Option Explicit

Sub Rocket()

'Declaring all variables'

Dim A\_Nozzle As Double 'area of the nozzle (m^2)'

Dim A\_Projected As Double 'projected frontal area of rocket (m^2)'

Dim A\_Rocket As Double 'acceleration of the rocket (m/s^2)

Dim c1 As Double 'speed of sound in air (m/s)'

Dim C2 As Double 'nozzle discharge coefficient (dimensionless)'

Dim C\_d As Double 'drag coefficient (dimensionless)'

Dim D\_n As Double 'diameter of nozzle (m)'

Dim delta\_t As Double 'time interval (s)'

Dim F As Double 'fill fraction (initial volume of water over volume of bottle)'

Dim F\_Drag As Double 'force of drag on bottle (N)'

Dim F\_g As Double 'force of gravity (N)'

Dim F\_Net As Double 'net force on bottle (N)'

Dim F\_Thrust As Double 'force of thrust (N)'

Dim g As Double 'local acceleration of gravity (m/s^2)'

Dim gamma As Double 'Cp/Cv (1.4 for air)'

Dim i1 As Integer 'printing interval (s)'

Dim i2 As Integer 'iteration (s)'

Dim L\_t As Double 'length of launch tube (m)'

Dim m1\_Air As Double 'mass of water propellant (kg)'

Dim M2\_Air As Double 'molecular mass of air (kg/mol)'

Dim M\_init As Double 'initial mass (kg)'

Dim M\_Payload As Double 'mass of altimeter (kg)'

Dim M\_Rocket As Double 'mass of rocket with fiber fill, without propellant, and without payload (kg)'

Dim M\_Total As Double 'total mass of water, rocket, payload, and air (kg)'

Dim M\_Water As Double 'mass of water (kg)'

Dim P\_Air As Double 'initial absolute pressure of air propellant (Pa)'

Dim P\_atm As Double 'absolute pressure of atmosphere (Pa)'

Dim R As Double 'ideal gas constant (Pa\*m^3/mol\*K)

Dim r\_m\_Air As Double 'rate the air propellant is expelled (kg/s)'

Dim r\_m\_Out As Double 'rate the propellant is expelled (kg/s)'

Dim r\_m\_Water As Double 'rate the water propellant is expelled (kg/s)'

Dim rho\_Air As Double 'density of air (kg/m^3)'

Dim rho\_atm As Double 'density of atmosphere (kg/m^3)'

Dim rho\_Water As Double 'density of water propellant (kg/m^3)'

Dim t1 As Double 'time since rocket left launchpad (s)'

Dim T2 As Double 'temperature (K)'

Dim T\_amb As Double 'ambient air temperature (K)'

Dim T\_init As Double 'initial temperature (K)'

Dim V\_Air As Double 'volume of air (m^3)'

Dim V\_Bottle As Double 'empty volume of bottle (m^3)'

Dim V\_init As Double 'initial velocity (m/s)'

Dim V\_Rocket As Double 'velocity of the rocket (m/s)

Dim V\_Water As Double 'Volume of water (m^3)'

Dim x As Double 'vertical distance (m)'

'Initial Parameters'

'This part of the code inputs values from the sheet specified by the user'

'It also calculates and assigns initial values for a series of established values'

delta\_t = Cells(2, 4)

i1 = Cells(3, 4)

V\_Bottle = Cells(5, 4)

F = Cells(6, 4)

D\_n = Cells(7, 4)

A\_Nozzle = Cells(8, 4)

A\_Projected = Cells(9, 4)

M\_Payload = Cells(10, 4)

M\_Rocket = Cells(11, 4)

P\_Air = Cells(12, 4)

C\_d = Cells(13, 4)

C2 = Cells(14, 4)

L\_t = Cells(16, 4)

g = Cells(18, 4)

c1 = Cells(19, 4)

M2\_Air = Cells(20, 4)

gamma = Cells(21, 4)

P\_atm = Cells(22, 4)

rho\_Water = Cells(23, 4)

T\_amb = Cells(24, 4)

T2 = Cells(24, 4)

T\_init = Cells(24, 4)

R = Cells(25, 4)

i2 = 1 'i2 used for keeping track of iterations and printing items onto to the sheet correctly'

