Reg. No.										

B.Tech. DEGREE EXAMINATION, NOVEMBER 2014
Sixth Semester

AS0306 – PROPULSION – II
(For the candidates admitted from the academic year 2007-2008 to 2012-2013)

Time: Three Hours Max. Marks: 100

Answer **ALL** Questions
PART – A (10 × 2 = 20 Marks)

1. Why clustering of booster rockets are commonly practiced?
2. What do you understand by choking of the nozzle?
3. Explain the difference between composite modified double base[CMDB] propellant and Nitramine propellant.
4. What is the function of nozzle closure disc in the solid propellant rocket?
5. Name two advantages of liquid propellant rockets and solid propellant rockets and explain.
6. Explain the difference between resistojet and arcjet.
7. Define flow coefficient and blade loading coefficient.
8. Mention the advantages and disadvantages of cooling of gas turbine blades.
9. Differentiate between Ramjet and Scramjet.
10. Write down the function of isolator in a Scramjet engine.

PART – B (5 × 16 = 80 Marks)

11. a. A rocket of mass 1000 kg contains 1500 kg of propellant that is consumed at a constant rate of 100 kg/sec. The specific impulse of the rocket is 1500 Ns/kg. Assume vertical flight and no variation in the gravitational field. Calculate the acceleration of the rocket at lift-off, 10 seconds after lift-off and just before burnout.

(OR)

b. A satellite launch vehicle is used for putting a satellite of mass 1900 kg in orbit. The launch vehicle has three stages with four strap-on rockets for the first stage. The mass of structure including inert, the mass of propellant and specific impulse of each stage and strap-on are given as follows:

Stage	Mass of structure and inert (kg)	Mass of propellant (kg)	Specific Impulse (Ns/kg)
Strap-on	6500	42,000	2740
First stage	25,000	1,40,000	2650
Second stage	6200	40,000	2950
Third stage	2500	13,000	4450

The strap-on stages and the first stage fire together. The thrust developed by each strap-on rocket is 800 kN and the thrust developed by the first stage is 4400 kN. Determine the following:

(i) Payload fraction
(ii) ΔV contribution by each stage
(iii) ΔV for the launch vehicle
(iv) Initial acceleration of the vehicle

12. a. A composite propellant containing 15% aluminium has solid loading of 90%. The fuel binder is HTPB resin and the oxidizer is ammonium per chlorate (AP). The molecular mass (g/gmole) of AP, aluminium and HTPB are 117.5, 27 and 2734 respectively. The chemical formulae are NH_4ClO_4, Al and $C_{200}H_{302}O_2$. Determine the mixture ratio of the composite propellant and molar composition of the propellant. Also find whether the composition is fuel rich or not.

(OR)

b. A solid propellant rocket has hollow cylindrical propellant grain having an inner diameter of 200 mm and outer diameter of 600 mm. The length of the grain is 1500 mm. The burning is radially outward from the inner cylindrical surface. The throat diameter of the nozzle is 100 mm. The propellant burn rate law is $1.5875*10^{-3}*P^{0.05}$mm/s. P is expressed in Pa. The characteristic velocity of the propellant is 1400 m/s and the density is 1600 kg/m^3. Calculate

(i) Initial chamber pressure and thrust
(ii) Final chamber pressure and thrust

13. a. A rocket with MMH-N_2O_4 system develops a thrust of 500N at a mixture ratio of 1.65 and chamber pressure of 0.70 MPa. The characteristic velocity C* is 1800 m/s and the thrust coefficient C_p is 1.50. The density of MMH is 868kg/m^3 and the density of N_2O_4 is 1400 kg/m^3. For the 10 doublet injection elements used, the injection pressure of MMH and N_2O_4 is 1 MPa and the discharge coefficient of the orifices is 0.95. Determine

(i) Nozzle throat area
(ii) Mass flow rate of MMH and N_2O_4
(iii) Diameter of injection holes for MMH and N_2O_4

(OR)

b. i A stream comprising 1g of positively charged Xenon gas with an average charge density of 2.5×10^4 C/kg is placed in linear electrostatic field of 5000 V/mm. Determine the acceleration force experienced by the stream. If the distance over which the stream is accelerated is 0.5 mm and if the initial velocity of the stream is negligible, determine the final velocity to which the charge is accelerated.

ii A steady stream of mercury ions is travelling with a mean velocity of 30 m/s from left to right in the plane of the paper in a uniform magnetic field strength of 0.6×10^{-3} T (Ns/Cm). The direction of the magnetic field is perpendicular to the plane of the paper, pointing towards you. The ions have an average charge of 10^4 C. Determine the force exerted by the magnetic field on the moving charge. Indicate the direction of the force in a neat sketch.

