MAE 158 PROJECT
Extra Credit

You may complete Part 1 alone for 1/3 credit (equivalent to 1 quiz score) or both Part 1 and 2 for full credit (equivalent to 3 quiz scores)

Any parts that you complete are Due Friday, March 12, 11:59pm (end of week 10)

The main project involves developing a tool (code) to calculate aircraft performance given information about the aircraft geometry and flight mission requirements. The plots should be digitized, and the code should be able to run without needing supplemental inputs from the charts, from the user.

You need to develop the ability for calculate performance of the aircraft at any airspeed. You will need to be able to generate plots of 'Thrust required versus airspeed', 'Power required versus airspeed', and 'L/D versus airspeed'. The following page shows and example of the charts.

For the aircraft you will be given:

- Wing geometry
  - Sweep
  - Thickness
  - Span
- Fuselage geometry
  - Length
  - Diameter
  - Wetted area
- Tail geometry
  - Similar to wing
- Additional drag contributions
  - Additional flat-plate drag area

You should be able to calculate:

- Total Drag (at any airspeed)
- Induced Drag
  - Coefficient of induced drag
- Parasitic Drag
  - Flat-plate drag area
  - Coefficient of parasitic drag

Part 1

For the first part, you will be need to use your code to generate performance data about the aircraft in problem 11.1 (Shevell). The data is shown below. This is most likely a DC-9-21/30 aircraft.

11.1. A twin turbofan transport airplane is cruising at 31,000 ft pressure altitude at a Mach number of 0.78. Outside air temperature is −60°F. The airplane gross weight is 98,000 lb. The airplane has unsealed aerodynamically balanced control surfaces. Following are the airplane dimensional data:

Wing

Span	= 93.2 ft
Planform area	= 1000 ft^2
Average t/c	= 0.106
Sweepback angle	= 24.5 deg
Taper ratio	= 0.2
Root chord	= 17.8 ft
Wing area covered by fuselage	= 17%

Horizontal Tail

Exposed planform area	= 261 ft^2
t/c	= 0.09
Sweepback	= 31.6 deg
Taper ratio	= 0.35
Root chord	= 11.1 ft

Pylons

Total wetted area	= 117 ft^2
t/c	= 0.06
Sweepback	= 0 deg
Taper ratio	= 1.0
Chord	= 16.2 ft

Fuselage

Length	= 107 ft
Diameter	= 11.5 ft
Wetted area	= 3280 ft^2

Vertical Tail

Exposed planform area	= 161 ft^2
t/c	= 0.09
Sweepback	= 43.5 deg
Taper ratio	= 0.80
Root chord	= 15.5 ft

Nacelles

Total wetted area	= 455 ft^2
Effective fineness ratio	= 5.0
Length	= 16.8 ft

Flap Hinge Fairings

Δf	= 0.15 ft^2

Example 15.2

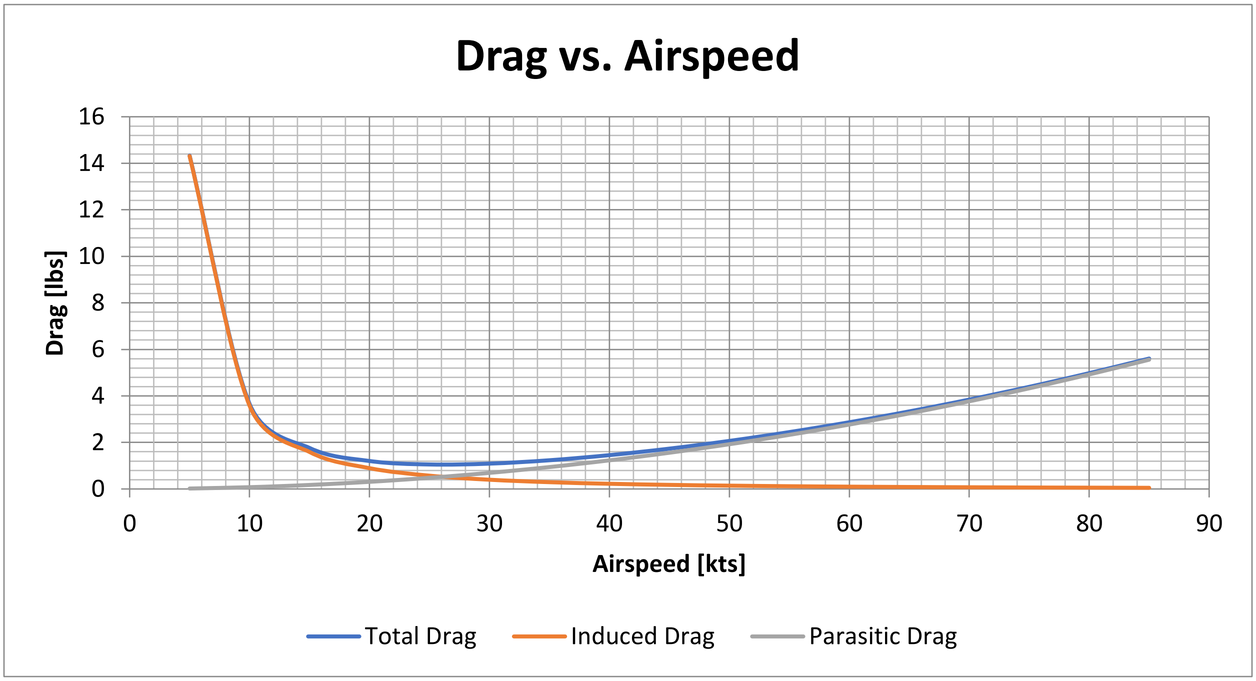
A DC-9-30 with a capacity of 100 passengers is cruising at ~~a Mach number of 0.78 at a pressure altitude of 30,000 ft. Outside air temperature is −38°F.~~ The initial cruise weight was 97,000 lb. According to the pilot's flight plan, he will start his descent at a weight of 82,000 lb. The DC-9-30 has a ~~C_{D_P} of 0.0202, an e of 0.816~~, a wing area of 1000 ft^2, a wing span of 93.6 ft, and three lavatories. ~~The compressibility drag coefficient ΔC_{D_C} is 0.0010.~~ The JT8D-15 turbofan engines have an installed specific fuel consumption at cruise of 0.82 lb/lb-h. Determine:

