

4) Imagine that you instead used the pump from the jetski to force water through a hose and build yourself a water jet-pack (yes, they exist). This is simply a jet-ski pump sitting in a boat that gets dragged behind the rider by the hose.

A) Do you believe that this vehicle will be able to achieve a higher lateral speed than the jetski for a pump of the same power output? Explain.

B) Name 3 important characteristics for sizing the nozzles of this device in order to optimize it for highest lateral speed.

Question 2: Aircraft Aerodynamics (25 points)

A small commercial airplane weighing 20,000 lbs flies at a cruising altitude of 33,000 feet. The ambient air density is 7.9656×10^{-4} slug/ft³. The wing surface area is 450 ft².

a) Draw a free body diagram of all of the forces acting on the airliner at cruising speed. What is the lift force?

b) Which of the following would be a reasonable lift/drag ratio? Select one value, then calculate the forward thrust of the airplane.

Select a L/D Ratio:

1/200

1/20

1

20

200

c) Given the L/D ratio selected in part b, we would like to determine the stall velocity of the airplane. Assume $C_D = 0.015$ as the airplane enters stall.

Question 3: Signal Processing (20 points)

The base signal in Figure 1 is modulated using Double-sideband suppressed-carrier transmission (DSB-SC), the result of which is also shown in Figure 1. In order to interpret the signal on the receiver end, we perform a fourier transform of the incoming data, with the output shown in figure 2.

Identify the carrier frequency and the frequency components of the base band signal.

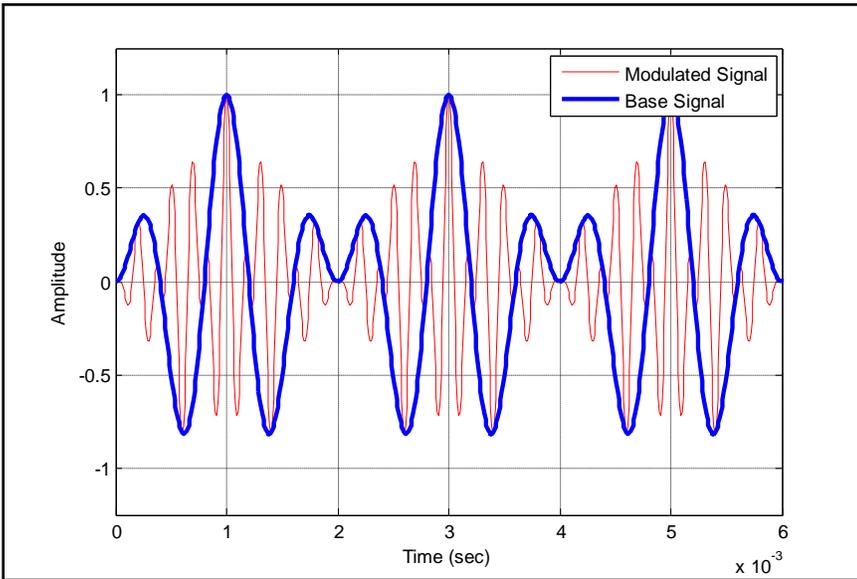


Figure 1: Base Signal and Amplitude Modulated Signal

Carrier Signal (Hz)

$F_c =$ _____

Base Band Signal (Hz)

(use as many frequencies as needed to fully describe the signal)

$F_{B1} =$ _____

$F_{B2} =$ _____

$F_{B3} =$ _____

$F_{B4} =$ _____

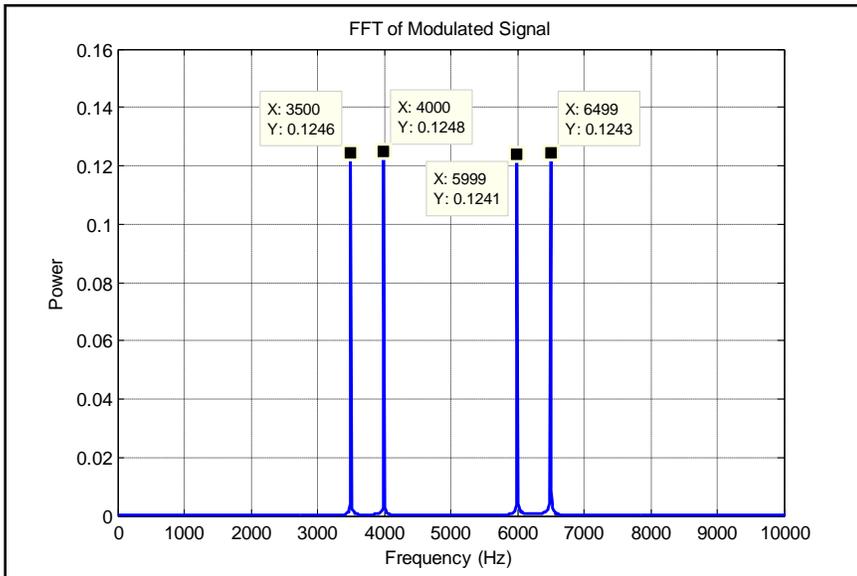


Figure 2: FFT of DSB-SC Signal (Positive Transform Only)

