JEPPIAAR ENGINEERING COLLEGE

Jeppiaar Nagar, Rajiv Gandhi Salai – 600 119

DEPARTMENT OF MECHANICAL ENGINEERING

QUESTION BANK

VI SEMESTER

ME6604 – Gas Dynamics and Jet Propulsion

Regulation – 2013

JEPPIAAR ENGINEERING COLLEGE

Vision of Institution

To build Jeppiaar Engineering College as an institution of academic excellence in technological and management education to become a world class university.

Mission of Institution

- To excel in teaching and learning, research and innovation by promoting the principles of scientific analysis and creative thinking.
- To participate in the production, development and dissemination of knowledge and interact with national and international communities.
- To equip students with values, ethics and life skills needed to enrich their lives and enable them to meaningfully contribute to the progress of society.
- To prepare students for higher studies and lifelong learning, enrich them with the practical and entrepreneurial skills necessary to excel as future professionals and contribute to Nation's economy.

PO1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations
PO4	**Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5	**Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO6	**The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO7	**Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	**Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9	**Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	**Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	**Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12	**Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

JEPPIAAR ENGINEERING COLLEGE

DEPARTMENT OF MECHANICAL ENGINEERING

VisionoftheDepartment

To create excellent professionals in the field of Mechanical Engineering and to uplift the quality of technical education on par with the International Standards.

Department Mission

1. **To reinforce** the fundamentals of Science and Mathematics to Mechanical Engineering **and critically and relatively investigate co**mplex mechanical systems and processes.
2. To engage in the **production, expansion and practice** of advanced engineering applications through knowledge sharing activities by interacting with global communities and industries.
3. To **equip** students with **engineering ethics, professional roles, corporate social responsibility** and life skills and **apply** them for the betterment of society.
4. **To promote** higher studies and lifelong learning and entrepreneurial skills and **develop** excellent professionals for empowering nation's economy.

PEO's

1. To **enrich** the technical knowledge of design, manufacturing and management of mechanical systems and **develop creative and analytical thinking** in research.
2. To **relate, strengthen and develop** the theoretical knowledge of the Mechanical Engineering by exhibiting various concepts applied through diverse industrial exposures and experts' guidance.
3. **Facilitate** the students to communicate effectively on complex social, professional and engineering activities with strict adherence to ethical principles.
4. **Create awareness for independent and life long learning and develop the ability to keep abreast of modern trends and adopt them for personal technological growth of the nation.**

PSO's

1. To understand the basic concept of various mechanical engineering field such as design, manufacturing, thermal and industrial engineering.
2. To apply the knowledge in advanced mechanical system and processes by using design and analysis techniques.
3. To develop student's professional skills to meet the industry requirements and entrepreneurial skills for improving nation's economy stronger.

COURSE OUTCOME

C314.1	Student will be able to understand the basic principles of compressible fluid flow with varying area and wide range of its application in aircraft systems
C314.2	Student will be able to understand the basic principles on shock waves and its effects on flow properties and its applications on constant area duct with friction-without heat transfer and vice-versa
C314.3	Student will be able to apply the basic principles of variation of flow properties across the normal and oblique shock waves with its application in air-craft engine
C314.4	Student will be able to apply the basic principles of various combustion statergy for propulsion applied in different types of jet engine
C314.5	Student will be able to apply the basic principles of space propulsion through the study of propellents, rocket engines and relations of escape velocity

ME6604 GAS DYNAMICS AND JET PROPULSION L T P C

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UNIT I BASIC CONCEPTS AND ISENTROPIC FLOWS 6

Energy and momentum equations of compressible fluid flows – Stagnation states, Mach waves and Mach cone – Effect of Mach number on compressibility – Isentropic flow through variable ducts – Nozzle and Diffusers

UNIT II FLOW THROUGH DUCTS 9

Flows through constant area ducts with heat transfer (Rayleigh flow) and Friction (Fanno flow) – variation of flow properties.

UNIT III NORMAL AND OBLIQUE SHOCKS 10

Governing equations – Variation of flow parameters across the normal and oblique shocks – Prandtl – Meyer relations – Applications..

UNIT IV JET PROPULSION 10

Theory of jet propulsion – Thrust equation – Thrust power and propulsive efficiency – Operating principle, cycle analysis and use of stagnation state performance of ram jet, turbojet, turbofan and turbo prop engines.

UNIT V SPACE PROPULSION 10

Types of rocket engines – Propellants-feeding systems – Ignition and combustion – Theory of rocket propulsion – Performance study – Staging – Terminal and characteristic velocity – Applications – space flights.

TOTAL: 45 PERIODS

TEXT BOOKS:

1. Anderson, J.D., "Modern Compressible flow", 3 rd Edition, McGraw Hill, 2003.

2. Yahya, S.M. "Fundamentals of Compressible Flow", New Age International (P) Limited, New Delhi, 1996.

REFERENCES:

1.Hill. P. and C. Peterson, "Mechanics and Thermodynamics of Propulsion",Addison – Wesley Publishing company, 1992.

2. Zucrow. N.J., "Aircraft and Missile Propulsion", Vol.1 & II, John Wiley, 1975.

3. Zucrow. N.J., "Principles of Jet Propulsion and Gas Turbines", John Wiley, New York, 1970.

4. Sutton. G.P., "Rocket Propulsion Elements", John wiley, New York,1986,.

5. Shapiro. A.H.," Dynamics and Thermodynamics of Compressible fluid Flow", John wiley, New York, 1953.

6. Ganesan. V., "Gas Turbines", Tata McGraw Hill Publishing Co., New Delhi, 1999.

7. Somasundaram. PR.S.L., "Gas Dynamics and Jet Propulsions", New Age International Publishers, 1996.
8. Babu. V., "Fundamentals of Gas Dynamics", ANE Books India, 2008.
9. Cohen. H., G.E.C. Rogers and Saravanamutto, "Gas Turbine Theory", Longman Group Ltd., 1980.

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DEPARTMENT OF MECHANICAL ENGINEERING QUESTION BANK

SUBJECT : ME6604 – Gas Dynamics and Jet Propulsion

YEAR /SEM:III /VI

UNIT I BASIC CONCEPTS AND ISENTROPIC FLOWS

Energy and momentum equations of compressible fluid flows – Stagnation states, Mach waves and Mach cone – Effect of Mach number on compressibility – Isentropic flow through variable ducts – Nozzle and Diffusers

PART – A

CO Mapping : C314.1

Q. No	Questions	BT Level	Competence	PO
1	Express the stagnation enthalpy in terms of static enthalpy and velocity of flow.	BTL-3	Applying	PO1,PO2
2	Explain the meaning of stagnation state with example.	BTL-2	Understanding	PO1,PO2, PO3
3	Distinguish between static and stagnation pressures.	BTL-4	Analyzing	PO1,PO2
4	Differentiate between the static and stagnation temperatures.	BTL-4	Analyzing	PO1,PO2
5	What is the use of Mach number?	BTL-1	Remembering	PO1
6	What is Crocco number?	BTL-1	Remembering	PO1
7	Give expression of P/P0 for an isentropic flow through a duct.	BTL-3	Applying	PO1,PO2
8	What are the different regions of compressible flow?	BTL-4	Analyzing	PO1,PO2
9	Define M* and give the relation between M and M*[	BTL-1	Remembering	PO1
10	A plane travels at a speed of 2400Km/hr in an atmosphere of 5 degree, find the Mach angle?	BTL-4	Analyzing	PO1,PO2,PO3, PO4
11	Define Mach angle and Mach wedge.	BTL-1	Remembering	PO1
12	What is meant by isentropic flow with variable area?	BTL-1	Remembering	PO1
13	Define Mach cone.	BTL-1	Remembering	PO1,PO2
14	What is characteristic Mach number?	BTL-1	Remembering	PO1
15	Distinguish between Mach wave and normal shock?	BTL-4	Analyzing	PO1,PO2
16	Define zone action and zone of silence.	BTL-1	Remembering	PO1
17	Define adiabatic process.	BTL-1	Remembering	PO1
18	What is meant by transonic flow?	BTL-1	Remembering	PO1, PO2

Q. No	Questions	BT Level	Competence	PO
19	What is meant by hypersonic flow?	BTL-1	Remembering	PO1, PO2,PO10
20	Distinguish between nozzle and diffuser?	BTL-4	Analyzing	PO1,PO2
21	What is Impulse function ?	BTL-1	Remembering	PO1,PO2
22	Differentiate between adiabatic flow and diabatic flow ?	BTL-4	Analyzing	PO1,PO2
23	State the expression for dA/A as a function of Mach number ?	BTL-5	Evaluating	PO1,PO2,PO3
24	Give the expression for T/To and T/T* for isentropic flow through variable area interms of Mach number ?	BTL-5	Evaluating	PO1,PO2,PO3
25	When does the maximum mass flow occur for an isentropic flow with variable area?	BTL-5	Evaluating	PO1,PO2,PO3
26	Write the equation for efficiency of the diffuser.	BTL-4	Analyzing	PO1,PO2
27	What is impulse function and give its uses?	BTL-4	Analyzing	PO1,PO2
28	State the necessary conditions for chocked flow to occur in a nozzle.	BTL-5	Evaluating	PO1,PO2,PO3
29	What is meant by normal shock as applied to compressible flow?	BTL-3	Applying	PO1,PO2,PO3
30	Define strength of a shock wave.	BTL-1	Remembering	PO1
31	What is the effect of Mach number on compressibility?	BTL-5	Evaluating	PO1,PO2,PO3
	PART – B & C			
1	An air craft flies at a velocity of 700Kmph in an atmosphere where the pressure is 75kPa and temperature is 5^oC. Calculate the Mach number and stagnation properties	BTL-5	Evaluating	PO1,PO2,PO3
2	Air expands isentropically through the convergent nozzle from constant inlet conditions P_o=4bar, T_o =550k. Exit area of nozzle is $1000cm^2$. Determine the exit velocity and mass flow rate for the following two cases at exit. (i) M=1 (ii)M=0.85	BTL-5	Evaluating	PO1,PO2,PO3
3	(i) Difference between transonic flow and hypersonic flow (ii) Derive the expression for pressure co-efficient equation for compressible flow (iii) Name the different regions of compressible fluid flow	BTL-4	Analyzing	PO1,PO2,PO3, PO5, PO6,PO9, PO12,
4	(i)Derive the expression for the mass flow rate in terms of Mach number (NOV/DEC 2014) (ii)A nozzle in a wind tunnel gives a test –section Mach number of 2.0. Air enters the nozzle from a large reservoir at 0.69 bar and 310K. The cross-sectional area of the throat is $1000cm^2$. Determine the following quantities for the tunnel for one dimensional isentropic flow: a. Pressures, temperatures and velocities at the throat and test sections, b. Area of cross-section of the test section c. Mass flow rate and Power required to drive the compressor	BTL-5	Evaluating	PO1,PO2,PO3, PO4

5	Air flows through a nozzle which has inlet areas of $0.001 m^2$. If the air has a velocity of 80m/s a temperature of 301K and a pressure of 700kPa at the inlet section and a pressure of 250kPa at the exit find the mass flow rate through the nozzle and assuming one -dimensional isentropic flow the velocity at the exit section of the nozzle.	**BTL-5**	**Evaluating**	**PO1,PO2,PO3, PO4**
6	A gas flows through a restricted passage with a speed of 850 m/s .Its local temperature is 1650 K; its specific heat ratio k and gas constant R are 1.25 and 250 J/kg K respectively. Calculate the local sonic velocity and Mach number.	**BTL-5**	**Evaluating**	**PO1,PO2,PO3**
7	A supersonic dliffuser, diffuses air in an isentropic flow from a Mach number of 3 to a Mach number of 1.5, the static conditions of air at inlet are 70 kPa and -7°C. If the mass flow rate of air is125 kg/s, determine (i)Stagnation conditions, (ii) Area at throat and exit. (iii) Static Conditions of air at exit.	**BTL-5**	**Evaluating**	**PO1,PO2,PO3**
8	(i).Discuss the changes of Mach number in CD nozzle under various back pressure.(ii)An airplane is travelling while you are observing from the ground.How will you know whether it is subsonic or supersonic? Explain.(iii)How fluid stagnation states will change if the fluid flow in diffuser follows an adiabatic process?	**BTL-5**	**Evaluating**	**PO1,PO2,PO3**
9	Air flows through a convergent-divergent (CD) nozzle. At some section in the nozzle, pressure =2bar, velocity=170m/s and temperature=200°C and cross sectional area =1000 mm^2.Assuming isentropic flow conditions, determine: (i) stagnation temperature and stagnation pressure (ii) sonic velocity and Mach number at this section (iii) velocity , Mach number and flow area at outlet section where pressure is 1.1 bar (iv) pressure, temperature, velocity and flow area at throat section.	**BTL-5**	**Evaluating**	**PO1,PO2,PO3**

UNIT II FLOW THROUGH DUCTS

Flows through constant area ducts with heat transfer (Rayleigh flow) and Friction (Fanno flow) – variation of flow properties.

