We first set up the basic assumptions and variables.

```
GRAV <- 9.8 # gravity (m/s^2)
MASS <- 1 # mass (kg)
I_ROT <- 1 # roational inertia (kg m^2)
L1 <- 0.5 # distance from rotation point to CoM (m)
L2 <- 1 # distance from rotation ponit to tension (m)
PHI <- 0 # angle of Ft relative to floor orthogoal (rad)
FT <- 11 # tension force (N)
OMEGA <- 0 # angle of line orthogonal to floor relative to gravity (rad) (because shifted axis)
```

Additionally, we set the time interval and seed values for time and theta (distance from flat):

```
dt <- 0.0001
t_max <- 5

vx <- 0
vy <- 0

theta <- 0
thetadot <- 0
time <- 0
```

First, let's create a function for torque in terms of theta (and the constants above:

```
net_torque <- function(theta) {
    return(L2 * FT * cos(theta + PHI) - L1 * MASS * GRAV * cos(theta - OMEGA))
}
```

Great. Let's start generating the table! We essentially write a for loop to appends to a few different vectors. Variables appended with `c` reflect the column vectors that we will put together.

```
cTime = NULL
cTheta = NULL
cDDTheta = NULL
cDTheta = NULL
cTorqueNet = NULL
cAccelX = NULL
cAccelY = NULL
cVelX = NULL
cVelY = NULL
cFFriction = NULL
cFNormal = NULL

# debugging values
cFNetY = NULL
cFTensionPhiComponent = NULL
cFGravityPhiComponent = NULL

cMuStatic = NULL
cKERot = NULL
cKETrans = NULL
```

Awesome. Let's now run a lovely little for loop to actually populate the values recursively.

```
for (i in 0:(t_max/dt)) {
    # We first populate the time column with the time, theta column with theta
    cTime[i] = time
    cTheta[i] = theta

    torque <- net_torque(theta)
    # Given the theta value, we calculate the net torque and set that
    cTorqueNet[i] = torque
    # Now that we know the net torque, we could know how much the angular
    # acceleration is by just dividing out the rotational inertia
    thetadotdot <- torque/I_ROT
    cDDTheta[i] = thetadotdot
    # We could also multiply the theta acceleration by time to get the
    # velocity at that point
    thetadot <- dt*thetadotdot + thetadot
    cDTheta[i] = thetadot
    # We could therefore component-ize the acceleration in theta into
    # ax and ay
    ax <- -1 * L1 * sin(theta) * thetadotdot
    cAccelX[i] = ax
    ay <- L1 * cos(theta) * thetadotdot
    cAccelY[i] = ay # @mark isn't sin and cos backwards?
    # We also tally the components seperately for velocity
    vx <- ax*dt + vx
    vy <- ay*dt + vy

    # Based on these accelerations, we therefore could calculate the relative
    # force of friction and normal force by subtracting the force in that direction
    # out of net
    ffriction <- FT*sin(PHI) + MASS*GRAV*sin(OMEGA)-MASS*ax
    fnormal <- MASS*ay-FT*cos(PHI)+MASS*GRAV*cos(OMEGA)

    cFNetY[i] = MASS*ay
    cFTensionPhiComponent[i] = FT*cos(PHI)
    cFGravityPhiComponent[i] = -MASS*GRAV*cos(OMEGA)

    cFFriction[i] = ffriction
    cFNormal[i] = fnormal

    # Then, we calculate the energies
    cKERot[i] = 0.5 * I_ROT * thetadot^2
    cKETrans[i] = 0.5 * MASS * (vx^2+vy^2)

    # Dividing the friction force by the normal force, of course, will result in
    # the (min?) friction coeff
    cMuStatic[i] = ffriction/fnormal

    # We incriment the time and also increment theta by multiplying the velocity
    # by dt to get change in the next increment
    time <- dt + time
    theta <- dt*thetadot + theta
}
```

We now put all of this together in a dataframe.

```
rotating_link <- data.frame(cTime,
    cTheta,
    cDTheta,
    cDDTheta,
    cTorqueNet,
    cAccelX,
    cAccelY,
    cFFriction,
    cFNormal,
    cMuStatic,
    cKERot,
    cKETrans)

names(rotating_link) <- c("time",
  "theta",
  "d.theta",
  "dd.theta",
  "net.torque",
  "accel.x",
  "accel.y",
  "friction.force",
  "normal.force",
  "friction.coeff",
  "ke.rot",
  "ke.trans")
```

