

## Program 1 – Satellite In Orbit Simulation

Comp 170

Due: September 2, 2001

Write a flowchart and C++ program that will; conclude a satellite is in perfect orbit, conclude a satellite will continue to travel away from the earth indefinitely, or report the distance from earth and net velocity of a satellite each second until it hits Earth's surface.

### Assumptions:

The satellite was propelled into space for you.  
The satellite will never run out of propulsion fuel.  
The satellite will maintain its initial away velocity.  
The satellite starts the simulation with a net velocity of 0.  
All friction with the Earth's atmosphere will be ignored.

### Variables to collect from user:

Satellite away velocity	Value set by user will never change (meters / second)
Mass of satellite	Value set by user will never change (kg)
Distance from surface of earth	Value set by user will change each second unless the satellite happens to be in perfect orbit (meters)

### Constants:

<i>Constant</i>	<i>Value</i>
Radius of Earth	6378000.14 (meters)
Mass of Earth	5.9736e+24 (kg)
Universal Gravitational Constant	6.669531020394004e-11(Newtons)
Earths Gravitational Constant	398411105034256.222944(Newtons x Kg)

### Formulas:

**Earth's gravitational force** is measured in Newtons. It is a measure of the amount of force the earth's gravitational field is pulling on an object. It is calculated as follows:

$$\text{Earth's gravitational force} = (\text{earth's gravitational constant} * \text{mass of satellite}) / \text{Satellite distance from center of Earth}^2$$

**Centripetal force** is measured in Newtons. It is the centrally directed force exerted on a body moving in a curved direction. In our scenario this is the force working against the Earth's gravitational force keeping a satellite in orbit. It is calculated as follows:

$$\text{Centripetal force} = (\text{mass of satellite} * \text{satellite away velocity}^2) / \text{Satellite distance from center of Earth}$$

**Net force** is measured in Newtons. It is the difference between the centripetal force and Earth's gravitational force. 0 indicates a perfect orbit. A positive value indicates that too much centripetal force has been applied and the satellite will continue to travel away from the earth indefinitely. A negative value indicates that not enough centripetal force was applied and the satellite will eventually collide with the surface of Earth.

$$\text{Net force} = \text{centripetal force} - \text{Earth's gravitational force}$$

**Acceleration due to gravity** is measured in meters per second squared. It is defined as “The rate of change of velocity with respect to time.

$$\text{Acceleration due to gravity} = |\text{Net force}| / \text{Mass of satellite}$$

**Net velocity** is measured in meters per second. It is the measure of speed from a third party’s prospective. It is the speed the satellite is actually traveling toward or away from the earth.

$$\text{Net velocity} = \text{net velocity} + \text{acceleration due to gravity}$$

**Distance traveled in last second** is measured in meters. It is how far the satellite traveled during the previous second.

$$\text{Distance traveled in last second} = (\text{net velocity} + \text{previous net velocity}) / 2$$

## How it all works:

Imagine a man rowing up stream in a canoe; we will call him Bob. He has a velocity of 5 mph but the river is flowing in the opposite direction at 4 miles per hour. A heckler, named Tom, is on shore in a lawn chair with a radar gun. He yells to Bob “You are only going 1 mile per hour.” Without looking up at Tom, Bob yells back “Leave me alone, I know I am going 5 mph.” Frustrated Bob loses strength and slows down to 4 mph. Tom now becomes frightened because Bob appears to have stopped in the river right beside him. Tom knows that he is not a match for someone who can row a canoe at “1mph” so he begins to hurl rocks at Bob and knocks him out. Bob, now not rowing at all, begins to be pulled down stream at 4 mph. Tom runs away because he knows that anyone who can row backward at 4 mph would crush him with one blow.

Lesson #1 – Velocity is relative to your prospective.

Lesson #2 – Bob and Tom are idiots.

This assignment deals with the same issues as Bob and Tom. We have a satellite traveling at a given velocity; you are guaranteed that the satellite will maintain this velocity. We also have to deal with the Earth’s gravitational field pulling the satellite toward its surface. You have been given formulas above for the necessary calculations. You must recalculate the **Earth’s gravitational force, centripetal force, net force, net velocity, and distance traveled during the last second** for each second of the simulation. Do not forget to subtract out the **distance traveled during the last second** from your **distance from center of earth**. Stop the simulation when the satellite reaches the surface of the earth, is in perfect orbit, or you continues to travel away from the earth indefinitely.

## Note:

- Use the “long double” data type for all variables.
- Use descriptive variable names. The more descriptive you are the more understandable your code will be.
- Do not wait until the last minute to ask questions.
- Do your own work.

## Step Length:

Allow the user to input the time interval for the each step in the simulation. The simulation description to this point assumes that each step represents 1 sec. You will need to slightly modify a couple of the formulas to do this. Remember, the smaller the time interval the more accurate the simulation.

### Example Runs:

Satellite away velocity (meters/second): 7598.732779880941  
Initial distance from surface of earth (meters): 521999.86  
Mass of satellite (kg): 10000  
Step length (sec): 1  
Perfect orbit

Satellite away velocity (meters/second): 9000  
Initial distance from surface of earth (meters): 5000000  
Mass of satellite (kg): 7500  
Step length (sec): 1  
Escaping Earth's gravitational pull

Satellite away velocity (meters/second): 10  
Initial distance from surface of earth (meters): 100  
Mass of satellite (kg): 800  
Step length (sec): 1

Time (sec)	Altitude(meters)	Velocity(meters/sec)
1	95.1031356128	9.7937287748
2	80.4125349317	19.5874725880
3	55.9281678787	29.3812615172
4	21.6499742996	39.1751256402
5	-22.4221360385	48.9690950363

Satellite away velocity (meters/second): 7598.73  
Initial distance from surface of earth (meters): 521999.86  
Mass of satellite (kg): 10000  
Step length (sec): 1

Time (sec)	Altitude(meters)	Velocity(meters/sec)
1	521999.8599969391	0.0000061228
2	521999.8599877553	0.0000122456
3	521999.8599724481	0.0000183683
4	521999.8599510184	0.0000244911
5	521999.8599234661	0.0000306140
6	521999.8598897904	0.0000367368
7	521999.8598499922	0.0000428598
8	521999.8598040706	0.0000489827
9	521999.8597520264	0.0000551057
10	521999.8596938588	0.0000612288
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11061	5922.0307479007	598.2863149720
11062	5323.3788412400	599.0174983497
11063	4723.9952584617	599.7496672059
11064	4123.8790133074	600.4828231026
11065	3523.0291179540	601.2169676047
11066	2921.4445830118	601.9521022806
11067	2319.1244175211	602.6882287014
11068	1716.0676289499	603.4253484415
11069	1112.2732231896	604.1634630784
11070	507.7402045541	604.9025741928
11071	-97.5324242264	605.6426833683