Zoe Maisel
Lab 4, R code and accompanying figures

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library(zoo)

# Read in data for Wave 1
Lab4_W1 <- read.csv("~/github/Coastal_Engineering/Lab 4/Lab4_W1.csv")
Lab4_W2 <- read.csv("~/github/Coastal_Engineering/Lab 4/Lab4_W2.csv")
Lab4_W3 <- read.csv("~/github/Coastal_Engineering/Lab 4/Lab4_W3.csv")
Lab4_W4 <- read.csv("~/github/Coastal_Engineering/Lab 4/Lab4_W4.csv")

# add 0.019s to force transducer time signal
# Convert everything to numeric values
Lab4_W1$time_s = as.numeric(Lab4_W1$time_s)
Lab4_W1$Force_newtons = as.numeric(Lab4_W1$Force_newtons)

Lab4_W2$time_s = as.numeric(Lab4_W2$time_s)
Lab4_W2$Force_newtons = as.numeric(Lab4_W2$Force_newtons)

Lab4_W3$time_s = as.numeric(Lab4_W3$time_s)
Lab4_W3$Force_newtons = as.numeric(Lab4_W3$Force_newtons)

Lab4_W4$time_s = as.numeric(Lab4_W4$time_s)
Lab4_W4$Force_newtons = as.numeric(Lab4_W4$Force_newtons)

# Reset the time series so it starts at 0 seconds
# correction factor
cf_per1 = 0.19 #s
cf_per05 = 0.17 #s
Lab4_W1$time_s = (Lab4_W1$time_s) - (Lab4_W1$time_s[1]) + cf_per05
Lab4_W2$time_s = (Lab4_W2$time_s) - (Lab4_W2$time_s[1]) + cf_per05
Lab4_W3$time_s = (Lab4_W3$time_s) - (Lab4_W3$time_s[1]) + cf_per1
Lab4_W4$time_s = (Lab4_W4$time_s) - (Lab4_W4$time_s[1]) + cf_per1

### 1. Plot the Wave Case 1 condition of force vs. time
plot(Lab4_W1$time_s, Lab4_W1$Force_newtons, ylab = "Force (N)", xlab = "Time (s)", main =
"Wave Case 1")
plot(Lab4_W1$time_s[0:1000], Lab4_W1$Force_newtons[0:1000], ylab = "Force (N)", xlab =
"Time (s)", main = "Wave Case 1")

# Plot Wave Case 2, 3, and 4 to determine the average maxima
plot(Lab4_W2$time_s, Lab4_W2$Force_newtons, ylab = "Force (N)", xlab = "Time (s)", main =
"Wave Case 2")
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plot(Lab4_W3$time_s, Lab4_W3$Force_newtons, ylab = "Force (N)", xlab = "Time (s)", main = "Wave Case 3")
plot(Lab4_W4$time_s, Lab4_W4$Force_newtons, ylab = "Force (N)", xlab = "Time (s)", main = "Wave Case 4")
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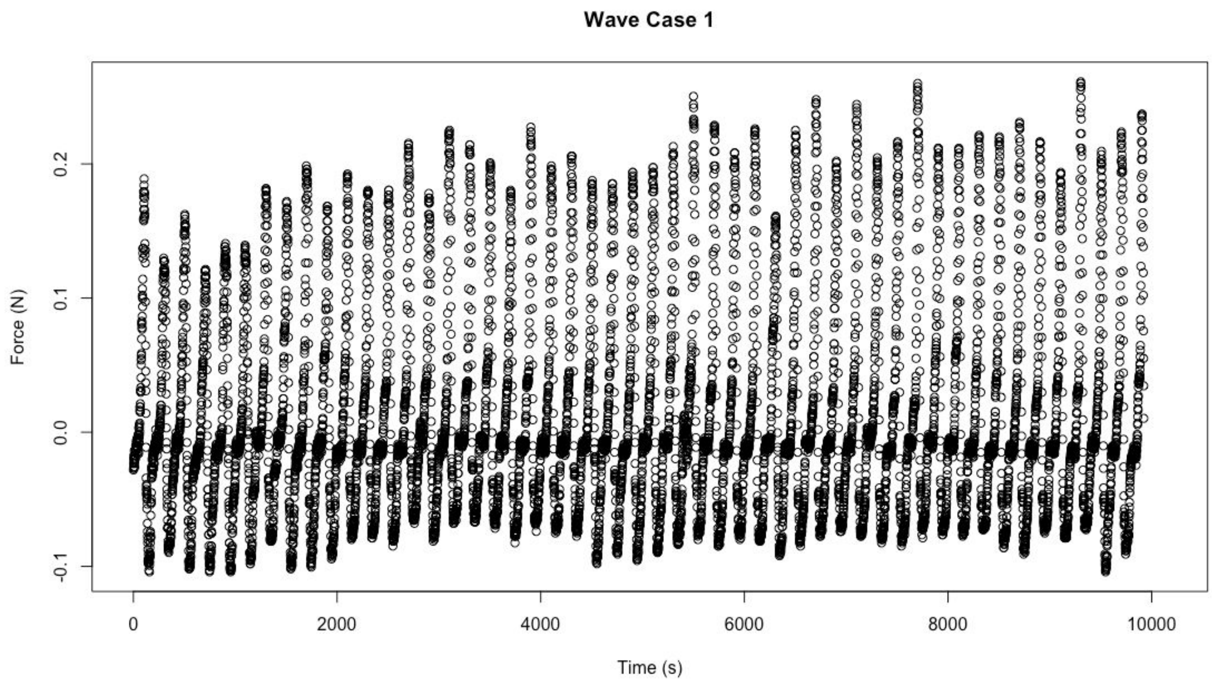