14. a. i Discuss the limiting factors in gas turbine design. (6 Marks)

ii In a single stage gas turbine, gas enters and leaves in axial direction. The nozzle efflux angle is 68°, the stagnation temperature and stagnation pressure at stage inlet are 800°C and 4 bar. The exhaust static pressure is 1bar, total to static efficiency is 0.85 and mean blade speed is 480 m/s. Assume $\gamma = 1.33$ and $C_{pg} = 1.147$ kJ/kg K. Determine the work done per mass flow rate, the axial velocity which is constant throughout the stage, the total-to-total efficiency and the degree of reaction. (10 Marks)

(OR)

b. A mean diameter design of a turbine stage having equal inlet and exit velocities leads to the following data:
Mass flow rate = 20 kg/s
Inlet temperature = 1000 K
Inlet stagnation pressure, $P_{01} = 4$ bar
The axial velocity constant along the stage = 260 m/s
Blade speed = 360 m/s
The absolute inlet velocity angle (with respect to axial direction) is 65° and exit swirl angle, $\alpha_3 = 10°$. Determine the rotor blade angle and the power output or work output.

15. a. A ramjet engine is to propel an aircraft at a Mach number of 3, at an altitude where the ambient conditions are P = 8.5 kPa, T = 220 K. The maximum allowable gas temperature is 2500 K. If the engine works under ideal conditions, determine the thermal efficiency and the propulsive efficiency.

(OR)

b. i What is meant by 'ram effect'? A ramjet operates at a flight Mach number M_o, assuming ideal flow condition and perfect gas properties. Derive an equation for the thermal efficiency of the engine.

ii An ideal ramjet operated at a flight Mach number of M = 4.0 at an altitude where T = 217 K and pressure = 2.3×10^4 Pa. The combustion process increases the temperature of the gas by 1400 K after combustion. Treating the gas as perfect with $\gamma = 1.4$ and the flow to be ideal throughout the ramjet. Find the thrust produced per unit mass flow rate and efficiency of the engine.

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B.Tech. DEGREE EXAMINATION, MAY 2017
Sixth Semester

AS0306 – PROPULSION –II
(For the candidates admitted from the academic year 2007-2008 to 2012-2013)

Time: Three hours — Max. Marks: 100

Answer **ALL** Questions

PART – A (10 × 2 = 20 Marks)

1. Define secondary loss and tip clearance loss.
2. List the factors affecting the gas turbine design.
3. Compare Ramjet and Scramjet combustion process.
4. List down the problems associated with sub critical mode of operation of ramjet.
5. Give three important applications of rockets.
6. Describe the role of residual kinetic energy of jet.
7. Give a brief explanation to statement 'Low area ratio nozzles produces high thrust coefficient at low altitudes.
8. Write a short notes on divergence loss in nozzle.
9. How burning rate of propellants in solid rockets in determined?
10. What are essential functions of injectors in liquid rockets?

PART – B (5 × 16 = 80 Marks)

11. a.i. Differentiate impulse turbine and reaction turbine with a neat sketch. (6 Marks)

ii. In a single stage gas turbine, gas enters and leaves in axial direction. The nozzle efflux angle is 68°, the stagnation temperature and stagnation pressure at stage inlet are 800°C and 4 bar. The exhaust static pressure is 1 bar, total to static efficiency is 0.85 and mean blade speed is 480 m/s. Assume $\gamma_g = 1.33$ and $C_{pg} = 1.147$ kJ/kg K. determine the work done per mass flow rate, the axial velocity which is constant throughout the stage, the total-to-total efficiency and the degree of reaction. (10 Marks)

(OR)

b.i. What is the need for turbine blade cooling? Explain any four cooling methods with a neat sketch. (10 Marks)

ii. Write the procedure followed in matching of compressor and turbine. Derive the turbine pressure ratio with a suitable sketch. (6 Marks)

12. a.i. Explain the working principle of a RAMJET engine with a neat sketch. Discuss the advantages, disadvantages and applications of a RAMJET engine. (10 Marks)

ii. Explain integral Ram Rocket with a neat sketch. (6 Marks)

(OR)

b. A ramjet engine operates at M = 2 at an altitude of 6500 m. the diameter of the inlet diffuser at entry is 50 cm and the stagnation temperature at the nozzle entry is 1600 K. The calorific value of the fuel used is 40 MJ/kg. The properties of the combustion gases are same as those of air (γ = 1.4, R = 287 J/kg K). The velocity of air at diffuser exit is negligible. Calculate

(i) Flight speed
(ii) Air flow rate
(iii) Diffuser pressure ratio
(iv) Nozzle jet Mach number
(v) Propulsive efficiency and
(vi) Thrust

Assume the following values: $\eta_D = 0.90, \eta_B = 0.98, \eta_N = 0.96$, stagnation pressure loss in the combustion chamber = 0.02 P_{o2}.