Let's import some visualization tools, etc.

```
library(tidyverse)
```

Let's first see the head of this table:

```
head(rotating_link)
```

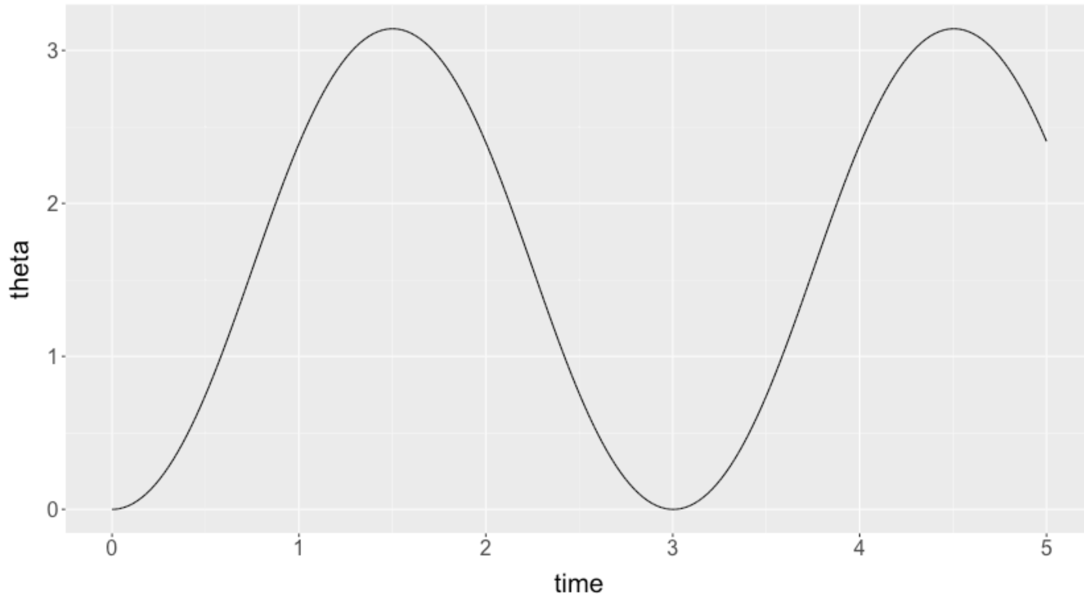
```
1e-04 6.1e-08 0.00122 6.09999999999999 6.09999999999999 -1.8605e-07 3.04999999999999 1.8605e-07
1.84999999999999 1.00567567567568e-07 7.44199999999999e-07 1.86049999999999e-07
2e-04 1.83e-07 0.00182999999999999 6.0999999999999 6.0999999999999 -5.58149999999987e-07 3.049999999999
5.58149999999987e-07 1.8499999999999 3.01702702702712e-07 1.67444999999998e-06 4.18612499999992e-07
3e-04 3.65999999999999e-07 0.00243999999999995 6.09999999999959 6.09999999999959 -1.1162999999999e-06
3.04999999999959 1.1162999999999e-06 1.84999999999959 6.03405405405483e-07 2.97679999999987e-06
7.44199999999953e-07
4e-04 6.09999999999994e-07 0.00304999999999983 6.09999999999887 6.09999999999887 -1.86049999999952e-06
3.04999999999887 1.86049999999952e-06 1.84999999999887 1.00567567567603e-06 4.65124999999949e-06
1.16281249999982e-06
5e-04 9.14999999999977e-07 0.00365999999999958 6.09999999999745 6.09999999999745 -2.79074999999837e-06
3.04999999999745 2.79074999999837e-06 1.84999999999745 1.50851351351472e-06 6.69779999999846e-06
1.67444999999944e-06
6e-04 1.28099999999993e-06 0.00426999999999908 6.09999999999499 6.09999999999499 -3.90704999999553e-06
3.04999999999499 3.90704999999553e-06 1.849999999995 2.11191891892221e-06 9.11644999999606e-06
2.27911249999858e-06
```

Before we start graphing, let's set a common graph there.

```
default.theme <- theme(text = element_text(size=20), axis.title.y = element_text(margin = margin(t = 0,
```

