Physics Impulse Program
Case Study

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ME1311
(MATLAB for Engineers)

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About the Program:

This program will solve for the impulse an object will receive when it hits the ground, the speed at which the object reaches the ground, the speed at which the object leaves the floor after hitting the ground, and the height the object reaches after leaving the ground. The user will need to input the total initial and final forces upon the object, height the object initially drops from, the time interval the object stays on the ground, and the mass of the object. This program is measured in the metric system. This program is based off of a physics problem from WebAssign included below:

Starting from rest, a 68.0 kg woman jumps down to the floor from a height of 0.720 m, and immediately jumps back up into the air. While she is in contact with the ground during the time interval $0 < t < 0.800$ s, the force she exerts on the floor can be modeled using the function

$$F = 9{,}200t - 11{,}500t^2$$

where F is in newtons and t is in seconds.

(a) What impulse (in N · s) did the woman receive from the floor? (Enter the magnitude. Round your answer to at least three significant figures.)
981.33 ✔ N · s

(b) With what speed (in m/s) did she reach the floor? (Round your answer to at least three significant figures.)
3.76 ✔ m/s

(c) With what speed (in m/s) did she leave it? (Round your answer to at least three significant figures.)
2.82 ✔ m/s

(d) To what height (in m) did she jump upon leaving the floor?
.41 ✔ m

Figure 1

Operating Objective:

The objective of this program is to take all of the “known” variables from the physics problem and input them when prompted into the program in order to solve for the requested information.

Starting from rest, a 68.0 kg woman jumps down to the floor from a height of...

Starting from rest, a 68.0 kg woman jumps down to the floor from a height of 0.790 m, and immediately jumps back up into the air. While she is in contact with the ground during the time interval

$0 < t < 0.800$ s,

the force she exerts on the floor can be modeled using the function

$F = 9{,}200t - 11{,}500t^2$

Figure 2

Equations:

Variables:

I= Impulse

tf= Final Time

ti= Initial Time **(this value is always equal to zero (0) in the program)**

Vr=Velocity Final (Reached)

Vl=Velocity Initial (Leaving)

hl=Height Left

hr=Height Reached

m=mass

g=gravitational constant (9.8 $\frac{m}{s^2}$)

This is the integral equation for deriving impulse when the object collides with the floor:

$(a) \quad I = \int_{ti}^{tf} \{x(fi) - x^2(ff)\}$ *Note again that the initial time will always be zero (0)

This is the equation that calculates the net impulse by subtracting mass times the gravitational constant, and the Δt:

$(b)\quad Inet = I - (m \cdot g \cdot tf)$

These are the equations used to derive the velocity (Vr) when the object reaches the ground and the velocity when the object leaves the ground (Vl):

$(c)\quad V\,r = \sqrt{2(g \cdot hr)}$

$(d)\quad (V\,l = \frac{Inet}{m} - V\,r)\ \ or\ \ (V\,l = \frac{I}{m} - (g \cdot tf) - \sqrt{2(g \cdot hr)})$

This equation is for finding the height the object reached after impacting the floor:

$(e)\quad hl = \frac{(V\,r^2 - V\,l^2)}{(2g)}$

Input Parameters:

The User will need to enter:

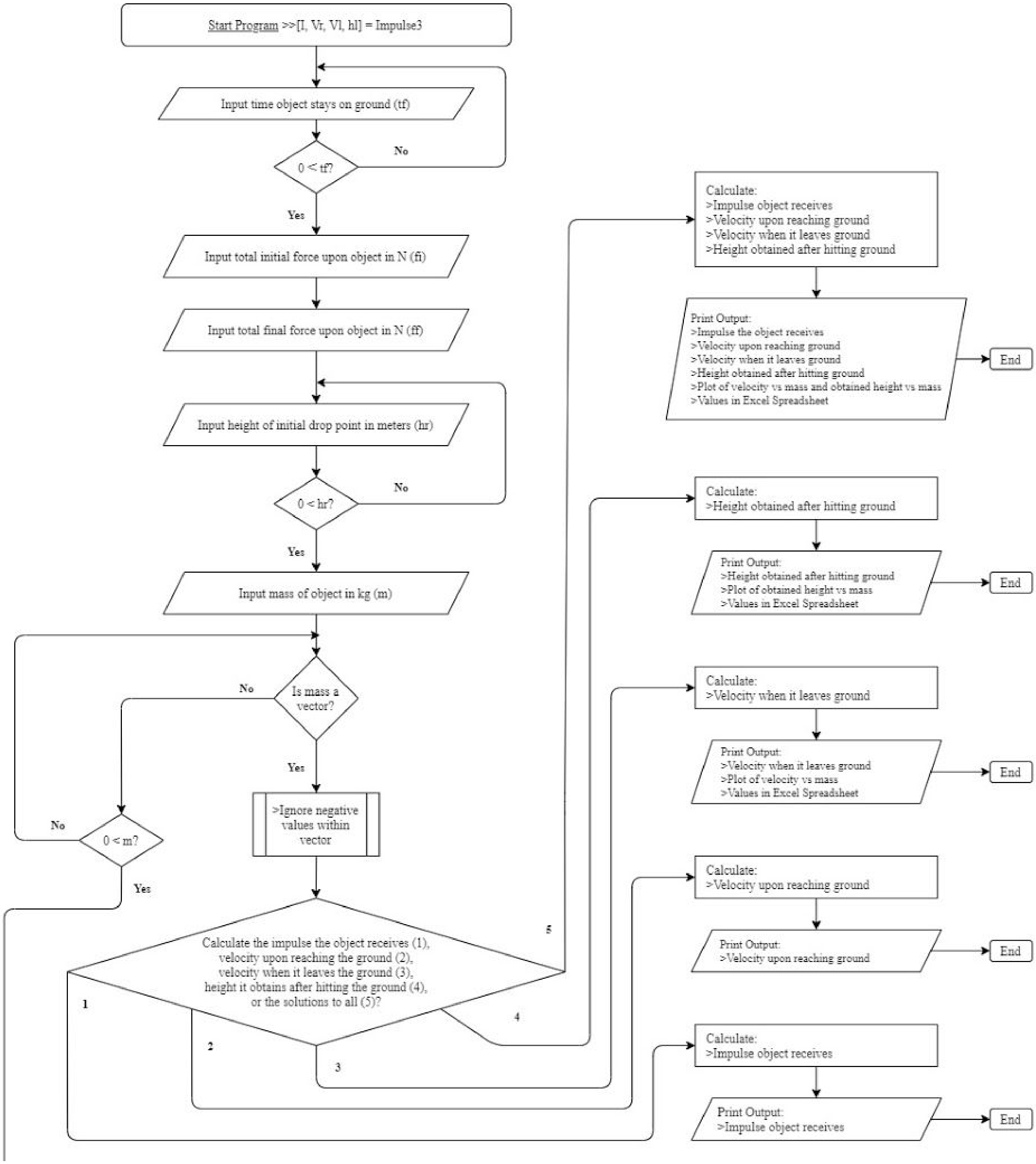
(a) the total initial forces upon the object, (b) the total final forces upon the object, (c) the height the object initially drops from, (d) the time interval the object stays on the ground,and (e) the mass of the object.