13. a.i. Parametrically compare the air breathing engine (jet engine) and rocket propulsion.

ii. Derive an expression for maximum mass flow rate through a nozzle and characteristics velocity from fundamentals.

(OR)

b.i. Using fundamentals and assuming vertical trajectory of a rocket, derive maximum velocity and attitude gain for a 3 stage rocket.

ii. Consider a rocket with the following data:

Thrust = 9000 kN
Total propellant used = 45,000 kg
Duration of firing of rocket = 15 seconds

Determine

(i) Impulse provided by the rocket
(ii) Specific impulse provided by the rocket
(iii) Effective jet velocity
(iv) Specific propellant consumption

14. a.i. Describe how nozzles are classified in rockets. List the differences in ideal and real nozzles.

ii. An end burning solid propellant rocket uses a cylindrical double base propellant grain with a diameter of 200 mm and generate a thrust of 350 N over a period of 300 seconds. The thrust co-efficient is 1.15. The characteristics of propellant are

Density of grain = 1500 kg/m^3

$a_{70} = 4 mm/s$

$\eta = 0.5$

$C_c = 1500 m/s$

Determine

(i) Length of the grain
(ii) Throat diameter of the nozzle.

(OR)

b.i. What are characteristic parameters and when they are mandatory for rocket performance analysis? List various characteristic, performance geometric parameters used.

ii. A missile of initial mass 2000 kg is launched vertically from a standard sea level condition. The initial acceleration of the missile is 3 g [where 'g' is standard acceleration due to gravity = 9.810 m/s]. At launch the chamber pressure of the solid rocket motor is 12 MPa. Determine

(i) Thrust at launch
(ii) Throat diameter of the rocket nozzle

Assume burn rate, r = $(8.84\times10^{-5})\ p^{0.3}$ m/s

C_C = 1600 m/s

C_F = 1.57

Density of the propellant, ρ_p = 1750 kg/m^3.

15. a.i. Parametrically compare a solid propellant rocket with a liquid propellant rocket.

ii. With the help of a graph, explain variation of the following quantities in rocket propulsion

(1) Rocket thrust with altitude
(2) Propulsive efficiency with speed ratio of rocket
(3) Thrust co-efficient with pressure ratio
(4) Exhaust velocity of rocket with pressure ratio

(OR)

b.i. What are the desirable physical, chemical and combustion properties of a liquid propellant?

ii. Write a short note on different advanced propulsive rocket system for propulsion.

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B.Tech. DEGREE EXAMINATION, NOVEMBER 2016

Sixth Semester

AS0306 – PROPULSION –II

(For the candidates admitted from the academic year 2007-2008 to 2012-2013)

Time: Three hours   Max. Marks: 100

Answer **ALL** Questions

PART – A (10 × 2 = 20 Marks)

1. Explain rocket equation.
2. What are the four major performance parameter of a rocket?
3. What do you understand by choking of the nozzle?
4. Compare the features of a conical nozzle and a bell nozzle.
5. What is the purpose of adding a metal powder like aluminium in a composite solid propellant?
6. How is the space storable liquid propellant in different from earth storable liquid propellant?
7. Explain action time and burn time of solid propellant rocket using a neat diagram.
8. Name four methods of cooling a liquid propellant thrust camber.
9. Explain the phenomenon of surge in a centrifugal compressor.
10. Write down Euler's turbine equation and explain the terms used.

PART – B (5 × 16 = 80 Marks)

11. a. Derive from fundamentals the equation for propulsive efficiency of rocket propulsion, given as $\eta_p = \dfrac{2(V/V_j)}{1+(V/V_j)^2}$ V = flight velocity of rocket

V_j = efflux velocity of rocket

Prove that maximum propulsive efficiency is reached when $V = V_j$.

ii. A rocket engine deliver a constant thrust of 300,000 N. its specific impulse is 4200 Ns/kg. If the rocket engine operator for 10 seconds at these conditions, calculate the impulse. Also calculate the total mass of propellant expelled for the engine.