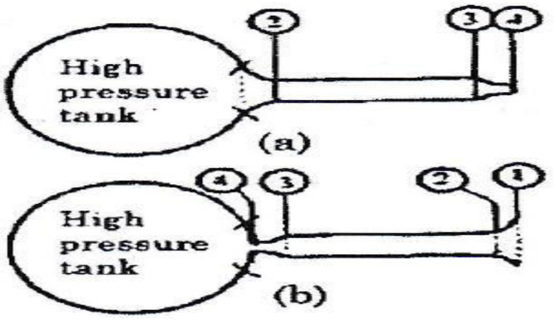
PART – A

CO Mapping : C314.2

Q .No	Questions	BT Level	Competence	PO
1	What are the assumptions made for fanno flow?	**BTL-4**	**Analyzing**	**PO2,PO3**
2	Differentiate Fanno flow and Rayleigh flow?	**BTL-4**	**Analyzing**	**PO1, PO2,PO3**
3	Explain chocking in Fanno flow?	**BTL-2**	**Understanding**	**PO1, PO2,PO3**
4	Explain the difference between Fanno flow and Isothermal flow?	**BTL-4**	**Analyzing**	**PO1,PO2**
5	Write down the ratio of velocities between any two sections in terms of their Mach number in a fannoflow ?	**BTL-5**	**Evaluating**	**PO1,PO3,PO4**
6	Write down the ratio of density between any two section in terms of their Mach number in a fanno	**BTL-5**	**Evaluating**	**PO1,PO2,PO4**

	flow?			
7	What are the three equation governing Fanno flow?	**BTL-5**	**Evaluating**	**PO1,PO2**
8	Give the expression to find increase in entropy for Fanno flow?	**BTL-5**	**Evaluating**	**PO1,PO2**
9	Give two practical examples where the Fanno flow occurs?	**BTL-4**	**Analyzing**	**PO1,PO2**
10	What is Rayleigh line and Fanno line?	**BTL-1**	**Remembering**	**PO1,PO4**
11	What are the assumptions of Fanno flow?	**BTL-4**	**Analyzing**	**PO1,PO2**
12	Write down expression to find increase in entropy for Fanno flow.	**BTL-5**	**Evaluating**	**PO1,PO4**
13	Define fanning"s coefficient of skin friction	**BTL-1**	**Remembering**	**PO1,PO2,PO4**
14	Define oblique shock.	**BTL-1**	**Remembering**	**PO1**
15	Define Fanno line.	**BTL-1**	**Remembering**	**PO1**
16	Define isothermal flow with friction.	**BTL-1**	**Remembering**	**PO1**
17	Give the applications of isothermal flow with friction.	**BTL-3**	**Applying**	**PO1**
18	State the assumptions made to derive the equations for isothermal flow.	**BTL-4**	**Analyzing**	**PO1,PO4**
19	Give the assumptions made in Rayleigh flow	**BTL-4**	**Analyzing**	**PO1,PO2**
20	Write the continuity equation	**BTL-5**	**Evaluating**	**PO1,PO2**
21	Give two practical examples for Rayleigh flow	**BTL-4**	**Analyzing**	**PO1,PO2**
22	Define fanning's coefficient of skin friction	**BTL-1**	**Remembering**	**PO1,PO2**
23	Write down the expression for the length of duct in terms of the two mach number M1 and M2 for a flow through a constant area duct with the influence of friction.	**BTL-5**	**Evaluating**	**PO1,PO2,PO4**
24	Write down the ratio of pressure between any two section in terms of their mach number in a Fanno flow.	**BTL-5**	**Evaluating**	**PO1,PO2**
25	Write down the expression for the temperature ratio between two sections in terms of Mach numbers for flow in a constant area duct with friction	**BTL-5**	**Evaluating**	**PO1,PO2**
26	Write down the expression for the pressure ratio of two section interms of mach number in Rayeligh flow.	**BTL-5**	**Evaluating**	**PO1,PO2,PO4**
27	What is the value of Mach number of air at the maximum point in Rayleigh heating process.	**BTL-4**	**Analyzing**	**PO1,PO4**
28	Shown a normal shock in h-s diagram with the help of Rayleigh line and Fanno line.	**BTL-6**	**Creating**	**PO1,PO2,PO4**
29	Give fanno line in h – s diagram with isentropic stagnation line and show various mach number regions.	**BTL-6**	**Creating**	**PO1,PO4**
30	Give the effect of increasing the flow length after reaching critical condition in a fanno flow.	**BTL-4**	**Analyzing**	**PO1,PO4**
31	List the governing equations that useful to describe the Rayleigh flow.	**BTL-3**	**Applying**	**PO1,PO2**
	PART – B & C			
1	The stagnation temperature of air is raised from	**BTL-5**	**Evaluating**	**PO1,PO2,**

	$85^{o}C$ to $376^{o}C$ in a heat exchanger. If the inlet Mach number is 0.4. Determine the final Mach number and percentage drop in pressure.			
2	Air at Po=11bar, To=420K enters at 45mm diameter pipe at a Mach number of 3 and the friction co-efficient for the pipe surface is 0.001. if the mach number at exit is 0.8. Determine (i) Mass flow rate (ii) Length of the pipe	**BTL-4**	**Analyzing**	**PO1,PO2**
3	Prove the variation of flow parameter and the maximum possible heat transfer $$Q_{max} = C_p T * \frac{(1-M^2)^2}{2(1+\gamma)M^2)}$$	**BTL-5**	**Evaluating**	**PO1,PO2,PO4**
4	(a)A circular duct of 35cm diameter passes gas at Mach number of 2.0. The static pressure and temperature are 1 bar and 410k respectively. A normal shock occurs at a Mach number of 1.4 and the exit Mach number is 1. If the co-efficient of friction is 0.02, calculate: (i)length of the duct upstream and downstream of the shock wave (ii)mass flow rate of the gas and (iii)change of entropy for upstream of the shock, across the shock and downstream of the shock. Take γ=1.3 and R=0.285kJ/kgK (b)Explain the difference between Fanno flow and Isothermal flow	**BTL-5**	**Evaluating**	**PO1,PO2,**
5	The condition of gas in a combustor at entry is P_1=0.343 bar,T_1=310K, C_1=60m/sec.Determine the Mach number, pressure, temperature and velocity at the exit if the increase in stagnation enthalpy of the gas between entry and exit is 1172.5kJ/kg.TakeCp=1.005kJ/kgK,γ=1.4.	**BTL-5**	**Evaluating**	**PO1,PO2,**
6	Air flows out of a pipe with a diameter of 0.3m at a rate of $1000m^3$/min at a pressure and temperature of 150kPa and 293K respectively. If the pipe is 50m long, find assuming that f=0.005, the Mach number at the exit, the inlet pressure and the inlet temperature.	**BTL-5**	**Evaluating**	**PO1,PO2,**
7	Air (γ= 1.4) flows into a constant-area insulated duct with a Mach number of 0.20. For a duct diameter of 1 cm and friction coefficient of 0.02, determine the duct length required to reach Mach 0.60. Determine the length required to attain Mach 1. Finally, if an additional 75 cm is added to the duct length needed to reach Mach l, while the initial stagnation conditions are maintained, determine the reduction in flow rate that would occur.	**BTL-5**	**Evaluating**	**PO1,PO2,PO4**
8	(i) In which configuration of Figure (a) or (b], will the high-pressure tank empty faster? Explain.	**BTL-5**	**Evaluating**	**PO1,PO2,PO4**

	 (ii) The stagnation temperature of air is raised from 85°C to 376°C in a heat exchanger. If the inlet Mach number is 0.4, determine the final Mach number and percentage drop in pressure.			
9	(i) Prove that the Mach numbers at the maximum enthalpy and maximum entropy points on the Rayleigh line are $1/\sqrt{\gamma}$ and 1.0 respectively. (ii)Show the h=constant and s =constant lines at these points on the Rayleigh line on the h-s and p-v planes. (Nov'17)	**BTL-5**	**Evaluating**	**PO1,PO2,PO4**

UNIT III NORMAL AND OBLIQUE SHOCKS

Governing equations – Variation of flow parameters across the normal and oblique shocks – Prandtl – Meyer relations – Applications.

PART – A

CO Mapping : C314.3

Q.No	Questions	BT Level	Competence	PO
1	What is mean by shock wave?	BTL-1	Remembering	PO1
2	What is mean by Normal shock?	BTL-1	Remembering	PO1
3	What is oblique shock?	BTL-1	Remembering	PO1
4	What are applications of moving shock wave ?	BTL-4	Analyzing	PO1
5	Shock waves cannot develop in subsonic flow? Why?	BTL-4	Analyzing	PO1,PO4
6	Define compression and rarefaction shock?	BTL-1	Remembering	PO1
7	State the necessary conditions for a normal shock to occur in compressible flow?	BTL-4	Analyzing	PO1
8	Give the difference between normal and oblique shock?	BTL-4	Analyzing	PO1,PO2
9	What are the properties change across a normal shock?	BTL-2	Understanding	PO1,PO4
10	What is Prandtl – Meyer relation?	BTL-1	Remembering	PO1,PO2
11	Define strength of shock wave.	BTL-1	Remembering	PO1
12	Is the flow through a normal shock an equilibrium one.	BTL-4	Analyzing	PO1,PO2
13	Calculate the strength of the shock waves when normal shock appears at M=2.	BTL-5	Evaluating	PO1,PO2
14	Write down the static pressure ratio expression for a normal shock.	BTL-5	Evaluating	PO1,PO2

