We first set up the same set of basic assumptions and variables.

```
GRAV <- 9.8 # gravity (m/s^2)
MASS <- 3.11*10^(-5) # mass (kg)
I_CM <- 9.85*10^(-5) # roational inertia (kg m^2)
PHI <- pi/6 # angle of Ft relative to floor (parallel) (rad)
L <- 0.5 # distance from the center of mass (of rotation point) to tenson (m)
FT <- 12 # tension force (N)
OMEGA <- 0.1 # angle of line orthogonal to floor relative to gravity (rad) (because shifted axis)
```

Additionally, we set the time interval and seed values for all values that's tallied:

```
dt <- 0.0001
t_max <- 5

vx <- 0
vy <- 0

x <- 0
y <- 0

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

Great. Let's start writing the loop now by setting up a bunch of arrays and writing their values in.

```
cTime = NULL
cTorqueNet = NULL
cDDTheta = NULL
cDTheta = NULL
cTheta = NULL

cAccelX = NULL
cAccelY = NULL
cVelX = NULL
cVelY = NULL
cPosX = NULL
cPosY = NULL

cFNetX = NULL
cFNetY = NULL

cKERot = NULL
cKETrans = NULL
```

Awesome, we will start tallying, then!

```
for (i in 0:(t_max/dt)) {
    # write down standard values
    cTime[i] = time
    cTheta[i] = theta
```

```
# torque is calculated via the dot product between the vector of the radius projected out
# and also the angle at which the thing is at (so like theta + phi)
#
# note that, unlike the tabled version, L here represets distance from CoM to tension
# application
torque <- FT*L*cos(theta+PHI)
cTorqueNet[i] = torque

# from knowing the torque, we could divide out the rotational inertia to figure the
# acceleration of rotation
thetadotdot <- torque/I_CM
cDDTheta[i] <- thetadotdot

# from this, we could of course tally for the velocity of theta as well
thetadot <- dt*thetadotdot + thetadot
cDTheta[i] <- thetadot

# After knowing the value for theta, we could use it to calculate the net forces in
# both components.
# we define up as +, down as -, right as +, left as -
fnet_x <- FT*sin(PHI) + MASS*GRAV*sin(OMEGA)
fnet_y <- FT*cos(PHI) - MASS*GRAV*cos(OMEGA)
# "I think ax and ay will be constant with time" --- Mark

cFNetX[i] = fnet_x
cFNetY[i] = fnet_y

# Dividing the mass out, we could get accelerations
ax <- fnet_x/MASS
ay <- fnet_y/MASS

# We also tally the components seperately for velocity
vx <- ax*dt + vx
vy <- ay*dt + vy

# We finally tally the positions as well
x <- vx*dt + x
y <- vy*dt + y

# And we add them together to tally
cAccelX[i] = ax
cAccelY[i] = ay

cVelX[i] = ax
cVelY[i] = ay

cPosX[i] = x
cPosY[i] = y

cKERot[i] = 0.5 * I_CM * thetadot^2
cKETrans[i] = 0.5 * MASS * (vx^2+vy^2)

# We increment the time and theta based on the tallying variable
time <- dt + time
```

```
    theta <- dt*thetadot + theta
}

rotating_link <- data.frame(cTime,
    cTheta,
    cDTheta,
    cDDTheta,
    cTorqueNet,
    cAccelX,
    cAccelY,
    cVelX,
    cVelY,
    cPosX,
    cPosY,
    cKERot,
    cKETrans)