(OR)

b.i. Explain the phenomenon of performance loss in a conical nozzle. How is this loss reduced in contour nozzle?

ii. The characteristic velocity C* of a composite propellant is 2200 m/s. The combustion product of this propellant have a molecular mass of 22 kg/k mole and a temperature of 2600 k. After the addition of aluminium powder to this propellant, the molecular mass of combustion products increase to 24 kg/k mole and the temperature of gas increases to 3200 k. If the specific heat ratio of combustion products of aluminized and non-aluminized propellants remain the same, determine C* of the aluminized propellant. If the above aluminized propellant in used in a solid propellant rocket having a thrust coefficient of 1.2, what is the specific impulse of the rocket?

12. a.i. The heats of formation of propellant ingredients should be less negative, if not positive; whereas the heats of formation of propellant combustion products should be highly negatively. Why?

ii. A composite propellant containing 15% aluminium has a solid loading 0f 90%. The fuel binder is HTPB resin and the oxidizer is ammonium perchlorate (AP). The molar mass of A.P aluminium, and HTPB are 117.5, 27 and 2734 g/g mole respectively. The corresponding chemical formulae are NH_4ClO_4, AL and $C_{200}H_{302}O_2$. Determine the mixture ratio of the composite propellant and molar composition of the propellant.

(OR)

b. Gaseous methane [ch_4] and gaseous oxygen are injected at 25°c in a rocket combustion chamber at a mixture ratio of 3. The specific heats at constant pressure for water, steam and co_2 can be assumed to be constant over the temperature of interest and are equal to 90, 58 and 37 kj/kg mole-k respectively. The standard heats of formation of CH_4, CO_2 and water are 75,000, –112,000 and –286,000 kJ/kg mole respectively. The latent heat of vaporization of water at its boiling point of 373 k is 40,000 kJ/kg mole. Calculate the temperature and the molecular mass of the combustion product.

13. a. A solid propellant rocket motor using a composite propellant has a radial burning cylindrical grain with ends inhibited. Grain dimensions are: internal diameter =20 mm; outer diameter = 80 mm; length = 4000 mm. The burn rate law is given by $r = aP^{0.4}$ m/s. with P expressed in Pa. the propellant has a burn rate of 8 mm/s at 7 MPa. Nozzle throat diameter is 14 mm. propellant density = 1750 kg/m³. Thrust coefficient C_F = 1.45. Characteristic velocity C^* = 1700 m/s. Determine the initial chamber pressure, burnout chamber pressure and the corresponding thrusts.

(OR)

b. A liquid rocket engine has to develop a thrust of 100 N. it uses MMH as the fuel and N_2O_4 as the oxidizer at a mixture ratio of 1.7. Chamber pressure = 1 Mpa. Characteristics velocity C^* = 1800 m/s. thrust coefficient C_F = 1.65. Twenty doublets (unlike) are to be provided with equal injection pressure of 1.7 MPA. Determine the following

(i) Nozzle thrust area
(ii) The mass flow rates of fuel and oxidizer
(iii) Orifice diameter of fuel and oxidizer.

Assume $C_{do} = C_{df} = 095$; P_{MMH} = 868 kg/m3; $P_{N_2O_4}$ = 1400 kg/m3.

14. a. An axial flow compressor operates under the following conditions: inlet temperature = 288 k, inlet pressure = 1 bar, blade mean diameter = 400 mm. Axial velocity = 130 m/s; blade speed = 260 m/s; degree of reaction = 50%, the inlet blade angle β_1 = 53.6 deg. Calculate the exit blade angle β_2 and the power developed.

(OR)

b. An axial flow compressor stage has a blade mean velocity of 200 m/s. the stage is to be designed for 50% reaction. The blade angles are $bete_1$ = 54.9 deg, $bete_2$ = 13.8 deg. The axial velocity = 150 m/s. Compute the stage stagnation pressure rise and the power required.

15. a.i. Define the efficiency of a diffuser and also of a nozzle and derive expression for the same.

ii. A ramjet propels an air craft of M = 3 at an altitude where the ambient condition are P_∞ = 8.5 kPa and T_∞ = 220 K. The diffuser of the engine isentropically decreases the inlet Mach into 2.0 when a normal shock occur. The air then passes through the combustion zone and at nozzle inlet the temperature of air is 2540 k. The nozzle works as an ideal nozzle with no less in any other parts. Calculate the thermal and propulsive efficiency of the engine.