15	What are expansion wave?	**BTL-1**	**Remembering**	**PO1**
16	What are compression wave?	**BTL-1**	**Remembering**	**PO1**
17	How the Mach number before and after the occurrence of a normal shock are related?	**BTL-4**	**Analyzing**	**PO1,PO2,PO4**
18	What are applications of moving shock wave?	**BTL-3**	**Applying**	**PO1**
19	What is meant by normal shock as applied to compressible flow?	**BTL-4**	**Analyzing**	**PO1**
20	Define oblique shock where it occurs.	**BTL-1**	**Remembering**	**PO1,PO2**
21	Write the equation for efficiency of a diffuser	**BTL-5**	**Evaluating**	**PO1,PO3**
22	Write down the Rankine-Hagoniot equation	**BTL-5**	**Evaluating**	**PO1,PO2**
23	Give the expression for T_y/T_x across the normal shock.	**BTL-5**	**Evaluating**	**PO1,PO2,PO3**
24	How to determine deflection angle θ.	**BTL-5**	**Evaluating**	**PO1**
25	What is mean by detached shock wave	**BTL-1**	**Remembering**	**PO1**
26	How do the various flow properties behave during expansion waves?	**BTL-4**	**Analyzing**	**PO1,PO3**
27	What is the condition of before and after shock?	**BTL-4**	**Analyzing**	**PO1,PO2,PO3**
28	Describe about Multiple Shock Waves	**BTL-2**	**Understanding**	**PO1**
29	What are the components of the velocity in oblique shock	**BTL-2**	**Understanding**	**PO1**
30	How the disturbances get changed	**BTL-4**	**Analyzing**	**PO1,PO2,PO3**
31	Mention the useful applications of shock wave.	**BTL-3**	**Applying**	**PO1,PO3**
	PART – B & C			
1	A jet of air at 270K and 0.7bar has an initial Mach number of 1.9. If it passes through a normal shockwave, determine the following for downstream of the shock. i. Mach number i. Pressure i. Temperature /. Speed of the sound /. Jet velocity i. Density	**BTL-5**	**Evaluating**	**PO1,PO2,PO4**
2	A normal shock occurs in the diverging section of a convergent-divergent air nozzle. The throat area is 1/3 times exit area and the static pressure at exit is 0.4 times the stagnation pressure at the entry. The flow is throughout isentropic expect through the shock. Determine: i. Mach number M_x and M_y i. The static pressure and i. The area of cross section of the nozzle at the section of nozzle where the normal shock occurs	**BTL-5**	**Evaluating**	**PO1,PO2, PO3,PO4**

3	Derive the expression for Rankine-Hugoniot equation (Density ratio across the shock)	**BTL-5**	**Evaluating**	**PO1,PO2,PO3**
4	(a)What Is oblique shock waves? And what are the assumptions are used for oblique shock flow? (b)Oblique shock waves occur at the leading edge of a symmetrical wedge. Air has a Mach number of 2.1 and deflection angle (δ) of 15^o. Determine the following for strong and weak waves. i. Wave angle i. Pressure ratio i. Density ratio /. Temperature ratio and /. Down stream Mach number.	**BTL-5**	**Evaluating**	**PO1,PO2, PO3,**
5	A gas at a pressure of 340m bar, temperature of 355K and entry Mach number of 1.4 is expanded isentropically to 140m bar. Calculate the following: i. Deflection angle i. Final mach number i. Final temperature of the gas. Take γ=1.3.	**BTL-5**	**Evaluating**	**PO1,PO2,**
6	A gas (γ=1.3) at p_1=345mbar,T_1=350K and M_1=1.5 is to be isentropically expanded to 138mbar. Determine i. The deflection angle i. Final Mach number i. The temperature of the gas.	**BTL-5**	**Evaluating**	**PO1,PO2,PO4**
7	State and prove Prandtl-Meyer relation for a normal shock.	**BTL-5**	**Evaluating**	**PO1,PO2,**
8	A gas at a pressure of 340 mbar, temperature of 355 K and entry Mach number of 1.4 is expanded isentropic ally to 140mbar. Calculate the following (i) deflection angle, (ii) final mach number, (iii) Final temperature of the gas. Take γ=1.3.	**BTL-5**	**Evaluating**	**PO1,PO2, PO3**
9	The stagnation pressure and temperature of air at the entry of a nozzle are 5bar and 500K respectively.The exit Mach number is 2 where a normal shock occurs.Calculate the following quantities before and after the shock;static and stagnation temperatures and pressures,air velocities and mach number. What are the values of stagnation pressure loss and increase in entropy across the shock?	**BTL-5**	**Evaluating**	**PO1,PO2,PO4**

UNIT IV JET PROPULSION				
Theory of jet propulsion – Thrust equation – Thrust power and propulsive efficiency – Operating principle, cycle analysis and use of stagnation state performance of ram jet, turbojet, turbofan and turbo prop engines.				
PART – A				
CO Mapping : C314.4				
Q. No	Questions	BT Level	Competence	PO
1	What is thrust co-efficient?	BTL-1	Remembering	PO1,PO2
2	Define propulsive efficiency?	BTL-1	Remembering	PO1,PO2
3	What is thrust or drag?	BTL-1	Remembering	PO1
4	Define Effective Speed ratio.	BTL-1	Remembering	PO1,PO2
5	Define specific thrust.	BTL-1	Remembering	PO1
6	What is thrust specific fuel consumption(TSFC)?	BTL-1	Remembering	PO1,PO2
7	Define specific impulse.	BTL-1	Remembering	PO1
8	What are the main parts of Ramjet engine?	BTL-4	Analyzing	PO1
9	Give the expression for the thrust developed b a turbojet engine.	BTL-5	Evaluating	PO1,PO2
10	Define overall efficiency.	BTL-1	Remembering	PO1,PO2
11	What is the type of compressor used in turbo jet? Why?	BTL-4	Analyzing	PO1,PO4
12	Define bye-pass ratio.	BTL-1	Remembering	PO1,PO2
13	What is turboprop unit?	BTL-1	Remembering	PO1
14	What is thrust augmentation?	BTL-1	Remembering	PO1
15	Why ramjet engine does not require a compressor and a turbine?	BTL-4	Analyzing	PO1,PO3
16	What is scram jet?	BTL-1	Remembering	PO1
17	Define the principle of Ram jet engine.	BTL-1	Remembering	PO1,PO3
18	Give the components of a turbo jet.	BTL-4	Analyzing	PO1,PO3
19	Give the difference between pulse jet and ram jet engine.	BTL-4	Analyzing	PO1
20	Give the difference between turbojet and ram jet engine.	BTL-4	Analyzing	PO1
21	What is the difference between turbo prop engine and turbo jet engine.	BTL-4	Analyzing	PO1,PO2
22	What is ram effect?	BTL-1	Remembering	PO1
23	Differentiate between pressure thrust and momentum thrust.	BTL-4	Analyzing	PO1,PO2
24	Why after burners are used in turbojet engine?	BTL-4	Analyzing	PO1,PO3
25	Why a ram jet engine does not require a compressor and a turbine?	BTL-4	Analyzing	PO1,PO2,PO3
26	What are the factors affecting the actual efficiency of the propeller?	BTL-4	Analyzing	PO1,PO2,PO3
27	Define Thrust grading.	BTL-1	Remembering	PO1,PO2
28	What factors make the efficiency of a propeller?	BTL-4	Analyzing	PO1,PO2
29	Define mean aerodynamic chord	BTL-1	Remembering	PO1
30	What are the various types of drag?	BTL-2	Understanding	PO1
31	Why axial flow compressors are preferred	BTL-4	Analyzing	PO1,PO2,PO4

	over centrifugal compressors in jet engines?			
	PART – B & C			
1	Explain with the neat sketches the principle of operation of (i) Turbofan engine and (ii) Turbojet engine..	**BTL-6**	**Creating**	**PO1,PO2, PO3**
2	An aircraft propeller flies at a speed of 440kmph. The diameter of the propeller is 4.1m and the speed ratio is 0.8. The ambient conditions of air at the flight altitude are T=255K and P=0.55bar. find the following Thrust, Thrust power and Propulsive efficiency.	**BTL-5**	**Evaluating**	**PO1,PO2**
3	Derive the expression for the jet thrust propeller thrust, propulsive efficiency, thermal efficiency, overall efficiency and the optimum value of the flight to jet speed ratio for a turbojet engine.	**BTL-5**	**Evaluating**	**PO1,PO2, PO4**
4	A ram jet engine propels an aircraft at a Mach number of 1.4 and at an altitude of 6000m. The diameter of the inner diffuser at entry is 40 cm and the calorific value of the fuel is 43MJ/kg. The stagnation temperature at the nozzle entry is 1500K. The properties of the combustion gases are same as those of air.(ﻻ=1.4, R=287J/kgk). i. Determine the following: ii. The efficiency of the ideal cycle, iii. Flight speed iv. Air flow rate v. Diffuser pressure ratio vi. Fuel air ratio vii. Nozzle pressure ratio viii. Nozzle jet Mach number ix. Propulsive efficiency and Thrust. Assume, Diffuser efficiency, η_D=0.92, Combustion efficiency, η_B=0.97 and Nozzle jet efficiency, η_N=(or)η_j=0.95 Stagnation pressure loss in the combustion chamber=0.02P_{02}.	**BTL-5**	**Evaluating**	**PO1,PO2, PO3,PO4**
5	Derive the following relation for aircraft engine Flight to jet speed ratio $\sigma = 1 - \frac{F}{m_a c_j}$ Thrust in a turbojet engine $F = m_a(c_j - u) = m_a(c_e - u) + (p_e - p_a)A_e$	**BTL-5**	**Evaluating**	**PO1,PO2**
6	An aircraft flies at 90 km/hr. One of its turbojet	**BTL-5**	**Evaluating**	**PO1,PO2,**

	engines takes in 40kg/s of air and expands the gases to the ambient pressure. The air-fuel ratio is 50 and the lower calorific value of the fuel is 43 MJ/kg. For maximum thrust power determine, Jet velocity, Thrust, Specific thrust, Thrust power and Propulsive thermal and overall efficiencies.			**PO3**
7	Explain turbo-prop propulsion engines with suitable Diagrams..	**BTL-6**	**Creating**	**PO1, PO3**
8	A ramjet engine operates at M = 1.2 at an altitude of 6500 m. The diameter of inlet diffuser at entry is 50cm and the stagnation temperature at the nozzle entry is 1500K.The calorific value of the fuel used is 40 MJ/kg. The properties of the combustion gases are same those of air(γ = 1.4, R =287 J/kgK).The velocity of the air at the diffuser exit is negligible, calculate:(i) the efficiency of the ideal cycle,(ii) Flight speed, (iii) Air flow rate, (iv)Diffuser pressure ratio, (v) FueI air ratio ,(vi) Nozzle jet Mach number. The efficiencies of the diffuser = 0.9,combustor = 0.98 and the nozzle= 0.96	**BTL-5**	**Evaluating**	**PO1,PO2**
9	1. (i) Discuss the function and need of afterburner in jet engines. (ii) Derive the thrust equation for turbo-prop engine. (iii)Draw the following performance curve for turbo-prob ,turbofan and turbojet engines: Propulsive efficiency Vs Flight Speed (Nov'17)	**BTL-2**	**Understanding**	**PO1,PO2,PO4**
10	Mach 2 aircraft engine employs a subsonic inlet diffuser of area ratio 3. A normal shock is formed just upstream of the diffuser inlet. The free stream conditions upstream of the diffuser are p=10 bar,T=300K. Determine (i) Mach number , pressure and temperature at the diffuser exit,(ii)Diffuser efficiency including the shock. Assume isentropic flow in the diffuser downstream of the shock.	**BTL-5**	**Evaluating**	**PO1,PO2, PO3**

UNIT V SPACE PROPULSION

Types of rocket engines – Propellants-feeding systems – Ignition and combustion – Theory of rocket propulsion – Performance study – Staging – Terminal and characteristic velocity – Applications – space flights.