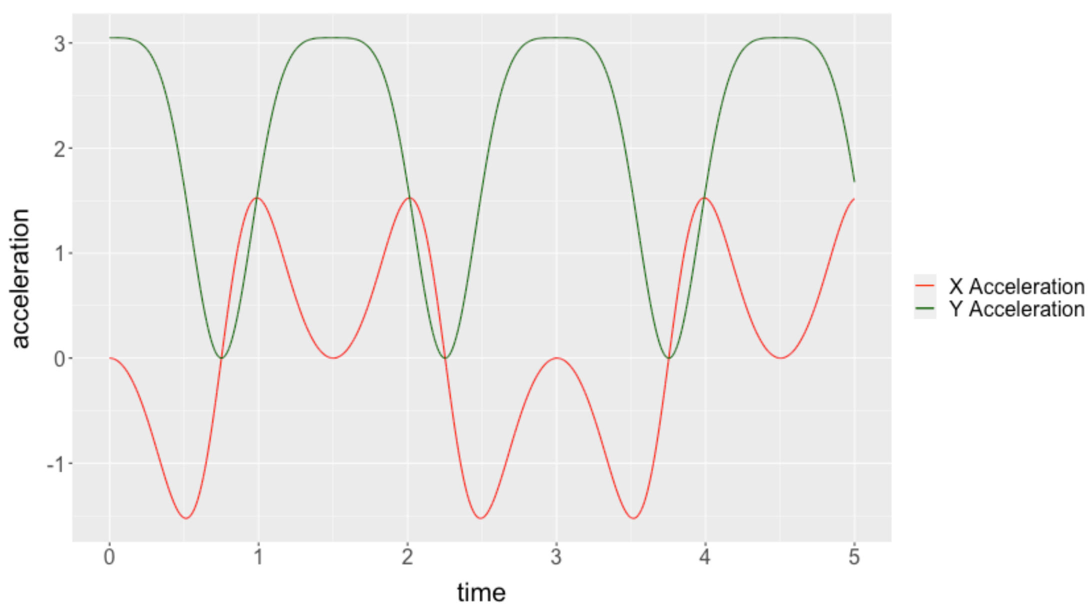
Cool! We could first graph a function for theta over time.

```
rotating_link %>% ggplot() + geom_line(aes(x=time, y=theta)) + default.theme
```



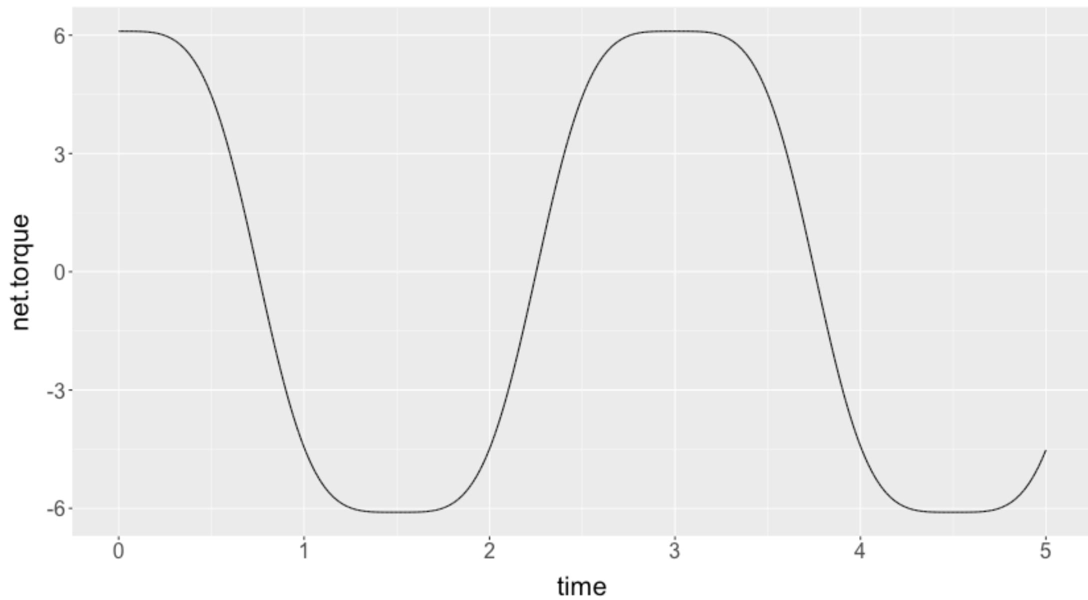
And, similarly, we will graph `ax` and `ay` on top of each other:

```
rotating_link %>% ggplot() + geom_line(aes(x=time, y=accel.x, colour="X Acceleration")) + geom_line(aes
```