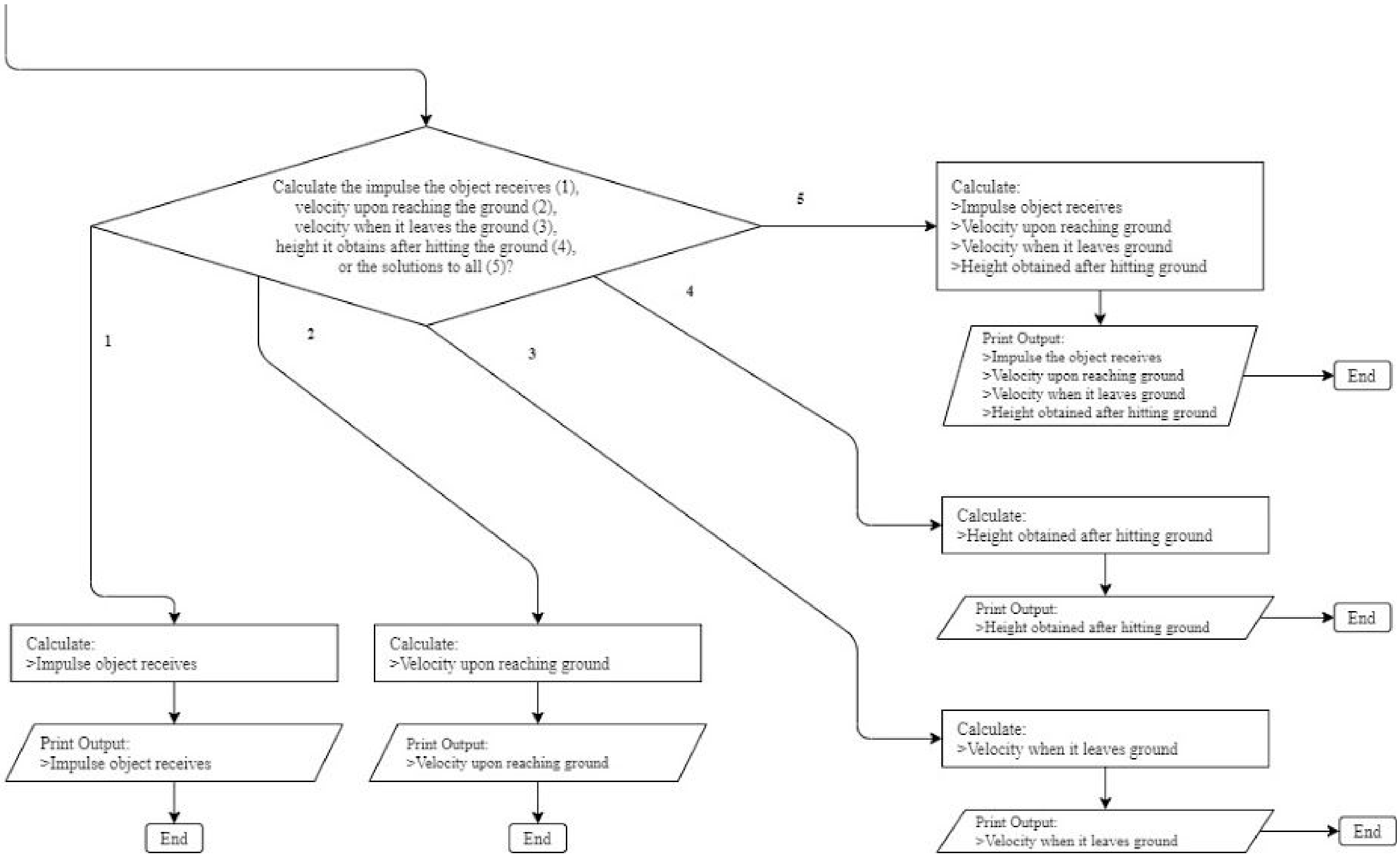
Output Parameters:

This program will solve for:

(a) the impulse an object will receive when it hits the ground, (b) the speed at which the object reaches the ground, (c) the speed at which the object leaves the floor after hitting the ground, and (d) the height the object reaches after leaving the ground.

Flowchart (continued on next page):


Start Program >>[I, Vr, Vl, hl] = Impulse3
Input time object stays on ground (tf)
0 < tf?
No
Yes
Input total initial force upon object in N (fi)
Input total final force upon object in N (ff)
Input height of initial drop point in meters (hr)
0 < hr?
No
Yes
Input mass of object in kg (m)
Is mass a vector?
No
Yes
>Ignore negative values within vector
0 < m?
No
Yes
Calculate the impulse the object receives (1), velocity upon reaching the ground (2), velocity when it leaves the ground (3), height it obtains after hitting the ground (4), or the solutions to all (5)?
1
2
3
4
5
Calculate:
>Impulse object receives
>Velocity upon reaching ground
>Velocity when it leaves ground
>Height obtained after hitting ground
Print Output:
>Impulse the object receives
>Velocity upon reaching ground
>Velocity when it leaves ground
>Height obtained after hitting ground
>Plot of velocity vs mass and obtained height vs mass
>Values in Excel Spreadsheet
End
Calculate:
>Height obtained after hitting ground
Print Output:
>Height obtained after hitting ground
>Plot of obtained height vs mass
>Values in Excel Spreadsheet
End
Calculate:
>Velocity when it leaves ground
Print Output:
>Velocity when it leaves ground
>Plot of velocity vs mass
>Values in Excel Spreadsheet
End
Calculate:
>Velocity upon reaching ground
Print Output:
>Velocity upon reaching ground
End
Calculate:
>Impulse object receives
Print Output:
>Impulse object receives
End



