AUBURN UNIVERSITY
SAMUEL GINN
COLLEGE OF ENGINEERING
AEROSPACE

AERO 4970/7970 **Rocket Propulsion I** **SET IV**

Flight Performance

1. For a vehicle in gravitationless space, determine the mass ratio necessary to boost the vehicle velocity by 1600 m/s when the effective exhaust velocity is 2000 m/s.
   Answer: 0.449.

2. What is the mass ratio m_p / m_0 for a vehicle that has one-fifth its original takeoff mass at the time of the completion of the rocket operation?
   Answer: 0.80.

3. Determine the burnout velocity and burnout altitude for a dragless projectile with the following parameters for a simplified vertical trajectory: $\bar{c} = 2209$ m/s; $m_p / m_0 = 0.57$; $t_p = 5.0$ s; and $u_0 = h_0 = 0$.
   Answers: $u_p = 1815$ m/s; $h_p = 3.89 \times 10^3$ m.

4. For a satellite cruising in a circular orbit at an altitude of 500 km, determine the period of revolution, the flight speed, and the energy expended to bring a unit mass into this orbit.
   Answers: 1.58 hr; 7613 m/s; 33.5 MJ/kg.

5. A large ballistic rocket vehicle has the following characteristics: propellant mass flow rate: 12 slugs/sec (1 slug = 32.2 lbm = 14.6 kg); nozzle exit velocity: 7100 ft/sec; nozzle exit pressure: 5 psia (assume no separation): atmospheric pressure: 14.7 psia (sea level); takeoff weight: 12 tons (1 ton = 2000 lbf); burning time: 50 sec; nozzle exit area: 400 in^2.

   Determine: (a) the sea-level thrust, (b) the sea-level effective exhaust velocity, (c) the initial thrust-to-weight ratio, (d) the initial acceleration, and (e) the mass ratio.
   Answers: 81,320 lbf; 6,775 ft/sec; 3.38; 2.38 g_0.

6. A two-stage planetary exploration vehicle is launched from a high-orbit satellite into a gravity-free vacuum trajectory. The following information is given:

Flight and velocity increment in gravity-free vacuum	6,200 m/s
Specific impulse, I_s	310 s
Effective exhaust velocity, c (all stages)	3,038 m/s
Initial launch vehicle mass	4,500 kg
Propellant mass fraction, ζ (each stage)	0.88
Structural mass fraction, $1-\zeta$ (each stage)	0.12

Determine the payload for two cases: (a) when the two stage masses are equal, and (b) when the mass ratios of the two stages are equal.
Answers: 275 kg; 336 kg.

7. A one-stage planetary exploration vehicle is launched from a high-orbit satellite into a gravity-free vacuum trajectory. The following information is given:

Flight and velocity increment in gravity-free vacuum	6,200 m/s
Specific impulse, I_s	310 s
Effective exhaust velocity, c	3,038 m/s
Initial launch vehicle mass	4,500 kg
Propellant mass fraction, ζ	0.88
Structural mass fraction, $1-\zeta$	0.12

Determine the payload for the vehicle. Compare it with the two-stage vehicle of Problem 6a.
Answer: 50.7 kg, which is 18.4% of the payload for a comparable two-stage vehicle.