RMIT University

School of Engineering

EEET2248 – Electrical Engineering Analysis

Group Lectorial Task 3

Gravitron Analysis

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Problem Statement

1. Determine forces applied to occupants of the gravitron
2. Given input data for time, x displacement and y displacement, find g-force applied to participants as a vector with respect to time

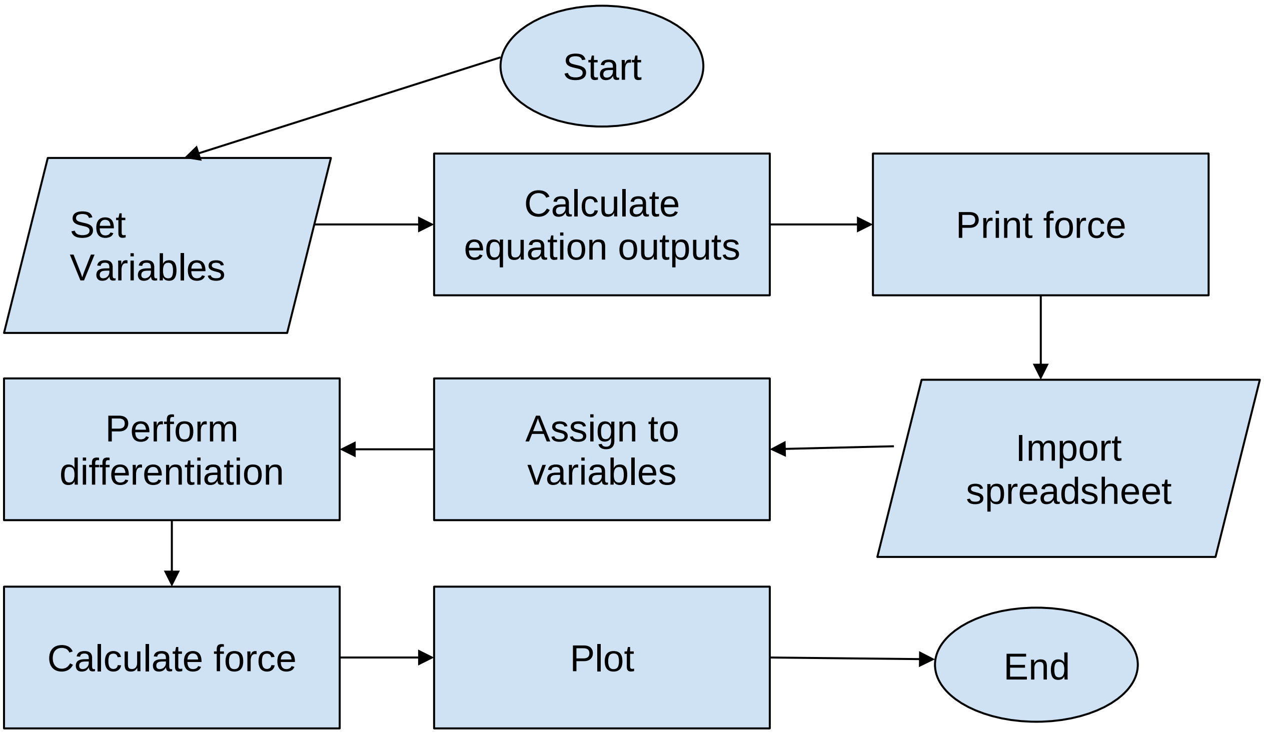
Input

- Diameter of gravitron
- Weight of participants
- Csv file containing time, x displacement and y displacement
- Value for g (acceleration due to gravity)
- Ride duration
- Max rpm

Output

- Tangential velocity
- Max g-force
- Max force
- G-force as a vector with respect to time
- Plot displaying velocity and g-force vs time

Design



The designs of our programs are centered around providing easily interpretable data to the user and minimising run time/computational power required. The first program begins by setting variables for mass, radius, revolutions per second (rps) from the task sheet supplied. Then using these variables calculations are performed to find the angular speed, tangential velocity, force and g force. The value for acceleration due to gravity used is 9.8 m/s/s [1]. Fprintf() is then used to print a string that efficiently displays the force and g-force respectively.

The second program reads the data from the spreadsheet supplied and assigns the columns to separate variables representing time, x displacement and y displacement. Variables are also set for radius, mass and g-force. The displacements are then differentiated with respect to time to find velocity on each axis and then overall velocity is calculated. Using this value we also calculate acceleration, force and g-force. Then g-force and force are are plotted on opposing axes against time on the x-axis.