Code:

```
////////////////////////////////////////

function [I, Vr, Vl, hl] = Impulse3
% This program will solve for the impulse an object will receive when it
% hits the ground, the speed at which the object reaches the ground, the
% speed at which the object leaves the floor after hitting the ground, and
% the height the object reaches after leaving the ground. The user will
% need to input the total initial and final forces upon the object,
% height the object initially drops from, the time interval the object
% stays on the ground, and the mass of the object. This program is based
% off of a physics problem from WebAssign. This program is measured in the
% metric system.
% Written by Ramisa Ahmed, Matt Mathias, and Philip Mostellar.
```

```
clc
clear all
clf
help Impulse3
disp('Here is the problem this program was based on:')
Image = imread('Impulse Problem.jpg');
imshow(Image)
disp(blanks(1))
disp('Let''s get started! First, we''ll need some values from you!')
disp(blanks(1))
g = 9.81; % m/s^2
ti = 0;
tf = input('What is the length of time the object stays on the ground for in seconds?\n = 
');
  while tf<0 || tf==0
    if tf<0
        tf = input('Negative time is impossible. Please input the time in seconds again. \n = 
');
    elseif tf==0
        disp('Zero means the object did not hit the ground, indicating no impulse.')
        tf = input('Please input the time in seconds again. \n = ');
    end
  end
fi = input('What is the total initial force upon the object in Newtons?\n = ');
ff = input('What is the total final force upon the object in Newtons?\n = ');
hr = input('What is the height the object initially drops from in meters?\n = ');
    while hr<0
     if hr<0
        disp('Negative height is not possible in this case.')
        hr = input('Please input the height in meters again. \n = ');
     else
```

```
    end
   end
m = input('What is the mass of the object in kilograms? You may enter a vector if
necessary. \n = ');
   while m<0
      if m<0
      m = input('Negative mass is impossible. Please input the mass in kilograms again.
\n = ');
      else

      end
   end
   if length(m) ~=1
         disp('Mass cannot be negative, so any negative elements have been removed.')
         m = m(m>=0);
   end
disp(blanks(1))
disp('Next, please choose what you would like to solve for!')
disp(blanks(1))
P = input('Choose \n 1 to solve for the impulse the object receives \n 2 for the velocity
upon it reaching the ground \n 3 for the velocity when it leaves the ground \n 4 for the
height it obtains after hitting the ground \n 5 to solve for everything\n --> ');

if P == 1
   I = integral(@(x)fi*(x)-ff*(x.^2), ti, tf);
   Vr = 0;
   Vl = 0;
   hl = 0;
   fprintf('The impulse the object received from the floor is %g N*s',I);
```

```
elseif P == 2
   Vr = sqrt(2*g*hr);
   I = 0;
   Vl = 0;
   hl = 0;
   fprintf('The speed when the object reached the floor is %g m/s',Vr)

elseif P == 3 && length(m)==1
   I = integral(@(x)fi*(x)-ff*(x.^2), ti, tf);
   Inet = I - m*g*tf;
   Vr = sqrt(2*g*hr);
   Vl = (Inet/m)-Vr;
   hl = 0;
   fprintf('The speed when the object left the floor is %g m/s', Vl)

elseif P == 3 && length(m)~= 1
   I = integral(@(x)fi*(x)-ff*(x.^2), ti, tf);
   Inet = I - m*g*tf;
   Vr = sqrt(2*g*hr);
   Vl = (Inet./m)-Vr;
   hl = 0;

   A = m';
   D = Vl';
   col_header={'Mass in kg','Leaving Velocity in m/s'};
   xlswrite('Impulse_Data.xlsx',A,2,'A2')
   xlswrite('Impulse_Data.xlsx',D,2,'B2')
   xlswrite('Impulse_Data.xlsx',col_header,2)
   plot(m,Vl,'g:s')
   xlabel('Mass in Kilograms')
   ylabel('Leaving Velocity in m/s')
```

```
    title('Leaving Velocity vs. Mass')
    grid on

elseif P == 4 && length(m) ==1
    I = integral(@(x)fi*(x)-ff*(x.^2), ti, tf);
    Inet = I - m*g*tf;
    Vr = sqrt(2*g*hr);
    Vl = (Inet/m)-Vr;
    hl= (Vr^2-Vl^2)/(2*g);
    fprintf('The height the object obtained upon leaving the floor is %g m', hl)

elseif P == 4 && length(m) ~=1
    I = integral(@(x)fi*(x)-ff*(x.^2), ti, tf);
    Inet = I - m*g*tf;
    Vr = sqrt(2*g*hr);
    Vl = (Inet./m)-Vr;
    hl= (Vr^2-Vl.^2)/(2*g);

    A = m';
    E = hl';
    col_header={'Mass in kg','Height Obtained in m'};
    xlswrite('Impulse_Data.xlsx',A,3,'A2')
    xlswrite('Impulse_Data.xlsx',E,3,'B2')
    xlswrite('Impulse_Data.xlsx',col_header,3)
    plot(m,hl,'g:s')
    xlabel('Mass in Kilograms')
    ylabel('Height Obtained in m')
    title('Height Obtained vs. Mass')
    grid on

elseif P == 5 && length(m) == 1
```

```
    I = integral(@(x)fi*(x)-ff*(x.^2), ti, tf);
    Vr = sqrt(2*g*hr);
    Inet = I - m*g*tf;
    Vl = (Inet/m)-Vr;
    hl= (Vr^2-Vl^2)/(2*g);
    fprintf('The impulse the object received from the floor is %g N*s',I)
    disp(blanks(1))
    fprintf('The speed when the object reached the floor is %g m/s',Vr)
    disp(blanks(1))
    fprintf('The speed when the object left the floor is %g m/s', Vl)
    disp(blanks(1))
    fprintf('The height the object obtained upon leaving the floor is %g m', hl)
    disp(blanks(1))

elseif P == 5 && length(m)~= 1
    I = integral(@(x)fi*(x)-ff*(x.^2), ti, tf);
    Vr = sqrt(2*g*hr);
    Inet = I - m.*g*tf;
    Vl = (Inet./m)-Vr;
    hl= (Vr^2-Vl.^2)/(2*g);

        A = m';
        B = I';
        C = Vr';
        D = Vl';
        E = hl';
        col_header={'Mass in kg','Impulse in N*s','Reaching Velocity in m/s','Leaving
Velocity in m/s','Height Obtained in m'};
        xlswrite('Impulse_Data.xlsx',A,1,'A2')
        xlswrite('Impulse_Data.xlsx',B,1,'B2')
        xlswrite('Impulse_Data.xlsx',C,1,'C2')
```

```
        xlswrite('Impulse_Data.xlsx',D,1,'D2')
        xlswrite('Impulse_Data.xlsx',E,1,'E2')
        xlswrite('Impulse_Data.xlsx',col_header,1)

        subplot(2,1,1)
        plot(m,Vl, 'g:s')
        xlabel('Mass in Kilograms')
        ylabel('Leaving Velocity in m/s')
        title('Leaving Velocity vs. Mass')
        grid on

        subplot(2,1,2)
        plot(m,hl, 'mo--')
        xlabel('Mass in Kilograms')
        ylabel('Height Obtained in m')
        title('Height Obtained vs. Mass')
        grid on

else
    disp('Error. Please select 1,2,3,4, or 5 to solve the problem! ')
    pause (3)
    [I, Vr, Vl, hl] = Impulse3;

end

/////////////////////////////////////////////////////////////
```