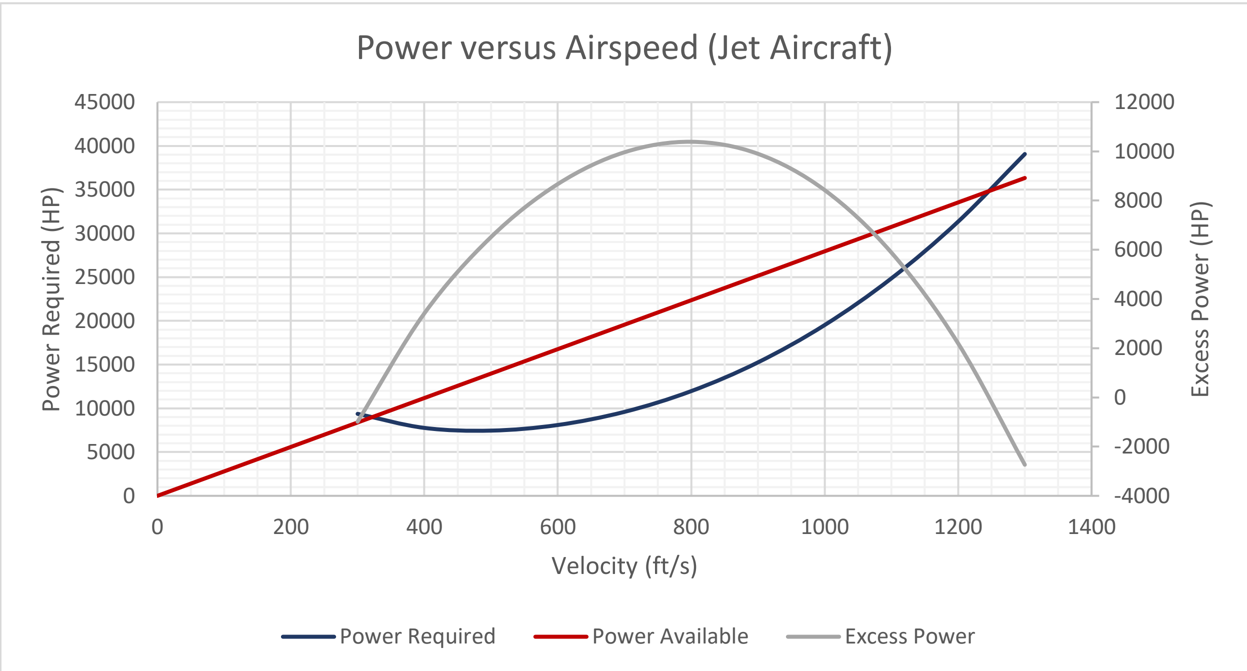
(a) Distance covered at cruise altitude (assume that conditions at average weight can be considered as the average for the flight).
(b) Required engine thrust (total for two engines) at the average cruise weight.
(c) Fuel flow in gallons per hour (kerosene weighs 6.7 lb/gal).
(d) Seat-miles produced per gallon.
(e) Compare the DC-9 seat-miles/gallon with a five-passenger automobile having a fuel consumption of 20 mi/gal.