PART – A

CO Mapping : C314.5

Q.No	Questions	BT Level	Competence	PO

1	**Define Rocket propulsion**.	**BTL-1**	**Remembering**	**PO1**
2	**Explain the performance of the rocket engine.**	**BTL-2**	**Understanding**	**PO1,PO2**
3	**Define specific propellant consumption**	**BTL-1**	**Remembering**	**PO1,PO3**
4	**Define thrust for a rocket engine and how it is produced.**	**BTL-1**	**Remembering**	**PO1**
5	**What are the types of rocket engines?**	**BTL-2**	**Understanding**	**PO1**
6	**What is over expanded nozzle?**	**BTL-1**	**Remembering**	**PO1**
7	**Compare solid and liquid propellant rockets.**	**BTL-4**	**Analyzing**	**PO1,PO2**
8	**What are the types of liquid propellants used in rocket engines?**	**BTL-2**	**Understanding**	**PO1,PO12**
9	**What are the types of propellant feed system?**	**BTL-2**	**Understanding**	**PO1,PO12**
10	**What are the basic combustion processes?**	**BTL-2**	**Understanding**	**PO12**
11	**What are the advantages of solid propellant rocket engine?**	**BTL-2**	**Understanding**	**PO1**
12	**What are the disadvantages of solid propellant rocket engine?**	**BTL-2**	**Understanding**	**PO1,PO3**
13	**What is the limitation of hybrid rocket engine?**	**BTL-2**	**Understanding**	**PO1,PO4**
14	**What are the advantages of hybrid rocket engine?**	**BTL-2**	**Understanding**	**PO1,PO3**
15	**Define heterogeneous propellants.**	**BTL-1**	**Remembering**	**PO1**
16	**Define homogenous propellants.**	**BTL-1**	**Remembering**	**PO1**
17	**Differentiate jet propulsion and rocket propulsion (or) differentiate between air breathing and rocket propulsion?**	**BTL-4**	**Analyzing**	**PO1,PO2**
18	**What is monopropellant?**	**BTL-1**	**Remembering**	**PO1**
19	**What is mono-propellants? Give example**.	**BTL-1**	**Remembering**	**PO1**
20	**What is bipropellant?**	**BTL-1**	**Remembering**	**PO1**
21	**Classify the rocket engines based on sources of energy employed?**	**BTL-4**	**Analyzing**	**PO1,PO12**
22	**What is specifying impulse of rocket?**	**BTL-1**	**Remembering**	**PO1,PO3**
23	**Define specific consumption?**	**BTL-1**	**Remembering**	**PO1**
24	**What is weight flow co-efficient?**	**BTL-1**	**Remembering**	**PO1,PO2**
25	**What is IWR?**	**BTL-1**	**Remembering**	**PO1**
26	**Name some oxidizers used in rockets.**	**BTL-2**	**Understanding**	**PO1**
27	**Name few advantages of liquid propellant rockets over solid propellant rockets.**	**BTL-2**	**Understanding**	**PO1,PO3**
28	**What is inhibitors?**	**BTL-1**	**Remembering**	**PO1**
29	**Give the important requirements of rocket engine fuels.**	**BTL-4**	**Analyzing**	**PO1**
30	**What is meant by restricted burning in rockets?**	**BTL-1**	**Remembering**	**PO1,PO3**
		PART – B & C		
1	List the main components of Liquid Propellant Rocket Engine and explain .	**BTL-4**	**Analyzing**	**PO1,PO3**
2	A rocket engine has the following data: Effective jet velocity=1200m/s Flight to jet speed ratio=0.82 Oxidizer flow rate=3.4kg/s	**BTL-5**	**Evaluating**	**PO1,PO2,PO3**

	Fuel flow rate=1.2kg/s Heat of reaction per kg of the exhaust gases =2520kJ/kg Calculate the following, Thrust, Specific impulse, Propulsive efficiency, Thermal efficiency and Overall efficiency.			
3	Explain the working principles of a Turbo-pump feed system with a schematic diagram for liquid propellant rocket engines.	**BTL-2**	**Understanding**	**PO1,PO3,PO12**
4	Describe briefly the important applications of rocket propulsion in the following fields i. Aircrafts ii. Military iii. Space iv. Scientific	**BTL-2**	**Understanding**	**PO1,PO3,PO12**
5	(a)Describe with schematic diagram the principle of working and construction of a magneto hydrodynamic rocket engine. (NOV/DEC 2014) (b)In the rocket engine, propellant flow rate is 5.2 kg/s, nozzle exit diameter is 9cm , nozzle exit pressure is 1.02bar, ambient pressure is 1.013bar, thrust chamber pressure is 22bar and thrust is 7.2 kN. Calculate the following i. Effective jet velocity ii. Actual jet velocity iii. Specific impulse and iv. Specific propellant consumption	**BTL-6**	**Creating**	**PO1,PO2, PO3,PO12**
6	(a)What are the advantages and disadvantages of liquid propellant rocket engine? (NOV/DEC 2014) (b)A rocket has the following data: combustion chamber pressure 36bar, combustion chamber temperature =3600K, Oxidizer flow rate = 41kg/s. Mixure ratio=5 and Ambient pressure =585N/m^2. Determine: i. Nozzle throat area	**BTL-2**	**Understanding**	**PO1,PO2, PO3,PO4**

	ii. Thrust iii. Thrust coefficient, iv. Characteristic velocity and v. Exit velocity of exhaust gases. Take γ=1.3. and R=287J/kg K			
7	Calculate the thrust,specific impulse, propulsive efficiency, thermal and overall effciencies of a rocket engine from the following data; Effective jet velocity = 1250 m/s, Flight to jet speed ratio = 0.8, oxidizer flow rate=3.5kg/s,fuel flow rate=1kg/s, heat of reaction of exhaust gases = 2,500 kJ/ks	**BTL-5**	**Evaluating**	**PO1,PO2, PO4**
8	A spacecraft's engine ejects mass at a rate of 30kg/s with an exhaust velocity of 3100m/s.The pressure at the nozzle exit is 5kPa and the exit area is 0.7m^2 .what is the thrust of the engine in a vacuum?	**BTL-5**	**Evaluating**	**PO1,PO2**
9	A rocket nozzle has a throat area of 18cm^2 and combustion chamber pressure of 25bar. If the specific impulse is 127.42 s and weight flow rate (iii) Specific propellant consumption (iv) Characteristics velocity.	**BTL-5**	**Evaluating**	**PO1,PO2,PO4**
10.	Describe with the aid of illustrative diagrams of any two arrangements of solid propellant grains employed for restricted and unrestricted burning. Indicate the directions of burning and flow of gases.	**BTL-5**	**Evaluating**	**PO1, PO3,PO4**

UNIT I BASIC CONCEPTS AND ISENTROPIC FLOWS
Energy and momentum equations of compressible fluid flows – Stagnation states, Mach waves and Mach cone – Effect of Mach number on compressibility – Isentropic flow through variable ducts – Nozzle and Diffusers
PART – A
1. Express the stagnation enthalpy in terms of static enthalpy and velocity of flow. (NOV/DEC 2009) In an adiabatic flow q = 0. Therefore energy equation becomes, $h_1 + c_1^2 /2 + gZ_1 = h_2 + c_2^2 /2 + gZ_2 + W_1$ Adiabatic energy equation is $h_0 = h + 1/2c_2^2$
2. Explain the meaning of stagnation state with example. (Nov/DEC 2010) The state of fluid attained by isentropically decelerating it to zero velocity at zero elevation is referred as stagnation state. E.g. Fluid in a reservoir or in a settling chamber.
3. Distinguish between static and stagnation pressures. (APR/MAY2015) In stagnation pressure state the velocity of the flowing fluid is zero whereas in the static pressure, the fluid velocity is not equal to zero
4. Differentiate between the static and stagnation temperatures. The actual temperature of the fluid in a particular state is known as static temperature whereas the temperature of the fluid when the fluid velocity is zero at zero elevation known as stagnation temperature $T_o = T+c^2 /2C_p$
5. What is the use of Mach number? (NOV/DEC2008, APR/MAY2015)

Mach number is defined as the ratio between the local fluid velocity to the velocity of sound. Mach number M=c/a. It is used for the analysis of compressible fluid flow problems. Critical mach number is a dimensionless number at which fluid velocity is equal to its sound velocity. $M_{criti} = (c/a) -1$

6. What is Crocco number? (Nov'16)
It is a non-dimensional fluid velocity which is defined as the ratio of fluid velocity to its maximum fluid velocity, $Cr=C/C_{max}$

7. Give expression of P/P_0 for an isentropic flow through a duct.
The expression is $P/P_0 = 1/\{[1+ (\gamma -1)/2] M^2 \} \gamma^{-1}$

8. What are the different regions of compressible flow? (APR/MAY2010)
1.Subsonic region 2.Supersonic region 3.Hypersonic region 4. Transonic region

9. Define M^* and give the relation between M and M^* (NOV/DEC2008)
It is a non-dimensional mach number and is defined by the ratio between the local fluid velocity to its critical velocity of sound, $M^* = c/a^*$

10. A plane travels at a speed of 2400Km/hr in an atmosphere of 5 degree, find the Mach angle?
C=2400/3.6 = 666.67
T=278K
$M=c/\sqrt{\gamma RT}=1.9947$
$\alpha=\sin^{-1} (1/M) = 30.0876^\circ$

11. Define Mach angle and Mach wedge. (APR/MAY2011)
Mach angle is formed when an object is moving with supersonic speed. The wave propagation and changes are smooth. When an object is moving with hypersonic speed the changes are abrupt is shown in figure. Hence for a supersonic flow over two dimensional object "mach wedge" is used instead of "mach cone".

12. What is meant by isentropic flow with variable area? (MAY/JUNE2014)
A steady one dimensional isentropic flow in a variable area passages is called "variable area flow". The heat transfer is negligible and there are no other ir-reversibilities due to fluid friction.

13. Define Mach cone.
Tangents drawn from the source point on the spheres define a conical surface referred to as Mach cone.

14. What is characteristic Mach number? (APR/MAY2010)
$M^* = [M^2 (\gamma-1)/2+ M^2 (\gamma-1)]^{1/2}$

15. Distinguish between Mach wave and normal shock?
Mach wave: The lines at which the pressure difference is concentrated and which generate cone are called mach lines or mach waves
Normal shock: A shock wave is nothing but a steep finite pressure wave. When the shock wave is right angle to the flow, it is called normal shock

16. Define zone action and zone of silence.
The region inside the Mach cone is called the zone of action an the region outside the Mach cone is termed as the zone of silence.

17. Define adiabatic process.
In an adiabatic process there is no heat transfer between the system and the surrounding, Q=0

18. What is meant by transonic flow?
If the fluid velocity is close to the speed of sound that type of flow is called as transonic flow. Mach number is between 0.8 and 1.2

19. What is meant by hypersonic flow? (APR/MAY 2011)
In hypersonic flow, fluid velocity is much greater than sound velocity. Mach number is always greater than 5

20. Distinguish between nozzle and diffuser? (MAY/JUNE 2014)
Nozzle:It is a device which is used to increase the velocity and decrease the pressure of fluids.
Diffuser:It is a device which is used to increase the pressure and decrease the velocity of fluids.

21. What is Impulse function ?
The sum of pressure force (pA) and impulse force (ρAc^2) gives Impulse function (F)
$F = pA + \rho ac^2$

22. Differentiate between adiabatic flow and diabatic flow ?

Diabatic flow :Flow in a constant area duct with heat transfer and without friction is known as diabatic flow (Rayleigh flow)

Adiabatic flow:Flow in a constant area duct with friction and without heat transfer is known as adiabatic flow (Fanno flow).

23. State the expression for dA/A as a function of Mach number ?

$dA/A = dp/\rho c^2 [1-M^2]$

24. Give the expression for T/To and T/T* for isentropic flow through variable area interms of Mach number ?

$To/T = 1+[\gamma-1/2]M^2$

To/T = 1

25. When does the maximum mass flow occur for an isentropic flow with variable area?

Mass flow rate will be maximum at throat section where the Mach number is one.

26. Write the equation for efficiency of the diffuser.

Diffuser efficiency = static pressure rise in actual process/ static pressure rise in ideal process

$P_2-P_1/P_2^{'}-P_1$

27. What is impulse function and give its uses?

Impulse function is defined as the sum of pressure force and inertia force. Impulse function F=Pressure force ρA + inertia force ρAc^2 . Since the unit of both the quantities is same as unit of force, it is very convenient for solving jet propulsion problems. The thrust exerted by the flowing fluid between two sectons can be obtained by using change in impulse function.

28. State the necessary conditions for chocked flow to occur in a nozzle.

The necessary conditions for this flow to occur in a nozzle is the nozzle exit pressure ratio must be equal to the critical pressure ratio where the mach number M=1.

