<u>Question Bank: AE1254 – PROPULSION I</u>

PART A (2 marks each)

UNIT I FUNDAMENTALS OF GAS TURBINE ENGINES

What are the methods of thrust augmentation ?

Define by-pass ratio.

Define propulsive efficiency.

Write the thrust equation of a gas turbine engine.

Draw the T-S diagram of gas turbine engine and the two important parameter of the cycle identity.

Draw the variation of thrust with Mach number for different altitudes.

What are the types of thrust ?

List out the methods of thrust augmentation.

What are the advantages of closed cycle gas turbine cycle ?

Water injection at inlet of a gas turbine engine increases thrust. Comment on the statement.

UNIT II SUBSONIC AND SUPERSONIC INLETS FOR JET ENGINES

What is the effect of spring door in inlets ?

Define spillage fraction.

What is the prime requirement of an inlet ? List out the characteristics of supersonic and subsonic inlets.

What is meant by sub-criticl mode of inlet operation ?

What are the factors considered while designing a subsonic inlet ?

State the phenomena of the stall in subsonic inlet.

Differentiate between internal compression and external compression in a supersonic inlet.

Define spillage fraction.

List out the difference between subsonic and supersonic inlets.

Draw T-S diagram for the inlet during low speed high thrust operation of a gas turbine engine.

Differentiate between subcritical and supercritical modes of inlet operation.

Define pattern factor. What is the desired range of this parameter ?

UNIT III COMBUSTION CHAMBERS

Specific work output is 137 kJ/kg. Theoretical fuel air ratio is 0.0094. Combustion efficiency is 0.98. Find out specific fuel consumption.

Name the flow losses in combustion chamber.

What is the function of liners inside the combustion chamber ?

Draw a stability curve of a combustion chamber and indicate the burning and non-burning zones.

How flame stabilization is achieved in a combustion chamber ?

List out the prime requirements of a combustion chamber.

What is meant by stability loops ?

What are the functions of dilution zone in combustion chamber of a gas turbine engine ?

UNIT IV NOZZLES

What is meant by chocked nozzle ?

What are meant by underexpanded and overexpanded nozzles ?

What is meant by over-expanded nozzle.

Explain nozzle choking.

State at least two functions of a convergent nozzle.

What is thrust reversal ?

Define nozzle efficiency.

What are ejector nozzles ?

Define nozzle efficiency.

What is the need for variable area nozzle for supersonic operation ?

UNIT V COMPRESSORS

Distinguish between surging and stalling.

What is meant by prewhirl ?

What is the function of impeller in a centrifugal compressor ?

Define the phenomenon of surging of compressor.

What is the need for a prewhirl in a centrifugal compressor ?

Define the term degree of reaction.

What are the advantages of axial flow compressors over centrifugal compressors ?

Define degree of reaction.

What are the advantages of the axial flow compressor over the centrifugal flow compressor ?

Define degree of reaction of an axial flow compressor.

PART B (16 marks each)

UNIT I FUNDAMENTALS OF GAS TURBINE ENGINES

(a) Define thrust of an engine and derive the thrust equation for a general propulsion system.

(b) Discuss the different methods of thrust augmentation. Draw T-S diagram for turbojet engine with thrust augmentation.

An advanced fighter engine operating at Mach 0.8 and 10 km altitude where, T_a = 223 K & P_a = 0.2649 bar has the following uninstalled performance data and uses a fuel with C.V. = 42,800 kJ/kg:

Thrust	= 50 kN
Mass flow of air	= 45 kg/s
Mass flow of fuel	= 2.65 kg/s

Determine the specific thrust, thrust specific fuel consumption, exit velocity, efficiency of energy conversion, propulsion efficiency, and overall efficiency (assume exit pressure equal to ambient pressure).

A turbojet engine is traveling at 270 m/s at an altitude of 5000 m. The compressor pressure ratio is 8:1 and maximum cycle temperature is 1200 K. By assuming the following data, calculate the specific thrust and TSFC.

Ram efficiency	93%
Isentropic efficiency of the compressor	87%
Pressure loss in the combustion chamber delivery	4% of comp.
Calorific value of the fuel	43,100 kJ/kg
Isentropic efficiency of the turbine	99%
Isentropic efficiency of propelling nozzle	90%

Ambient condition at 5000 m are 0.505 bar and 255.7 K.