(OR)

b. A ramjet is flying at Mach number 2.0 at an altitude of 9000 m where T = 230 k and P = 0.3 bar. The maximum combustion temperature is limited to 1300 k. Assuming the diffuser and nozzle to be 100% efficient, find the specific thrust and specific fuel consumption.

* * * *

ii. The following data refers to stage of an axial flow compressor at mean blade diameter of 360 mm. Rotational speed =18,000 rpm; degree of reaction =0.5: Air angle at rotor and stator exit =2.5; Axial velocity =180 m/s: Work done factor =0.88; Stage efficiency =0.85. The temperature and pressure at the entry are 27°C and 100 KP_a respectively. Calculate the following

(1) The pressure required to drive the compressor

(2) The pressure ratio developed by the stage.

15. a.i. Briefly describe the flow process through a ramjet engine and indicate the same on the T –S diagram.

ii. An ideal ramjet engine operates at a constant combustion temperature of 2240 k and a flight mach number of M =3.0. The working fluid is assumed to be a perfect gas with γ =1.4. Calculate the thrust per square meter of the frontal area and TSFC at sea level. The clarifier value of fuel=44.1×10^6 J/kg.

(OR)

b.i. Write down an expression for the power generated by a turbine and indicate the flow process in the h –s diagram.

ii. A mean diameter design of a turbine stage having equal inlet and outlet velocities gives the following data:
Mass flow rate $\dot{m}$ =20 kg/s; Inlet temperature T_{01} =1000k.
Inlet pressure P_{01} =4×10^5 P_a: Blade speed U =360 m/s.
Angle of C_1 to C_a =65° ; Exit angle is 10° to the axial direction. Axial velocity which is constant through the stage C_a =260 m/s. Determine the degree of reaction and power output.

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B.Tech. DEGREE EXAMINATION, MAY 2016

Sixth Semester

AS0306 – PROPULSION -II

(For the candidates admitted from the academic year 2007-2008 to 2012-2013)

Time: Three hours Max. Marks: 100

Answer **ALL** Questions

PART – A (10 × 2 = 20 Marks)

1. Explain the significance of the parameter specific impulse in rocket.
2. Why staging of a rocket is necessary?
3. What do you understand by flow separation in a convergent –divergent nozzle?
4. What are double base propellants? Give a brief description.
5. With the help of a neat sketch explain a pyrogen type igniter.
6. List any two advantages of liquid propellant rocket engines over solid propellant rocket motors.
7. Name two functions of injector in liquid propellant engine.
8. Explain the difference between resistojet and arcjet.
9. What are the merits of axial flow compressor?
10. What do you understand by reaction turbine?

PART – B (5 × 16 = 80 Marks)

11. a.i. Using continuity equation and assuming isentropic flow, prove that the mass flow rate through a choked nozzle – throat is given by

$$\dot{m}=\frac{\Gamma.p_cA_t}{\sqrt{R_0T_c/\overline{m}}}\text{ where }\Gamma=\sqrt{\gamma}\left(\frac{2}{\gamma+1}\right)\frac{\gamma+1}{2(\gamma-1)}.$$

$p_c, A_t, \overline{m}, T_c$ and γ are stagnation pressure, throat area, molecular mass, stagnation temperature and ratio of specific heats respectively.

ii. Calculate the mass flow rate through a choked nozzle given the following. Also calculate the characteristic velocity C*. Throat diameter = 10 mm. Stagnation pressure = 7 MPa. Molecular mass = 22 kg/kg mole, Stagnation temperature = 3400 k, Specific hat at constant pressure = 1890 J/kg.k.

(OR)

b.i. The operating mixture ratio in rockets are generally fuel rich. Why?

ii. Determine the stoichiometric ratio of RP1 kerosene [$C_{12}H_{14}$] –oxygen combination. If the mixture ratio of this propellant combination in a rocket engine is fuel rich at 2.6, Calculate the molecular mass of the combination products assuming only H_2O, CO and CO_2 are present in the combustion products.

12. a.i. Under quasi steady state assumption prove that the equilibrium chamber pressure P_c in a solid propellant rocket motor is given by $P_c = \left[\rho_p a \frac{A_b}{A_t} c^* \right]^{1/(1-n)}$ where ρ_p, Ab, A_t and c^* are propellant density, grain burning area, nozzle throat area and characteristic velocity respectively. Propellant burn rate r in as per the burning rate law $r = a\, p_c^n$ where a and n constants.

ii. A solid rocket motor is operating at an equilibrium pressure of 6.5 MPa. The propellant burning rate is given by $r = a\, P_c^{0.35}$ m/s with P_c expressed in P_a. suddenly a large crack develops in the gain, thereby the burning area increases by 20%. Determine the new equilibrium pressure. Assume all other parameters remains unchanged.

