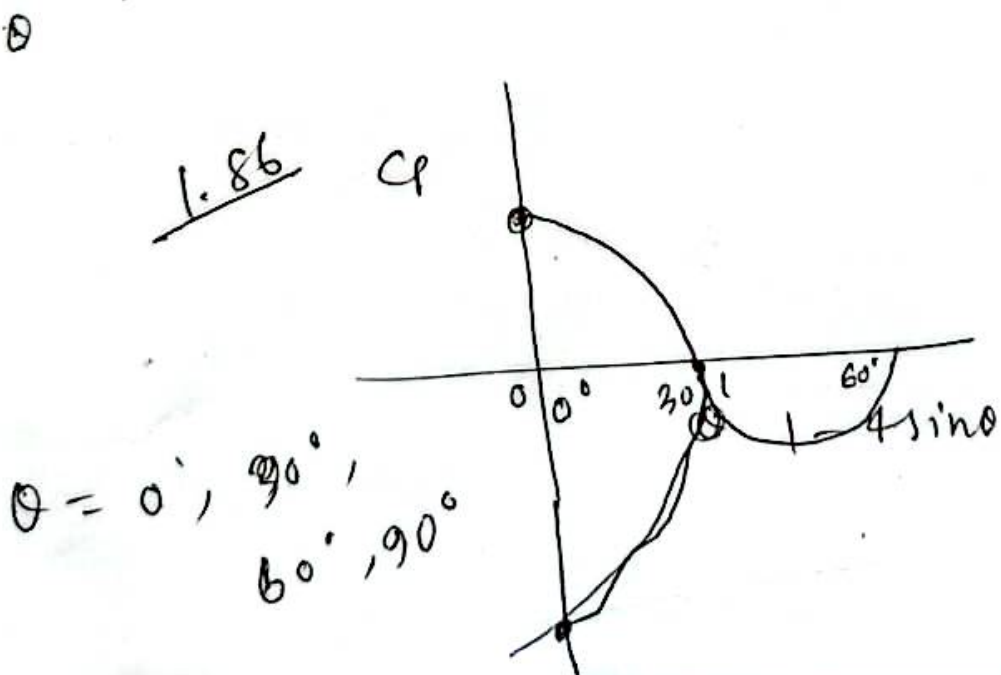


TABLE 1.2A U.S. Standard Atmosphere, 1976 SI Units

Geometric Altitude (km)	Pressure (N/m ²)	Temperature (K)	Density (kg/m ³)	Viscosity (kg/m·s)	Speed of Sound (m/s)
0	1.0133 E + 05	288.150	1.2250 E + 00	1.7894 E - 05	340.29
1	8.9875 E + 04	281.651	1.1117 E + 00	1.7579 E - 05	336.43
2	7.9501 E + 04	275.154	1.0066 E + 00	1.7260 E - 05	332.53
3	7.0121 E + 04	268.659	9.0926 E - 01	1.6938 E - 05	328.58
4	6.1669 E + 04	262.166	8.1934 E - 01	1.6612 E - 05	324.59
5	5.4048 E + 04	255.676	7.3643 E - 01	1.7885 E - 05	320.55
6	4.7217 E + 04	249.187	6.6012 E - 01	1.5949 E - 05	316.45
7	4.1105 E + 04	242.700	5.9002 E - 01	1.5612 E - 05	312.31
8	3.5651 E + 04	236.215	5.2578 E - 01	1.5271 E - 05	308.11
9	3.0800 E + 04	229.733	4.6707 E - 01	1.4926 E - 05	303.85
10	2.6500 E + 04	223.252	4.1351 E - 01	1.4577 E - 05	299.53
11	2.2700 E + 04	216.774	3.6481 E - 01	1.4223 E - 05	295.15
12	1.9399 E + 04	216.650	3.1193 E - 01	1.4216 E - 05	295.07
13	1.6579 E + 04	216.650	2.6660 E - 01	1.4216 E - 05	295.07
14	1.4170 E + 04	216.650	2.2786 E - 01	1.4216 E - 05	295.07
15	1.2111 E + 04	216.650	1.9475 E - 01	1.4216 E - 05	295.07
16	1.0352 E + 04	216.650	1.6647 E - 01	1.4216 E - 05	295.07
17	8.8497 E + 03	216.650	1.4230 E - 01	1.4216 E - 05	295.07
18	7.5652 E + 03	216.650	1.2165 E - 01	1.4216 E - 05	295.07
19	6.4675 E + 03	216.650	1.0400 E - 01	1.4216 E - 05	295.07
20	5.5293 E + 03	216.650	8.8911 E - 02	1.4216 E - 05	295.07
21	4.7289 E + 03	217.581	7.5715 E - 02	1.4267 E - 05	295.70
22	4.0474 E + 03	218.574	6.4510 E - 02	1.4322 E - 05	296.38
23	3.4668 E + 03	219.567	5.5006 E - 02	1.4376 E - 05	297.05
24	2.9717 E + 03	220.560	4.6938 E - 02	1.4430 E - 05	297.72
25	2.5491 E + 03	221.552	4.0084 E - 02	1.4484 E - 05	298.39
26	2.1883 E + 03	222.544	3.4257 E - 02	1.4538 E - 05	299.06
27	1.8799 E + 03	223.536	2.9298 E - 02	1.4592 E - 05	299.72
28	1.6161 E + 03	224.527	2.5076 E - 02	1.4646 E - 05	300.39
29	1.3904 E + 03	225.518	2.1478 E - 02	1.4699 E - 05	301.05
30	1.1970 E + 03	226.509	1.8411 E - 02	1.4753 E - 05	301.71