M\_Water = F \* V\_Bottle \* rho\_Water 'determines the mass of water (kg) from the fill fraction'

rho\_atm = (M2\_Air \* P\_atm) / (R \* T\_amb) 'determines density of atmosphere from molar mass of air (kg/mol), Pressure of the atmosphere (Pa), R Gas constant (Pa\*m^3/mol\*K) and ambient air temperature (K)'

rho\_Air = (M2\_Air \* P\_Air) / (R \* T2) 'detrmines density of air in the bottle from from molar mass of air (kg/mol) Pressure of the bottle (Pa) R Gas constant (Pa\*m^3/mol\*K) and tempereature (K)'

V\_Air = (1 - F) \* V\_Bottle 'determines volume of air in the bottle from the fill fraction and the volume of the bottle (m^3)

m1\_Air = rho\_Air \* V\_Air 'determines mass of the air in the bottle from the density of the air (kg/m^3) and the volume of the air in the bottle (m^3)'

M\_Total = M\_Rocket + M\_Payload + M\_Water + m1\_Air 'determines the total mass of the bottle from the mass of the roket (kg) mass of the payload (kg) mass of the water (kg) and mass of the air (kg)'

t1 = 0 'assigns the value t1 to 0. also used for iteration count and output use'

x = 0 'establishes the initial height of the rocket to start at 0 m'

V\_Rocket = 0 'establishes the initial velocity of the rocket to start at 0 m/s'

V\_init = (1 - F) \* V\_Bottle 'determines the initial velocity from the fill fraction and volume of the bottle (m^3)'

'Phase 1'

'This phase is before the takeoff of the rocket'

'It calculates values for t = 0 and outputs it onto the sheet'

'Phase 1 Calculations'

V\_Rocket = Sqr((2 \* L\_t \* (P\_Air - P\_atm) \* A\_Nozzle - M\_Total \* g) / M\_Total) 'determines velocity of the rocket from length of launch tube (m) pressure of the air (Pa) pressure of the atmosphere (Pa) area of the nozzle (m^2) total mass (kg) and acceleration due to gravity (m/s^2)'

x = L\_t 'determines initial takeoff height from the length of launch tube (m)'

F\_Thrust = (P\_Air - P\_atm) \* A\_Nozzle 'determines force of thrust from pressure of the air in the bottle (Pa) pressure of the atmosphere (Pa) and area of the nozzle (m^2)'

F\_g = M\_Total \* g 'determines force of gravity from local gravity (m/s^2) and total mass (kg)'

F\_Drag = (0.5) \* C\_d \* rho\_atm \* A\_Projected \* V\_Rocket ^ 2 'determines force of drag from drag coefficient density of the atmosphere (kg/m^3) area projected (m^2) and velocity of the rocket (m/s)'

F\_Net = F\_Thrust - F\_g - F\_Drag 'determines force net from force thrust (N) force gravity (N) force drag (N)'

A\_Rocket = F\_Net / M\_Total 'determines acceleration of the rocket from force net (N) and total mass (kg)'

'Phase 1 Outputs'

Cells(29 + i2 / i1, 1) = t1

Cells(29, 2) = P\_Air

Cells(29, 3) = T2

Cells(29, 4) = F\_Thrust

Cells(29, 5) = F\_g

Cells(29, 6) = F\_Drag

Cells(29, 7) = F\_Net

Cells(29, 8) = M\_Water

Cells(29, 9) = m1\_Air

Cells(29, 10) = M\_Total

Cells(29, 11) = A\_Rocket

Cells(29, 12) = V\_Rocket

Cells(29, 13) = x

'Phase 2'

'This is the intial takeoff of the rocket using pressurized water'

'A loop will run so long as the mass of water is greater than 0'

'The loop calculates several values and outputs every 10th calculation onto the sheet'

While M\_Water > 0

'Phase 2 Calculations'

V\_Air = V\_Bottle - (M\_Water / rho\_Water) 'determines volume of air from volume of bottle (m^3) mass of water (kg) and density of water (kg/m^3)'

T2 = T\_init \* (V\_init / V\_Air) ^ (gamma - 1) 'determines temperature from initial temperature (K) initial volume (m^3) volume of air in bottle (m^3) and gamma'