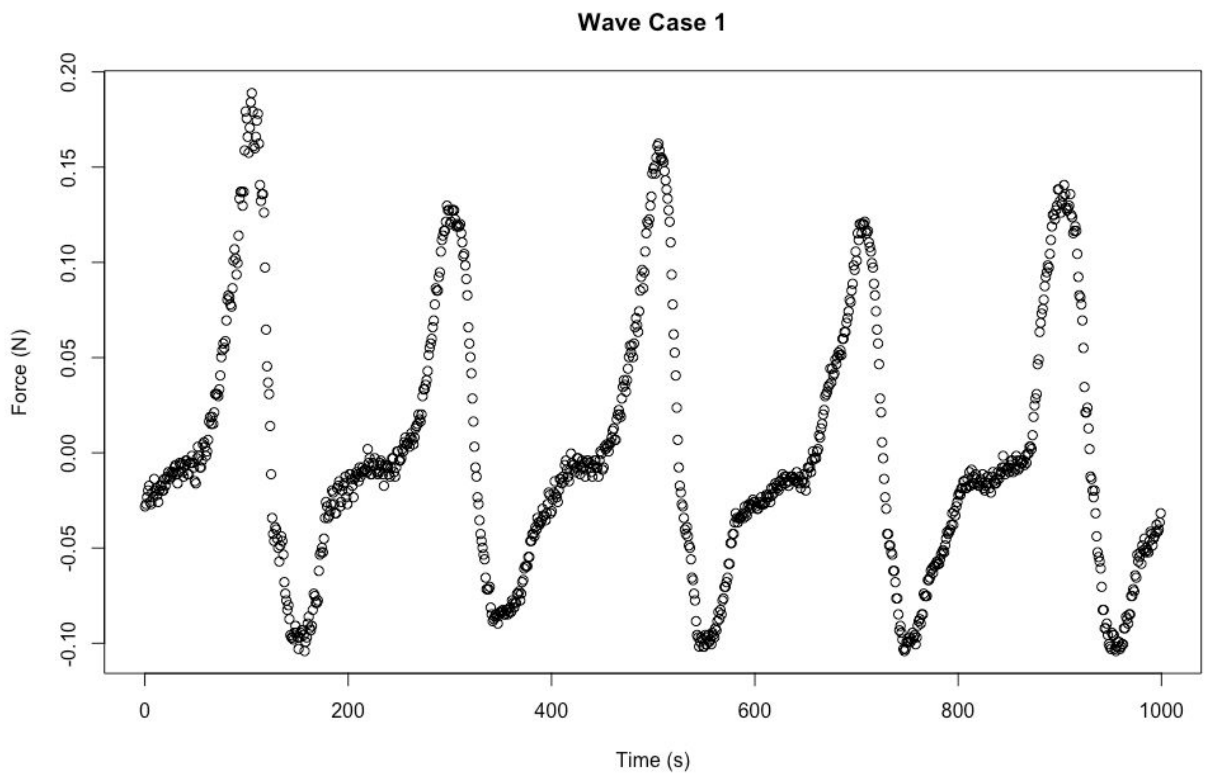

2. Calculate D/lambda for each wave case and compare with slender body assumption
# Calculate lambda using the dispersion relationship
# sigma^2 = gktanh(kh)
# T = 1/freq
h_m = 0.2
W1_freq_Hz = 0.5
T12 = 2
T34 = 1
g_m = 9.81 # m/s^2