29. What is meant by normal shock as applied to compressible flow?

Compression wave front being normal to the direction of compressible fluid flow. It occurs when the flow is decelerating from supersonic flow. The fluid properties jump across the normal shock.

30. Define strength of a shock wave. (APR/MAY2010, NOV/DEC2009)

Strength of a shock wave is defined as the ratio of increase in static pressure across the shock to the inlet static pressure.

Strength of shock = $(P_y - P_x)/P_x$

31. What is the effect of Mach number on compressibility? (Nov'17)

1. For low speed, or subsonic conditions, the Mach number is less than one, M < 1 and the square of the Mach number is very small. Then the left hand side of the equation is very small, and the change in density is very small. For the low subsonic conditions, compressibility can be ignored.
2. As the speed of the object approaches the speed of sound, the flight Mach number is nearly equal to one, M = 1, and the flow is said to be transonic. If the Mach number is near one, the square of the Mach number is also nearly equal to one. For transonic flows, the change in density is nearly equal to the change in velocity, and compressibility effects can not be ignored.
3. As the speed increases beyond the speed of sound, the flight Mach number is greater than one M > 1 and the flow is said to be supersonic or hypersonic. For supersonic and hypersonic flows, the density changes faster than the velocity changes by a factor equl to the square of the Mach number. Compressibility effects become more important with higher Mach numbers.

PART – B & C

1.An air craft flies at a velocity of 700Kmph in an atmosphere where the pressure is 75kPa and temperature is 5°C. Calculate the Mach number and stagnation properties (APR/MAY 2015)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya Pg.No: 90

2. Air expands isentropically through the convergent nozzle from constant inlet conditions P_o=4bar, T_o =550k. Exit area of nozzle is 1000cm^2. Determine the exit velocity and mass flow rate for the following two cases at exit. (APR/MAY 2015)

(i) M=1

(ii)M=0.85

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya Pg.No: 93

3.

i. **Difference between transonic flow and hypersonic flow**
ii. **Derive the expression for pressure co-efficient equation for compressible flow**
iii. **Name the different regions of compressible fluid flow (NOV/DEC 2014)**

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No: 42

4. (i)Derive the expression for the mass flow rate in terms of Mach number (NOV/DEC 2014)

(ii)A nozzle in a wind tunnel gives a test –section Mach number of 2.0. Air enters the nozzle from a large reservoir at 0.69 bar and 310K. The cross-sectional area of the throat is 1000cm^2. Determine the following quantities for the tunnel for one dimensional isentropic flow:

d. **Pressures, temperatures and velocities at the throat and test sections,**
e. **Area of cross-section of the test section**
f. **Mass flow rate and**
g. **Power required to drive the compressor (NOV/DEC 2014)**

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No: 93

5. Air flows through a nozzle which has inlet areas of 0.001m^2. If the air has a velocity of 80m/s a temperature of 301K and a pressure of 700kPa at the inlet section and a pressure of 250kPa at the exit find the mass flow rate through the nozzle and assuming one -dimensional isentropic flow the velocity at the exit section of the nozzle. (MAY/JUNE 2014)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No: 93

6. A gas flows through a restricted passage with a speed of 850 m/s .Its local temperature is 1650 K; its specific heat ratio k and gas constant R are 1.25 and 250 J/kg K respectively. Calculate the local sonic velocity and Mach number. (Nov'16)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No: 50

7. A supersonic diffuser, diffuses air in an isentropic flow from a Mach number of 3 to a Mach number of 1.5, the static conditions of air at inlet are 70 kPa and -7°C. If the mass flow rate of air is125 kg/s, determine (i)Stagnation conditions, (ii) Area at throat and exit. (iii) Static Conditions of air at exit. (Nov'16)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No: 101

8. (i).Discuss the changes of Mach number in CD nozzle under various back pressure.(ii)An airplane is travelling while you are observing from the ground. How will you know whether it is subsonic or supersonic? Explain.(iii)How fluid stagnation states will change if the fluid flow in diffuser follows an adiabatic process? (Nov'17)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No: 84

9. Air flows through a convergent-divergent (CD) nozzle. At some section in the nozzle, pressure =2bar, velocity=170m/s and temperature=200°C and cross sectional area =1000 mm^2.Assuming isentropic flow conditions, determine: (i) stagnation temperature and stagnation pressure (ii) sonic velocity and Mach number at this section (iii) velocity , Mach number and flow area at outlet section where pressure is 1.1 bar (iv) pressure, temperature, velocity and flow area at throat section. (Nov'17)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No: 93

UNIT II FLOW THROUGH DUCTS

Flows through constant area ducts with heat transfer (Rayleigh flow) and Friction (Fanno flow) –

variation of flow properties.
PART – A
1. What are the assumptions made for fanno flow? (APR/MAY2014,NOV/DEC2014) One dimensional steady flow. Flow takes place in constant sectional area. There is no heat transfer The gas is perfect with constant specific heats.
2. Differentiate Fanno flow and Rayleigh flow? (NOV/DEC2009) Rayleigh flow :Flow in a constant area duct with heat transfer and without friction is known as Rayleighs flow. Fanno Flow: Flow in a constant area duct with friction and without heat transfer is known as Fanno flow.
3. Explain chocking in Fanno flow? (Nov'16) In a fanno flow, subsonic flow region, the effect of friction will increase the velocity and Mach number and to decrease the enthalpy and pressure of the gas. In supersonic flow region, the effect of friction will decrease the velocity and Mach number and to increase the enthalpy and pressure of the gas. In both cases entropy increases up to limiting state where the Mach number is one(M=1) and it is constant afterwards. At this point flow is said to be chocked flow.
4. Explain the difference between Fanno flow and Isothermal flow? (NOV/DEC2009) Fanno Flow Isothermal Flow Flow in a constant area duct with friction and without heat transfer is known as fanno flow. Flow in a constant area duct with friction and the heat transfer is known as isothermal flow. Static temperature is not constant Static temperature remains constant
5. Write down the ratio of velocities between any two sections in terms of their Mach number in a fanno flow ? $C_2/C_1=M_2/M_1\ [1+[\gamma-1/2]\ M_1^2]^{1/2}/[1+[\gamma-1/2]\ M_2^2]^{1/2}$
6. Write down the ratio of density between any two section in terms of their Mach number in a fanno flow? $\rho_2/\rho_1= M_1/M_2\ [1+[\gamma-1/2]\ M_2^2]^{1/2}/[1+[\gamma-1/2]\ M_1^2]^{1/2}$
7. What are the three equation governing Fanno flow? Energy equation, continuity equation and equation of state.
8. Give the expression to find increase in entropy for Fanno flow? $(S_2-S_1)/R = \ln M_2/M_1\ [1+[\gamma-1/2]\ M_1^2]^{(\gamma+1)/2(\gamma-1)}\ [1+[\gamma-1/2]\ M_2^2]^{(\gamma+1)/2(\gamma-1)}$
9. Give two practical examples where the Fanno flow occurs? (NOV/DEC2014) Flow in air breathing engines Flow in refrigeration and air conditioning Flow of fluids in long pipes.
10. What is Rayleigh line and Fanno line? (NOV/DEC2009) Rayleigh line: Flow in a constant duct area with heat transfer and without friction is described by a curve is known as Rayleigh line. Fanno Line: Flow in a constant duct area without heat transfer and with friction is described by a curve is Fanno line
11. What are the assumptions of Fanno flow? One dimensional steady flow Flow takes place in constant sectional area There is no heat transfer The gas is perfect with constant specific heats
12. Write down expression to find increase in entropy for Fanno flow. $(S_2-S_1)/R = \ln M_1/M_2$
13. Define fanning"s coefficient of skin friction It is the ratio between wall shear stress and dynamic head F = wall shear stress/dynamic head
14. Define oblique shock. (APR/MAY2011) Also mention where it occurs. The shock wave which is inclined at an angle to the two dimensional flow direction is called as oblique shock. When the flow is supersonic, the oblique shock occurs at the corner due to the turning of supersonic flow.
15. Define Fanno line. The locus of the state which satisfy the continuity and energy equation for a frictional flow is known as fanno line.

16. Define isothermal flow with friction.

A steady one dimensional flow with friction and heat transfer in a constant area duct is called isothermal flow with friction.

17. Give the applications of isothermal flow with friction.

In long ducts where sufficient time is available for the heat transfer to occur and therefore the temperature may remain constant.

18. State the assumptions made to derive the equations for isothermal flow.

One dimensional flow with friction and heat transfer Constant area duct Perfect gas with constant specific heats and molecular weights Isothermal flow

19. Give the assumptions made in Rayleigh flow (APR/MAY2010,2014)

One dimensional flow without friction and heat transfer Constant area duct Perfect gas with constant specific heats and molecular weights Absence of body forces.

20. Write the continuity equation

$C_1/C_2 = \rho_2/\rho_1$

21. Give two practical examples for Rayleigh flow (APR/MAY2010)

Flow in combustion chamber
Flow in regenerators
Flow in heat exchangers
Flow in intercoolers.

22. Define fanning's coefficient of skin friction

It is ratio between wall shear stress and dynamic head
F=wall shear stress/Dynamic head

23. Write down the expression for the length of duct in terms of the two mach number M_1 and M_2 for a flow through a constant area duct with the influence of friction.

$4fL/D=[4fl/D]M_1-[4fl/D]M_2$

24. Write down the ratio of pressure between any two section in terms of their mach number in a Fanno flow.

$P_2/P_1=M_1/M_2[[1+(\gamma-1)/2M_1^2]/[1+(\gamma-1)/2M_1^2]]^{1/2}$

25. Write down the expression for the temperature ratio between two sections in terms of Mach numbers for flow in a constant area duct with friction

$T_1/T_2=[1+ (\gamma-1)/2M_1^2]/[1+ (\gamma-1)/2M_2^2]$

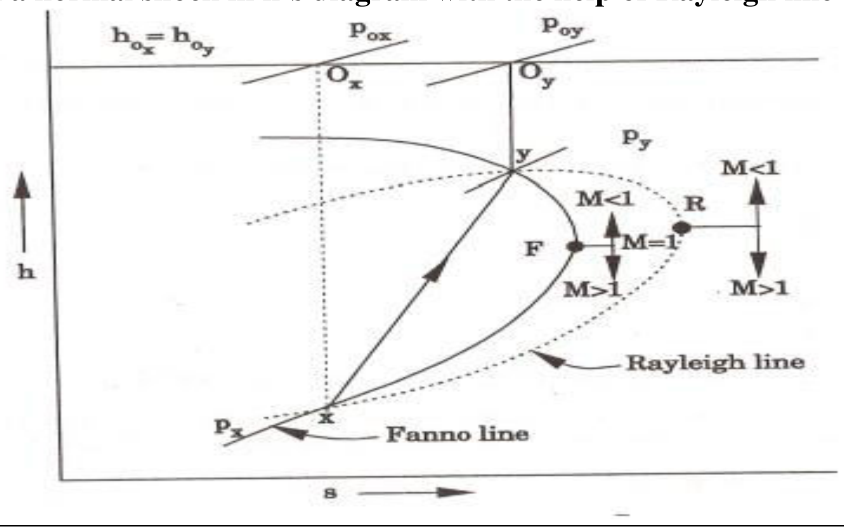
26. Write down the expression for the pressure ratio of two section interms of mach number in Rayeligh flow. (Nov'16)

$P_2/P_1=(1+\gamma M_1^2)/(1+\gamma M_2^2)$

27. What is the value of Mach number of air at the maximum point in Rayleigh heating process.

At maximum point in Rayeligh curve, the value of mach number is one.

