Spring 2016
ME 257/357 – Midterm Examination

Write your name on this handout and on the notebook(s), and sign the honor code.

Name: ………………………………………………………………………………………

Honor Code: I have neither given nor received unauthorized aid on this examination, nor have I concealed any violations of the Honor Code.

Signature

This midterm an open-book, open-notes exam. However, no laptops or phones with internet connections are allowed. Show all your work on every problem to obtain partial credit wherever possible. After the exam, return this handout and all other work.

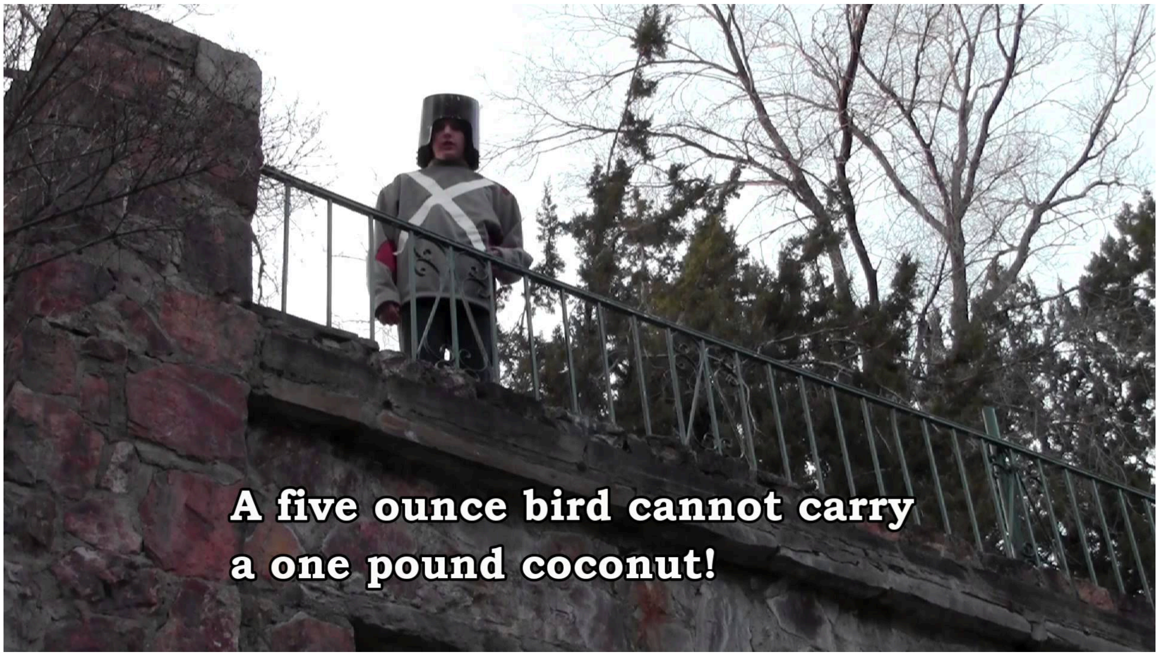
Overview: In this exam, we will apply the skills we've developed in the course to address the classic question from Monty Python and the Holy Grail, namely,

What is the airspeed velocity of an unladen swallow?

Problem 1

For this analysis, we will assume that the swallow in question is a European swallow, not an African swallow. The bird has a mass of 20 g, and its wingspan is 30 cm. The wing area is $0.05 m^2$, and the aspect ratio is 7. The profile drag coefficient for most birds of comparable size is $C_{d,0} = 0.4$ and the span efficiency factor is around 0.8. The density is $\rho = 1.2\ kg/m^3$.

