***Keith Anderson***

***Hard Code in Rstudio***

library(grid)

xdot <- function(y,x,t) (x-y)

ydot <- function(y,x,t) (1-(exp(x)))

Twooderk4 <- function(f, g, t0, t1, x0, y0, n) {

vt <- double(n + 1)

vx <- double(n + 1)

vy <- double(n + 1)

vt[1] <- t <- t0

vx[1] <- x <- x0

vy[1] <- y <- y0

h <- (t1 - t0)/n

for(i in 1:n) {

k1 <- h\*f(y, x, t)

l1 <- h\*g(y, x, t)

k2 <- h\*f(y + 0.5\*l1, x + 0.5\*k1, t + 0.5\*h)

l2 <- h\*g(y + 0.5\*l1, x + 0.5\*k1, t + 0.5\*h)

k3 <- h\*f(y + 0.5\*l2, x + 0.5\*k2, t + 0.5\*h)

l3 <- h\*g(y + 0.5\*l2, x + 0.5\*k2, t + 0.5\*h)

k4 <- h\*f(y + l3, x + k3, t + h)

l4 <- h\*g(y + l3, x + k3, t + h)

vx[i + 1] <- x <- x + (k1 + k2 + k2 + k3 + k3 + k4)/6

vy[i + 1] <- y <- y + (l1 + l2 + l2 + l3 + l3 + l4)/6

vt[i + 1] <- t <- x0 + i\*h

}

return(data.frame(x=vx,y=vy))

}

sol1 <- Twooderk4(xdot, ydot, 0, 5, 4, 4, 400)

sol2 <- Twooderk4(xdot, ydot, 0, 5, 2, 4, 400)

sol3 <- Twooderk4(xdot, ydot, 0, 5, 3, 5, 400)

sol4 <- Twooderk4(xdot, ydot, 0, 5, 2, 5, 400)

sol5 <- Twooderk4(xdot, ydot, 0, 5, -1, -1.3, 400)

sol6 <- Twooderk4(xdot, ydot, 0, 5, -2.4, -3.7, 400)

sol7 <- Twooderk4(xdot, ydot, 0, 5, 0, -0.01, 400)

sol8 <- Twooderk4(xdot, ydot, 0, 5, 0, 0.01, 400)

sol9 <- Twooderk4(xdot, ydot, 0, 5, -3.15, -4, 400)

sola <- Twooderk4(xdot, ydot, 0, 5, 1.6, 3.4, 400)

solb <- Twooderk4(xdot, ydot, 0, 5, 0.5, 1, 400)

solc <- Twooderk4(xdot, ydot, 0, 5, -0.5, -2, 400)

ggplot() +

geom\_point(data=sol1, col="red", aes(x=x, y=y)) +

geom\_point(data=sol2, col="sienna1", aes(x=x, y=y)) +

geom\_point(data=sol3, col="yellow3", aes(x=x, y=y)) +

geom\_point(data=sol4, col="green", aes(x=x, y=y)) +

geom\_point(data=sol5, col="cyan", aes(x=x, y=y)) +

geom\_point(data=sol6, col="blue3", aes(x=x, y=y)) +

geom\_point(data=sol7, col="purple", aes(x=x, y=y)) +

geom\_point(data=sol8, col="black", aes(x=x, y=y)) +

geom\_point(data=sol9, col="hotpink", aes(x=x, y=y)) +

geom\_point(data=sola, col="gold4", aes(x=x, y=y)) +

geom\_point(data=solb, col="firebrick", aes(x=x, y=y)) +

geom\_point(data=solc, col="maroon3", aes(x=x, y=y)) +

coord\_cartesian(xlim=c(-5, 5), ylim=c(-5, 5)) +

labs(title="6.1.1 Quatitative phase portrait", subtitle="By Keith Anderson", y="y", x="x", caption="Math")

***Keith Anderson***

***Hard Code in Rstudio***

library(grid)

xdot <- function(y,x,t) (x-(x\*x\*x))

ydot <- function(y,x,t) (-y)

Twooderk4 <- function(f, g, t0, t1, x0, y0, n) {

vt <- double(n + 1)

vx <- double(n + 1)

vy <- double(n + 1)

vt[1] <- t <- t0

vx[1] <- x <- x0

vy[1] <- y <- y0

h <- (t1 - t0)/n

for(i in 1:n) {

k1 <- h\*f(y, x, t)

l1 <- h\*g(y, x, t)

k2 <- h\*f(y + 0.5\*l1, x + 0.5\*k1, t + 0.5\*h)

l2 <- h\*g(y + 0.5\*l1, x + 0.5\*k1, t + 0.5\*h)

k3 <- h\*f(y + 0.5\*l2, x + 0.5\*k2, t + 0.5\*h)

l3 <- h\*g(y + 0.5\*l2, x + 0.5\*k2, t + 0.5\*h)

k4 <- h\*f(y + l3, x + k3, t + h)

l4 <- h\*g(y + l3, x + k3, t + h)

vx[i + 1] <- x <- x + (k1 + k2 + k2 + k3 + k3 + k4)/6

vy[i + 1] <- y <- y + (l1 + l2 + l2 + l3 + l3 + l4)/6

vt[i + 1] <- t <- x0 + i\*h

}

return(data.frame(x=vx,y=vy))