P\_Air = m1\_Air \* R \* T2 / (M2\_Air \* V\_Air) 'determines pressure of air from mass of air (kg) ideal gas constant (Pa\*m^3/mol\*K) temperature (K) molecular mass of air (mol/kg) and volume of air in bottle (m^3)'

r\_m\_Water = C2 \* A\_Nozzle \* Sqr(2 \* rho\_Water \* (P\_Air - P\_atm)) 'determines rate of expelled water propellant from nozzle discharge coefficient area of nozzle (m^2) density of water (kg/m^3) pressure of air in bottle (Pa) and pressure of atmosphere (Pa)'

M\_Water = M\_Water - r\_m\_Water \* delta\_t 'determines mass of the water from mass of water (kg) expelled water propellant (kg/s) and change in time (s)'

M\_Total = M\_Rocket + M\_Payload + M\_Water + m1\_Air 'determines the total mass of the bottle from the mass of the roket (kg) mass of the payload (kg) mass of the water (kg) and mass of the air (kg)'

V\_Water = C2 \* Sqr(2 \* (P\_Air - P\_atm) / rho\_Water) 'determines volume of water from nozzle discharge coefficient pressure of air in bottle (Pa) pressure of the atmosphere (Pa) and density of water (kg/m^3)'

F\_Thrust = r\_m\_Water \* V\_Water 'determines force of thrust from rate of expelled water propellant (kg/s) and volume of water (m^3)'

F\_g = M\_Total \* g 'determines force of gravity from total mass (kg) and gravity (m/s^2)'

F\_Drag = 0.5 \* C\_d \* rho\_atm \* A\_Projected \* V\_Rocket ^ 2 'determines force of drag from drag coefficient density of the atmosphere (kg/m^3) area projected (m^2) and velocity of the rocket (m/s)'

F\_Net = F\_Thrust - F\_g - F\_Drag 'determines force net from force thrust (N) force gravity (N) force drag (N)'

A\_Rocket = F\_Net / M\_Total 'determines acceleration of the rocket from force net (N) and total mass (kg)'

V\_Rocket = V\_Rocket + (A\_Rocket \* delta\_t) 'determines velocity of the rocket from velocity of the rocket (m/s) acceleration of the rocket (m/s^2) and change in time (s)'

x = x + V\_Rocket \* delta\_t 'determines the height of the rocket from height of the rocket (m) velocity of the rocket (m/s) and change in time (s)'

t1 = t1 + delta\_t 'determines new time interval from time interval (s) and change in time (s)'

If (i2 Mod i1) = 0 Then

If M\_Water > 0 Then

'Phase 2 Outputs'

Cells(29 + i2 / i1, 1) = t1

Cells(29 + i2 / i1, 2) = P\_Air

Cells(29 + i2 / i1, 3) = T2

Cells(29 + i2 / i1, 4) = F\_Thrust

Cells(29 + i2 / i1, 5) = F\_g

Cells(29 + i2 / i1, 6) = F\_Drag

Cells(29 + i2 / i1, 7) = F\_Net

Cells(29 + i2 / i1, 8) = M\_Water

Cells(29 + i2 / i1, 9) = m1\_Air

Cells(29 + i2 / i1, 10) = M\_Total

Cells(29 + i2 / i1, 11) = A\_Rocket

Cells(29 + i2 / i1, 12) = V\_Rocket

Cells(29 + i2 / i1, 13) = x

End If

End If

i2 = i2 + 1

Wend

'By assigning the variables below we are preparing for Phase 3'

T\_init = T2

M\_init = m1\_Air

'Phase 3'

'The Rocket is being propelled by the pressurized air'

'A loop will run so long as the pressure of the air in the bottle is greater than pressure of the atmosphere'

'The loop calculates several values and outputs every 10th calculation onto the sheet'

While P\_Air > P\_atm

'Phase 3 Calculations'

M\_Water = 0

V\_Air = V\_Bottle - (M\_Water / rho\_Water) 'determines volume of air from volume of bottle (m^3) mass of water (kg) and density of water (kg/m^3)'

