# C200 Programming Assignment № 3

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## Introduction

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**Student Pairs** are provided at the end of this document.
Please read through the problems carefully. Some reminders from lecture:

- A **constant** function is a function whose output value is the same for every input value. For example: f(x) = 3, irrespective of what we plug in for x, the function f will allways output 3.
- Now we know that a **constant** (or fixed) function $f(x)$ returns the same constant value, *e.g.*,

$$f(x, y) = 3 \tag{1}$$

No matter the inputs, the value is three.

- We can convert between $\log_a, \log_k$:

$$\log_b(x) = \frac{\log_k(x)}{\log_k(b)} \tag{2}$$

Why? Remember that if $\log_b(x) = r$, then $b^r = x$. So, let's first write

$$\log_b(x) = r \tag{3}$$
$$\log_k(x) = s \tag{4}$$
$$\log_k(b) = t \tag{5}$$

This means

$$b^r = x \tag{6}$$
$$k^s = x \tag{7}$$
$$k^t = b \tag{8}$$

We see that $b^r = x = k^s$. Since $b = k^t$, we can write:

$$(k^t)^r = k^{rt} = x = k^s \tag{9}$$

Then

$$\log_k(k^{rt}) = \log_k(x) = \log_k(k^s) \tag{10}$$

$$rt = \log_k(x) = s \tag{11}$$

Using equations 3,5 for $r, t$ we have

$$\log_b(x)\log_k(b) = \log_k(x) \tag{12}$$

$$\log_b(x) = \frac{\log_k(x)}{\log_k(b)} \tag{13}$$

## Problem 1: Functions and math module

All the following functions are drawn from real-world sources. This is an exercise for you to learn how to use a module on your own. From the math module use

- `math.exp(x)` for $e^x$
- `math.ceil(x)` for $\lceil x \rceil$ rounds x UP to the nearest integer $k$ such that $x \leq k$
- `math.log(x)` for $\log_e(x) = \ln(x)$.

1. According to the Center for Disease Control (CDC) the bacteria *Salmonella* causes about 20K hospitalizations and nearly 400 deaths a year. The formula for how fast this bacteria grows is:

$$N(n_0, m, t) = n_0 e^{mt} \tag{14}$$

$$\tag{15}$$

   where $n_0$ is the initial number of bacteria, $m$ is the growth rate *e.g.*, 100 per hr, and $t$ is time in hours. Here is how you would calculate the size for an initial colony of 500 that grows at the rate of 100 per hr, for four hours.

$$N(500, 100, 4) = 2.610734844882072 \times 10^{176} \tag{16}$$

2. The number of teeth $N_t(t)$ after $t$ days from incubation for *Alligator mississippiensis* is:

$$N_t(t) = 71.8e^{-8.96e^{-0.0685t}} \tag{17}$$

$$N_t(1000) = \lceil 71.8 \rceil = 72 \tag{18}$$

3. If we want to calculate the work done when an ideal gas expands isothermally (and reversibly) we use for initial and final pressure $P_i = 10\ bar, P_f = 1\ bar$ respectively at $300^o K$. In this problem we are using $\ln$ which is $\log_e$ ('math.log uses base e by default'). Because $\log_e$ is used so often, you'll see it just as often abbreivated as $\ln$.

$$W(P_i, P_f) = RT \ln(P_i/P_f) \tag{19}$$

$$W(10, 1) = \lceil 8.314(300)(\ln 10) \rceil = 5744 \tag{20}$$

   at temperature $T$ (Kelvin) and $R = 8.314\ J/mol$ the universal gas constant.

4. The Wright Brothers are known for their Flyer and its maiden flight. The formula for lift is:

$$L(V, A, C_\ell) = kV^2 A C_\ell \tag{21}$$

$$L(33.8, 512, 0.515) = \lceil 0.0033(33.8)^2(512)0.515 \rceil = 995 \tag{22}$$

where $k$ is Smeaton's Coefficient ($k = 0.0033$ from their wind tunnel), $V = 33.8\ mph$ is relative velocity over the wing, $A = 512\ ft$ area of wing, and $C_\ell = 0.515$ coefficient of lift. The Flyer weighed $600\,lbs$ and Orville was about $145\,lbs$. We can see that the lift was sufficient since $994 > 745$.

**Deliverables for Problem 1**

- Complete the functions described above.

## Problem 2: Quadratic

We saw, and also know from basic algebra that for $ax^2 + bx + c = 0$ the roots (values that make the equation zero) are given by:

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \tag{23}$$

The expression $b^2 - 4ac$ is called the discriminant. By looking at the discriminant we can deteremine properties of the roots:

- If $b^2 - 4ac > 0$, then both roots are real
- If $b^2 - 4ac = 0$, then both roots are $-b/2a$
- If $b^2 - 4ac < 0$, then both roots are imaginary

Write a function $q(t)$ that takes a tuple $t = (a, b, c)$ and returns 1 if the roots are real, 0 otherwise:

$$q((a, b, c)) = \begin{cases} 1 & \text{roots are real} \\ 0 & \text{otherwise} \end{cases} \tag{24}$$

For example,

$$q((1, 4, -21)) = \text{True} \tag{25}$$
$$q((3, 6, 10)) = \text{False} \tag{26}$$
$$q((1, 0, -4)) = \text{True} \tag{27}$$

**Deliverables for Problem 2**

- Review integers and reals.
- You are not allowed to use the module `cmath`.
- Complete the function.

