Lab Assignment 2

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QUESTION – 1

Computationally analyze the motion of freely falling body using Euler’s method as discussed during the lecture. Consider realistic initial conditions (height, initial velocity etc.) Compare your result with analytical solution and study the effect of discretization (timestep) on computational result.

Plot the results showing the velocity of the body and the distance travelled by it at different instant of time.

The above problem is not realistic from Earth’s viewpoint, use the code to analyze the motion of falling body on the moon (there is hardly any atmosphere, so in reality also we can neglect the effect of atmosphere, however initial conditions will be different).

ASSUMPTIONS:

1. The gravitational force remains constant all heights.
2. Effect of atmosphere and hence the drag is neglected.

INITIALIZATION:

1. g\_earth is the acceleration caused by gravity, g = 9.8m/s2
2. g\_moon is the acceleration caused on moon g\_moon = 1.63 m/s2
3. max\_t is the time duration
4. initial\_height is the height the freely falling body is thrown.
5. v is the velocity of the body
6. x is the position of the body

COMPUTATIONAL MODEL:

position(i+1) = position(i) + dt\*velocity(i)

velocity(i+1) = velocity(i) + dt\*g\_moon

ANALYTICAL SOLUTION:

Equations:

OBERSARVATIONS:

Decreasing the value of dt decreases and the analytical and computational models converge.

QUESTION – 2

Write down the equation for position of an object moving horizontally with a constant velocity “v”.

Assume v=50 m/s, use the Euler method (finite difference) to solve the equation as a function of time.

• Compare your computational result with the exact solution.

• Compare the result for different values of the time-step.

ASSUMPTIONS:

1. The surface under consideration is frictionless.
2. The drag force due to air is neglected.

INITIALIZATION:

1. max\_t is the time duration.
2. Intial velocity v = 50 m/s.
3. x is the position
4. x\_analytical is the analytical solution of the problem.

COMPUTATIONAL MODEL:

ANALYTICAL SOLUTION:

OBERSVATIONS:

As the given model is linear, there is no difference between the analytical and computational model.

QUESTION – 3

(a) Add the effect of atmosphere to problem 1 (still neglecting viscosity and drag). Suppose the falling object is a sphere of radius “r”, computationally study the effect of buoyancy on the motion of the object. Net force needs to be modeled properly (as discussed during lecture); choose proper density of air. Study the effect of “r” and “mass”. You can assume constant “g”.

(b) Also computationally investigate the motion of the same object traveling through aliquid (say water), and compare the motion with the case of air. Use computational data andplots to explain your answer (motion as a function of time).

ASSUMPTIONS:

1. The gravitational force remains constant all heights.
2. Drag force due to atmosphere is absent.
3. Viscosity of the medium has to be neglected.
4. Density of the given body is larger than the density of the medium in which its falling

INITIALIZATIONS:

1. init\_height is the height from which the object is released.
2. g is the gravitation due to earth = 9.8m/s2
3. rho\_air is the density of air = 1.225 kg/m3
4. rho\_water is the density of water = 996 kg/m3
5. mass\_ball is the mass of the ball.
6. volume\_ball is the volume of the ball

COMPUTATIONAL MODEL:

ANALYTICAL SOLUTION:

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OBSERVATION:

1. If we compare this graph with that in question 1 we will see that in this case the motion continues for a longer time, as the net acceleration in the downward direction is not ’g’ but less than it.(Due to the presence of buoyancy).
2. With increase in the radius of the body, the volume also increases. This implies that the net resultant force acting on the body in the downward direction increases. So, more the radius of the object faster it will reach the ground.
3. As the mass of the object increases the net acceleration acting on the body decreases. Therefore, the net resultant force acting on the body decreases. So, a body with higher mass will take more time to reach the ground as compared to a body with lesser mass.
4. By changing the medium from water to air : The density of water is 816 times more than the density of air, so a much greater buoyant force is applied on the object as compared to that in air.