28. Shown a normal shock in h-s diagram with the help of Rayleigh line and Fanno line.

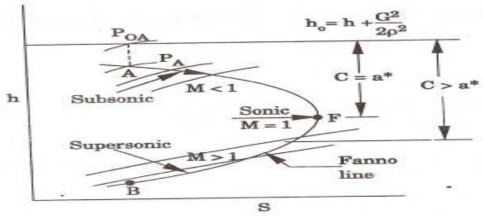


29. Give fanno line in h – s diagram with isentropic stagnation line and show various mach number regions.

A to F - heating process ⎤
F to A - cooling process ⎦ M < 1

B to F - heating process ⎤
F to B - cooling process ⎦ M > 1

Point F is critical point where mach number M = 1.



The equation which yields the fanno line for the given values of h_0 and G is called "fanno flow equation".

i.e., $h = h_0 - \frac{G^2}{2[f(h,s)^2]}$ ⇒ Fanno equation

.

30. Give the effect of increasing the flow length after reaching critical condition in a fanno flow.

The mass flow rate will increase only upto the critical condition and is constant afterwards. Therefore, if the length of pipe is increased afterwards will not give any effect.

31. List the governing equations that useful to describe the Rayleigh flow. (Nov'17)

Energy equation, continuity equation and equation of state.

PART – B & C

1. The stagnation temperature of air is raised from 85°C to 376°C in a heat exchanger. If the inlet Mach number is 0.4. Determine the final Mach number and percentage drop in pressure. (. APR/MAY 2015)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No: 266

2. Air at Po=11bar, To=420K enters at 45mm diameter pipe at a Mach number of 3 and the friction co-efficient for the pipe surface is 0.001. if the mach number at exit is 0.8. Determine (i) Mass flow rate (ii) Length of the pipe .(APR/MAY 2015)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No: 235

3. Prove the variation of flow parameter and the maximum possible heat transfer (NOV/DEC 2014)

$$Q_{max} = C_p T * \frac{(1 - M^2)^2}{2(1 + \gamma)M^2)}$$

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No: 257

4. (a)A circular duct of 35cm diameter passes gas at Mach number of 2.0. The static pressure and temperature are 1 bar and 410k respectively. A normal shock occurs at a Mach number of 1.4 and the exit Mach number is 1. If the co-efficient of friction is 0.02, calculate:

(i)length of the duct upstream and downstream of the shock wave

(ii)mass flow rate of the gas and

(iii)change of entropy for upstream of the shock, across the shock and downstream of the shock. Take γ=1.3 and R=0.285kJ/kgK(NOV/DEC 2014)

(b)Explain the difference between Fanno flow and Isothermal flow.(NOV/DEC 2014)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No: 236

5. The condition of gas in a combustor at entry is P_1=0.343 bar,T_1=310K, C_1=60m/sec.Determine the Mach number, pressure, temperature and velocity at the exit if the increase in stagnation enthalpy of the gas between entry and exit is 1172.5kJ/kg.TakeCp=1.005kJ/kgK,γ=1.4. (MAY/JUNE 2014)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No: 262

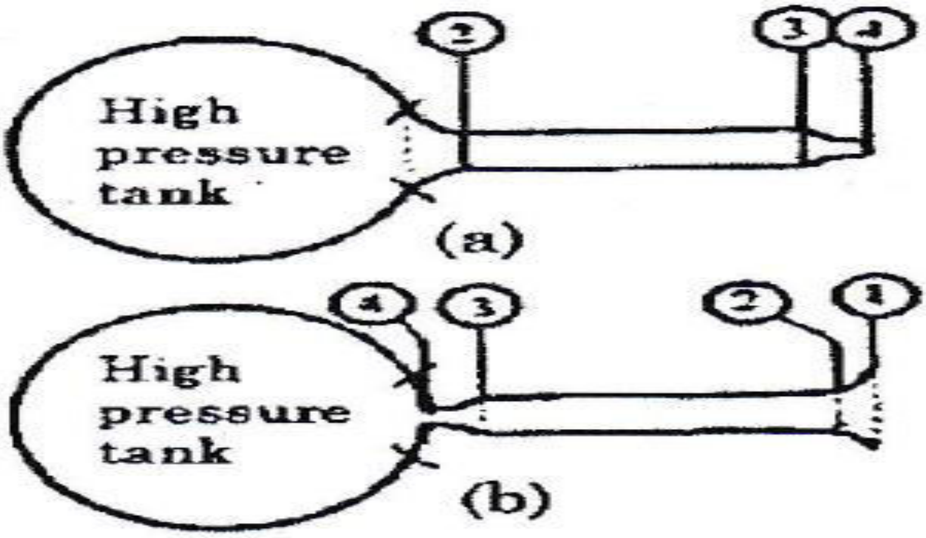
6. Air flows out of a pipe with a diameter of 0.3m at a rate of 1000m^3/min at a pressure and temperature of 150kPa and 293K respectively. If the pipe is 50m long, find assuming that f=0.005, the Mach number at the exit, the inlet pressure and the inlet temperature. (MAY/JUNE 2014)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No: 245

7. Air (γ= 1.4) flows into a constant-area insulated duct with a Mach number of 0.20. For a duct diameter of 1 cm and friction coefficient of 0.02, determine the duct length required to reach Mach 0.60. Determine the length required to attain Mach 1. Finally, if an additional 75 cm is added to the duct length needed to reach Mach l, while the initial stagnation conditions are maintained, determine the reduction in flow rate that would occur. (Nov'16)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No: 238

8. (i) In which configuration of Figure (a) or (b], will the high-pressure tank empty faster? Explain.



(ii) The stagnation temperature of air is raised from 85°C to 376°C in a heat exchanger. If the inlet Mach number is 0.4, determine the final Mach number and percentage drop in pressure.(Nov'16)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No: 266

9. (i) Prove that the Mach numbers at the maximum enthalpy and maximum entropy points on the Rayleigh line are $1/\sqrt{\gamma}$ and 1.0 respectively.

(ii)Show the h=constant and s =constant lines at these points on the Rayleigh line on the h-s and p-v planes. (Nov'17)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No: 250

UNIT III NORMAL AND OBLIQUE SHOCKS

Governing equations – Variation of flow parameters across the normal and oblique shocks – Prandtl – Meyer relations – Applications.

PART – A

1. **What is mean by shock wave? (APR/MAY2010)**
   A shock wave nothing but a steep finite pressure wave. The shock wave may be described as a compression wave front in a subsonic flow field across which there is abrupt change in flow properties.
2. **What is mean by Normal shock?**
   When the shock wave at right angle to the flow it is called normal shock.
3. **What is oblique shock? (NOV/DEC2010, 2014APR/MAY2015)**
   When the shock wave is inclined at an angle to the flow it is called oblique shock.
4. **What are applications of moving shock wave ?**
   It is used in Jet engines, Shock tubes, Supersonic wind tunnel and Practical admission turbines

5. Shock waves cannot develop in subsonic flow? Why?

In subsonic flow the velocity of fluid is less tan the velocity of sound .Due to this reason, deceleration is not possible in subsonic flow so shock waves cannot develop in subsonic flow.

6. Define compression and rarefaction shock?

A shock wave which is at a higher pressure than the fluid into which it is moving is called a compression wave. The shock wave which is at a lower pressure than the fluid into which it is moving is called a expansion shock wave or rarefaction shock wave.

7. State the necessary conditions for a normal shock to occur in compressible flow?

1. The compression wave is to be at right angle to the compression flow 2. Flow should be supersonic

8. Give the difference between normal and oblique shock?(APR/MAY2011,NOV/DEC2014)

In Normal Shock, the wave is right angle to the Flow and its is a one dimensional flow In oblique shock, Shock wave is inclined at an angle to the flow and it is a two dimensional flow.

9. What are the properties change across a normal shock ?

1. Stagnation pressure decreases 2. Stagnation temperature remains const 3. Static pressure and temperature increase

10. What is Prandtl – Meyer relation? (APR/MAY2011, 2015)

It is the basis of other equation for shock waves. It gives the relationship between the gas velocities before and after the normal shock and the critical velocity of sound.

11. Define strength of shock wave. (NOV/DEC2008,2009)

It is defined as the ratio of difference in downstream and upstream shock pressures to upstream shock pressure. It is denoted by (Py-Px)/Px

12. Is the flow through a normal shock an equilibrium one.

No. Since the fluid properties like pressure, temperature and density are changed during normal shock.

13. Calculate the strength of the shock waves when normal shock appears at M=2.

Strength of shock = $(P_y-P_x)/P_x$ For, Normal shocks table for Mx=2 and γ=1.4, Py/Px = 4.5 Therefore, strength = 4.5 – 1 = 3.5

14. Write down the static pressure ratio expression for a normal shock.

$P_y/P_x = (2\gamma/\gamma+1) \times M_x^2 - [(\gamma-1)/\gamma+1)]$

15. What are expansion wave?

A wave which is at a lower pressure than the fluid in to which it is moving is called an expansion wave or refraction wave.

16. What are compression wave?

A wave which is at a higher pressure than the fluid in to which it is moving is called compression wave.

17. How the Mach number before and after the occurrence of a normal shock are related?

Mach number after the normal shock = $M_y^2= (2/\gamma-1)+M_x^2/(2\gamma/\gamma-1)+M_x^2-1$

18. What are applications of moving shock wave?

It is used in Jet engine, shock tubes, supersonic wind tunnel, Practical admission turbines

19. What is meant by normal shock as applied to compressible flow?

Compression wave front being normal to the direction of compressible fluid flow. It occurs when the flow is decelerating from supersonic flow. The fluid properties jump across the normal shock.

20. Define oblique shock where it occurs. (NOV/DEC2010)

The shock wave which is inclined at an angle to the two dimensional flow direction is called as oblique shock. When the flow is supersonic, the oblique shock occurs at the corner due to the turning of supersonic flow.

21. Write the equation for efficiency of a diffuser

$\eta_D= (T_{o1}/T_1)[Poy/Pox]^{\gamma-1/\gamma} -1/[(\gamma-1)/2]M_1^2)$

22. Write down the Rankine-Hagoniot equation

$\rho_y/\rho_x= [1+(\gamma+1/\gamma-1) *P_y/P_x]/(\gamma+1/\gamma-1) +P_y/P_x$

23. Give the expression for T_y/T_x across the normal shock. (Nov'17)

$T_y/T_x=[(2\gamma/\gamma-1)M_x^2-1] [1+(\gamma-1/2)M_x^2] / [M_x^2/2(\gamma-1)*(\gamma+1)^2]$

24. How to determine deflection angle θ.

This angle is usually determined by the shape of the object causing the shock waves.

25. What is mean by detached shock wave

If we put a rather blunt body in a supersonic flow, we won't get an (attached) oblique shock wave. Instead, we will get a detached shock wave.

26. How do the various flow properties behave during expansion waves?

In a shock wave the pressure, density and temperature increase. In an expansion wave it is exactly opposite: they all decrease.

27. What is the condition of before and after shock?

The properties of this shock wave vary along the shock wave. At the front of the shock wave, the wave angle β is 90◦ . So we have a normal shock wave there. Behind this shock wave, the flow is subsonic.

28. Describe about Multiple Shock Waves

This flow has been deflected towards the wall by an angle θ. Since the flow can't go through the wall, it needs to be deflected the other way, by the same angle θ. To accomplish this, there will be a new shock wave.

29. What are the components of the velocity in oblique shock

Two components of this velocity: The component normal to the shock wave u1 and the component tangential to the shock wave w_1

30. How the disturbances get changed

When the airplane flies at a subsonic velocity (V < a), the disturbances can move upstream.
If the airplane, however, flies at a supersonic speed (V > a), the disturbances can not

31. Mention the useful applications of shock wave. (Nov'16)

The capability of shock waves to generate non-linear pressure and temperature spikes in the medium of propagation finds very interesting applications in variety of areas such as medicine, biological sciences, material processing, manufacturing, and microelectronic industries.