Department of Mechanical Engineering
Chittagong University of Engineering and Technology (C U E T)
Level 4, Term II Examination 2020

Course No: ME 423	Full Marks: 210	Time: 03 hours
Course Title: Aerodynamics	Date: 17 / 04 / 2022	

The figures in the right margin indicate full marks. The questions are of equal value. There are 04 questions in each section. Answer any 03 questions from each section. Use separate script for each section.

Section: A

Marks

1. a) Explain the importance of aerodynamics citing at least two examples. 09
- b) What are the different types of drag? Explain induced drag. 08
- c) An aircraft flies at a Mach number of 0.85 at 18300 m where the pressure is 7160 N/m² and temperature is -56.5°C. A model of 1/10 -th scale is to be tested in a high speed wind-tunnel. Determine the total pressure of the tunnel stream necessary to give dynamic similarity, if the total temperature is 50°C. It may be assumed that the dynamic viscosity is related to the temperature as follows: 18

$$\frac{\mu}{\mu_0} = \left(\frac{T}{T_0} \right)^{3/4}$$

where $T_0 = 273^\circ\text{C}$ and $\mu_0 = 1.71 \times 10^{-5} \text{ kg/m-s}$.

2. a) What are the importance of stream function and velocity potential function in fluid dynamics analysis. Show that streamline and equipotential line are mutually perpendicular. 10
- b) Derive the relationship between circulation and vorticity. 7
- c) In a two-dimensional incompressible flow, the velocity components are given by: 18

$$u = x - 4y \quad \text{and} \quad v = -y - 4x$$
 - (i) Show that the flow satisfies the continuity equation and obtain the expression for the stream function.
 - (ii) If the flow is irrotational, obtain also the expression for the velocity potential.

3. a) What is doublet flow? Show that for doublet flow, the stream function is 17

$$\psi = -\frac{k \sin \theta}{2\pi r}$$

where the symbols have their usual meaning.

- b) A uniform flow with a velocity of 3 m/s is flowing over a plane source of strength 30 m²/s. The uniform flow and the source flow are in the same plane. A point P is situated in the flow field. The distance of the point P from source is 0.5 m and it is at an angle of 30° to the uniform flow. Determine (i) Stream function at point P 18
 (ii) Resultant velocity of flow at P, and
 (iii) Location of stagnation point from the source
4. a) Derive the fundamental equation of thin airfoil theory. 17
- b) Consider an NACA 2412 airfoil with a cord of 0.64 in an air-stream at standard sea level conditions. The free stream velocity is 70 m/s. The lift per unit span is 1254 N/m. Determine: 18
 - (i) the angle of attack and drag force per unit span, and
 - (ii) the moment per unit span about the aerodynamic center.

Section: B

5. a) What is drag polar? Write down the drag polar of complete airplane and explain each term. 07
- b) Using the momentum theory of propeller, show that 12

$$\eta_p = \frac{V}{V_0}$$

where the symbols have their usual meaning.

- c) A propeller with a diameter of 3m produces a positive thrust of 4450 N at 45 m/s under standard sea level conditions ($\rho = 1.226 \text{ kg/m}^3$). Determine: 16
 - (i) the maximum efficiency
 - (ii) The pressure difference between atmospheric pressure and pressure immediately in front of the propeller
6. a) What is after-burning? Why it is used? 09
- b) How does a turboprop engine differ from a turbofan engine? 08
- c) A turbine aircraft flies with a velocity of 300 m/sec at an altitude where the air is at 0.35 bar and -40°C. The compressor has a pressure ratio of 10, and the temperature of the gases at the turbine inlet is 1100°C. Air enters the compressor at a rate of 50 kg/sec. Determine: 18
 - (i) the temperature and pressure of the gases at the turbine exit.
 - (ii) the velocity of the gases at the nozzle exit, and
 - (iii) the propulsive efficiency of the cycle.

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7. a) What do you mean by airplane performance? 15
b) Derive the general equation of motion of airplane and hence show that during level and unaccelerated flight lift force is balanced by weight of the airplane.
c) A lift, single engine, propeller-driven, private airplane, approximately modeled after the Cessna Sky lane. For convenience, we will designate our hypothetical airplane as the Cp-1, having the following characteristics: 15

Wingspan = 10.912 m

Wing area = 16.165 m²

Normal gross weight = 13127.5 N

Fuel capacity: 65 gal of aviation gasoline

Power plant: One-piston engine of 230 hp at sea-level

Specific fuel consumption = 2.0025 N/(hp)(h)

Parasite drag coefficient, $C_p = 0.025$

Oswald efficiency factor, $e = 0.80$

Propeller efficiency = 0.80

Calculate the TR curves at sea-level.

