Setup

```
knitr::opts_chunk$set(echo = TRUE, comment = "#>")
library(glue)
library(ggforce)
library(gganimate)
library(tidyverse)
theme_set(theme_minimal())
```

Simulation

Global constants

Below are a few constants to define from the beginning. `time_step_size` is the distance traveled at each time step of the simulation. `minimum_distance` is the minimum safe distance that the two people need to stay from each other.

```
time_step_size <- 0.01
minimum_distance <- 6
```

Subroutines

The `update_tracker()` function updates a data table with a person's current location for a given time step.

```
update_tracker <- function(pos, time_step, tracker_tib) {
bind_rows(
tracker_tib,
tibble(x = pos[[1]], y = pos[[2]], t = time_step)
)
}
```

The `move_person()` function moves a person left or right by a given amount `x`.

```
move_person <- function(person, x, right = TRUE) {
if (right) {
person[[1]] <- person[[1]] + x
} else {
person[[1]] <- person[[1]] - x
}
return(person)
}
```

The `shift_person()` function shifts a person up or down by a given about `y`.

```
shift_person <- function(person, y, down = TRUE) {
if (down) {
person[[2]] <- person[[2]] - y
} else {
person[[2]] <- person[[2]] + y
}
return(person)
}
```

The `measure_distance()` function measures the distances between two ((x, y)) coordinates `a` and `b`.

```
measure_distance <- function(a, b) {
dist(matrix(c(a, b), nrow = 2, byrow = TRUE))[[1]]
}
```

Main simulation loop

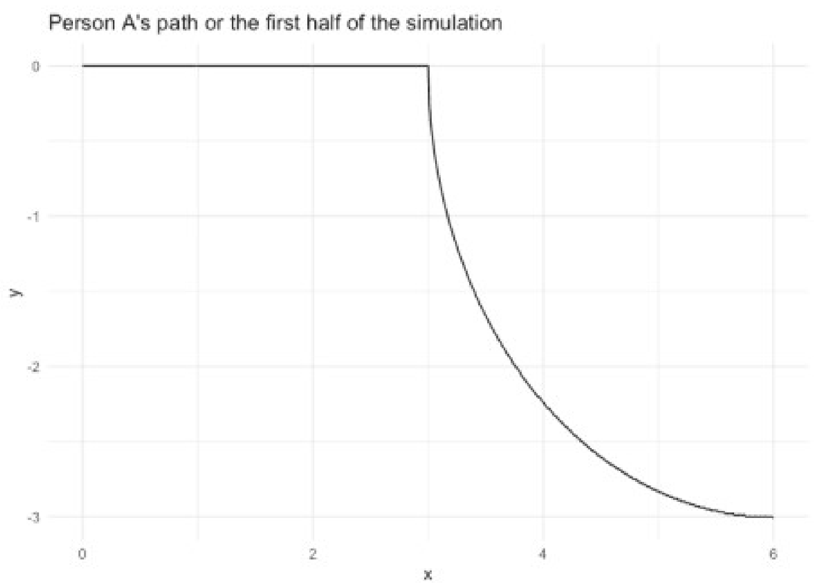
The following for-loop moves each person, `A` and `B`, towards each other from 12 feet away. At each step, the distance between one another is measured, and if they are too close to each other, they are slowly moved apart until they are again safe. The movement of each person is tracked in a data table.

One complication I ran into was how to move the people back towards the middle after they passed each other. Instead, I realized that the problem is symmetric, so I could just run the first half of the simulation – from 12 to 6 feet apart – and then use the symmetry to get the second half.

```
A <- c(0, 0)
B <- c(12, 0)
A_tracker <- update_tracker(A, 0, tibble())
B_tracker <- update_tracker(B, 0, tibble())
for (t in seq(time_step_size, 6, time_step_size)) {
A <- move_person(A, time_step_size)
B <- move_person(B, time_step_size, right = FALSE)
while (measure_distance(A, B) < minimum_distance) {
A <- shift_person(A, 0.01, down = TRUE)
B <- shift_person(B, 0.01, down = FALSE)
}
A_tracker <- update_tracker(A, t, A_tracker)
B_tracker <- update_tracker(B, t, B_tracker)
}
```

The plot below shows the path of `A` for the first half of the simulation.

```
A_tracker %>%
ggplot(aes(x = x, y = y)) +
geom_line() +
labs(title = "Person A's path or the first half of the simulation")
```

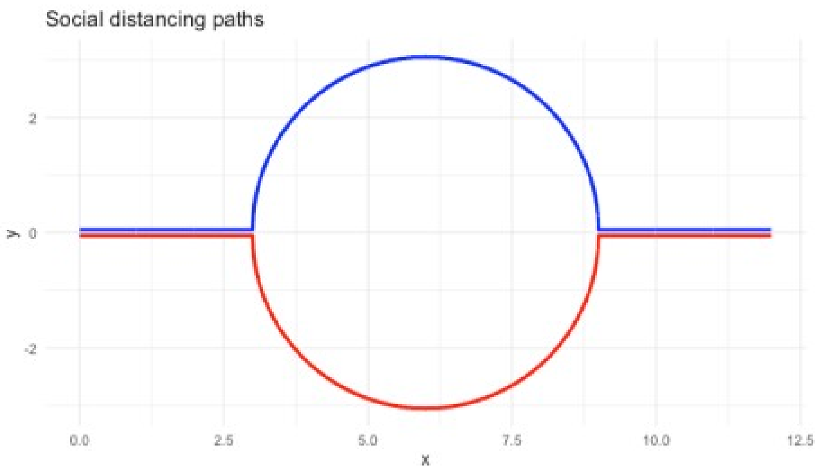


The simulation was completed by copying the tracker data tables for `A` and `B` and combing these into a single `people_tracker` data table.

```
A_tracker <- bind_rows(
A_tracker,
A_tracker %>%
mutate(x = 6 + x, y = rev(y), t = 6 + t) %>%
filter(t != 6)
)
B_tracker <- bind_rows(
B_tracker,
B_tracker %>%
mutate(x = x - 6, y = rev(y), t = 6 + t) %>%
filter(t != 6)
)
ppl_tracker <- inner_join(A_tracker,
B_tracker,
by = "t",
suffix = c("_A", "_B"))
```

Finally, I could plot the paths taken by the two individuals while always remaining as close to the middle of the sidewalk as possible and keeping 6 feet apart.

