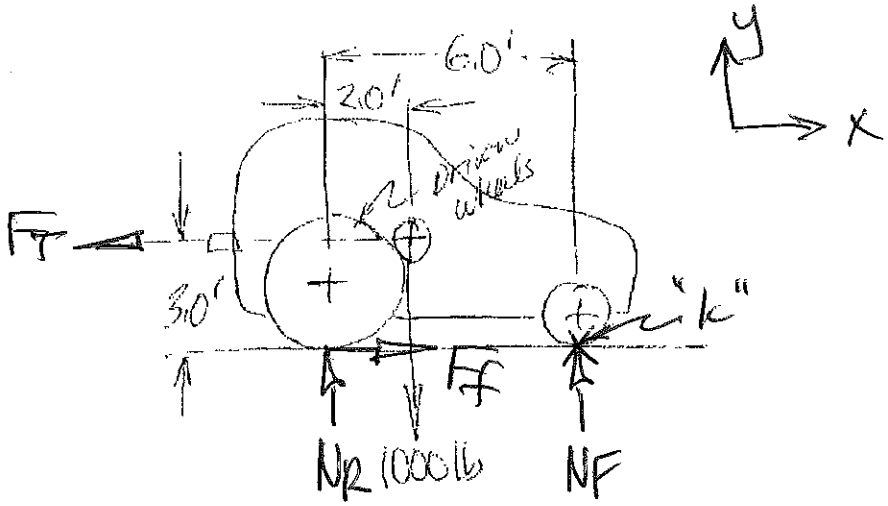
RBE1001: Introduction to Robotics
(2017D)

Quiz #1

Name: Solutions

1. (40 pts total) You have been contracted to build a robotic rear-wheel drive tractor. You are told that the tires can develop a coefficient of friction of 1.1 with the ground. Your vehicle is unlimited by torque and has the dimensions as shown below. You need to determine how much horizontal pulling force (tractive effort) can be developed from the attachment point as shown.

a) (20 pts) Add content to the following sketch to form it into a complete FBD of the **robot for the situation described**.



b) (10 pts) Using your FBD (above), complete the following Equations of Equilibrium that may be used to solve the problem. (***Specify your selected point for computing moments on the FBD above and ΣM_z eqn below.**)

$\Sigma F_x = 0 =$ $F_f - F_T$

$\Sigma F_y = 0 =$ $N_R + N_F - 1000$

$\Sigma M_{z\,@\,k} = 0 =$ $F_T(3) + 1000(6-2) - N_R(6)$

It tips over before it spins out! And to actually develop 1630 lb, the NF would equal −4801b!

c) (10 pts) What is the maximum (not torque-limited) pulling force the robot can develop?

1) Assume traction limit:

$\therefore F_f = F_T = 1.1 N_R$; $N_R = \frac{F_T}{1.1}$

$\Sigma M_Z = F_T(3) + 4000 - \frac{F_T}{1.1}(6) = 0$

$\therefore F_T = 1630\text{lb}$

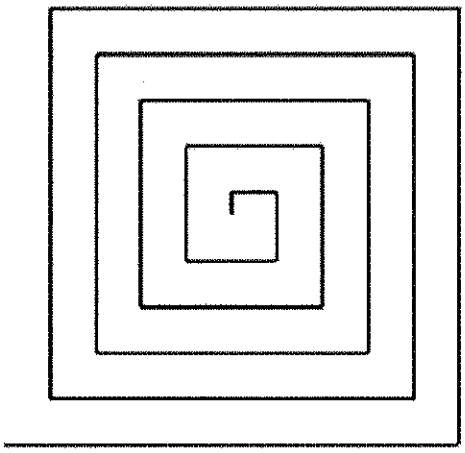
2) Assume stability limit:

$\therefore N_F = 0$; $N_R = 1000$

$\Sigma M_Z = F_T(3) + 4000 - 1000(6)$

$\therefore F_T = 667\text{lb}$ ←

2. (30 pts total) As a consultant you delivered a robot to you client that would search an area by making vertical columns that moved across the room. Your new customer likes that but really wants you to build and program a robot that does a search of an area using a square spiral program that looks like this:



This robot should start in the center with the robot facing up (at the beginning of the smallest vertical line). The first short vertical line is 10 inches, and each subsequent line is 10" longer than the previous one. Exit the program after doing this pattern as shown in the picture.

