```
knitr::opts_knit$set(root.dir = '~/Desktop/bio_modelling_course/mod4/proj4')
```

R code for question 1

```
library(magrittr)
library(tidyverse)
```

```
## ── Attaching packages ─────────────────────────────────────────────────────────────────────── tidyverse 1.2.1 ──
```

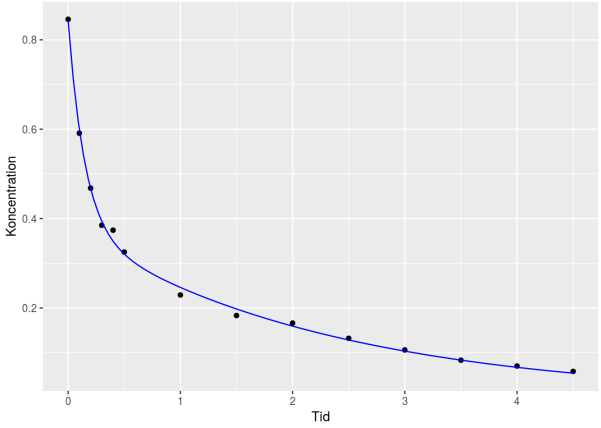
```
## ✔ ggplot2 2.2.1     ✔ purrr   0.2.4
## ✔ tibble  1.4.2     ✔ dplyr   0.7.4
## ✔ tidyr   0.8.0     ✔ stringr 1.3.0
## ✔ readr   1.1.1     ✔ forcats 0.3.0
```

```
## ── Conflicts ────────────────────────────────────────────────────────────────────────── tidyverse_conflicts() ──
## ✖ tidyr::extract()   masks magrittr::extract()
## ✖ dplyr::filter()    masks stats::filter()
## ✖ dplyr::lag()       masks stats::lag()
## ✖ purrr::set_names() masks magrittr::set_names()
```

```
data <- read_delim('anaestesi-data.txt',' ')
```

```
## Parsed with column specification:
## cols(
##   Tid = col_double(),
##   Koncentration = col_double()
## )
```

```
#f
fit <- nls(Koncentration~A1*exp(l1*Tid)+A2*exp(l2*Tid),
           data=data,
           start=list(A1=1, A2=1, l1=-1, l2=-2))
pars <- fit$m$getPars()
Kb <- function(t) {
  unname(pars['A1']*exp(pars['l1']*t) + pars['A2']*exp(pars['l2']*t))
}
ggplot(data, aes(Tid, Koncentration)) +
  geom_point() +
  stat_function(fun=Kb, color='blue')
```




```
#g
Kb0 <- 0.846
a2_1 <- pars['A1']*(pars['l1']-pars['l2'])/Kb0 - pars['l1']
a2_2 <- pars['A1']*(pars['l2']-pars['l1'])/Kb0 - pars['l2']
a2 <- mean(c(a2_1,a2_2))
a2
```

```
## [1] 3.585659
```

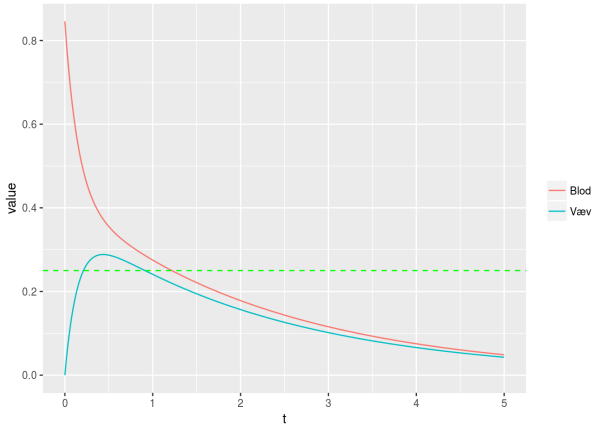
```
a3 <- unname(pars['l1']*pars['l2']/a2)
a3
```

```
## [1] 0.8124418
```

```
a1 <- unname(-pars['l1']-pars['l2']-a2-a3)
a1
```

```
## [1] 2.773217
```

```
#h
c1 <- unname(Kb0/(pars['l1']-pars['l2']))
c2 <- unname(Kb0/(pars['l2']-pars['l1']))
q1 <- unname(c(a2 + pars['l1'], a1))
q2 <- unname(c(a2 + pars['l2'], a1))
model <- function(t) unname(exp(pars['l1']*t)*c1*q1 + exp(pars['l2']*t)*c2*q2)
ts <- seq(0,5,0.01)
sim <- data.frame(t(as.matrix(data.frame(map(ts, model)))))
rownames(sim) <- NULL
colnames(sim) <- c('Blod', 'Væv')
sim %<>% mutate(t = ts)
sim %>%
  gather(key='key', value='value', -t) %>%
  ggplot(aes(t, value, color=key)) +
  geom_line() +
  geom_hline(yintercept = 0.25, color='green', linetype='dashed') +
  theme(legend.title = element_blank())
```




```
uniroot(function(t) model(t)[2] - 0.25, c(0,0.75))$root
```

```
## [1] 0.2113731
```