The task seemed to have quite a linear path to the solution so no alternatives were seriously considered however we did consider different methods of outputting the data. The original design consisted of multiple plots until the idea was proposed to simply use left and right axes for force and g-force respectively to plot the data on the same figure.

<u>Solution and Testing</u>

Created Scripts:

The two created scripts are included below in appendix A. The first script covers task 1 and the second script covers task 2.

Software Solution Demonstration and Results:

Task 1

The following method is used to determine the G Force being applied:

Firstly, the given diameter is divided by 2 to attain the radius of the gravitron:

15/2 = 7.5

r = 7.5

The mass is given as 65kg:

m = 65kg

The angular speed in radians per second is calculated:

w = (2*pi)*(24/60);

w = 2.5133

We then take the tangential velocity of the gravitron:

v = w * 7.5

v = 2.5133 * 7.5

v = 18.8496

From the calculated values we can attain the force being applied to an occupant:

f = m * (((v)^2)/r);

f = 65 * (((18.8496)^2)/7.5);

f = 3.0793e+03

f = 3079.3N

We now need to find the force being applied to the occupants when at rest, or with 1 g force:

g = m * gravity

g = 65 * 9.8

g = 637N

Lastly, to calculate the G Force we require to attain the difference between the force applied by the gravitron when at rest:

g force = f / g;

g force = 3079.3 / 637

g force = 4.83 G

From the above calculations, when the Gravitron is at maximum speed the occupants inside the Gravitron are experiencing a G Force 4.83 times greater than while at rest.

The above can be achieved in MATLAB by creating a simple script that will calculate these values and output the result to the command window. A copy of the simple script is included below with the provided output and workspace values.

Script

```
m = 65; %mass(kg)
r = 7.5; %radius(m)
rps = 24/60; %revolutions per second
w = 2*pi*rps; %angular speed(rads/sec)
v = w*r; %tangential velocity(m/s)
f = m*(v^2/r); %Force (N)
g = m*9.8; %one g-force
g_force = f/g; %total g-force
```

fprintf('The force experienced by the riders is %1.2f Newtons, and the g-force is %1.2f', f, g_force)

Figure 1: Command Window Output

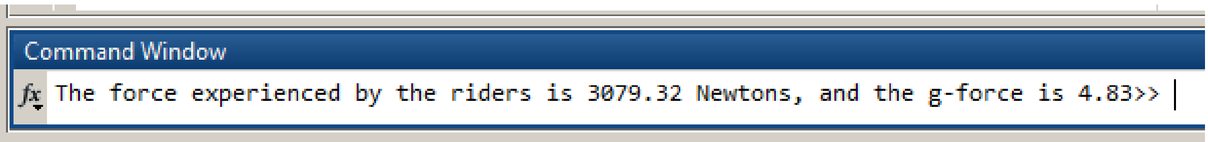
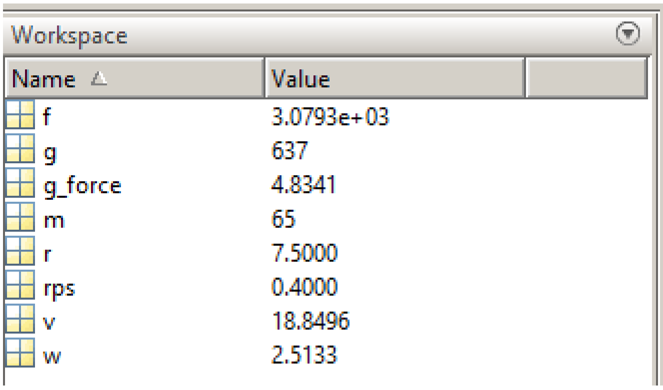


Figure 2: Workspace Values



Workspace

Name	Value
f	3.0793e+03
g	637
g_force	4.8341
m	65
r	7.5000
rps	0.4000
v	18.8496
w	2.5133

From the output and workspace values it can she shown to match the previous hand workings included above.