You have the following functions available to your program:

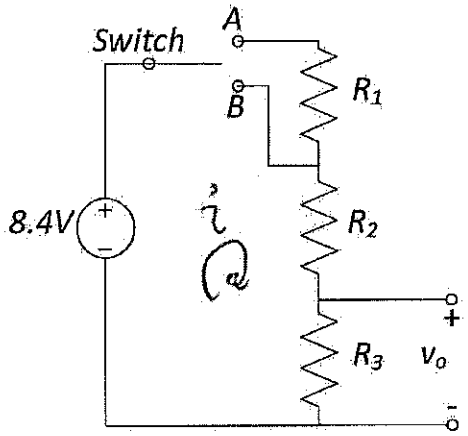
forward(int inches): move the robot forward for some distance in inches
turn(degrees): turn the robot some number of degrees, positive degrees are for right turns, and negative degrees are for left turns.
exit(): exits the program.

You should show the setup() and loop() functions as you would in any other Arduino program but you don't have to set up the motors, that's contained inside the forward and turn functions. `#include "Arduino.h"`

```
void forward(int inches);
void turn(int degrees);
void exit();

const int sideInitial = 10;    // initial line length in inches
const int sideIncrement = 10;  // side increment after each turn

int sideLength;
// length of current side
int numberSides;
// number of sides drawn so far
```

```
void setup()
{
sideLength = sideInitial;
// initialize length
numberSides = 0;
// initialize number of sides drawn
}

/*
 * Program to draw a rectangular spiral starting from the inside and
 * increasing the side length after each face.
 */
void loop()
{
forward(sideLength);       // draw one of the lines
turn(90);
// turn to the right
sideLength = sideLength + sideIncrement;  // increment the side length
numberSides = numberSides + 1;  // increment the number of sides drawn
if (numberSides == 20)
  // exit if finished with the drawing
exit();

}
```

3. (30 pts) A robot operated by an 8.4V battery uses a sensor that requires either 5.1V or 6.3V as a supply voltage (i.e. v_0 = 5.1V or 6.3V) depending on the position of a switch. The switch connects the battery to either A or B as shown on the circuit below.



a) (12 pts) With the switch in Position B, v_0 is 6.3V and the current drawn from the battery is 10mA. Find R_2 and R_3.

R_3: $v_0 = iR_3$ $\quad R_3 = \frac{v_0}{i} = \frac{6.3V}{0.01A} \times \left(\frac{1\Omega A}{V}\right) = 630\Omega$

R_2: $\quad R_2 = \frac{(8.4V - v_0)}{0.01A} \times \frac{1\Omega A}{V} = \frac{2.1V}{0.01A} \times \frac{1\Omega A}{V} = 210\Omega$ (6.3V)

b) (10 pts) With the switch in Position A, v_0 is 5.1V. Find R_1. (*Note that the current in the circuit will* ***not*** *be the same as part (a).)*

$i = \frac{5.1V}{630\Omega} \times \frac{1\Omega A}{V} = 8.1mA$

$(R_1 + R_2 + R_3)\, i = 8.4V$

$R_1 = \frac{8.4V}{8.1mA} \times \frac{1000mA}{A} \times \frac{1\Omega A}{V} - R_2 - R_3 = 198\Omega \sim 200\Omega$ (630Ω, 210Ω)

c) (8 pts) What is the power supplied by the battery in part (b)?

$P = iv = 8.4V \; 8.1mA \times \frac{1A}{1000mA} \times \frac{1W}{VA} = 68mW$