}

sol1 <- Twooderk4(xdot, ydot, 0, 5, 1, 3, 400)

sol2 <- Twooderk4(xdot, ydot, 0, 5, 0, 3, 400)

sol3 <- Twooderk4(xdot, ydot, 0, 5, -1, 3, 400)

sol4 <- Twooderk4(xdot, ydot, 0, 5, 0.55, -3, 400)

sol5 <- Twooderk4(xdot, ydot, 0, 5, -1, -3, 400)

sol6 <- Twooderk4(xdot, ydot, 0, 5, 3, -1, 400)

sol7 <- Twooderk4(xdot, ydot, 0, 5, 0, -3, 400)

sol8 <- Twooderk4(xdot, ydot, 0, 5, 0, 3, 400)

sol9 <- Twooderk4(xdot, ydot, 0, 5, -3, -0.5, 400)

sola <- Twooderk4(xdot, ydot, 0, 5, 3, 3, 400)

solb <- Twooderk4(xdot, ydot, 0, 5, 0.05, 3, 400)

solc <- Twooderk4(xdot, ydot, 0, 5, -0.45, -3, 400)

ggplot() +

geom\_point(data=sol1, col="red", aes(x=x, y=y)) +

geom\_point(data=sol2, col="sienna1", aes(x=x, y=y)) +

geom\_point(data=sol3, col="yellow3", aes(x=x, y=y)) +

geom\_point(data=sol4, col="green", aes(x=x, y=y)) +

geom\_point(data=sol5, col="cyan", aes(x=x, y=y)) +

geom\_point(data=sol6, col="blue3", aes(x=x, y=y)) +

geom\_point(data=sol7, col="purple", aes(x=x, y=y)) +

geom\_point(data=sol8, col="black", aes(x=x, y=y)) +

geom\_point(data=sol9, col="hotpink", aes(x=x, y=y)) +

geom\_point(data=sola, col="gold4", aes(x=x, y=y)) +

geom\_point(data=solb, col="firebrick", aes(x=x, y=y)) +

geom\_point(data=solc, col="maroon3", aes(x=x, y=y)) +

coord\_cartesian(xlim=c(-3, 3), ylim=c(-3, 3)) +

labs(title="6.1.1 Quatitative phase portrait", subtitle="By Keith Anderson", y="y", x="x", caption="Math")

***Keith Anderson***

***Hard Code in Rstudio***

library(grid)

xdot <- function(y,x,t) (y)

ydot <- function(y,x,t) (-x+(y\*(1-(x^2))))

Twooderk4 <- function(f, g, t0, t1, x0, y0, n) {

vt <- double(n + 1)

vx <- double(n + 1)

vy <- double(n + 1)

vt[1] <- t <- t0

vx[1] <- x <- x0

vy[1] <- y <- y0

h <- (t1 - t0)/n

for(i in 1:n) {

k1 <- h\*f(y, x, t)

l1 <- h\*g(y, x, t)

k2 <- h\*f(y + 0.5\*l1, x + 0.5\*k1, t + 0.5\*h)

l2 <- h\*g(y + 0.5\*l1, x + 0.5\*k1, t + 0.5\*h)

k3 <- h\*f(y + 0.5\*l2, x + 0.5\*k2, t + 0.5\*h)

l3 <- h\*g(y + 0.5\*l2, x + 0.5\*k2, t + 0.5\*h)

k4 <- h\*f(y + l3, x + k3, t + h)

l4 <- h\*g(y + l3, x + k3, t + h)

vx[i + 1] <- x <- x + (k1 + k2 + k2 + k3 + k3 + k4)/6

vy[i + 1] <- y <- y + (l1 + l2 + l2 + l3 + l3 + l4)/6

vt[i + 1] <- t <- x0 + i\*h

}

return(data.frame(x=vx,y=vy))

}

sol1 <- Twooderk4(xdot, ydot, 0, 10, 0.01, 0.03, 400)

sol2 <- Twooderk4(xdot, ydot, 0, 10, -1.25, -1.25, 400)

sol3 <- Twooderk4(xdot, ydot, 0, 10, -1.25, 2.5, 400)

sol4 <- Twooderk4(xdot, ydot, 0, 10, 1.25, 1.25, 400)

sol5 <- Twooderk4(xdot, ydot, 0, 10, 1.25, -2.5, 400)

sol6 <- Twooderk4(xdot, ydot, 0, 10, 3, -3, 400)

sol7 <- Twooderk4(xdot, ydot, 0, 10, 0, -4, 400)

sol8 <- Twooderk4(xdot, ydot, 0, 10, 0, 4, 400)

sol9 <- Twooderk4(xdot, ydot, 0, 10, -3, -2.5, 400)

sola <- Twooderk4(xdot, ydot, 0, 10, -3, 4, 400)

solb <- Twooderk4(xdot, ydot, 0, 10, 5, 5, 400)

solc <- Twooderk4(xdot, ydot, 0, 10, -5, -5, 400)

ggplot() +

geom\_point(data=sol1, col="red", aes(x=x, y=y)) +

geom\_point(data=sol2, col="sienna1", aes(x=x, y=y)) +

geom\_point(data=sol3, col="yellow3", aes(x=x, y=y)) +

geom\_point(data=sol4, col="green", aes(x=x, y=y)) +

geom\_point(data=sol5, col="cyan", aes(x=x, y=y)) +

geom\_point(data=sol6, col="blue3", aes(x=x, y=y)) +

geom\_point(data=sol7, col="purple", aes(x=x, y=y)) +

geom\_point(data=sol8, col="black", aes(x=x, y=y)) +

geom\_point(data=sol9, col="hotpink", aes(x=x, y=y)) +

geom\_point(data=sola, col="gold4", aes(x=x, y=y)) +

geom\_point(data=solb, col="firebrick", aes(x=x, y=y)) +

geom\_point(data=solc, col="maroon3", aes(x=x, y=y)) +

coord\_cartesian(xlim=c(-5, 5), ylim=c(-5, 5)) +

labs(title="6.1.8 Quatitative phase portrait", subtitle="By Keith Anderson", y="y", x="x", caption="Math")