Assignment #1

1. The lunar module Eagle carrying Neil Armstrong and Edwin Aldrin landed on the moon on July 20, 1969 after separating from the mother-ship Columbia, which kept orbiting around the moon. After space walks on the moon were over, Armstrong and Aldrin got back into Eagle and took off from the moon to join the mother-ship Columbia in order to return to Earth. Assuming that Columbia had a circular orbit at an altitude of 150 Km around the moon, determine the velocity increment that was provided to Eagle to join Columbia.

2. The Pegasus rocket is launched from a jet aircraft at a height of 15 km above the Earth. The Pegasus rocket puts a satellite in circular orbit at a height of 500 km above the Earth's surface. Determine:
   i. The ideal velocity to be provided by the Pegasus rocket for the mission.
   ii. Pegasus is a three stage rocket. If a single stage rocket having an effective jet velocity of 4500 m/s is to be used for the same mission, determine the mass of propellant required. You can assume the mass of the useful payload (satellite) and the mass of the rocket structure including the inert put together as 800 kg.

3. A particular crater on the surface of Mars is to be viewed continuously from a spacecraft orbiting Mars. Determine the height of the orbit of this spacecraft above the surface of Mars. You can assume the period of rotation of Mars about its axis to be 24 hours and 40 minutes.

4. The orbit of an unmanned space capsule has to be increased from a circular Low Earth Orbit (LEO) of 350 Km to a Medium circular orbit (MEO) of 1500 Km without any change of inclination of the orbital plane. Determine the incremental velocity required.

5. a.) The International Space Station (ISS) orbits the Earth at an altitude between 350 and 460 Km. Experiments are carried out in ISS at microgravity conditions. The variation in altitude of ISS is due to atmospheric drag. On an average, the drag and other perturbations cause the altitude to drop by 200 m each day.
   To counteract this decrease in altitude, a periodic incremental velocity is given once in every 15 days to boost up the altitude. Calculate the value of the incremental velocity required to be given per boost.
   b.) If the average ΔV required for maintaining the altitude is 48.6 m/s <u>per year,</u> calculate the amount of propellant required to provide the compensation for drag for one year. You can assume the efflux velocity of the rockets used for this purpose to be 3100 m/s and the initial mass of ISS as equal to 460,000 Kg.

6. The Polar Satellite Launch Vehicle PSLV is used for putting Indian Remote Sensing Satellites (IRS) in a polar orbit around the Earth at an altitude 1000 km. The satellite IRS has a mass of 1400 kg. The PSLV comprises of four stages with six strap-on for the first stage. The mass of the structure including inert, the mass of the propellant and the specific impulse each stage and the strap-on are given below:

Stage	Mass of Structure and Inert (Tons)	Mass of Propellant (Tons)	Specific Impulse (Ns/kg)
Strap-on	1.5	9	2570
First stage	25	140	2640
Second stage	8.2	40	2920
Third stage	1.4	7	2930
Fourth stage	2.2	1.2	3040

Assume that the six strap-on and the first stage fire together. The thrust of each strap on is 640 kN while the thrust of the first stage is 4800 kN. Determine the following:

i. Payload fraction (α) for the second, third and fourth stage
ii. Initial acceleration of the vehicle
iii. ΔV contributed by each stage and the total vehicle
iv. Orbital velocity of the IRS satellite in 1000 km polar orbit
v. Net ΔV required to inject into the orbit.

You can neglect the mass of the different inter-stages.
What are the factors which are overlooked in the above calculations?

7. A space mission performed by an electrical rocket requires an incremental velocity of 10 Km/s. The mass of payload required is 1500 Kg. If the specific impulse of the propellant used is 18000 N-s/Kg and the structural mass fraction of the vehicle is 0.2, estimate

a. The propellant mass required
b. The overall mass.

8. The following data is given for a rocket:

Thrust: 9000 KN
Propellant Consumption Rate: 3000 Kg/s

Determine:

a. Effective jet velocity
b. Specific impulse of the propellant
c. Propulsive efficiency when the rocket is traveling at a velocity of (i.) 2000 m/s and (ii.) 4000 m/s

9. Hot gases are generated at a temperature of 2000 K and a pressure of 15 MPa in a rocket chamber. The molecular mass of the gas is 22 kg/kmole and the specific heat ratio of the gas is 1.32. The gases are expanded to the ambient pressure of 0.1 MPa in a convergent divergent nozzle having a throat area of 0.1 m^2. Calculate: (i) Exit jet velocity,(ii) Characteristic velocity, (iii) Ideal optimum thrust coefficient, (iv) Specific impulse and (v) Thrust generated.

10. A rocket is propelled by the expansion of room temperature hydrogen at 300 K from a pressure of 2MPa to 0.1 MPa. Calculate the jet velocity, given that the specific heat ratio of hydrogen gas is 1.4 and its molecular mass is $2\,kg/kmole$.

11. In a liquid propellant rocket, high temperature and high pressure gases at 3000 K and 10 MPa are generated in the combustion chamber and expanded in a nozzle to give thrust. The characteristic velocity of the propellant (C*) is 2000 m/s and the thrust coefficient (C_F) is 1.5.
    What is the specific impulse of the rocket?
    What must be the throat diameter of the nozzle to give a thrust of 5 kN?

12. (i) A rocket is designed to produce 5 MN of thrust at sea level. The pressure in the combustion chamber is 7 MPa and the temperature is 2800K. If the working fluid is assumed to be an ideal gas with properties of nitrogen at room temperature, determine the following: (a) specific impulse, (b) mass flow rate and (c) throat diameter. The specific heat ratio, γ , for nitrogen can be taken to be 1.4.

    You can assume that the gases expand in the nozzle to the ambient pressure of 0.1 MPa which is the ambient pressure at sea level.

    (ii) If the above rocket fires in deep space (ambient pressure is vacuum), what would be the specific impulse? (The exit area of the nozzle corresponds to expansion to a pressure of 0.1 MPa)