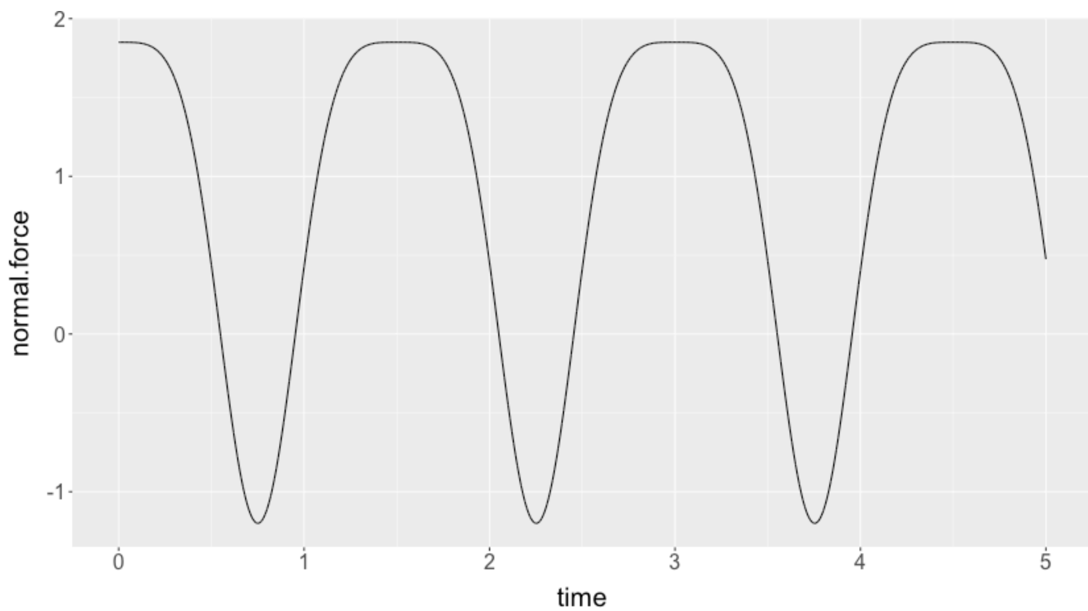
Let's also plot torque as well.

```
rotating_link %>% ggplot() + geom_line(aes(x=time, y=net.torque)) + default.theme
```



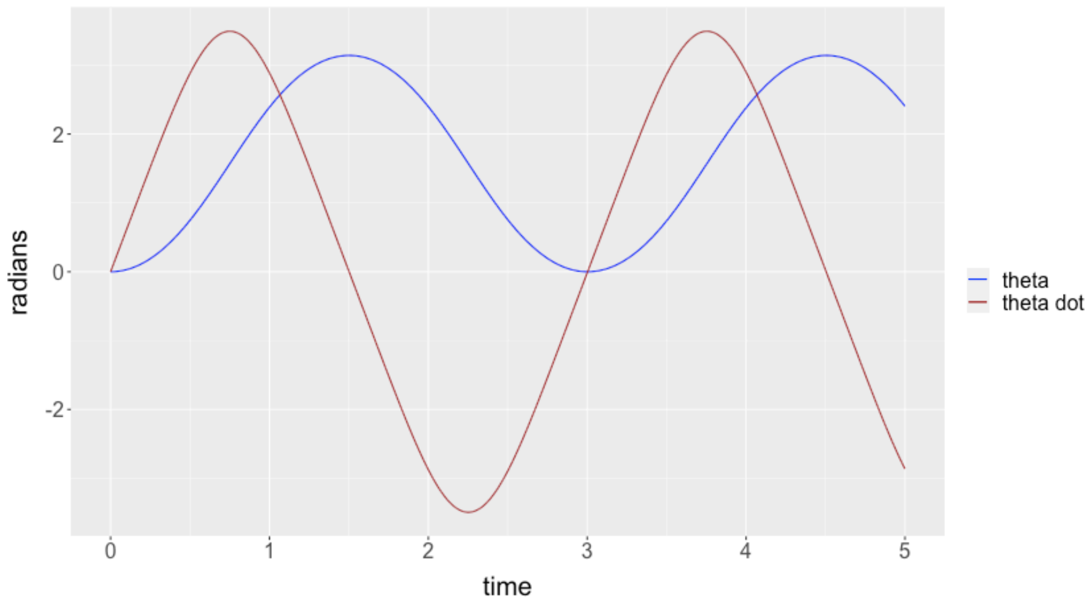
And. **Most importantly!** Let's plot the normal force.

```
rotating_link %>% ggplot() + geom_line(aes(x=time, y=normal.force)) + default.theme
```



Obviously, after the normal force becomes negative, this graph stops being useful.
Theta dot atop theta:

```
rotating_link %>% ggplot() + geom_line(aes(x=time, y=theta, colour="theta")) + geom_line(aes(x=time, y=
```



We finally, plot KE rotation and translation

```
rotating_link %>% ggplot() + geom_line(aes(x=time, y=ke.rot, colour="ke rotation")) + geom_line(aes(x=t
```