A turboprop engine operates at an altitude of 3000 meters above mean sea level and an aircraft speed of 525 kmph. The data for the engine is given below:

Diffuser efficiency	0.875
Isentropic efficiency of the compressor	0.79
Velocity of air at the compressor	90 m/s
Temperature rise through the compressor	230^{o}C

Temperature, pressure and density at 3000 m altitude are 268.65 K, 0.701 bar and 0.909 kg/m^3 respectively.

Calculate the pressure rise through the diffuser, pressure ratio developed by the compressor, power required by the compressor and the air standard efficiency.

Explain the working principle of a turbofan engine with a neat sketch. Describe the advantages of turboprop engine in comparison with turbojet engine.

A turbojet engine flying at sea level and at a Mach number equal to 0.7, ingests air at a rate of 75 kg/s. The compressor total pressure ratio is 15. The calorific value of fuel is 41 MJ/kg and the burner exit total temperature is 1400 K. Assuming the specific heat ratio of 1.4 determine the thrust devloped and the thrust specific fuel consumption (TSFC).

Determine the specific thrust and s.f.c for a simple turbojet engine, having the following component performance at the design point at which the cruising speed and altitude are 270 m/s and 5000 m. Pressure and temperature at this altitude are o.545 bar and 255.7 K.

Compressor pressure ratio	8.0
Turbine inlet temperature	1200 K
Isentropic efficiency	
Of compressor	0.87
Of turbine	0.9
Of intake	0.93
Of propelling nozzle	0.95
Mechanical transmission efficiency	0.99
Combustion efficiency	0.98
Combustion pressure loss	4% of compressor delivery pressure.

In a twin spool turbofan engine, with the fan driven by the LP turbine and the compressor by the HP turbine, separate cold and hot nozzles are used.

Overall pressure ratio	19
Fan pressure ratio	1.65
By-pass ratio	3.0
Turbine inlet temperature	1300 K
Fan, compressor and turbine polytropic efficiency	0.90
Isentropic efficiency of each propelling nozzle	0.95
Mechanical efficiency of each spool	0.99
Combustion pressure loss	1.25 bar
Total mass flow rate of air	115 kg/s

Calculate thrust under sea level static conditions where the ambient pressure and temperature are 1.0 bar and 288 K.

UNIT II SUBSONIC AND SUPERSONIC INLETS FOR JET ENGINES

(a) Explain successive steps in the acceleration and overspeeding of a one dimensional supersonic inlet with sketches.

(b) Derive the relation between area ratio A_{max} / A_i and external deceleration ration u_i / u_a.

(a) Explain starting problem in case of supersonic inlets. What is shock swallowing by area variation ?

(b) Explain the successive steps in the acceleration and over-speeding of a one dimensional supersonic inlet. (Fixed geometry convergent-divergent inlet).

Explain various types of supersonic inlets and its modes of operations.

Air enters a two dimensional supersonic diffuser at a pressure of 14.102 kPa, a temperature of 217 K with a Mach number of 3.0. The two dimensional oblique shock diffuser has an oblique shock angle of 27.8^o, which is followed by a normal shock. Determine the following:
Velocity, total temperature and pressure of the air entering the oblique shock.
Mach number, total pressure, static pressure and temperature after the oblique shock.
The flow deflection angle.
Mach number, total pressure, static pressure and temperature after the normal shock.

Discuss in detail the working of various types of subsonic and supersonic inlets.

(a) Explain the features of external flow near a subsonic inlet.

(b) Derive a relation between area ratio A_{max} / A_i and external deceleration ratio u_i / u_a.

Explain the following:
(i) Supersonic inlets,
(ii) Factors affecting diffuser performance.

Explain the following:
(i) Relation between minimum area ratio and external deceleration ratio.
(ii) Shock swallowing.

UNIT III COMBUSTION CHAMBERS

(a) What are the important factors affecting combusor design ?

(b) With a neat sketch explain the working of a combustion chamber.

(a) What are the three types of combustion chamber ? Compare its advantages and disadvantages.

(b) With the aid of a simplified picture explain the operation of a flame holder.

(a) With a neat sketch explain the various factors affecting combustion chamber design.

(b) Discuss in detail the various methods of flame stabilization.

Explain various types of combustors used in aircraft engines. What are the important factors to be considered for the selection of a gas turbine combustion chamber ?

Explain the following:
(i) Flame stabilization.
(ii) Flame tube cooling.
(iii) Flame holders.

