Biology 427 Biomechanics
Problem Set 6
Due – Friday Nov. 18

Some basic relationships:

Assume induced drag is negligible for all that follows.

Lift = L = $0.5 \rho S C_L U^2$

Drag = D = $0.5 \rho S C_D U^2$

For gliding vultures:

$L = m g \cos(\theta)$

$D = m g \sin(\theta)$

θ = glide angle

Data (ignore effects of angle of attack).

For humans

mass = 70 kg
chest height = 1.5 m
pelvis height = 1 m
drag coefficient = 0.5
area for drag estimate = 1 m^2

For vultures

mass = 1 kg
span of wings = 2.0 m
Area of wings = 1.0 m^2
Wing drag coefficient = 0.3
Wing lift coefficient = 1.0
Body drag coefficient = 0.3
Body projected area = 0.2 m^2

Density of air = 1 kg/m^3
Dynamic viscosity of air = $15\ 10^{-5}$ kg/ m s

1. Blown away (covered in lecture Monday Nov 7).

Seattle has seen some fairly dramatic winds over the past years. Just standing in these gale force winds is challenging and, to avoid toppling over we lean into the wind. For the purposes of this problem assume the drag is centered at your chest height and your weight is centered at your pelvis. (3 pts)

(a) Draw a diagram of forces and moments for a person leaning into the wind
(b) Derive an expression that relates the angle you must tilt for the moment generated by drag to equal the moment generated by your weight. Note that drag is a function of wind speed.
(c) Using the chest height and pelvis height from the above, plot the tilt angle as a function of wind speed for winds up to 20 m/s.

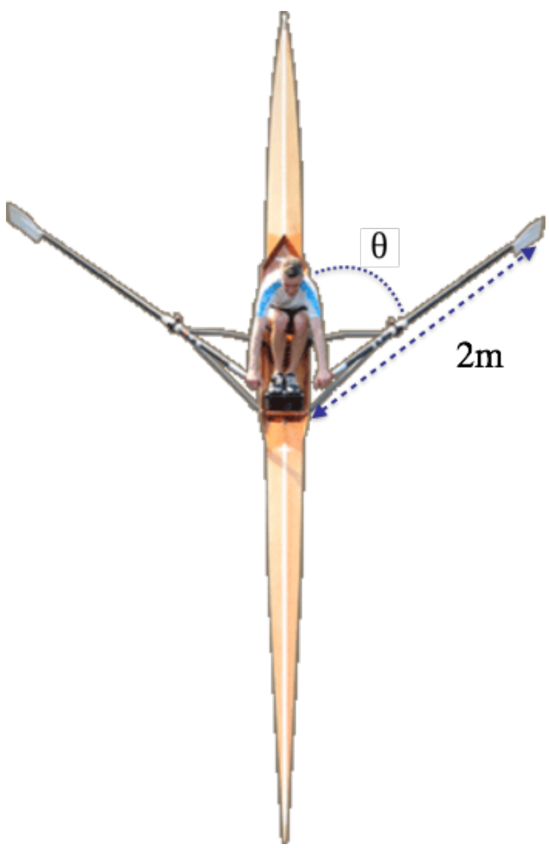
2. A rower pulls back on a paddle to propel her boat through water (covered in lecture Mon Nov 7). In many swimming creatures, appendages undergo rowing motions. The rearward stroke of the fin or leg propels the animal forward by the thrust generated from the drag in the flow on the appendage. This is exactly the same principle that governs rowing on the surface of water. In this problem, we analyze the thrust of a rower for a simplified version of the problem.

Here, the oar has a paddle (circular disc) area of 0.2 m^2 and a drag coefficient (C_d) of 1.0. In one second, the oar swings through a 90 degree arc centered about the mid-section of the boat. The angular velocity of the oar is constant. The length from the point of rotation of the oar (to the center of the disc) is 2 m. (2 pts)

(a) Derive an equation that predicts how the thrust (forward force) changes in time if the boat forward velocity is assumed to be tiny with respect to the rearward oar velocity (i.e. ignore the forward velocity of the boat)

(b) Plot the thrust as a function of time

(c) How might the fact that the boat is actually moving in a direction opposite to the oar modify your analysis?



3. A soar topic, but uplifting nonetheless (covered in lecture Wed Nov 14).
A sailplane pilot followed a vulture traveling across the Kalahari Desert. With no noticeable flapping, the bird was able to travel many kilometers by clever use of thermals spaced throughout the desert. In this problem, we will use simple aerodynamics to compute the average distance between thermals that would permit long distance migration of vultures. (4 pts)

(a) Compute the glide angle of the vulture (be sure to include both wing and body drag in your analysis).
(b) You are now armed with the glide angle. If vultures rise vertically in a thermal to a height of 100m, how far apart must these thermals be for long distance migration? (i.e. What is the spacing of thermals that would allow vultures to travel without flapping wings?)
(c) If thermals elevate vultures at an average vertical velocity of 1 m/s, how long will it take a vulture to travel 1 km with thermals spaced every 200 m starting from the bottom of the first thermal? They may need to rise to a different height than in (b).
(d) If vultures from (c) rise in a thermal by flying in a circular spiral with a radius of 50 m, what is the average speed of the vulture relative to the ground? Assume each upward journey takes 10 complete revolutions.