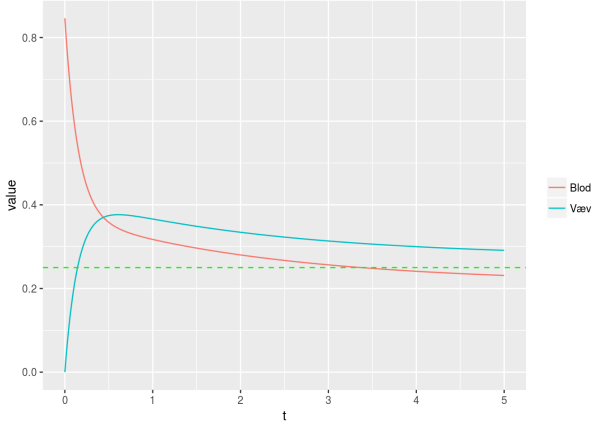
```
uniroot(function(t) model(t)[2] - 0.25, c(0.75,1.5))$root
```

```
## [1] 0.9120789
```

```
#
d0 <- a3/a2*0.275
equib <- c(d0*a1/a3,d0*a2/a3)
b <- c(Kb0,0)-equib
A <- matrix(c(q1,q2),nrow = 2)
cs <- solve(A, b)
cs
```

```
## [1]  0.05083618 -0.14999899
```

```
model <- function(t) unname(exp(pars['l1']*t)*cs[1]*q1 + exp(pars['l2']*t)*cs[2]*q2 + equib)
ts <- seq(0,5,0.01)
sim <- data.frame(t(as.matrix(data.frame(map(ts, model)))))
rownames(sim) <- NULL
colnames(sim) <- c('Blod', 'Væv')
sim %<>% mutate(t = ts)
sim %>%
  gather(key='key', value='value', -t) %>%
  ggplot(aes(t, value, color=key)) +
  geom_line() +
  geom_hline(yintercept = 0.25, color='green', linetype='dashed') +
  theme(legend.title = element_blank())
```

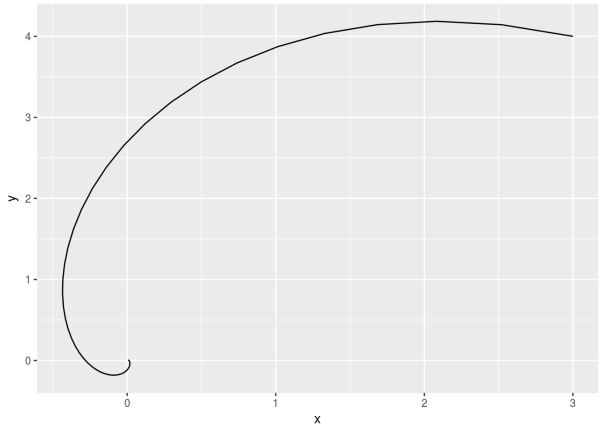



```
uniroot(function(t) model(t)[2] - 0.25, c(0,0.75))$root
```

