PHYS304 HW1

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1. EXERCISE 2.10: THE SEMI-EMPIRICAL MASS FORMULA

In this problem, we are asked to write a program based on the formula for calculating the approximate nuclear binding energy B of an atomic nucleus with atomic number Z and mass number A:

$$B = a_1 A - a_2 A^{2/3} - a_3 \frac{Z^2}{A^{1/3}} - a4 \frac{(A-2Z)^2}{A} + \frac{a_5}{A^{1/2}} \quad (1)$$

where, in units of millions of electron volts, the constants are a1 = 15.67, a2 = 17.23, a3 = 0.75, a4 = 93.2, and a5 = 0 if A is odd, 12.0 if A and Z are both even, -12.0 if A is even and Z is odd.

a, b) I start with having my program to take the input of A and Z and given A = 58 and Z = 28. Then define all the values of constants stated in the problem and use if and elif function to satisfy the condition of a5. After the calculation, I assign the program to print B and B/A. For the test, A = 58 and Z = 28, The binding energy of the atom (B) = 493.93560680136824 MeV, and the binding energy per nucleon (B/A) = 8.516131151747729. The result is as expected.

c) In order to have my program to find the most stable nucleus of A from given Z and then goes through all values of A from A = Z to A = 3Z, I start with the input of a single value of Z. Then I create a list of A value to run from A = Z to A = 3Z which I use the for loop function to have the calculation runs from Z to 3Z to find the most stable A for each in the list of A value. For the test, Z = 28, the most stable nucleus with the given atomic number (best A) is 58 and the value of the binding energy per nucleon (B/A) is 8.516131151747729. The result is as expected.

d) In order to find the most stable nucleus of A from given value of Z from 1 to 100, I approach it a similar way to c) as I create a new list of Z value to run through all values of Z from 1 to 100 then I use the modified loop from part c to be under the loop of Z list, and have it calculates the most stable nucleus of A for each in the list of Z value. For the test, the maximum binding energy per nucleon occurs at value of Z of 24. The result is not exactly as expected in real life which is nickel at Z = 28 but approximately close.

2. EXERCISE 2.2: ALTITUDE OF A SATELLITE

a) We need to show that the altitude h above the Earth's surface that the satellite is

$$h = (\frac{GMT^2}{4 * \pi^2}) \quad (2)$$

where $G = 6.67 \times 10^{-11} m^3 kg^{-1} s^{-2}$ is Newton's gravitational constant, $M = 5.97 \times 10^{24} kg$ is the mass of the Earth, and $R = 6371 km$ is its radius.

According to Kepler's third law, and the total height of $a = h + R$.

$$T^2 = \frac{4\pi^2 a^3}{GM} \quad (3)$$

$$a^3 = \frac{GMT^2}{4\pi^2} \quad (4)$$

$$(h+R)^3 = \frac{GMT^2}{4\pi^2} \quad (5)$$

Therefore, the altitude h above the Earth's surface that the satellite is

$$h = \frac{GMT^2}{4\pi^2}^{\frac{1}{3}} - R \quad (6)$$

b) I simply put the equation stating all the variables and constants in the problem and have it to take the input of T in seconds and print h altitude in meters.

c) For the calculation tested in the program, for satellites that orbit the Earth once a day, T = 24 hours (86400 secs), the altitude h that the satellite must have is 35855844.34638021 m or 3585.84 km which is considerably further away for satellites. For satellites that orbit the Earth every 90 mins, T = 90 mins (5400 secs), the altitude h that the satellite must have is 279311.257829844 m or 279.31 km which is plausible for satellites. For satellites that orbit the Earth every 45 mins, T = 45 mins (2700 secs), the altitude h that the satellite must have is -2181566.428953664 m which is impossible for satellites to orbit.

d) A sidereal day is the time it takes for the Earth to rotate about its axis so that the distant stars appear in the same position in the sky, lasted for 23 hours 56 minutes 4.091 seconds. Therefore, it is shorter than the solar day measured from noon to noon for 24 hours. For a sidereal day the period T is 86164 seconds, and for a solar day is 86400 seconds. The difference in the altitude h for satellites to orbit is 76929.61081 m or 76.93 km lower for a period of sidereal day.