PART – B & C

2. **A jet of air at 270K and 0.7bar has an initial Mach number of 1.9. If it passes through a normal shockwave, determine the following for downstream of the shock.**
   i. **Mach number**
   ii. **Pressure**
   iii. **Temperature**
   iv. **Speed of the sound**
   v. **Jet velocity**
   vi. **Density (APR/MAY 2015)**

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya,Pg.No:161

3. **A normal shock occurs in the diverging section of a convergent-divergent air nozzle. The throat area is 1/3 times exit area and the static pressure at exit is 0.4 times the stagnation pressure at the entry. The flow is throughout isentropic expect through the shock. Determine:**
   iv. **Mach number M_x and M_y**
   v. **The static pressure and**
   vi. **The area of cross section of the nozzle at the section of nozzle where the normal shock occurs (MAY/JUNE 2014)**

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya,Pg.No:165

4. **Derive the expression for Rankine-Hugoniot equation (Density ratio across the shock) (NOV/DEC 2014)**

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya,Pg.No:144

4. (a)What Is oblique shock waves? And what are the assumptions are used for oblique shock flow? (NOV/DEC 2014)

(b)Oblique shock waves occur at the leading edge of a symmetrical wedge. Air has a Mach number of 2.1 and deflection angle (δ) of 15^o. Determine the following for strong and weak waves.

i. **Wave angle**

ii. Pressure ratio
iii. Density ratio
iv. Temperature ratio and
v. Down stream Mach number. (NOV/DEC 2014)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya,Pg.No:174,177 &204

5. A gas at a pressure of 340m bar, temperature of 355K and entry Mach number of 1.4 is expanded isentropically to 140m bar. Calculate the following:
iv. Deflection angle
v. Final mach number
vi. Final temperature of the gas. Take γ=1.3. (APR/MAY 2015)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya,Pg.No:207

6. A gas (γ=1.3) at p_1=345mbar,T_1=350K and M_1=1.5 is to be isentropically expanded to 138mbar. Determine
iv. The deflection angle
v. Final Mach number
vi. The temperature of the gas. (MAY/JUNE 2014)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya ,Pg.No:207

7. State and prove Prandtl-Meyer relation for a normal shock. (Nov'16)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya,Pg.No:139

8. A gas at a pressure of 340 mbar, temperature of 355 K and entry Mach number of 1.4 is expanded isentropic ally to 140mbar. Calculate the following (i) deflection angle, (ii) final mach number, (iii) Final temperature of the gas. Take γ=1.3. (Nov'16)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya,Pg.No:207

9. The stagnation pressure and temperature of air at the entry of a nozzle are 5bar and 500K respectively.The exit Mach number is 2 where a normal shock occurs.Calculate the following quantities before and after the shock;static and stagnation temperatures and pressures,air velocities and mach number. What are the values of stagnation pressure loss and increase in entropy across the shock? (Nov'17)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya,Pg.No:173

UNIT IV JET PROPULSION

Theory of jet propulsion – Thrust equation – Thrust power and propulsive efficiency – Operating principle, cycle analysis and use of stagnation state performance of ram jet, turbojet, turbofan and turbo prop engines.

PART – A

1. What is thrust co-efficient? (NOV/DEC2009)

It is the ratio of the thrust to the thrust force. Cf = F/po A*

2. Define propulsive efficiency? (NOV/DEC2009, APR/MAY2015,MAY/JUNE 2015)

It is ratio of the propulsive power to the power output of the engine ηp =propulsive power/power output of the engine.

3. What is thrust or drag?

The force which propels the aircraft towards at an given speed is called as thrust or propulsive force. This thrust mainly depends on the velocity of gases at the exit of the nozzle.

4. Define Effective Speed ratio.

The ratio of flight speed to jet velocity is known as effective speed ratio. $\Sigma = u/c_j$

5. Define specific thrust.

The thrust developed per unit mass flow rate is known as specific thrust

(Fsp) = F/m.

6. What is thrust specific fuel consumption(TSFC)?

It is defined as the ratio of fuel consumption rate per unit thrust.

7. Define specific impulse.

The thrust developed per unit weight flow rate is known as specific impulse.

Isp = F/W

8. What are the main parts of Ramjet engine?

The main parts of Ramjet engine are, Supersonic diffuser, subsonic diffuser, combustion chamber and discharge nozzle.

9 . Give the expression for the thrust developed b a turbojet engine.

Thrust F = m. cj - m .a u

10. Define overall efficiency.

It is the ratio of propulsive power to the power input to the engine.

ηo = Propulsive power / power input to the engine.

11. What is the type of compressor used in turbo jet? Why? (NOV/DEC2010, APR/MAY2015)

Rotary compressor is used in turbojet engine due to its high thrust and high efficiency.

12. Define bye-pass ratio.(APR/MAY2010)

Bye-pass ratio is defined as the ratio of mass flow passing through the fan, via bye pass duct to the mass flow passing through the core itself

13. What is turboprop unit?

Turboprop engine is very similar to turbojet engine. In this type, a turbine which is used to drive the compressor and propeller.

14. What is thrust augmentation? (NOV/DEC2009)

To achieve better take-off performance, additional fuel is burnt in the tail pipe between the turbine exhaust section and entrance section of the exhaust nozzle. This is called as thrust augmentation

15. Why ramjet engine does not require a compressor and a turbine? (MAY/JUNE 2014, NOV/DEC 2014)

In ramjet engine due to supersonic and subsonic diffuser, the static pressure of air is increased to ignition pressure. So there is no need of compressor and turbine.

16. What is scram jet?

A supersonic combustion ramjet engine is known as scramjet

17. Define the principle of Ram jet engine.

The principle of jet engine is obtained from the application of Newton's law of motion. We know that when a fluid is accelerated, a force is required to produce this acceleration is the fluid and at the same time, there is an equal and opposite reaction force of the fluid on the engine is known as the thrust, and therefore the principle of jet propulsion is based on the reaction principle.

18. Give the components of a turbo jet.

i. Diffuser, ii. Mechanical compressor, iii. Combustion chamber, iv. Turbine & Exhaust nozzle.

19. Give the difference between pulse jet and ram jet engine.

PULSE JET	RAM JET
a) Mechanical valve arrangements are used during combustion. b) The stagnation temperature at the diffuser exit is comparatively less.	a) Works without the aid of any mechanical device and needs no moving parts. b) Since the mach number in Ram jet engine is supersonic, the stagnation temperature is very high.

20. Give the difference between turbojet and ram jet engine.

TURBO JET	RAM JET
a) Compressor and turbine are used.	a) Compressor and turbine are not used but diffuser and nozzle are used.
b) Lower thrust and propulsive efficiency at lower speeds.	b) It provides high thrust per unit weight.
c) Construction cost is more.	c) In the absence of rotating machines, the construction is simple and cheap.

21. What is the difference between turbo prop engine and turbo jet engine.

TURBO – PROP	TURBO - JET
a) The specific fuel consumption based on thrust is low.	a) TSFC is comparatively higher at lower speeds and altitudes.
b) Propulsive efficiency within the range of operation is higher.	b) Propulsive efficiency is low.
c) On account of higher thrust at low speeds the take-off role is short and requiring shorter runway.	c) Take – off role is longer and requiring longer run way.
d) Use of centrifugal compressor stages increases the frontal area.	d) Lower Frontal area.
e) Higher weight per unit thrust.	e) Lower weight per unit thrust.

22. What is ram effect?

When an aircraft flies with high velocity, the incoming air is compressed to high pressure without external work at the expense of velocity energy is known as "ram effect".

23. Differentiate between pressure thrust and momentum thrust. (Nov'16)

Pressure thrust is mainly depends on the difference in pressure between the nozzle exit pressure and the ambient pressure and is given by

Pressure thrust = $(P_e - P_a) A$

Momentum thrust depends on the difference in velocity between the aircraft velocity and jet velocity is given by

Momentum thrust = $m (c_j - u)$ where,

P_e = nozzle exit pressure

P_a = ambient pressure

A = Area of cross section at the nozzle exit

C_j = jet velocity and

u = forward speed of aircraft

24. Why after burners are used in turbojet engine? (Nov'16)

Exhaust gases from the turbine have large quantity of oxygen, which can support the combustion of additional fuel. Thus if a suitable burner is installed between the turbine and exhaust nozzle, a considerable amount of fuel can be burned in this section to produce temperatures entering the nozzle as high as 1900°C. The increased temperature greatly augments the exhaust gas velocity, and hence provides the thrust increase.

25. Why a ram jet engine does not require a compressor and a turbine?

In general, the speed of a ram jet engine is supersonic (the range of Mach number) is very high. At this flight speed the contribution of the compressor to the total static pressure rise is insignificant. Hence, arm jet engine does not require compressor and turbine.

26. What are the factors affecting the actual efficiency of the propeller?

a) Thrust is not uniform over the disc due to losses at root and tip of blades. b) There is loss of energy due to the rotation of the slip stream of real fluid. c) Losses due to skin friction drag as the fluid is a real one.

27. Define Thrust grading.

The ratio of change of thrust to torque with radius is called thrust grading

28. What factors make the efficiency of a propeller?

It is dependent on Forward velocity Thrust of propeller Rotational Speed Torque exerted by engine

29. Define mean aerodynamic chord

The mean aerodynamic chord is defined as the chord length that when multiplied by the wing area, the dynamic pressure and the moment coefficient about the aerodynamic Centre yields the value of the aerodynamic moment about the airplane's aerodynamic Centre.

30. What are the various types of drag?

Parasite drag, skin friction drag, wave drag, form drag, pressure drag, interference drag etc.

31. Why axial flow compressors are preferred over centrifugal compressors in jet engines? (Nov'17)

Axial flow compressors are typically used at applications with low differential pressure (head) requirements and high flow rates. Contrary to centrifugal compressors, axial flow compressors do not change the direction of the gas: the gas typically enters and exits the compressor in an axial direction (parallel to the axis of rotation).. Axial compressors have relatively high peak efficiency. On the other hand, their efficiency is good over a narrow rotational speed range.

PART – B & C

1. Explain with the neat sketches the principle of operation of (i) Turbofan engine and (ii) Turbojet engine. (APR/MAY 2015, Nov'16)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No: 364 & 363

2. An aircraft propeller flies at a speed of 440kmph. The diameter of the propeller is 4.1m and the speed ratio is 0.8. The ambient conditions of air at the flight altitude are T=255K and P=0.55bar. find the following Thrust, Thrust power and Propulsive efficiency. (APR/MAY 2015)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No: 394

3. Derive the expression for the jet thrust propeller thrust, propulsive efficiency, thermal efficiency, overall efficiency and the optimum value of the flight to jet speed ratio for a turbojet engine.(NOV/DEC 2014)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No:373

4. A ram jet engine propels an aircraft at a Mach number of 1.4 and at an altitude of 6000m. The diameter of the inner diffuser at entry is 40 cm and the calorific value of the fuel is 43MJ/kg. The stagnation temperature at the nozzle entry is 1500K. The properties of the combustion gases are same as those of air.(ɣ=1.4, R=287J/kgk).