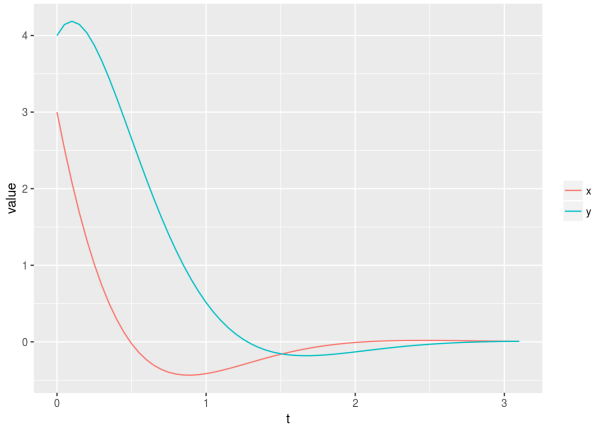
```
## [1] 0.1441508
```

R code for question 2

```
b1 <- 3
b2 <- -2
x <- function(t) {
  b1*exp(-2*t)*cos(2*t) +
    b2*exp(-2*t)*sin(2*t)
}
y <- function(t) {
  b1*exp(-2*t)*2*sin(2*t) +
    b2*exp(-2*t)*-2*cos(2*t)
}
sim <- data_frame(t = seq(0,pi,by=0.05),
                  x = x(t),
                  y = y(t))
sim %>% ggplot(aes(x,y)) + geom_path()
```




```
sim %>%
  gather(key = 'key', value = 'value', -t) %>%
  ggplot(aes(t, value, color=key)) +
  geom_line() +
  theme(legend.title = element_blank())
```




```
solve(matrix(c(-4,-4,1,-4),nrow = 2), c(1,-2))
```

```
## [1] -0.1  0.6
```

R code for question 3

```
library(tidyverse)
kg <- 2.2
kd <- 0.15
yg <- 0.8
p0 <- 10
equib <- c(p0*yg/kd*(1-yg), p0/kg*(1-yg))
A <- matrix(c(-kg,yg*kg,kd,-kd),nrow=2)
l1 <- eigen(A)$values[1]
l2 <- eigen(A)$values[2]
q1 <- eigen(A)$vectors[1,]
q2 <- eigen(A)$vectors[2,]
l1
```

```
## [1] -2.321571
```

```
l2
```

```
## [1] -0.02842903
```

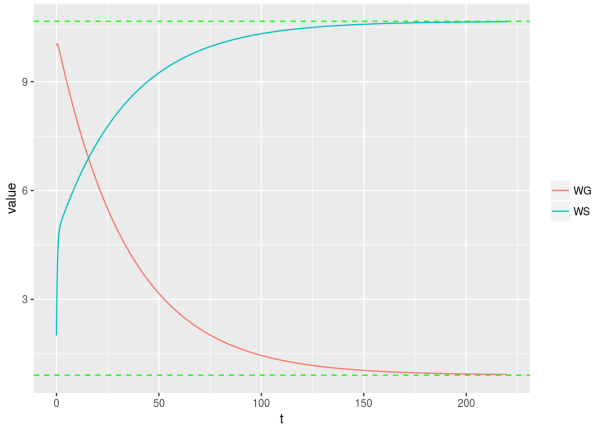
```
q1
```

```
## [1] -0.77688406 -0.06891022
```

```
q2
```

```
## [1]  0.6296437 -0.9976229
```

```
cs <- solve(matrix(c(q1,q2),nrow=2), c(2,10)-equib)
x <- function(t) cs[1]*exp(l1*t)*q1[1] + cs[2]*exp(l2*t)*q2[1] + equib[1]
y <- function(t) cs[1]*exp(l1*t)*q1[2] + cs[2]*exp(l2*t)*q2[2] + equib[2]
sim <- data_frame(t = seq(0,220,by=0.05),
                  WS = x(t),
                  WG = y(t))
sim %>%
  gather(key = 'key', value = 'value', -t) %>%
  ggplot(aes(t, value, color=key)) +
  geom_line() +
  geom_hline(yintercept = equib[1], color='green', linetype='dashed') +
  geom_hline(yintercept = equib[2], color='green', linetype='dashed') +
  theme(legend.title = element_blank())
```


value
9
6
3
0
50
100
150
200
t
WG
WS