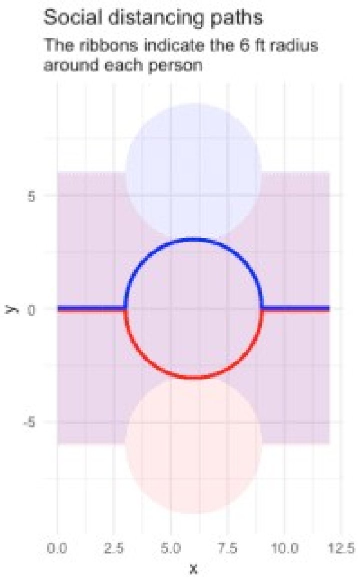
```
ppl_tracker %>%
mutate(y_A = y_A - 0.05,
y_B = y_B + 0.05) %>%
ggplot() +
geom_line(aes(x = x_A, y = y_A), color = "red", size = 1.1) +
geom_line(aes(x = x_B, y = y_B), color = "blue", size = 1.1) +
coord_equal() +
labs(x = "x", y = "y",
title = "Social distancing paths")
```



The social distancing rules guides are shown in the plot below, they they overlap a lot because there is no time dimension.

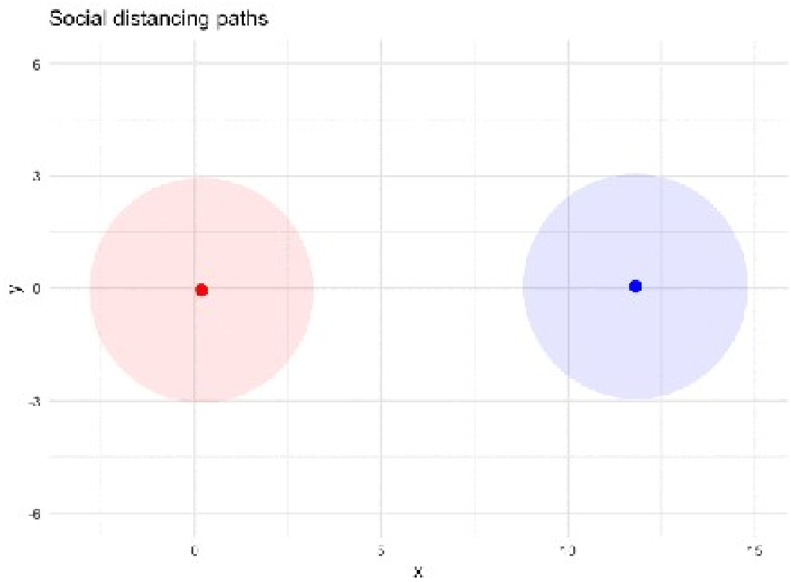
```
ppl_tracker %>%
mutate(y_A = y_A - 0.05,
y_B = y_B + 0.05) %>%
ggplot() +
```

```
geom_ribbon(aes(x = x_A,
ymin = y_A-minimum_distance, ymax = y_A+minimum_distance),
fill = "red", color = NA, alpha = 0.1) +
geom_ribbon(aes(x = x_B,
ymin = y_B-minimum_distance, ymax = y_B+minimum_distance),
fill = "blue", color = NA, alpha = 0.1) +
geom_line(aes(x = x_A, y = y_A), color = "red", size = 1.1) +
geom_line(aes(x = x_B, y = y_B), color = "blue", size = 1.1) +
coord_equal() +
labs(x = "x", y = "y",
title = "Social distancing paths",
subtitle = "The ribbons indicate the 6 ft radius\naround each person")
```



I used
'gganimate' to show the two people
walking towards each other with their 6-foot social distancing guides.

```
ppl_tracker %>%
mutate(y_A = y_A - 0.05,
y_B = y_B + 0.05) %>%
filter(row_number() %% 20 == 0) %>%
ggplot() +
geom_point(aes(x = x_A, y = y_A), color = "red", size = 3) +
geom_point(aes(x = x_B, y = y_B), color = "blue", size = 3) +
geom_circle(aes(x0 = x_A, y0 = y_A, r = minimum_distance / 2),
fill = "red", alpha = 0.1, color = NA) +
geom_circle(aes(x0 = x_B, y0 = y_B, r = minimum_distance / 2),
fill = "blue", alpha = 0.1, color = NA) +
coord_equal() +
labs(x = "x", y = "y", title = "Social distancing paths") +
transition_states(t, transition_length = 0.01,
state_length = 0, wrap = FALSE)
```



Total distance traveled

Finally, as the Riddler requested, I calculated the total distance traveled by person `A`.

```
total_distance <- 0
for (i in seq(2, nrow(A_tracker))) {
a <- c(A_tracker$x[[i - 1]], A_tracker$y[[i - 1]])
b <- c(A_tracker$x[[i]], A_tracker$y[[i]])
total_distance <- total_distance + measure_distance(a, b)
}
total_distance <- round(total_distance, 1)
```

Each person travels a total of 15.7 ft, 3.7 more feet than without the need for social distancing.