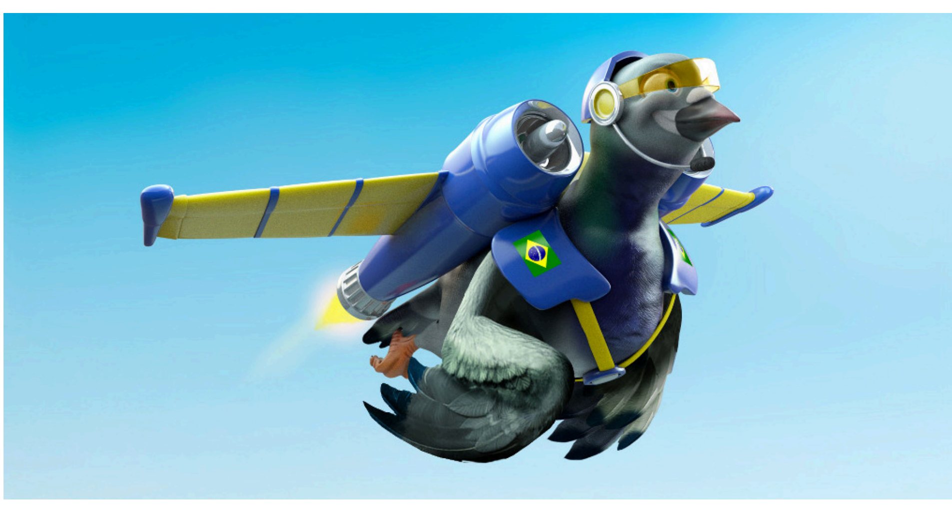
a) Using the above information and the knowledge that a sparrow can generate 2N of thrust, compute the cruising speed (or airspeed velocity) of a European swallow.
b) Based on your solution to a), what are the lift and drag coefficients for a sparrow at "cruise?"
c) Body fat has an energy density of 37 kJ/g and makes up about 30% of the swallow's frame by mass. Assuming the typical swallow burns through fat at a rate of 10 g per hour-Newton of thrust produced, compute the maximum range and flight time before the swallow would need to find food.



Problem 2

Since a typical coconut weighs 1 lb or 4.48 N, or 23 times the weight of a European swallow, it would be quite difficult for a swallow to transport the fruit over long distances. To help the bird in its quest, we will now engineer a small piece of turbojet-engine to aid our flyer (see figure below).

a) Assuming our single-engine design calls for 5 N of thrust at a cruise speed of 20 m/s and a flight altitude of 1000 feet (where the air density is 1.2 kg/m^3), how fast would the exhaust velocity need to be, given a mass flow rate of 0.25 kg/s?
b) To increase the device's thrust, we implement a turbofan design with the core flow unchanged and a post-fan bypass exhaust velocity of 30 m/s. What would the bypass ratio need to be to triple the amount of thrust produced?



Problem 3

Our swallow jet pack will be powered by n-heptane (C_7H_{16}) as fuel.

a) Write a balanced chemical equation for the stoichiometric combustion of n-heptane in air.

b) Based on the information in the table below, compute the heat of reaction at standard conditions (p = 1 bar, T = 293 K) for stoichiometric n-heptane combustion. State whether the reaction is exothermic or endothermic.

c) Assuming a constant specific heat for all species of c_p = 2000 J/kg-K and that the fuel and air enter the combustion chamber at 500K, compute the adiabatic flame temperature at stoichiometric condition.

Species Name	Enthalpy of Formation (kJ/mol)
C_7H_{16}	-167.4
CO_2	-393.5
H_2O	-241.82

Problem 4

Lastly, in an attempt to further extend the avian theme, we'll determine the flapping frequency of a swallow's wings. Assume that the bird is cruising at 10 m/s.

a) At the top of the bird's stroke, the flow approaching the bird's wing can be modeled as traveling horizontally in the absolute frame. If we assume the relative velocity of the flow is at a 30 angle (above) the wing tip, what is the speed of the blade … err … wingtip?

b) Making the further assumption that the absolute velocity of the flow coming off the wing travels at an angle of 60 degrees downward from the wing and that the blade speed is constant throughout the stroke, what is the mass specific work done by the wing?

c) Fill in the corresponding velocity triangles for this case.