3. EXERCISE 2.6: PLANETARY ORBITS

a, b) Given the distance l_1 of closest approach that a planet makes to the Sun, also called its perihelion, its linear velocity v_1 at perihelion, and m is the planet's mass, $M = 1.9891 \times 10^{30}$ kg is the mass of the Sun, and $G = 6.6738 \times 10^{-11} m^3 kg^{-1} s^{-2}$ is Newton's gravitational constant, according to the energy conservation,

$$1/2mv_1^2 - G(\frac{mM}{l1}) = 1/2mv_2^2 - G(\frac{mM}{l2}) \qquad (7)$$

rearranging we have

$$v_2^2 - \frac{2GM}{l_2} - [v_1^2 - \frac{2GM}{l_1}] = 0 \qquad (8)$$

given that $l_2 = \frac{l_1 v_1}{v_2}$. Therefore, we have the quadratic equation of

$$v_2^2 - \frac{2GM}{v_1 l_1} v_2 - [v_1^2 - \frac{2GM}{l_1}] = 0 \qquad (9)$$

Then I define the equation in my program along with all the values as the calculation for quadratic equation for $a = 1$, $b = -2GM/(v_1 l_1)$, $c = -(v_1^2 - 2GM/l_1)$, solving for b and c in $ax^2 + bx + c$, resulted in two roots of $(-b - d^{1/2})/2$ and $(-b + d^{1/2})/2$, where $d = b^2 - 4ac$. I use the function min for the calculation to use the smaller root of v_2 and have it taking the input for the distance to the Sun l_1 and velocity v_1 at perihelion, and then calculates and prints the quantities l_2, v_2, T, and e.

c) For the test, the orbital period of the Earth is 1.0002238777234564 years, and the orbital period of Halley's comet is 76.08170065465461 years, resulted as expected.

4. FEEDBACK

I spent about 12-14 hours on this homework including meeting with classmates and attending office hours. Since I don't have a strong programming background, I found myself struggling to use the tools we learned in class. I feel that we are introduced to the tools but don't really get to know how to use them enough to tackle the problems we had in this homework. I would like to have more time in the class to use more of these tools and go through more of the problems similar to the homework problems. So that we will develop strong enough skill to use the tools and spend time on the homework in a more appropriate length for the course. I would also like to spend more time in class developing analyzing skill through flow chart and pseudo code. It would be helpful to have more examples of how to approach the problems by walking through the thinking process to solve the problems. Additionally, there are parts of problems with mathematical calculation which can be time consuming aside from the programming part which I found myself less enjoy doing so.

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Judy

(2.10) a) → $a_1 = 15.67$
$a_2 = 17.23$
$a_3 = 0.75$
$a_4 = 93.2$

→ $a_5 = \begin{cases} 0 & \text{if } A \text{ is odd} \\ 12.0 & \text{if } A \text{ and } Z \text{ even} \\ -12.0 & \text{if } A \text{ is even, } Z \text{ is odd} \end{cases}$

if $A/2 \,!\!= 0$

dif $A/2 = 0$ and $Z/2 \,!\!= 0$

dif $\frac{A \text{ and } Z}{2} = 0$

→ ~~if~~ B = ~~mmm~~

→ input A, Z

A = 58 , Z = 28

b) → print B , B/A

c) A , A = Z , A = 3Z
print A stable

Alist → list of A . array
from Z to 3Z

→ for x in range
"math"
if B/A → list of A
find best A
→ x = x + 1
print best A,

loop

d) ~~A/Z~~ Z from 1 - 100
print A stable

Zlist → list of Z . array
from 1 to 100

for Z list
loop c)

loop again

↳ ~~j=~~ j + 1
print best A,
for best Z,

2.2 a) show that $h = \left(\frac{GMT^2}{4\pi^2}\right)^{1/2} - R$

~~Kepler's~~ 3rd law

$\to$ $T^2 = 4\pi^2 a^3 / GM$

$\to a^3 = \frac{T^2 GM}{4\pi^2}$

$(h+R)^3 = \frac{GMT^2}{4\pi^2}$

$h = \left(\frac{4MT^2}{4\pi^2}\right)^{1/3} - R$

b) $\to$ T $\to$ Input (s)
"math"
$\to$ print h (m)

2.6 a) show v_2 is the smaller root of

$$v_2^2 - \frac{2GM}{v_1 l_1} v_2 - \left[v_1^2 - \frac{2GM}{l_1}\right] = 0$$

$\to$ solve as $ax^2 + bx + c$
for $a = 1$ we can find b, c

$\to$ root 1, root 2

$\to$ $v_2 = \min(\text{root1}, \text{root2})$

put values in "math"

$\to$ print l_2, v_2, T, e