names(rotating_link) <- c("time",
  "theta",
  "d.theta",
  "dd.theta",
  "net.torque",
  "accel.x",
  "accel.y",
  "vel.x",
  "vel.y",
  "pos.x",
  "pos.y",
  "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 6.23538290724796e-07 0.0124707635697569 62.353806625089 5.19615055209075 6.97836748313892
0.64126402568861 6.97836748313892 0.64126402568861 2.09351024494167e-07 1.92379207706583e-08
6.47999766719895e-06 9.82176645607458e-07
2e-04 1.87061464770048e-06 0.0187061397427812 62.3537617302432 5.1961468108536 6.97836748313892
0.64126402568861 6.97836748313892 0.64126402568861 4.18702048988335e-07 3.84758415413166e-08
1.45799860031857e-05 2.20989745261678e-06
3e-04 3.7412286219786e-06 0.0249415091815625 62.3536943878128 5.1961411989844 6.97836748313892
0.64126402568861 6.97836748313892 0.64126402568861 6.97836748313892e-07 6.4126402568861e-08
2.59199533439152e-05 3.92870658242983e-06
4e-04 6.23537954013485e-06 0.0311768696413229 62.353604597604 5.196133716467 6.97836748313892
0.64126402568861 6.97836748313892 0.64126402568861 1.04675512247084e-06 9.61896038532915e-08
4.04998833596683e-05 6.13860403504662e-06
5e-04 9.35306650426713e-06 0.0374122188772587 62.3534923593581 5.19612436327984 6.97836748313892