T2 = T\_init \* (m1\_Air / M\_init) ^ (gamma - 1) 'determines temperature from initial temperature (K) initial volume (m^3) volume of air in bottle (m^3) and gamma'

P\_Air = (m1\_Air \* R \* T2) / (M2\_Air \* V\_Air) 'determines pressure of air from mass of air (kg) ideal gas constant (Pa\*m^3/mol\*K) temperature (K) molecular mass of air (mol/kg) and volume of air in bottle (m^3)'

rho\_Air = (M2\_Air \* P\_Air) / (R \* T2) 'detrmines density of air in the bottle from from molar mass of air (kg/mol) Pressure of the bottle (Pa) R Gas constant (Pa\*m^3/mol\*K) and tempereature (K)'

r\_m\_Air = C2 \* A\_Nozzle \* Sqr(((2 / (gamma + 1)) ^ ((gamma + 1) / (gamma - 1))) \* gamma \* rho\_Air \* P\_Air) 'determines the rate of expelled air from expulsion coefficient area of the nozzle (m^2) gamma density of air (kg/m^3) and pressure of air in the bottle (Pa)'

m1\_Air = m1\_Air - (r\_m\_Air \* delta\_t) 'determines mass of the air in the bottle from the density of the air (kg/m^3) and the volume of the air in the bottle (m^3)'

M\_Total = M\_Rocket + M\_Payload + M\_Water + m1\_Air 'determines the total mass of the bottle from the mass of the roket (kg) mass of the payload (kg) mass of the water (kg) and mass of the air (kg)'

F\_Thrust = r\_m\_Air \* c1 'determines force of thrust from the rate of expelled air (kg/s) and speed of sound in air (m/s)'

F\_g = M\_Total \* g 'determines force of gravity from local gravity (m/s^2) and total mass (kg)'

F\_Drag = (0.5) \* C\_d \* rho\_atm \* A\_Projected \* V\_Rocket ^ 2 'determines force of drag from drag coefficient density of the atmosphere (kg/m^3) area projected (m^2) and velocity of the rocket (m/s)'

F\_Net = F\_Thrust - F\_g - F\_Drag 'determines force net from force thrust (N) force gravity (N) force drag (N)'

A\_Rocket = F\_Net / M\_Total 'determines acceleration of the rocket from force net (N) and total mass (kg)'l

V\_Rocket = V\_Rocket + (A\_Rocket \* delta\_t) 'determines velocity of the rocket from velocity of the rocket (m/s) acceleration of the rocket (m/s^2) and change in time (s)'

x = x + V\_Rocket \* delta\_t 'determines the height of the rocket from height of the rocket (m) velocity of the rocket (m/s) and change in time (s)'

t1 = t1 + delta\_t 'determines new time interval from time interval (s) and change in time (s)'

If (i2 Mod i1) = 0 Then

If P\_Air > P\_atm Then

'Phase 3 Output'

Cells(29 + i2 / i1, 1) = t1

Cells(29 + i2 / i1, 2) = P\_Air

Cells(29 + i2 / i1, 3) = T2

Cells(29 + i2 / i1, 4) = F\_Thrust

Cells(29 + i2 / i1, 5) = F\_g

Cells(29 + i2 / i1, 6) = F\_Drag

Cells(29 + i2 / i1, 7) = F\_Net

Cells(29 + i2 / i1, 8) = M\_Water

Cells(29 + i2 / i1, 9) = m1\_Air

Cells(29 + i2 / i1, 10) = M\_Total

Cells(29 + i2 / i1, 11) = A\_Rocket

Cells(29 + i2 / i1, 12) = V\_Rocket

Cells(29 + i2 / i1, 13) = x

End If

End If

i2 = i2 + 1

Wend

'Phase 4'

'The Rocket is in freefall. It is at this point only affected by the force of gravity. Velocity may still be positive'

'A loop will run so long as the the bottle has not yet hit the ground (x not equal to 0)'

'The loop calculates several values and outputs every 10th calculation onto the sheet'

While x > 0

'Phase 4 Calculations'

M\_Water = 0

V\_Air = V\_Bottle - (M\_Water / rho\_Water) 'determines volume of air from volume of bottle (m^3) mass of water (kg) and density of water (kg/m^3)'