(OR)

b.i. What are the three basic feed –system cycles adopted in turbo –pump fed liquid propellant engine? With neat sketches of these cycles, Cleary mark the flow directions and the names of components.

ii. What is a mono propellant rocket thruster? With a neat sketch, briefly explain its operating principles. List its applications. Name any two mono –propellants.

iii. With a neat sketch, briefly explain the operating principles of a hybrid rocket engine. What are its advantages and disadvantages? Indicate any two propellant combinations adopted.

13. a. A 10 N thruster a satellite uses MMH and MON -3 as propellants. Mixture ratio =1.65. Chamber pressure = 7 bar. Molecular mass of combustion products = 20.5 kg/kg mole. Ratio of specific heats =1.24. Characteristic velocity =1560 m/s. thrust coefficient =1.83. Choose a single triplet injector with two oxidizer streams. $P_{MON\ -3}$ =1420 kg/m^3: P_{MMH} =864 kg/m^3. Cd_0= Cd_F =0.7. Pressure drops across the injector are equal at 3.5 bar. Calculate the injector diameter. Also calculate the nozzle throat diameter.

(OR)

b. Positively charged Xenon gas of mass 100 mg, charged to an average density of 2×10^4 C/kg is placed in a linear electro static field of 1000 V/mm. Determine the accelerating force experienced by the stream. If the distance between the electrodes is 4 mm and if the initial velocity of the stream can be neglected, determine the velocity to which the mass will be accelerated. Determine the thrust if the flow rate of Xenon gas is = 100 mg/s.

14. a.i. Indicate the compression process in an axial flow compressor stage on the T.S diagram.

ii. As axial flow compressor stage has a mean radial velocity of 200 m/s and is designed for a stagnation temperature rise of 20 k and an axial velocity of 150 m/s. assuming 50% reaction, calculate the air angles (or β_1 and β_2).

(OR)

b.i. Define the degree of reaction for an axial flow compressor.

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B.Tech. DEGREE EXAMINATION, NOVEMBER 2015
Sixth Semester

AS0306 – PROPULSION - II
(For the candidates admitted from the academic year 2007-2008 to 2012-2013)

Time: Three hours Max. Marks: 100

Answer **ALL** Questions
PART – A (10 × 2 = 20 Marks)

1. Define Flow co-efficient and blade loading co-efficient.
2. Calculate the number of blades for a single stage axial flow gas turbine with mean height rotor blades of 0.0619m, $(S/C)_R$=0.83, $(h/c)_R$=3.6 mean radius of 0.216m.
3. Write down the function of isolator in a Scramjet engine.
4. Explain the sub-critical operation inlet.
5. Define overall efficiency of a rocket and factors affecting it.
6. What is specific impulse? Why it is important in rocket propulsion?
7. Why is clustering of rockets important?
8. What is meant by thrust termination? What are the methods to achieve it?
9. What is the function of injectors in liquid propellant rockets and name the different types of injections used?
10. What are the limitations of hybrid propellant rockets?

PART – B (5 × 16 = 80 Marks)

11. a.i. Explain free vortex theory with a neat sketch and derive the gas angles and blade angels at any radius '*r*'. (10 Marks)

ii. Consider a single stage axial flow gas turbine with the following parameters.

$\alpha_{2m} = 58.38°$: $\beta_{2m} = 20.49°$

$\alpha_{3m} = 10°$: $\beta_{3m} = 54.96°$

$h = 0.0612m$: $r_m = 0.216m$

Calculate the air angles and blade angles at root and tip of the blade. (6 Marks)

(OR)

b. A single stage turbine having flow co-efficient of 0.8, mass flow rate of 24 Kg/s, isertropic efficiency of 0.90, turbine inlet temperature of 1200K, temperature drop $(T_{01} - T_{03})$ of 165K, pressure ratio (P_{01}/P_{03}) of 1.853, inlet pressure P_{01} of 4 bar, rotational speed of 350 rev/sec and mean blade speed of 360 m/s, nozzle loss co-efficient λ_N of 0.05 and $\alpha_3 = 10°$ calculate the blade loading coefficient, the blade angle and gas angle at various phases, area, blade height, tip and root radius of the blade at phase 2. (Assume inlet velocity is axial and follow NGTE norms).