# Use root-solver function to find the k values for the different waves
W1_k = 2.3209 # 1/m
W2_k = 2.3209
W3_k = 5.17913
W4_k = 5.17913

# lambda = 2*pi/k #m
W1_lmbda = 2*pi/W1_k
W2_lmbda = 2*pi/W2_k
W3_lmbda = 2*pi/W3_k
W4_lmbda = 2*pi/W4_k

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# D/lambda to check slender body assumption
D = 0.0508 #m
W1_Dl = D/W1_lmbda
W2_Dl = D/W2_lmbda
W3_Dl = D/W3_lmbda
W4_Dl = D/W4_lmbda

W1_Dl = 0.0188
W2_Dl = 0.0188
W3_Dl = 0.0142
W4_Dl = 0.0142

# The slender body assumption may hold because wavelength is greater than D. However, it is unclear whether the
# difference is large enough for the slender body assumption to hold.

### 3. Calculate the Reynolds number for each wave
W1_a = 0.013 #m
W2_a = 0.003
W3_a = 0.012
W4_a = 0.003

# Find sigma using sigma = 2*pi/T
W1_sig = 2*pi/T12 # 1/s
W2_sig = 2*pi/T12
W3_sig = 2*pi/T34
W4_sig = 2*pi/T34

# Find u using u = g*a*k/sigma
# or use sigma k
#shallow water wave assume velocity constant with depth
W1_u = g_m * W1_a * W1_k / W1_sig
W2_u = g_m * W2_a * W2_k / W2_sig
W3_u = g_m * W3_a * W3_k / W3_sig
W4_u = g_m * W4_a * W4_k / W4_sig

# Find Reynolds number using Re = u*D/v
v = 1*10^-6 #m^2/s
W1_Re = W1_u * D/v
W2_Re = W2_u * D/v
W3_Re = W3_u * D/v
W4_Re = W4_u * D/v
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W1_Re = 4786
W2_Re = 1104
W3_Re = 4929
W4_Re = 1232

# We expect very large Reynolds number for the waves.

### 4. Find Cd and Cm for each wave case
rho_kg_m3 = 1000
# To find Cd, first find local maxima of Fd timeseries and take average to find Fd average
# At du/dt = 0, Ftot = Fd, which means that at the wave peak, the entire force is equal to the
drag force
# There is an offset between the force gauge data and the wave amplitude data, as given above
in the correction factor, cf
# The following Fd values were determined by taking the maximum force data, offset by the
correction factor, to find the wave peak
# These values were then averaged to find estimates for the force values. It would be more
precise if wave amplitude
# data was obtained to avoid these estimates. This simplification in analysis is imprecise but
should suffice as a first attempt at analysis.
W1_Fd = 0.2
W2_Fd = 0.018
W3_Fd = 0.35
W4_Fd = 0.07

# Cd = 2*Fd/(rho*A*u^2), from Dean and Dalrymple page 224
L = 0.2 #m
W1_Cd = 2* W1_Fd/(rho_kg_m3*(D*L)*(W1_u)^2)
W2_Cd = 2* W2_Fd/(rho_kg_m3*(D*L)*(W2_u)^2)
W3_Cd = 2* W3_Fd/(rho_kg_m3*(D*L)*(W3_u)^2)
W4_Cd = 2* W4_Fd/(rho_kg_m3*(D*L)*(W4_u)^2)

W1_Cd = 4.44
W2_Cd = 7.5
W3_Cd = 7.32
W4_Cd = 23.4

Cd = c(W1_Cd, W2_Cd, W3_Cd, W4_Cd)

# still use shallow water form of u and take temporal derivative of that
# u = a*sigma*cos(kx-sigmat)
# du/dt = a*sigma*(sigma*sin(sigma*t))
```

```
# use t at t = (1/4)T, because that is the time that the wave passes through the zero point and u = 0, assuming that the wave starts at a crest.
t_12 = (1/4)*T12
t_34 = (1/4)*T34

der_u1 = W1_a * W1_sig^2 * sin(W1_sig*t_12)
der_u2 = W2_a * W2_sig^2 * sin(W2_sig*t_12)
der_u3 = W3_a * W3_sig^2 * sin(W3_sig*t_12)
der_u4 = W4_a * W4_sig^2 * sin(W4_sig*t_12)