P\_Air = P\_atm 'assigns pressure of air equal to the pressure of the atmosphere'

T2 = T\_init \* (m1\_Air / M\_init) ^ (gamma - 1) 'determines temperature from initial temperature (K) initial volume (m^3) volume of air in bottle (m^3) and gamma'

rho\_Air = (M2\_Air \* P\_Air) / (R \* T2) 'detrmines density of air in the bottle from from molar mass of air (kg/mol) Pressure of the bottle (Pa) R Gas constant (Pa\*m^3/mol\*K) and tempereature (K)'

m1\_Air = rho\_Air \* V\_Air 'determines mass of the air in the bottle from the density of the air (kg/m^3) and the volume of the air in the bottle (m^3)'

M\_Total = M\_Rocket + M\_Payload + M\_Water + m1\_Air 'determines the total mass of the bottle from the mass of the roket (kg) mass of the payload (kg) mass of the water (kg) and mass of the air (kg)'

F\_Thrust = 0

F\_g = M\_Total \* g 'determines force of gravity from local gravity (m/s^2) and total mass (kg)'

F\_Drag = (0.5) \* C\_d \* rho\_atm \* A\_Projected \* (V\_Rocket) ^ 2 'determines force of drag from drag coefficient density of the atmosphere (kg/m^3) area projected (m^2) and velocity of the rocket (m/s)'

If V\_Rocket > 0 Then

F\_Net = F\_Thrust - F\_g - F\_Drag 'If the rocket is moving up (velocity > 0) force of drag is negative; determines force net from force thrust (N) force gravity (N) force drag (N)'

Else

F\_Net = F\_Drag - F\_g 'If the rocket is moving down (velocity < 0) force of drag is positive; determines force net from force thrust (N) force gravity (N) force drag (N)'

End If

A\_Rocket = F\_Net / M\_Total 'determines acceleration of the rocket from force net (N) and total mass (kg)'l

V\_Rocket = V\_Rocket + (A\_Rocket \* delta\_t) 'determines velocity of the rocket from velocity of the rocket (m/s) acceleration of the rocket (m/s^2) and change in time (s)'

x = x + V\_Rocket \* delta\_t 'determines the height of the rocket from height of the rocket (m) velocity of the rocket (m/s) and change in time (s)'

t1 = t1 + delta\_t 'determines new time interval from time interval (s) and change in time (s)'

If (i2 Mod i1) = 0 Then

If x > 0 Then

'Phase 4 Output'

Cells(29 + i2 / i1, 1) = t1

Cells(29 + i2 / i1, 2) = P\_Air

Cells(29 + i2 / i1, 3) = T2

Cells(29 + i2 / i1, 4) = F\_Thrust

Cells(29 + i2 / i1, 5) = F\_g

Cells(29 + i2 / i1, 6) = F\_Drag

Cells(29 + i2 / i1, 7) = F\_Net

Cells(29 + i2 / i1, 8) = M\_Water

Cells(29 + i2 / i1, 9) = m1\_Air

Cells(29 + i2 / i1, 10) = M\_Total

Cells(29 + i2 / i1, 11) = A\_Rocket

Cells(29 + i2 / i1, 12) = V\_Rocket

Cells(29 + i2 / i1, 13) = x

End If

End If

i2 = i2 + 1

Wend

'By assigning the height to 0 we are preparing to output the final results'

x = 0

'Output Final Results'

Cells(29 + i2 / i1, 1) = t1

Cells(29 + i2 / i1, 2) = P\_Air

Cells(29 + i2 / i1, 3) = T2

Cells(29 + i2 / i1, 4) = F\_Thrust

Cells(29 + i2 / i1, 5) = F\_g

Cells(29 + i2 / i1, 6) = F\_Drag

Cells(29 + i2 / i1, 7) = F\_Net

Cells(29 + i2 / i1, 8) = M\_Water

Cells(29 + i2 / i1, 9) = m1\_Air

Cells(29 + i2 / i1, 10) = M\_Total

Cells(29 + i2 / i1, 11) = A\_Rocket

Cells(29 + i2 / i1, 12) = V\_Rocket

Cells(29 + i2 / i1, 13) = x

End Sub