Runs with Mass as a Scalar:

For the following five runs, all input data will remain the same. These runs are intended to display the output values received when mass is inputted as a scalar value. As a fool-proofing method: (a) the program will ask the user to re-enter the time value if the user inputs a negative value or 0, (b) the program will ask the user to re-enter the initial height value if the user inputs a negative value, and (c) the program will ask the user to re-enter the mass value if the user inputs a negative value.

Command Window

```
  This program will solve for the impulse an object will receive when it
  hits the ground, the speed at which the object reaches the ground, the
  speed at which the object leaves the floor after hitting the ground, and
  the height the object reaches after leaving the ground. The user will
  need to input the total initial and final forces upon the object,
  height the object initially drops from, the time interval the object
  stays on the ground, and the mass of the object. This program is based
  off of a physics problem from WebAssign. This program is measured in the
  metric system.
  Written by Ramisa Ahmed, Matt Mathias, and Philip Mostellar.

Here is the problem this program was based on:

Let's get started! First, we'll need some values from you!

What is the length of time the object stays on the ground for in seconds?
 = .8
What is the total intial force upon the object in Newtons?
 = 9200
What is the total final force upon the object in Newtons?
 = 11500
What is the height the object initially drops from in meters?
 = .79
What is the mass of the object in kilograms? You may enter a vector if necessary.
 = 68

Next, please choose what you would like to solve for!

Choose
 1 to solve for the impulse the object receives
 2 for the velocity upon it reaching the ground
 3 for the velocity when it leaves the ground
 4 for the height it obtains after hitting the ground
 5 to solve for everything
```

Figure 3

Run 1:

By choosing 1 when prompted to choose what the user would like to solve for, the program will solve for the impulse value, or I. All other output values will be zero.

```
Choose
 1 to solve for the impulse the object receives
 2 for the velocity upon it reaching the ground
 3 for the velocity when it leaves the ground
 4 for the height it obtains after hitting the ground
 5 to solve for everything
 --> 1
fx The impulse the object received from the floor is 981.333 N*s>>
```

Figure 4

Run #2:

By choosing 2, the program will solve for and output the speed when the object reaches the floor, or Vr. All other output values will be zero.

```
Choose
 1 to solve for the impulse the object receives
 2 for the velocity upon it reaching the ground
 3 for the velocity when it leaves the ground
 4 for the height it obtains after hitting the ground
 5 to solve for everything
 --> 2
fx The speed when the object reached the floor is 3.93698 m/s>>
```

Figure 5

Run #3:

By choosing 3, the program will solve for the velocity when the object leaves the ground (Vl). The program will still output the impulse value (I) and the velocity when the object reaches the ground (Vr) because they are used in the equations required to solve Vl. The height the object obtains after leaving the ground is 0.

```
Choose
 1 to solve for the impulse the object receives
 2 for the velocity upon it reaching the ground
 3 for the velocity when it leaves the ground
 4 for the height it obtains after hitting the ground
 5 to solve for everything
 --> 3
fx The speed when the object left the floor is 2.64639 m/s>>
```

Figure 6

<u>Run #4:</u>

By choosing 4, the program will solve for the height (hl) the object obtains after leaving the ground. The program will still output the impulse value (I), the velocity when the object reaches the ground (Vr), and the velocity when the object leaves the ground (Vl) because they are used in the equations required to solve hl.

```
Choose
 1 to solve for the impulse the object receives
 2 for the velocity upon it reaching the ground
 3 for the velocity when it leaves the ground
 4 for the height it obtains after hitting the ground
 5 to solve for everything
 --> 4
fx The height the object obtained upon leaving the floor is 0.433048 m>>
```

Figure 7

<u>Run #5:</u>

By choosing 5, the program will solve for all output values and display them in the command window. All outputs will be saved in the workspace window.

```
Choose
 1 to solve for the impulse the object receives
 2 for the velocity upon it reaching the ground
 3 for the velocity when it leaves the ground
 4 for the height it obtains after hitting the ground
 5 to solve for everything
 --> 5
The impulse the object received from the floor is 981.333 N*s
The speed when the object reached the floor is 3.93698 m/s
The speed when the object left the floor is 2.64639 m/s
The height the object obtained upon leaving the floor is 0.433048 m
>>
```

Figure 8

Runs with Mass as a Vector:

For the following three runs, all input data will remain the same. We will not consider choices 1 and 2 when the program asks the user to choose what they would like to solve for because mass is not used to solve for the impulse the object receives or the velocity of the object when it reaches the ground. Mass will be entered as a vector this time, ranging from 63 kg to 68 kg. These runs are intended to display the output values received when mass is inputted as a vector value. The program will also display plots and Excel sheets that adhere to each choice. The fool-proofing methods are the same as the last, with one added step. Now, if the user enters negative mass values in the vector, the program will automatically take out the negative values and set mass equal to a new vector without the negative values.

```
Command Window
  This program will solve for the impulse an object will receive when it
  hits the ground, the speed at which the object reaches the ground, the
  speed at which the object leaves the floor after hitting the ground, and
  the height the object reaches after leaving the ground. The user will
  need to input the total initial and final forces upon the object,
  height the object initially drops from, the time interval the object
  stays on the ground, and the mass of the object. This program is based
  off of a physics problem from WebAssign. This program is measured in the
  metric system.
  Written by Ramisa Ahmed, Matt Mathias, and Philip Mostellar.

Here is the problem this program was based on:

Let's get started! First, we'll need some values from you!

What is the length of time the object stays on the ground for in seconds?
 = .8
What is the total intial force upon the object in Newtons?
 = 9200
What is the total final force upon the object in Newtons?
 = 11500
What is the height the object initially drops from in meters?
 = .79
What is the mass of the object in kilograms? You may enter a vector if necessary.
 = [63 64 65 66 67 68]
Mass cannot be negative, so any negative elements have been removed.

Next, please choose what you would like to solve for!

Choose
 1 to solve for the impulse the object receives
 2 for the velocity upon it reaching the ground
 3 for the velocity when it leaves the ground
 4 for the height it obtains after hitting the ground
 5 to solve for everything
```

Figure 9

<u>Run #3:</u>

By choosing 3 when asked to choose what the user would like to solve for, the program will output the velocity when the object leaves the ground as a vector in the workspace window according to the mass input vector. The program will also plot the leaving velocity versus the mass, as shown in Figure 10. The program will additionally input the mass values and the corresponding leaving velocities in the second sheet of an Excel spreadsheet titled Impulse_Data, as shown below in Figure 11.

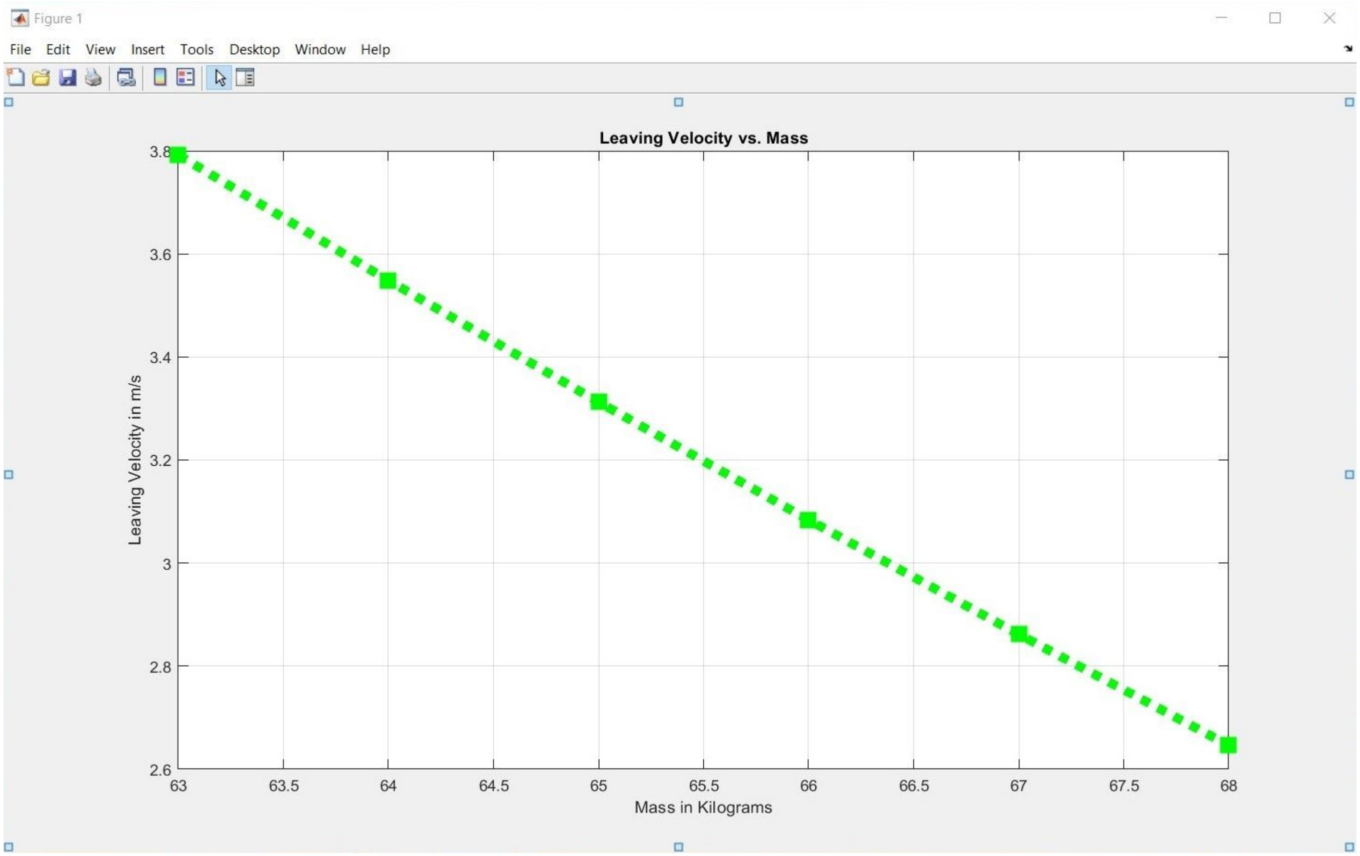
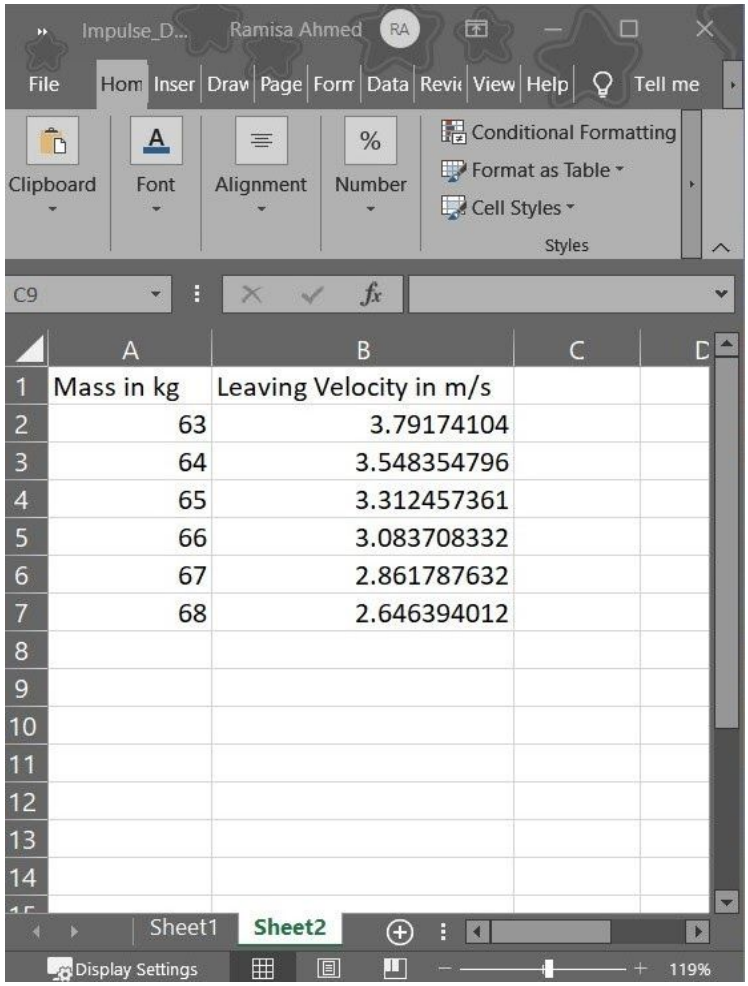