Deliverables

1. Total parasitic drag coefficient
2. Flat plate drag area
3. Max Range and airspeed for max range
4. Max Endurance and airspeed for max endurance
5. Plot of drag (Total, Parasitic, Induced) versus airspeed
6. Plot of Power required, Power Available, and Rate of Climb versus airspeed

Example Plots:





Part 2

For part 2, you will analyze an electric or fuel-burning, propeller-driven aircraft you create. You can base your aircraft on an existing aircraft and make some geometry changes or come up with your own design (make sure it has reasonable specifications!) You may have to make some 'educated guesses' regarding geometry of the aircraft that is not readily available (this is common for conceptual and preliminary aircraft design).

Remember, this is a theoretical example and it DOES NOT account for limitations of cooling, packing factor of cells, wiring, battery control units, etc.

<u>For electric:</u> Use 130 Wh/lb for the cells and an installed propulsion efficiency of 180 Watts/lb thrust

<u>For fuel:</u> Use 0.5 lb/HP-lb for the engine and 6 lbs/gallon for aviation fuel

You need to generate plots of performance that you completed in Part 1 (i.e. Drag vs Airspeed, ROC, Power, etc.). Additionally, you will need to create a table of the aircraft parameters, similar to problem 11.1 (include ALL relevant geometry data as well as the AIRCRAFT WEIGHT INCLUDING 'FUEL' WEIGHT)

Example Table:

Parameter	Aircraft	Performance Metric	Aircraft
Wing Area		*ROC max*	
Span		*V_ROC max*	
t/c		*L/D max*	
Sweep		*V_L/D max*	
Fuselage length		*Max Range*	
Tail geometry		*Max Endurance*	
Additional geometric data…		*Additional parameters of your choice…*	

Wing		*Fuselage*	
Span	= 93.2 ft	Length	= 107 ft
Planform area	= 1000 ft^2	Diameter	= 11.5 ft
Average t/c	= 0.106	Wetted area	= 3280 ft^2
Sweepback angle	= 24.5 deg		
Taper ratio	= 0.2		
Root chord	= 17.8 ft		
Wing area covered by fuselage	= 17%	*Vertical Tail*	
		Exposed planform area	= 161 ft^2
Horizontal Tail		t/c	= 0.09
Exposed planform area	= 261 ft^2	Sweepback	= 43.5 deg
t/c	= 0.09	Taper ratio	= 0.80
Sweepback	= 31.6 deg	Root chord	= 15.5 ft
Taper ratio	= 0.35	*Nacelles*	
Root chord	= 11.1 ft	Total wetted area	= 455 ft^2
Pylons		Effective fineness ratio	= 5.0
Total wetted area	= 117 ft^2	Length	= 16.8 ft
t/c	= 0.06		
Sweepback	= 0 deg		
Taper ratio	= 1.0	*Flap Hinge Fairings*	
Chord	= 16.2 ft	Δf	= 0.15 ft^2

Equations to use:

Please use these equations below for some simplifications and to avoid digitizing an excessive number of plots:

$$C_f = (0.208)RN^{-.27845} + 0.00101$$

The above equation is Shevell Fig 11.2 digitized for typical transport roughness (from when I took MAE159 in 2012). I don't remember exactly how this was digitized, I might have had a friend help me!

$$\mu = 0.3170(°R)^{3/2}\left(\frac{734.7}{°R + 216}\right)\left(\frac{1}{10^{10}}\right)$$

For straight wing:

$$e = 1.78(1 - 0.045AR^{0.68}) - 0.64$$

For swept wing (sweep >= 30 degrees):

$$e = 4.61(1 - 0.045AR^{0.68})(cos\Lambda_{LE})^{0.15} - 3.1$$

For sweeps in between 0-30 degrees, linearly interpolate between the equations. You may also use the chart from Shevell if this seems overly complicated.

Remember:

$$P = IV$$

$$P = Force \times Velocity$$

<u>Watt - hours is a unit of energy and Watt is a unit of power</u>. You can think that if I have a device that uses 100 Watts and I have a 100 Watt-hour battery, I can power the device at 100 Watts for 1 hour!

You can find range by knowing how long the aircraft flies and the speed. For example, if I have an aircraft that can fly for 1 hour at 100 miles per hour, I will cover 100 miles. Sometimes these basic physics principles can be useful for the electric aircraft.