12. a.i. Explain the working principle of SCRAMJET engine with a neat sketch. Discuss the advantages and disadvantages of a scramjet engine along with its applications. (10 Marks)

ii. Explain the problem faced in supersonic combustion. (6 Marks)

(OR)

b. A ramjet engine operates at M=2.5 at an altitude of 7500m. The diameter of the inlet diffuser at entry is 50cm and the stagnation temperature at the nozzle entry is 1800K. The calorific value of the fuel used is 46MJ/kg. The properties of the combustion gases are same as that of air (γ = 1.4, R = 287 J/kg K). The velocity of air at the diffuser exit is negligible. Calculate

(i) Flight speed
(ii) Air flow rate
(iii) Fuel-air ratio
(iv) Nozzle jet mach number
(v) Propulsive efficiency and
(vi) Thrust

Assume the diffuser efficiency of 90% , burner efficiency of 98%, nozzle efficiency of 96% and the stagnation pressure loss in the combustion chamber = 0.02 P_{02}.

13. a.i. Draw the energy balance diagram for Rockets and systematically derive various efficiencies.

ii. A rocket produces 5MN thrust at sea level with chamber pressure of 7MPa and combustion temperature 2800K. The exhaust gas expands in the nozzle at the sea level ambient pressure of 0.1MPa. Assume the specific heat ratio as 1.4 and molecular weight of gas as 28. Determine

(i) Specific impulse
(ii) Mass flow rate
(iii) Characteristics velocity
(iv) Throat diameter of nozzle

(OR)

b.i. From basic fundamentals, derive an expression for thrust co-efficient of rocket. Explain variation of parameters and their respective effect on thrust co-efficient.

ii. Measurement were made in a sea level test of a solid propellant motor. Data obtained was given as follows.
Initial mass before test = 1210 kg
Mass of rocket after test = 215 kg
Average thrust = 62250 N
Chamber pressure = 7 MPa
Nozzle exist pressure = 0.070 MPa
Nozzle throat diameter = 0.0855 m
Nozzle exist diameter = 0.2703 m
Determine performance of rocket motor at sea level and in space in terms of

(i) Propellant mass flow rate
(ii) Effective jet velocity
(iii) Thrust co-efficient
(iv) Characteristics velocity

14. a.i. Describe the essence of using quality factors for rocket analysis and explain essential types and their functions.

ii. An end burning solid propellant rocket with a burn rate of $r = 0.004\ P^{0.45}$ (r in mm/s; P in Pascal) has the following data:

Thrust developed = 5kN
Nozzle throat diameter = 28 mm,
Specific impulse = 1900 N-S/kg
Burning duration = 200 sec,
Propellant grain density = 1540 kg/mm^3
Characteristics velocity = 1600 mm/s
Compute

(i) Diameter of propellant grain
(ii) Length of propellant grain

(OR)

b. i. Describe physical, chemical, combustion, desirable properties of solid propellants.

ii. A two stage rocket motor is used for placing a satellite of mass 300 kg in an orbit. The data relevant is given below:

	Propellant mass (kg)	Dry mass (kg)	Specific impulse (sec)
First stage	1,20,000	9,000	260
Second stage	30,000	3,000	320

Determine

(i) Mass fraction and propellant mass fraction of both stages
(ii) Incremental velocity (Δv) contributed by each stage
(iii) Net velocity gain
(iv) Maximum altitude gain

15. a.i. Compare a solid propellant rocket with liquid propellant rocket and accordingly give its applications.

ii. Discuss electric propulsion as an advanced rocket propulsion system and discuss controlling parameters.

(OR)

b.i. What are the different types of liquid propellant? Describe it with examples.

ii. Discuss various types of advanced propulsion system in comparison to chemical propulsion of rockets.

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B.Tech. DEGREE EXAMINATION, MAY 2015

Sixth Semester

AS0306 – PROPULSION - II

(For the candidates admitted from the academic year 2007-2008 to 2012-2013)

Time: Three hours Max. Marks: 100

Answer **ALL** Questions

PART – A (10 × 2 = 20 Marks)

1. Define: Degree of reaction. Calculate the Degree of reaction for a single stage axial flow gas turbine with the flow co-efficient of 0.72 and blade angles β_2 = 29° and β_3=57°.
2. Define: Profile loss and annular loss.
3. Explain the super critical operation inlet.
4. Write down the function of isolator in a scramjet engine.
5. What are the uniqueness of rockets?
6. Briefly describe the essence of mass ratio in rockets.
7. What are quality factors? Give importance of specific impulse quality factor.
8. What is erosive burning? Explain factors affecting it.
9. Explain hybrid and reverse hybrid propellant combination.
10. List the different types of electric rockets with suitable examples.