Question 4: Short answer (30 points, 6 points each)

1) Hull Stability

The following two boat hulls (Figure 1) are impacted by a wave that tips each ship by the same angle (Figure 2). 'G' represents the center of gravity of the ship and 'B' represents the center of buoyancy. Which boat becomes unstable as it is tipped by the wave? Prove your answer by drawing all relevant forces and moments on Figure 2. Solve for the equation of the moment acting on each ship in terms of the given forces (sketch in any distance values that you need for the answer – you DO NOT need to solve this in terms of the angle alpha).

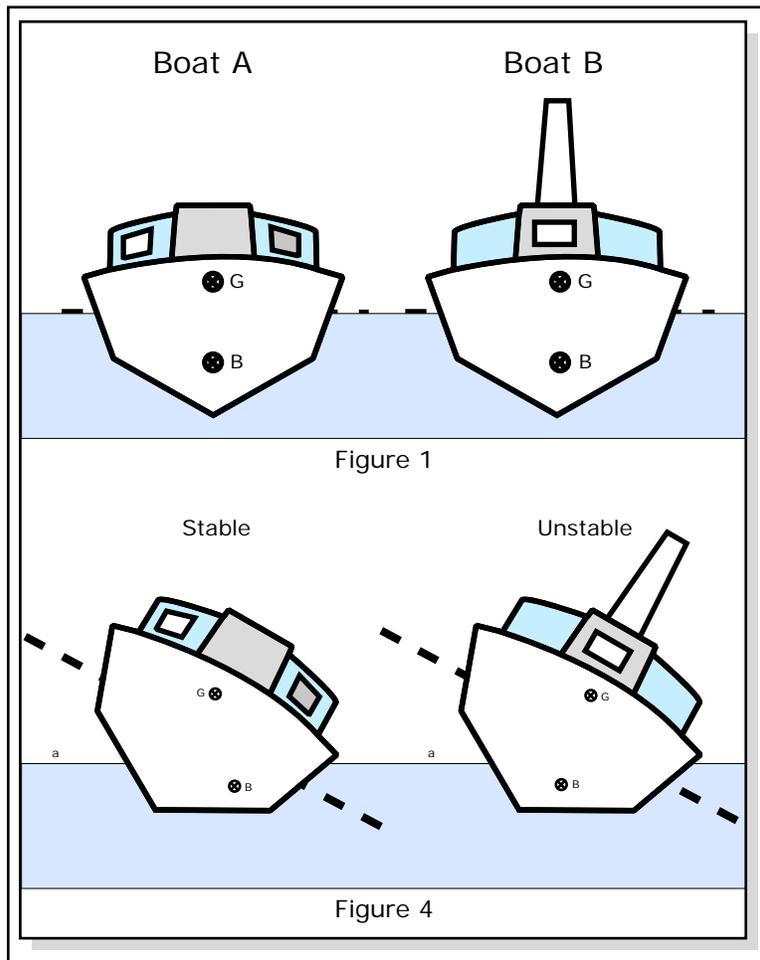
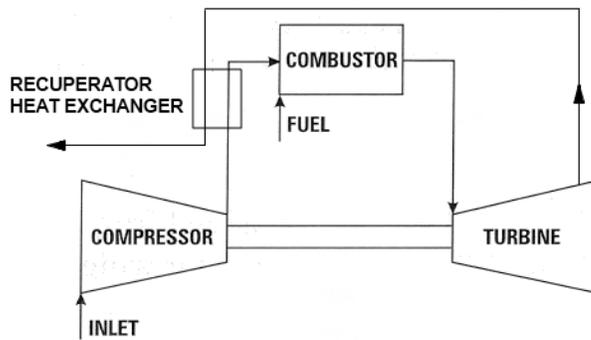


Image by MIT OpenCourseWare.

Moment Acting on Ship A = _____

Moment Acting on Ship B = _____

- 2) Remembering the gas turbine power plant problem from PS4 – making use of the waste heat in the exhaust gases can significantly increase turbine efficiency. Explain in two sentences or less how the recuperator heat exchanger design in the [compact power-generation turbine](#) sketch below reduces fuel consumption.



- 3) We are attempting to resolve our location via GPS. How many satellites are necessary to obtain a location fix? Why would additional satellites improve the accuracy of our answer further?

- 4) How would an engineer decide whether to use a turbofan or turbojet on a new plane?

- 5) For an airplane of a given shape flying at a given Mach and Reynolds number, C_d and C_l are a function of what flight parameter?

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