Task 2

The initial step for task 2 was to import the data into MATLAB and set he given variables, this was achieved by the following commands:

```
data = csvread('gravitron.csv');
t = data(:,1); %time
x = data(:,2); %x displacement
```

```
y = data(:,3); %y displacement
r = 7.5; %radius
m = 65; %mass
g = m*9.8; %1 g
```

Once all the data has been successfully imported the next step required was to find the velocity at each given point, this requires differentiating the X and Y displacement values with respect to time. The required code is included below:

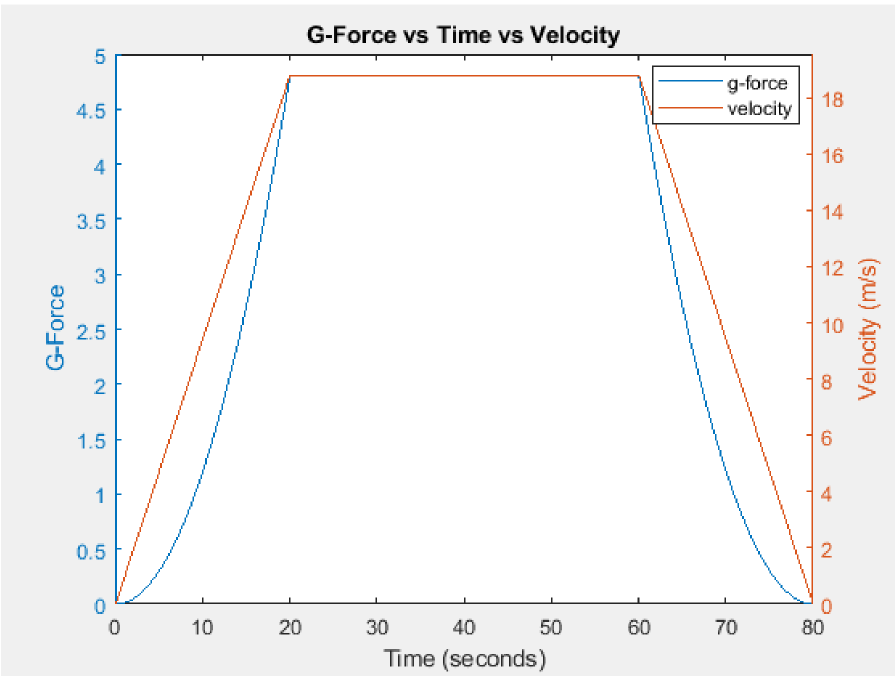
```
dxdt = diff(x)./diff(t);
dydt = diff(y)./diff(t);
v = sqrt((dxdt.^2)+(dydt.^2));
```

Given the new velocities, the G-Force can now be found for each point given in the excel file by executing the below code:

```
a = (v.^2)/r;
f = m*a;
g_frc = f/g;
```

With the calculated G-Force and Velocity the following graph can be plotted, G-Force vs Time vs Velocity:

Figure 3: Created Plot



The above results show that the Gravitron accelerates for around 20 seconds, then continues a relatively constant velocity for about 40 seconds, then decelerates for the remaining 20 seconds.

References

[1] NIST. (2018, 24/05/2018). *Fundamental Physics Constants*. Available: https://physics.nist.gov/cgi-bin/cuu/Value?gn

Appendix A

Task 1

```
clear
clc

m = 65; %mass(kg)
r = 7.5; %radius(m)
rps = 24/60; %revolutions per second
w = 2*pi*rps; %angular speed(rads/sec)
v = w*r; %tangential velocity(m/s)
f = m*(v^2/r); %Force (N)
g = m*9.8; %one g-force
g_force = f/g; %total g-force

fprintf('The force experienced by the riders is %1.2f Newtons, and
the g-force is %1.2f', f, g_force)
```

Task 2

```
clear
clc

data = csvread('gravitron.csv');
```

```
t = data(:,1); %time
x = data(:,2); %x displacement
y = data(:,3); %y displacement
r = 7.5; %radius
m = 65; %mass
g = m*9.8; %1 g

dxdt = diff(x)./diff(t);
dydt = diff(y)./diff(t);

v = sqrt((dxdt.^2)+(dydt.^2));

a = (v.^2)/r;
f = m*a;
g_frc = f/g;

yyaxis left
plot(t(2:end,1),g_frc)
xlabel 'Time (seconds)'
ylabel 'G-Force'
ylim([0 5])
title 'G-Force vs Time vs Velocity'



yyaxis right
plot(t(2:end,1),v)
ylabel 'Velocity (m/s)'
ylim([0 19.5473])

legend('g-force','velocity', 'Location', 'best')
```