PART – B (5 × 16 = 80 Marks)

11. a.i. Explain elementary theory with a neat sketch and derive the power output and blade angles in terms of gas angles. (10 Marks)

ii. Derive the blade angles and gas angles in terms of the degree of reaction, blade co-efficient and flow co-efficient. (6 Marks)

(OR)

b.i. Consider a single stage axial flow gas turbine with the following parameters.

α_{2m} = 58.38° ; β_{2m} = 20.49° ; h = 0.0612m

α_{3m} = 10° ; β_{3m} = 54.96° ; h = 0.216m

Calculate the air angles and blade angles at root and tip of the blades. (6 Marks)

ii. Derive the equation for turbine pressure ratio for an ideal turbojet engine. (5 Marks)

iii. Calculate the turbine pressure ratio for the turbojet engine having compressor pressure ratio of 4, turbine inlet temperature of 1110 K, temperature at the inlet of compressor is 452 K, isentropic efficiency of compressor and turbine is 0.85 and 0.87. (Assume C_{p_a} = 1005 J/kg K, γ_a = 1.4; C_{p_g} = 1147 J / kg K and γ_g = 1.33). (5 Marks)

12. a.i. Explain the working principle and T-S diagram of a RAMJET engine with a neat sketch. Discuss the advantages, disadvantages and application of a RAMJET engine. (12 Marks)

ii. Differentiate RAMJET and SCRAMJET engine. (4 Marks)

(OR)

b. Consider an ideal ramjet engine flying at the Mach number of 3.2 at an attitude of 33000 ft. The colorific value of fuel is 43264 KJ/kg and the burner exit total temperature is 1889 K. A thrust of 42.258 N is needed. Calculate
   (i) The required air flow
   (ii) The resulting nozzle exist diameter and
   (iii) The resulting TSFC

13. a.i. Using proper assumptions, theoretically derive and prove that speed ratio $(\sigma = U / C_J)$ in rockets can be less than or greater than 1.

ii. A rocket projectile has following characteristics
The initial mass = 200 kg
Mass after rocket operation = 130 kg
Payload and structural mass = 110 kg
Rocket operation duration = 3 seconds
Specific impulse of propellant = 240 sec
Determine
1. Vehicle mass ratio
2. Propellant mass fraction
3. Propellant flow rate
4. Thrust
5. Thrust to weight ratio
6. Acceleration of rockets
7. Effective jet velocity and
8. Specific propellant consumption

(OR)

b.i. Explain the essence of multistaging and clustering in rockets. Detail the precautions need to be accounted.

ii. A three stage rocket comprises of following data:
Stage 1:
Propellant mass = 10000 kg
Structural mass = 2000 kg
Effective jet velocity 1500 m/s
Burning time = 20 sec
Stage 2 :
Propellant mass = 6000 kg
Structural mass = 2000 kg
Effective jet velocity 2000 m/s
Burning time = 15 sec
Stage 3:
Propellant mass = 5000 kg
Structural mass = 1000 kg
Burning time = 10 sec
Specific impulse = 450 sec
The payload mass is 1000kg. Find the net velocity and altitude by
   (i) considering gravity effect
   (ii) without considering gravity effect.

14. a.i. How solid propellant rockets are classified? Write down the desirable properties of solid propellant rockets.

ii. Assume a solid propellant rocket motor, with the help of a schematic, explain the effect of back pressure variation on nozzle working and outcome.

(OR)

b. i. Broadly compare the solid propellant rockets with liquid propellant rockets and mention their areas of application.

ii. A double base propellant consists of 40% NG and 60% NC by mass. The other substances in the propellant are in small quantities and can be neglected. Determine the number of moles and NG per mole of NC in the propellant. The chemical formula for NC is $C_6H_7O_7\,[NO_3]_2$ and for NG is $C_3H_5\,[ONO_2]_3$. Find whether the propellant is fuel rich or oxidizer rich.

15. a.i. Describe the desirable properties of liquid propellant and give some examples.

ii. Explain the ion propulsion rocket with a neat sketch.

(OR)

b.i. A composite propellant contains ammonium percholrate $[NH_4Clo_4]$ as oxidizer and hydroxide terminated poly butadiene [HTPB] as fuel in stoichiometic proportion. Chemical formula for HTPB is $C_{200}H_{302}O_2$. Determine (i) Mixture ratio (ii) Solid bonding in the propellant.

ii. List three types of electrical rockets. Give one example for each type.

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