0.64126402568861 6.97836748313892 0.64126402568861 1.46545717145917e-06 1.34665445394608e-07
5.83197550549962e-05 8.83958981046713e-06
```

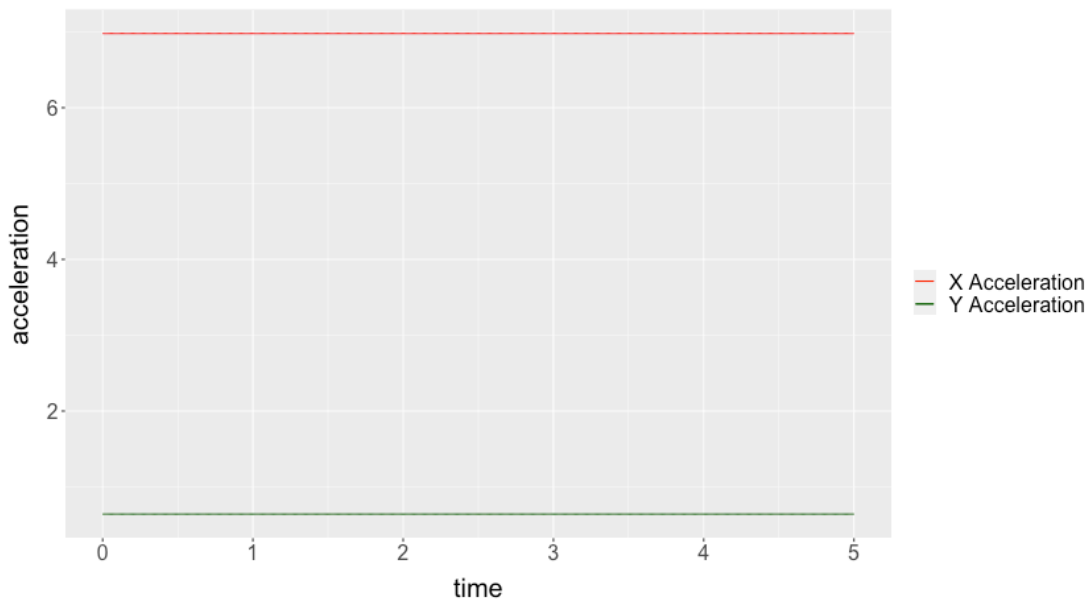
```
6e-04 1.3094288391993e-05 0.0436475546445339 62.3533576727519 5.19611313939599 6.97836748313892
0.64126402568861 6.97836748313892 0.64126402568861 1.9539428952789e-06 1.79553927192811e-07
7.93795427686487e-05 1.20316639086914e-05
```

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

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

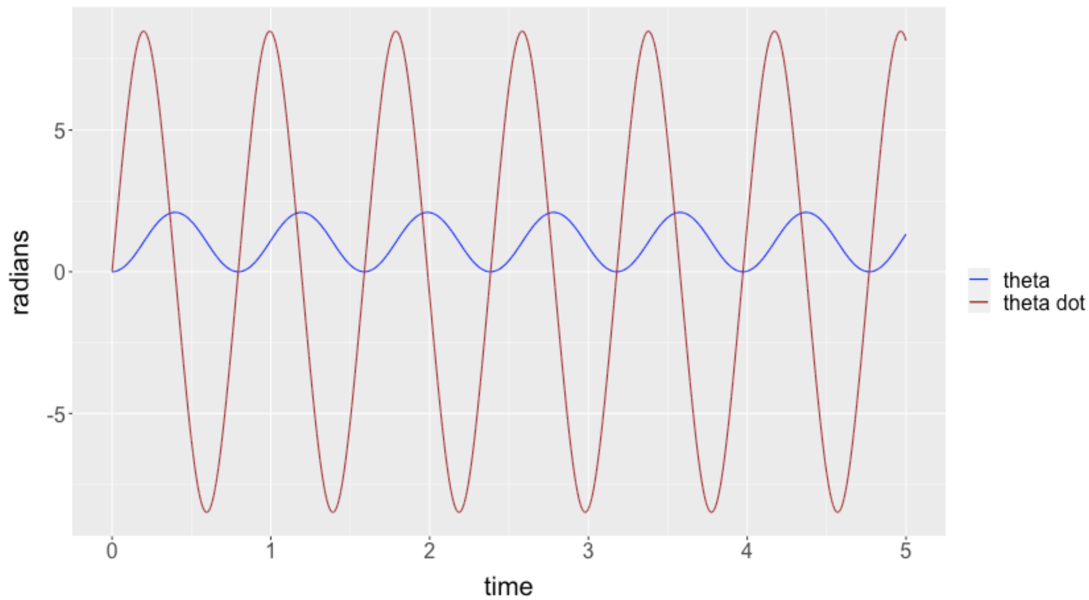
We will graph `ax` and `ay` on top of each other:

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



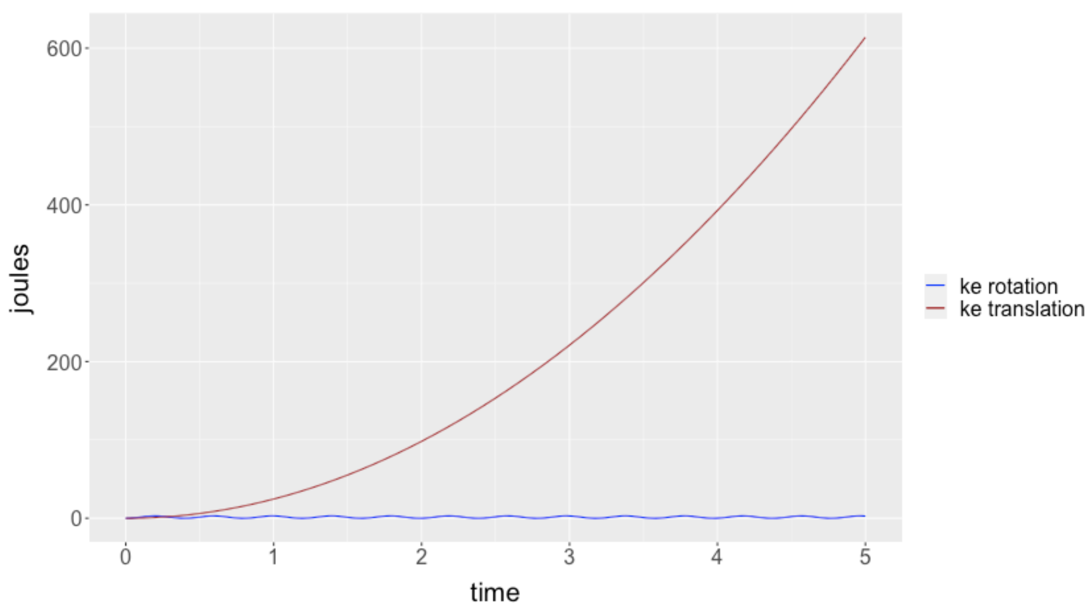
Theta dot atop theta:

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



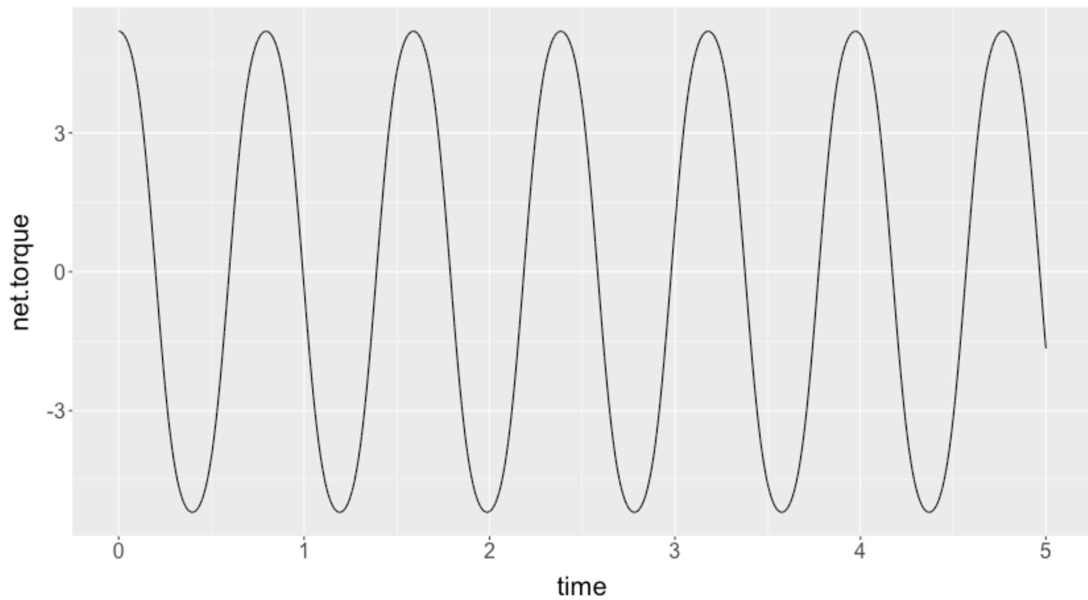
We finally, plot KE rotation and translation

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



Let's also plot torque as well.

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



Finally, let's plot velocity and position

```
rotating_link %>% ggplot() + geom_line(aes(x=time, y=pos.x, colour="x position")) + geom_line(aes(x=tim
```