Figure 10



	A	B
1	Mass in kg	Leaving Velocity in m/s
2	63	3.79174104
3	64	3.548354796
4	65	3.312457361
5	66	3.083708332
6	67	2.861787632
7	68	2.646394012

Figure 11

<u>Run #4:</u>

By choosing 4, the program will output the height obtained when the object leaves the ground as a vector in the workspace window according to the mass input vector. The program will also plot the height obtained versus the mass, as shown in Figure 12. The program will additionally input the mass values and the corresponding heights obtained in the third sheet of an Excel spreadsheet titled Impulse_Data, as shown below in Figure 13.

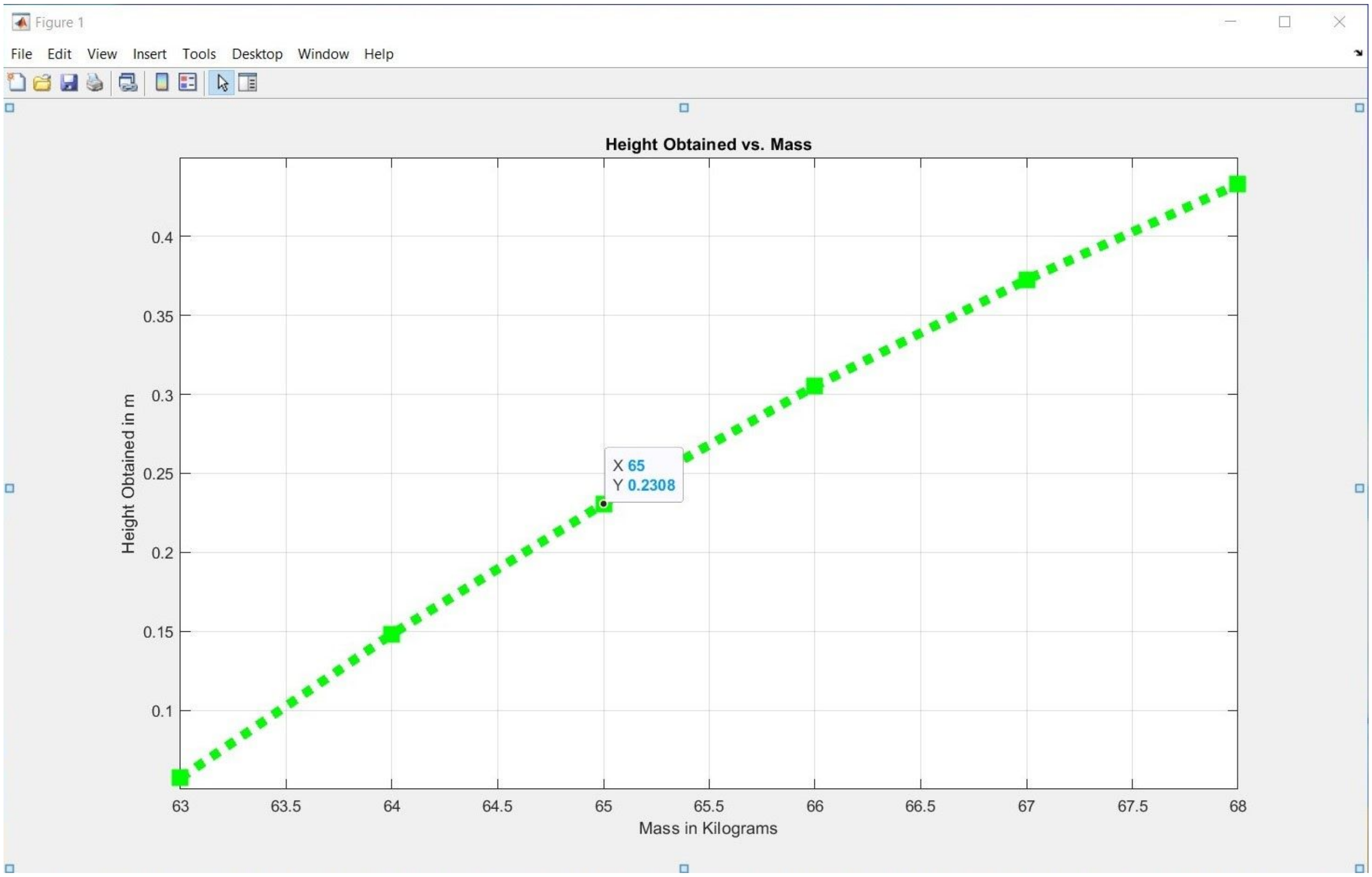
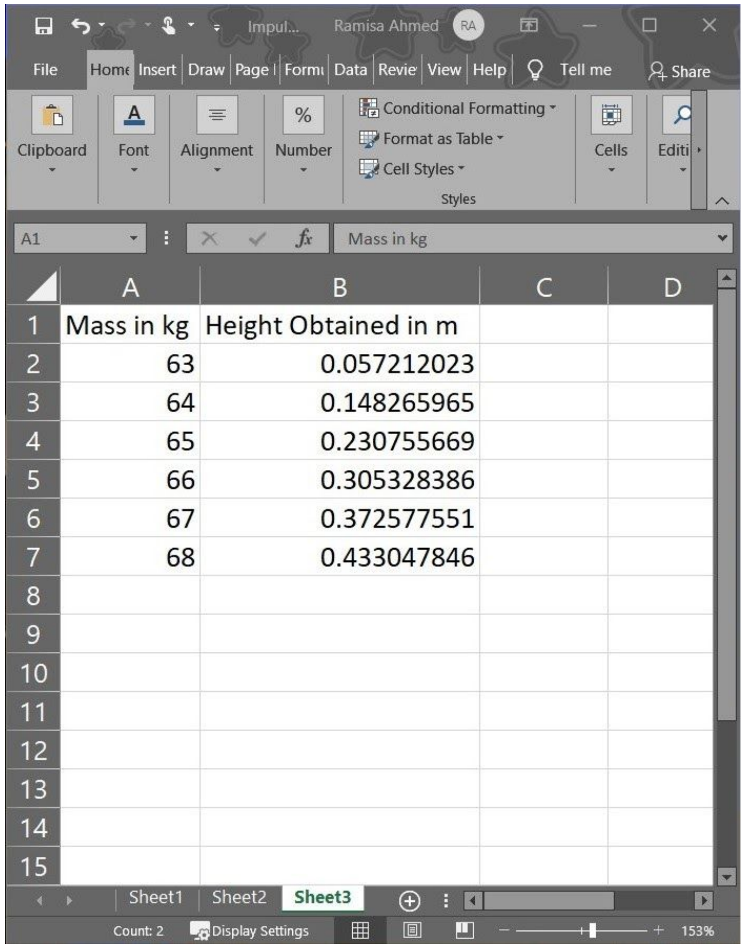