QUESTION – 4

Now add the effect of viscous drag to the problem 3(b) assuming a small sphere is falling through the liquid with low speed. Model the system using viscous force given by Stokes law as discussed during the class. Choose proper coefficient of viscosity (look at the unit), and analyze the phenomena of terminal velocity.

ASSUMPTIONS:

1. Acceleration due the earth, g, remains constant.
2. The size of the given ball is small

INITIALIZATIONS:

1. height is the height from which the sphere is dropped.
2. g is the gravitational acceleration due to earth = 9.8 m/s2
3. rho\_water is the density of water = 1
4. max\_t is the time duration for which its to be modelled.
5. r is the radius of the sphere.
6. coeff\_viscosity\_water is the coefficient of viscosity of water = 8.9\*10e-4.
7. Initial velocity v(1) is 0COMPUTATIONAL MODEL:
8. Mass of ball is 1

COMPUTATIONAL MODEL:

ANALYTICAL SOLUTION:

OBSERVATION:

1. We can see that after a certain point the velocity of the object becomes constant as it reaches terminal velocity.
2. Greater the velocity of the body a greater viscous force acts on the body, as the viscous force is directly proportional to velocity.
3. As, acceleration increases, velocity increases and after a point of time, the (viscous force + buoyant force) balances gravitational force.Therefore, a = 0. And the body continues motion with constant velocity within the fluid. This velocity is known as Terminal Velocity.

QUESTION – 5

Modify the program (problem 3) and include the variation of “g” with height. Use the program to computationally investigate the motion of a body dropped from a height of 20 KM (assume constant air density).

How will you use the above program to investigate free fall in a deep mine (by taking proper initial conditions from Google).

ASSUMPTIONS:

1. Gravitational force varies with height
2. The drag force due to atmosphere is neglected
3. Buoyancy is neglected.

INITIALIZATIONS:

1. height from which its dropped
2. g is the gravitational acceleration = 9.8m/s2
3. rad\_earth is the radius of earth = 6400km
4. rho\_air ist he density of air = 1.225 kg/m3
5. rho\_water is the density of water = 997 kg/m3.
6. rho\_ball is the density of ball = 940 kg/m3 .
7. max\_t is the time duration for which the experiment is performed.

COMPUT9iATIONAL MODEL:

v(i+1) = v(i) + g\*(1-2\*(x(i)/rad\_earth))\*dt\*(1-rho\_air/rho\_ball)

x(i+1) = x(i) – v(i)\*dt

ANALYTICAL SOLUTION:

OBSERVATION:

1. Not much change in the displacement and velocity when we take ‘g’ to be varying.
2. This is because for small heights ‘g’ doesn’t change much and can be considered to be constant.

QUESTION – 6

A stone is thrown vertically upwards from the ground with some initial velocity in vacuum (choose a proper realistic velocity). Track the complete motion till it comes down to the ground (computationally). What is the velocity when it strikes the ground, compare with analytical result?.

• Compare the result for different values of the time-step

ASSUMPTIONS:

1. Gravitational acceleration remains constant
2. Absence of drag force from atmosphere
3. Buoyancy is neglected

INITIALIZATIONS:

1. g is the acceleration due to gravity
2. max\_t is the duration of the experiment
3. u is the velocity with which its thrown.

COMPUTATIONAL MODEL:

1. v(i+1) = v(i) – g\*dt
2. x(i+1) = x(i) + v(i)\*dt

ANALYTICAL SOLUTION:

x\_analytical = u \* t – ½ \* g \* t2

OBSERVATION:

The body after reaching maximum height starts falling like a free falling body. Since the body returns back to the ground the displacement of the body at the end of the motion is zero.

QUESTION – 2

Write down the equation for position of an object moving horizontally with a constant velocity “v”.

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• Compare your computational result with the exact solution.

• Compare the result for different values of the time-step

ASSUMPTIONS:

INITIALIZATIONS:

COMPUTATIONAL MODEL:

ANALYTICAL SOLUTION:

OBSERVATION: s