Explain in detail with neat sketches, the types of combustion chamber for gas turbine engine and the factors affecting the combustion chamber performance.

UNIT IV NOZZLES

(a) What are the types of nozzle ? Explain various operating conditions of a C-D nozzle with suitable sketch.

(b) Write short notes on the following: (i) Ejector (ii) Nozzle efficiency.

A converging-diverging nozzle is designed to operate with an exit Mach number of 1.75. The nozzle is supplied from an air reservoir at 68 bar (abs.). Assuming 1-d flow, calculate:
(i) Maximum back pressure to choke the nozzle.
(ii) Range of backpressure over which a normal shock will appear in the nozzle.

Explain in detail the working of convergent and convergent-divergent nozzles use in gas turbine engines.

Write short notes on:
(i) Ejector and variable area nozzles and
(ii) Thrust reversing

Air stream enters a convergent nozzle at 200 kPa and 400 K at a velocity of 100 m/s and expand isentropically to an exit pressure of 150 kPa. If the inlet diameter is 75 mm, find the temperature, the Mach number and the diameter at the nozzle exit. Also estimate the mass flow rate through the nozzle.

Air flows isentropically through a convergent-divergent nozzle of inlet area 12 cm^2 at a rate of 0.7 kg/s. The conditions at the inlet and exit of the nozzle are 8 kg/m^2 and 300K respectively. Find the cross-sectional area, the pressure and Mach number at the exit of the nozzle.

UNIT V COMPRESSORS

(a) Explain the working of a centrifugal compressor and draw the velocity triangles.

(b) A centrifugal compressor has an impeller tip speed of 366 m/s. Determine the absolute Mach number of the flow leaving the radial vanes of the impeller when the radial component of velocity at impeller exit is 30.5 m/s and the slip factor is 0.9. Given that the flow area at impeller exit is 0.1 m^2 and the total-to-total efficiency of the impeller is 90%, determine the mass flow rate.

A stage of a radial compressor is to be analyzed. It rotates at 12,300 rpm and compresses 31.75 kg/s of air. The inlet pressure and temperature are 241 kPa and 306 K respectively. The hub and tip radii of the blades at the inlet are 7.62 and 13.97 cm respectively. The exit radius is 27.94 cm and the exit blade height is 2.54 cm. The slip factor is unity. Flow enters the inlet with no prewhirl and the impeller has straight radial blades. The efficiency of the stage is 88%. The value of C_p and γ are 1.005 kJ/kg-K and 1.397 respectively.

Find the following:

Mean relative flow angle at the inlet.
The static pressure at the impeller exit.
The total pressure ratio for the stage.
The Mach numbers at the impeller inlet and exit.
The required power for the stage.

A stage of a radial compressor is to be analyzed. It rotates at 12,300 rpm and compresses 31.75 kg/s of air. The inlet pressure and temperature are 241.35 kPa and 306 K respectively. The hub and tip radii of the blades at inlet are 7.62 and 13.97 cm, respectively. The exit radius is 27.94 cm and the exit blade height is 2.54 cm. The slip factor is unity. The efficiency of the stage is 88%. The values of C_p and γ are 1005 J/kg K and 1.397 respectively. Determine (a) mean relative flow angle at the inlet, (b) the total pressure ratio for the stage, (c) the static pressure at the impeller exit and (d) the Mach numbers at the impeller inlet and exit. Assume that flow enters the inducer with no pre-swirl and the impeller has straight radial blades.

Sketch and explain the performance characteristic curves of centrifugal compressor and axial flow compressors.

A 10 stage axial flow compressor provides an overall pressure ratio of 5:1 with an overall isentropic efficiency of 87% when the temperature of air at the inlet is 15^{O}C. Work is equally distributed between the stages. A 50% reaction is used with a blade speed of 210 m/s and constant axial velocity of 170 m/s. Estimate the blade angles. Assume $\Omega = 1$.

The mass rate of flow at 288K and 101.3 kPa at the inlet to the impeller of the centrifugal flow compressor is 1.814 kg/s. The inlet flow is in the axial direction. The impeller eye has the minimum diameter of 3.81 cm and a maximum diameter of 12.7 cm and rotates at 35,000 rpm. Assuming no blockage due to the blade calculate the ideal angle at the bub and tip at the inlet to the impeller. Draw velocity diagram at the hub and at the tip.