Figure 1
File Edit View Insert Tools Desktop Window Help
Height Obtained vs. Mass
Height Obtained in m
0.4
0.35
0.3
0.25
0.2
0.15
0.1
X 65
Y 0.2308
63
63.5
64
64.5
65
65.5
66
66.5
67
67.5
68
Mass in Kilograms

Figure 12



	A	B
1	Mass in kg	Height Obtained in m
2	63	0.057212023
3	64	0.148265965
4	65	0.230755669
5	66	0.305328386
6	67	0.372577551
7	68	0.433047846

Figure 13

Run #5:

By choosing 5, the program will put all output values into the workspace window. The Leaving Velocities and Heights obtained will be vectors, while the Impulse and Reaching Velocity are still scalar values since they do not rely upon mass. The program will also create two plots, the leaving velocities versus the mass and the height obtained versus the mass, as shown in Figure 14. The program will additionally put all output values into the first sheet of an Excel spreadsheet titled Impulse_Data, as shown below in Figure 15.

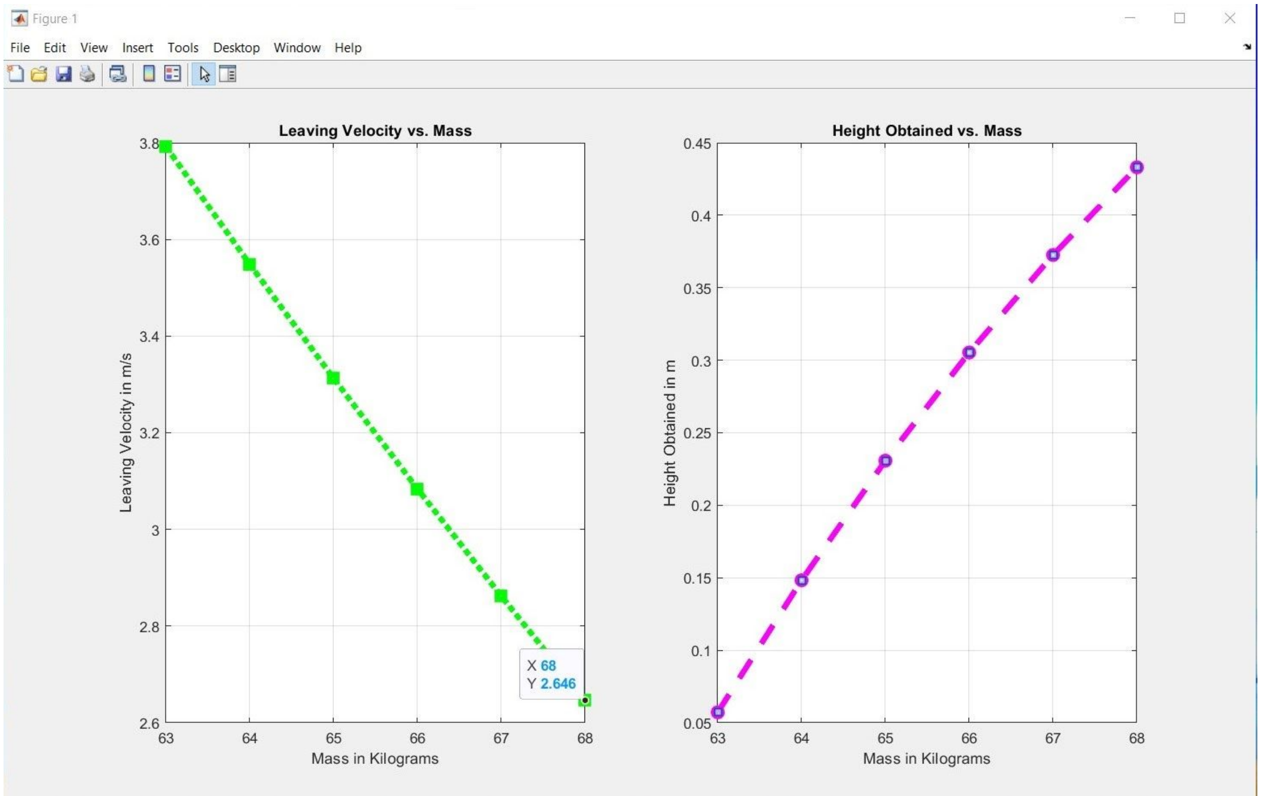
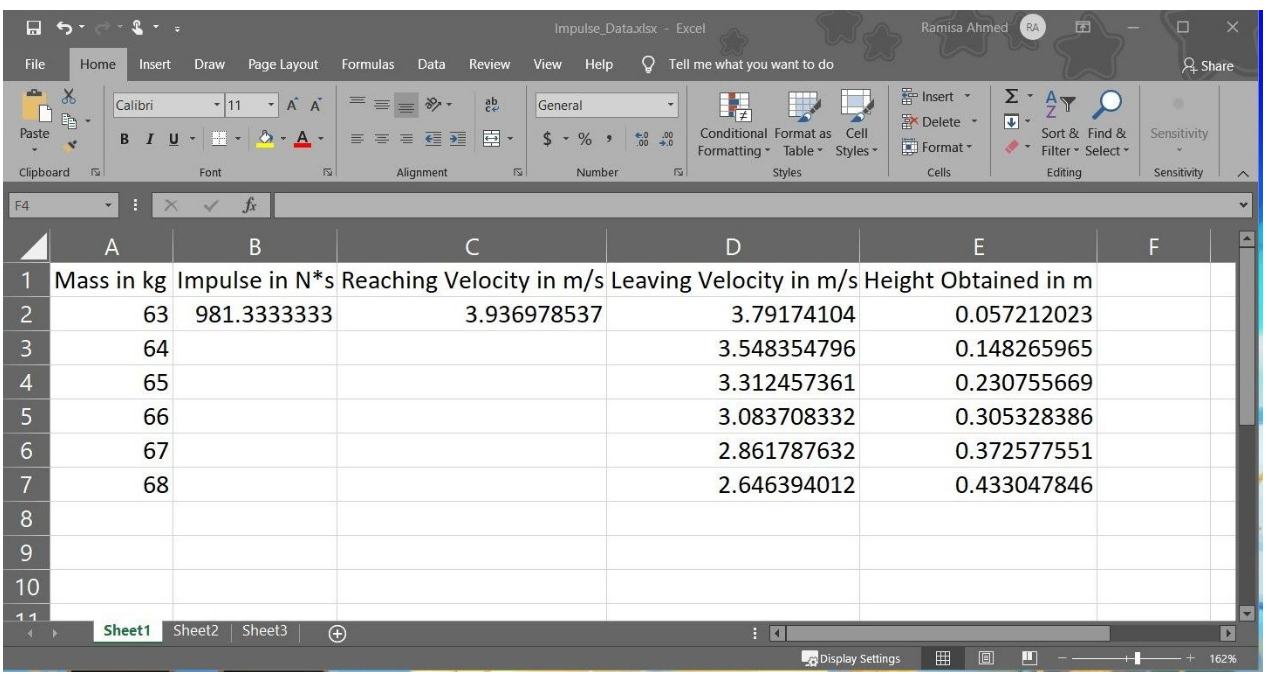


Figure 14



	A	B	C	D	E	F
1	Mass in kg	Impulse in N*s	Reaching Velocity in m/s	Leaving Velocity in m/s	Height Obtained in m	
2	63	981.3333333	3.936978537	3.79174104	0.057212023	
3	64			3.548354796	0.148265965	
4	65			3.312457361	0.230755669	
5	66			3.083708332	0.305328386	
6	67			2.861787632	0.372577551	
7	68			2.646394012	0.433047846	

Figure 15

Solutions:

Answer #1 Report

(a)

The impulse received from the floor is,

$$I = \int_0^{0.800} F dt$$

$$= \int_0^{0.800} \left(9200t - 11500t^2\right) dt$$