# Fi values will be found in a similar manner to how Fd values were found. The force gauge data is offset from the
# wave amplitude data. Accounting for the offset, all force should be inertial when the wave passes through the zero point
# The force data can be used find the point where the wave is at the node.
W1_Fi = 0.02
W2_Fi = 0.005
W3_Fi = 0.03
W4_Fi = 0.003

# Cm = (Fi*2*4)/(L*rho*pi()*D^2*(du/dt))
W1_Cm = (W1_Fi*2*4)/(L*rho_kg_m3*pi*(D^2)*der_u1)
W2_Cm = (W2_Fi*2*4)/(L*rho_kg_m3*pi*(D^2)*der_u2)
W3_Cm = (W3_Fi*2*4)/(L*rho_kg_m3*pi*(D^2)*der_u3)
W4_Cm = (W4_Fi*2*4)/(L*rho_kg_m3*pi*(D^2)*der_u4)

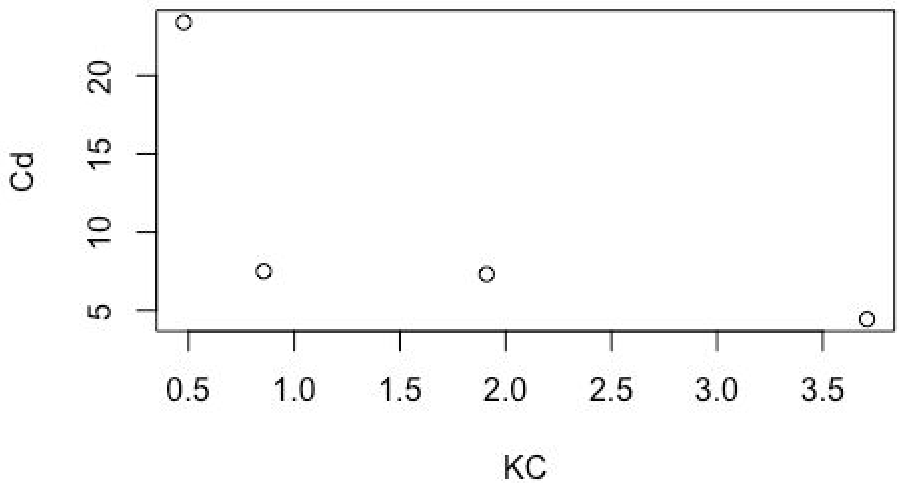
W1_Cm = 0.79
W2_Cm = 0.86
W3_Cm = 0.323
W4_Cm = 0.129

Cm = c(W1_Cm, W2_Cm, W3_Cm, W4_Cm)

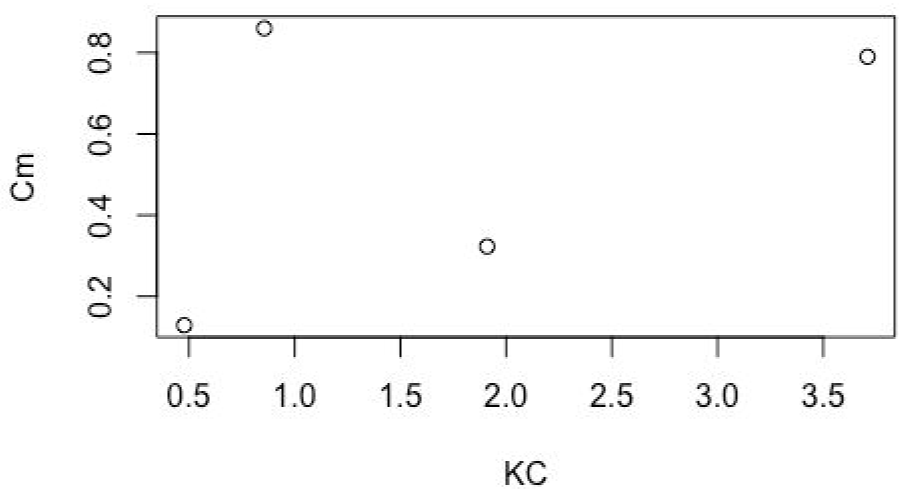
# Calculate KC values
# KC = UT/D
W1_KC = (W1_u * T12) / D
W2_KC = (W2_u * T12) / D
W3_KC = (W3_u * T34) / D
W4_KC = (W4_u * T34) / D

KC = c(W1_KC, W2_KC, W3_KC, W4_KC)
```

plot(KC, Cd)



plot(KC, Cm)



The values for Cd are at least an order of magnitude larger than they should be. Cm values are smaller than they should be.
In general, the lab analysis is very different from the expected values as dictated in the lab.