8. a) What is static stability margin? What are the setbacks of large static stability margin? 10
b) How the "down wash" affect the airplane performance? 10
c) Write short notes (any three) of the following: 15
- (i) Swept wing
 - (ii) Dutch roll
 - (iii) Keel surface

Department of Mechanical Engineering
Chittagong University of Engineering & Technology (C U E T)
Level 4 Term 2 Examination 2017

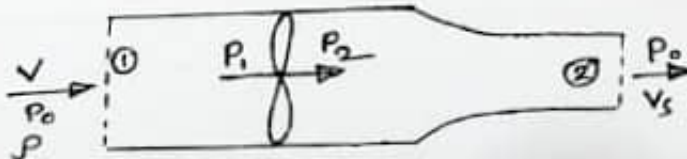
Course No: ME 423	Full Marks: 210	Time: 03 hours
Course Title: Aerodynamics	Date: 29/07/ 2018	

The figures in the right margin indicate full marks. The questions are of equal value. There are 04 questions in each section. Answer any 03 questions from each section. Use separate script for each section.

Section: A

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|----|--|----|
| 1. | a) Define streamlined body. Differentiate between friction drag and pressure drag. | 15 |
| | b) What are the sources of aerodynamic forces and moments that can be developed on aeronautical vehicles. | |
| | c) In low-speed, incompressible flow, the following experimental data were obtained for NACA4412 airfoil section at an angle of attack of 4° ; $C_L = 0.85$ and $C_{m, c/4} = -0.09$. Determine the location of center of pressure. | 15 |
| 2. | a) Define circulation. Derive the relationship between circulation and vortices. | |
| | b) Define stream function and velocity potential. Show that streamline and equipotential line are mutually perpendicular. | |
| | c) For a two-dimensional flow the velocity potential function is given by the expression –
$\phi = x^2 - y^2$ | 18 |
| 3. | a) Explain Magnus effect in moving fluid. How is it applied to a moving body? | 15 |
| | b) An airfoil 1.5 m x 1.5 m moves at 15 m/s in stationary air of specific weight 1.15 kg/m^3 . If the coefficients of drag and lift are 0.15 and 0.75 respectively, determine (i) the lift force (ii) the drag force (iii) power required to keep the airfoil in motion. | 20 |
| 4. | a) What is drag polar? Write down the drag polar of complete airplane and explain each term. | 05 |
| | b) Derive the fundamental equation of thin airfoil theory. | 12 |
| | c) Consider an NACA 23012 airfoil. The mean Camber line for this airfoil is given by
$z/c = 2.6595 \left[(x/c)^3 - 0.6075(x/c)^2 + 0.1147(x/c) \right]$ for $0 \leq x/c \leq 0.2025$
and
$z/c = 0.02208 [1 - (x/c)]$ for $0.2025 \leq x/c \leq 1.0$ | 18 |

Section: B

- | | | |
|----|--|----|
| 5. | a) Prove that idea propulsive efficiency of the propulsion system (Fig.5(a)) | 17 |
| | $\eta_i = \frac{V}{\frac{1}{2}(V_s + V)}$ | |
| |  | |
| | Fig.5(a) | |
| | b) The engine of an airplane moving through air at a speed of 100 m/s delivers 882.9 kW to a propeller 3 m in diameter. Calculate the thrust developed and the efficiency of the propeller. Given that the mean density of air = 1 kg/m^3 . | 18 |
| 6. | a) What is meant by airscrew? | 03 |
| | b) Using Froude's momentum theory of propulsion, show that Froude efficiency of propulsion system
$\eta_i = V/V_0$
Where symbols have their usual meaning. | 15 |
| | c) An airscrew is required to produce thrust of 4000 N at a flight speed of 120 m/s at sea level. If the diameter is 2.5 m, estimate the minimum power that must be supplied, on the basis of Froude's theory. | 17 |
| 7. | a) Define range and endurance of an airplane. | 06 |
| | b) Show that the rate of climb is directly proportional to the excess power developed by an airplane engine. | 11 |
| | c) A light aircraft of mass 3500 kg descends with engines off at a glide angle of 4° from an altitude of 5 km. Determine (i) the drag and lift components that act during the glide, and (ii) the range covered from the start of the glide to touchdown. | 18 |
| 8. | a) What is static stability margin? What are the setbacks of large static stability margin? | 10 |
| | b) Discuss briefly the function of different airplane control surfaces with neat sketches. | 15 |
| | c) Explain the effect of downwash on the local flow over a local airfoil section of a finite wing using necessary sketches. | 10 |