$$= \left(\frac{9200t^2}{2} - \frac{11500t^3}{3}\right)_0^{0.800}$$

$$= (4600)(0.800)^2 - (3833.33)(0.800)^3$$

$$= 981 \text{ N} \cdot \text{s}$$

(b)

The speed when the woman reached the floor is,

$$\frac{1}{2}mv^2 = mgh$$

$$v = \sqrt{2gh}$$

$$= \sqrt{2\left(9.8 \text{ m/s}^2\right)(0.790 \text{ m})}$$

$$= 3.934 \text{ m/s}$$

(c)

The net impulse that acts on the women is,

$$I_{net} = I - mgt$$

$$= 981 \text{N.s} - (68 \text{ kg})\left(9.8 \text{ m/s}^2\right)(0.8 \text{ s})$$

$$= 447.88 \text{ N} \cdot \text{s}$$

From the definition of impulse, it is equal to change in momentum.

$$I_{net} = mv - m(-v')$$

$$= m(v + v')$$

Use above equation to solve for speed that the woman leaves from the floor.

$$m(v + v') = 447.88 \text{ N} \cdot \text{s}$$

$$v' = \frac{447.88 \text{ N.s}}{m} - v$$

$$= \frac{447.88 \text{ N.s}}{68 \text{ kg}} - 3.934 \text{ m/s}$$

$$= 2.652 \text{ m/s}$$

(d)

Use the following kinematic equation to solve for height.

$$v^2 = v'^2 + 2gh$$

$$h = \frac{v^2 - v'^2}{2g}$$

$$h = \frac{0^2 - (2.652 \text{ m/s})^2}{2\left(-9.8 \text{ m/s}^2\right)}$$

$$h = 0.358 \text{ m}$$

0 0

Figure 16

Appendix

References Used:

1) Physics for Scientists and Engineers + Webassign Printed Access Card for Serway/Jewett's Physics ... for Scientists and Engineers, 10th Ed; Raymond A. Serway, Brooks Cole, 2018.
2) Solving Mechanical Engineering Problems with MATLAB; Dr. Simin Nasseri, ISBN 10: 1-60797-524-6, Linus Publishing Co. 2015