- **x. Determine the following:**
- **xi. The efficiency of the ideal cycle,**
- **xii. Flight speed**
- **xiii. Air flow rate**
- **xiv. Diffuser pressure ratio**
- **xv. Fuel air ratio**
- **xvi. Nozzle pressure ratio**
- **xvii. Nozzle jet Mach number**
- **xviii. Propulsive efficiency and**
- **xix. Thrust. Assume, Diffuser efficiency, η_D=0.92, Combustion efficiency, η_B=0.97 and Nozzle jet efficiency, η_N=(or)η_j=0.95 Stagnation pressure loss in the combustion chamber=0.02P_{02}. (NOV/DEC 2014)**

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No:391

5. Derive the following relation for aircraft engine

Flight to jet speed ratio $\boldsymbol{\sigma = 1 - \frac{F}{m_a c_j}}$

Thrust in a turbojet engine

$\boldsymbol{F = m_a(c_j - u) = m_a(c_e - u) + (p_e - p_a)A_e}$ **(MAY/JUNE 2014)**

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No:373
6. **An aircraft flies at 90 km/hr. One of its turbojet engines takes in 40kg/s of air and expands the gases to the ambient pressure. The air-fuel ratio is 50 and the lower calorific value of the fuel is 43 MJ/kg. For maximum thrust power determine, Jet velocity, Thrust, Specific thrust, Thrust power and Propulsive thermal and overall efficiencies. (MAY/JUNE 2014)** Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No:388
7. **Explain turbo-prop propulsion engines with suitable Diagrams. (Nov'16)** Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No:363
8. **A ramjet engine operates at M = 1.2 at an altitude of 6500 m. The diameter of inlet diffuser at entry is 50cm and the stagnation temperature at the nozzle entry is 1500K.The calorific value of the fuel used is 40 MJ/kg. The properties of the combustion gases are same those of air(γ = 1.4, R =287 J/kgK).The velocity of the air at the diffuser exit is negligible, calculate:(i) the efficiency of the ideal cycle,(ii) Flight speed, (iii) Air flow rate, (iv)Diffuser pressure ratio, (v) FueI air ratio ,(vi) Nozzle jet Mach number. The efficiencies of the diffuser = 0.9,combustor = 0.98 and the nozzle= 0.96 (Nov'16)** Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No:395
9. **(i) Discuss the function and need of afterburner in jet engines.** **(ii) Derive the thrust equation for turbo-prop engine.** **(iii)Draw the following performance curve for turbo-prob ,turbofan and turbojet engines: Propulsive efficiency Vs Flight Speed (Nov'17)** Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No:373&377
10. Mach 2 aircraft engine employs a subsonic inlet diffuser of area ratio 3. A normal shock is formed just upstream of the diffuser inlet. The free stream conditions upstream of the diffuser are p=10 bar,T=300K. Determine (i) Mach number , pressure and temperature at the diffuser exit,(ii)Diffuser efficiency including the shock. Assume isentropic flow in the diffuser downstream of the shock. (Nov'17) Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No:Refer 3 unit

UNIT V SPACE PROPULSION
Types of rocket engines – Propellants-feeding systems – Ignition and combustion – Theory of rocket propulsion – Performance study – Staging – Terminal and characteristic velocity – Applications – space flights.
PART – A
1. **Define Rocket propulsion**. If the propulsion unit contains its own oxygen supply for combustion purposes, the system is known as "Rocket propulsion".
2. **Explain the performance of the rocket engine.** In rocket engine, if the speed is increased, the propulsive efficiency is increased and reaches the maximum value of one. Then propulsive efficiency is decreased with increase in speed ratio.
3. **Define specific propellant consumption** The propellant consumption rate per thrust is called as specific propellant consumption
4. **Define thrust for a rocket engine and how it is produced.** The force that propels the rocket at a given velocity is known as thrust. This is produced due to the change in momentum flux of the outgoing gases as well as the difference between

the nozzle exit pressure and the ambient pressure.

5. What are the types of rocket engines? (APR/MAY2015)

Rocket engines are classified in the following manner.

a) On the basis of source of energy employed

i. Chemical rockets,
ii. Solar rockets
iii. Nuclear rockets and
iv. Electrical rockets

b) On the basis of propellants used

i. Liquid propellant
ii. Solid propellant
iii. Hybrid propellant rockets.

6. What is over expanded nozzle?

It is a nozzle which discharges fluid at exit pressure lower than external pressure, because the exit area is too large.

7. Compare solid and liquid propellant rockets. (Nov'17)

SOLID PROPELLANT	LIQUID PROPELLANT
a) Solid fuels and oxidizers are used in rocket engines	a) Liquid fuels and oxidizers are used.
b) Generally stored in combustion chamber (both oxidizer and fuel).	b) Separate oxidizer and fuel tanks are used for storing purposes.
c) Burning in the combustion chamber is uncontrolled rate.	c) Controlled rate.

8. What are the types of liquid propellants used in rocket engines?

i. Mono propellants
ii. Bi – propellants

9. What are the types of propellant feed system?

Gas pressure feed system
Pump feed system

10. What are the basic combustion processes?

- Injection
- Atomization
- Mixing
- Ignition
- Chemical reaction between fuel and oxidizer.

11. What are the advantages of solid propellant rocket engine?

- Simple in design and construction
- Less vibration due to absence of moving parts
- Less maintenance

12. What are the disadvantages of solid propellant rocket engine?

- It is difficult to stop the engine
- Low specific impulse
- Decrease of speed is not possible

13. What is the limitation of hybrid rocket engine?

In the hybrid rocket engine, the nozzle erosion cannot be avoided.

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14. What are the advantages of hybrid rocket engine?

- Speed regulation is possible by regulating the supply of oxidizer
- High load capacity
- High fuel density

- Lighter compared to liquid propellant rockets

15. Define heterogeneous propellants.

In heterogeneous propellants solid propellants plastics, polymers and polyvinylchloride are used as fuels. Nitrates and perchlorates are used as oxidizer.

16. Define homogenous propellants.

In homogenous propellants solid propellants nitroglycerine and nitrocellulose are used. It combines the properties of fuels and oxidizer

17. Differentiate jet propulsion and rocket propulsion (or) differentiate between air breathing and rocket propulsion? (NOV/DEC2009)

Jet propulsion Rocket propulsion Oxygen required for combustion purpose is taken from the atmosphere Oxygen is filled in a tank in the rocket engine itself and used for combustion purpose Altitude limitation No altitude limitation Flight speed always less than jet velocity. Flight speed can be greater than jet velocity Reasonable efficiency Low efficiency expect at extremely high flight speed Trust decreases with altitude Trust improves slightly with altitude.

18. What is monopropellant? (APR/MAY 2015)

Give one example for that? The liquid propellant both the fuel and oxidizer in a single chemical is known as a Mono propellant. It is stable at normal ambient conditions and liberates thermal chemical energy on heating. Example: Nitroglycerine and Nitro methane

19. What is mono-propellants? Give example.

A liquid propellant which contains both the fuel and oxidizer in a single chemical is known as "mono propellant". e.g.,
Hydrogen peroxide ,Hydrazine, Nitroglycerine and Nitromethane, etc.

20. What is bipropellant?

If the fuel and oxidizer are different from each other in its chemical nature, the propellant is called the bipropellant. Example: Liquid oxygen –gasoline and Hydrogen peroxide – hydrazine

21. Classify the rocket engines based on sources of energy employed?

On the basis of source of energy employed rocket engine is classified as: Chemical rocket engines Solar rocket engines Nuclear rocket engines Electrical rocket engines

22. What is specifying impulse of rocket?

The thrust developed by unit weight flow rate of the propellant is known as specific impulse.
Isp =F/Wp

23.Define specific consumption?

The propellant consumption rate per unit thrust is known as specific propellant consumption.
SPC =Wp/F

24. What is weight flow co-efficient?

It is the ratio of propellant flow rate to the throat force.
Cw =Wp/poA*

25. What is IWR?

IWR (impulse to weight ratio) is the ratio of total impulse of the rocket to the total weight of the rocket.
IWR = I total/Wtotal

26. Name some oxidizers used in rockets. (Nov'16)

A liquid propellant which contains the fuel and oxidizer in separate units is known as bi-propellant. The commonly used bi-propellant combinations are:

OXIDIZER	FUEL
a) Liquid oxygen	a) Gasoline
b) Hydrogen peroxide	b) Liquid bydrogen
c) Nitrogen tetroxide	c) UDMH
d) Nitric acid	d) Alcohol, ethanol

27. Name few advantages of liquid propellant rockets over solid propellant rockets. (APR/MAY2011,Nov'17)

i. Liquid propellant can be reused or recharged. Hence it is economical.
ii. Increase or decrease of speed is possible when it is in operation.
iii. Storing and transportation is easy as the fuel and oxidizer are kept separately.
iv. Specific impulse is very high.

28. What is inhibitors? (MAY/JUNE2014)

Inhibitors are used to regulate (or prevent) the burning of propellant at some sections.

29. Give the important requirements of rocket engine fuels.

i. It must be able to produce a high chamber temperature. It should have a high calorific value per unit of propellant.
ii. It should not chemically react with motor system including tanks, piping, valves and injection nozzles

30. What is meant by restricted burning in rockets?

In this case, the inhibition material (or) restrictions prevent the propellant grain from burning in all directions. The propellant grain burns only at some surfaces while other surfaces are prevented from burning.

PART – B & C

1. List the main components of Liquid Propellant Rocket Engine and explain . (APR/MAY 2015)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No:404

2. A rocket engine has the following data:

Effective jet velocity=1200m/s
Flight to jet speed ratio=0.82
Oxidizer flow rate=3.4kg/s
Fuel flow rate=1.2kg/s
Heat of reaction per kg of the exhaust gases =2520kJ/kg
Calculate the following,Thrust,Specific impulse,Propulsive efficiency,Thermal efficiency andOverall efficiency. (APR/MAY 2015)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No:452 &457

3. Explain the working principles of a Turbo-pump feed system with a schematic diagram for liquid propellant rocket engines. (MAY/JUNE 2014)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No:409

4. Describe briefly the important applications of rocket propulsion in the following fields

v. **Aircrafts**
vi. **Military**
vii. **Space**
viii. **Scientific (MAY/JUNE 2014)**

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No:431

5. (a)Describe with schematic diagram the principle of working and construction of a magneto hydrodynamic rocket engine. (NOV/DEC 2014)

(b)In the rocket engine, propellant flow rate is 5.2 kg/s, nozzle exit diameter is 9cm , nozzle exit pressure is 1.02bar, ambient pressure is 1.013bar, thrust chamber pressure is 22bar and thrust is 7.2 kN. Calculate the following

v. **Effective jet velocity**
vi. **Actual jet velocity**
vii. **Specific impulse and**
viii. **Specific propellant consumption (NOV/DEC 2014)**

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No:403 & 448

6. (a)What are the advantages and disadvantages of liquid propellant rocket engine? (NOV/DEC 2014)
(b)A rocket has the following data: combustion chamber pressure 36bar, combustion chamber temperature =3600K, Oxidizer flow rate = 41kg/s. Mixure ratio=5 and Ambient pressure =585N/m^2. Determine:

- **vi. Nozzle throat area**
- **vii. Thrust**
- **viii. Thrust coefficient,**
- **ix. Characteristic velocity and**
- **x. Exit velocity of exhaust gases.**

Take ɣ=1.3. and R=287J/kg K (NOV/DEC 2014)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No:413& 458

7. Calculate the thrust,specific impulse, propulsive efficiency, thermal and overall effciencies of a rocket engine from the following data; Effective jet velocity = 1250 m/s, Flight to jet speed ratio = 0.8, oxidizer flow rate=3.5kg/s,fuel flow rate=1kg/s, heat of reaction of exhaust gases = 2,500 kJ/ks (Nov'16)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No:457

8. A spacecraft's engine ejects mass at a rate of 30kg/s with an exhaust velocity of 3100m/s.The pressure at the nozzle exit is 5kPa and the exit area is 0.7m^2 .what is the thrust of the engine in a vacuum? (Nov'17)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No:448

9. A rocket nozzle has a throat area of 18cm^2 and combustion chamber pressure of 25bar. If the specific impulse is 127.42 s and weight flow rate (iii) Specific propellant consumption (iv) Characteristics velocity. (Nov'17)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahya, Pg.No:458

10. Describe with the aid of illustrative diagrams of any two arrangements of solid propellant grains employed for restricted and unrestricted burning. Indicate the directions of burning and flow of gases. (Nov'17)

Ref: Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion By S.M.Yahyas, Pg.No:419