AE 234/711 Aircraft Propulsion
Quiz 2

Consider a twin-engine aircraft with a maximum Lift to Drag ratio of 21.6 (at $C_L = 0.5$), and an sfc of 14.2 gm/kN-s. The aircraft cruises at $M = 0.78$, with the cruise beginning at an altitude of 37,000 ft. The lift coefficient at take-off and for landing is not to exceed 1.56. Similarly, the flight speed at take-off should not exceed 85 m/s. The limit for the landing speed is 70 m/s. The aircraft has a maximum take-off weight of 175 tons. The reserve fuel, approximated as 4% of take-off weight, may effectively be added to the empty weight. When flying at the maximum take-off weight, and carrying the maximum payload, the aircraft burns 27.6 tons of fuel over the entire flight. As reasonable approximations, the fuel burned during take-off and climb is 2% of take-off weight, and the fuel burned during descent is 0.2% of take-off weight.

1. Find the wing area needed for take-off and landing while maintaining the given constraints. Assume standard sea level conditions. Fix the aircraft wing area based on your calculations.
   Mass at take-off is 175.0 tons, and the required wing area at take-of is $249m^2$. Mass is 147.4 tons at landing, and the required wing area at landing is $309m^2$. So, the plane wing area should be $309m^2$.

2. Find the aircraft mass at the beginning and end of cruise for maximum payload and maximum take-off weight conditions. Estimate the range assuming the aircraft flies at the peak L/D value and maintains a constant speed.
   Mass is 171.5 tons at the beginning of cruise, and 147.8 tons at its end. Aircraft cruise speed is 230.0 m/s $\approx$ 829.0 km/hr. Vehicle speed is 230.0 m/s $\approx$ 829.0 km/h. Range is 5,335.4 km $\approx$ 2,880.9 nm.

3. Suppose that the engines at the top-of-climb condition produce 20% more thrust than that required for steady cruise. What is the inclination of flight to the horizontal and what is the rate of climb?
   Thrust at Top-of-Climb is 93.5 kN = 46.7 kN/engine. Thrust at steady cruise is 77.9 kN = 38.9 kN/engine. Angle of climb is 0.00926 rad $\approx 0.53^o$. Rate of climb is 2.13 m/s $\approx$ 7 ft/s = 420.0 ft/min.

4. If it were decided to fly at sea-level, while maintaining the peak L/D, how far can the aircraft fly?
   For Sealevel cruise at $C_L = 0.5$, Velocity changes from 133.4 m/s to 123.8 m/s. In terms of kmph, the velocity changes from 480 km/hr to 446 km/hr. Range for L/D = 21.6 for sea-level cruise is 2,979.0 km. Here, the airplane is flying at constant attitude and altitude. So, we use the formula

$$R = \frac{1}{\text{TSFC}} \frac{2}{g_0} \frac{\mathcal{L}}{\mathcal{D}} \left(V_{ini} - V_{end}\right)$$