## Problem 3: Somethings Are Taxed, Somethings Are Not

Search on this phrase "what food isn't taxed in indiana". You're writing software that allows for customer checkout at a grocery store. A customer will have a have receipt $r$ which is a list of pairs $r = [[i_0, p_0], [i_1, p_1], \ldots, [i_n, p_n]]$ where $i$ is an item and $p$ the cost. You have access to a list of items that are not taxed $no\_tax = [j_0, j_1, \ldots, j_m]$. The tax rate in Indiana is 7%. Write a function amt that takes the receipt and and the items that are not taxed and gives the total amount owed. For this function you will have to implement the member function $m(x, lst)$ that returns True if $x$ is a member of $lst$.

For example, let $r = [[1, 1.45], [3, 10.00], [2, 1.45], [5, 2.00]]$ and $no\_tax = [33, 5, 2]$. Then

$$amt(r, no\_tax) = round(((1.45 + 10.00)1.07 + 1.45 + 2.00), 2) \quad (28)$$

$$= \$15.7 \quad (29)$$

**Deliverables for Problem 3**

- Complete the function
- for $m(x, lst)$ you must seach for x in lst by looping through lst. If you use python's **in** keyword to search for you, you will recieve a 0.

## Problem 4: Building a line in 2D

A line in 2D Euclidean space is given by $y = mx + b$ ('m' and 'b' are the slope and intercept respectively). Write a function $f$ that takes two points $p_0 = (x_0, y_0), p_1 = (x_1, y_1)$ that returns the tuple $(m, b)$:

$$f((x_0, y_0), (x_1, y_1)) = \begin{cases} (m, b) & x_0 \neq x_1 \\ () & \text{otherwise} \end{cases} \tag{30}$$

For example,

$$f((2, 3), (6, 4)) = (0.25, 2.5) \tag{31}$$

$$f((1, 6), (3, 2)) = (-2.0, 8.0) \tag{32}$$

$$f((1, 3), (1, 5)) = () \tag{33}$$

**Deliverables for Problem 4**

- Complete the function.

## Problem 5: Means

When analyzing data, we often want to summarize it: make it concise. Each of these functions takes a list nlst of numbers. The mean of a list of numbers gives a summary through one number. You're probably aware of the arithmetic mean:

$$\text{arithmetic\_mean(nlst)} = \frac{(x_0 + x_1 + \cdots + x_{n-1})}{n} \tag{34}$$

For example, the arithmetic mean of [1,2,3] is 2.0.

The geometric mean (usually done with logs) is:

$$\text{geo\_mean(nlst)} = a^{sum/n} \tag{35}$$

$$sum = \log_a(x_0) + \log_a(x_1) + \cdots + \log_a(x_{n-1}) \tag{36}$$

where $\log_a$ is an arbitrary log to base $a$. For example, the geometric mean of [2,4,8] is 4.0. Use $\log_{10}$ as default–but it doesn't actually matter. The harmonic mean is:

$$\text{har\_mean(nlst)} = \frac{n}{1/x_0 + 1/x_1 + \cdots + 1/x_{n-1}} \tag{37}$$

For example, the harmonic mean of [1,2,3] is approximately 1.64.

The root mean square is:

$$\text{RMS\_mean(nlst)} = \sqrt{\frac{sum}{n}} \tag{38}$$

$$sum = x_0^2 + x_1^2 + \cdots + x_{n-1}^2 \tag{39}$$

For example, the root mean square of [1,3,4,5,7] is approximately 4.47.

All of these functions take a (possibly empty) list of numbers. If there is a list of numbers, then return the mean. **If the list is empty, return the string "Data Error: 0 values".** If there is a zero in the list of numbers for the harmonic mean, then return the string "Data Error: 0 in data". To help codify the problem, take a look at the unit testing. We give these two errors, because we face division by zero if we don't.

**Deliverables for Problem 5**

- Complete the functions as specified above.
- You can not use the python's **in** keyword to search for 0s.

## Problem 6: Cost Function

Suppose AirPure, a manufacturer of air filers, has a monthly fixed cost of \$10,000 and a variable cost of $-0.0001x^2 + 10x$ for $0 \leq x \leq 40,000$ where $x$ denotes the number of filters manufacturer per month. Total cost $C$ is the sum of variable and fixed cost:

$$C(x) = V(x) + F(x) \tag{40}$$

where $V(x)$ is variable cost and $F(x)$ is fixed cost. For example,

$$C(0) = 10000.0 \tag{41}$$

$$C(100) = 10999.0 \tag{42}$$

$$C(1000) = 19900.0 \tag{43}$$

**Deliverables for Problem 6**

- Complete the functions all three functions.
- Hint: Read the Introduction again to get some help on this problem.

## Problem 7: Mortgage

A *mortgage* is what you pay when you cannot purchase, usually a home, outright. You pay in installments that have to do with *terms* of the agreement. This includes an interest rate that is added to your payments. Here is the formula for your monthly payment:

$$m = P\frac{i(1+i)^n}{(1+i)^n - 1}$$

where $P$ is the cost of the home, $i$ is the percentage over 12 months, $n$ is the total number of months. Let's say our data is: \$300,000 house at 2.9% for 30 years. Then

$$\begin{aligned}
m &= 300000\frac{.029/12(1+.029/12)^{30\times 12}}{(1+.029/12)^{30\times 12} - 1} \\
&= 300000\frac{.0024166(1.0024166)^{360}}{(1.0024166)^{360} - 1} \\
&= 300000\frac{.0024166(2.38440696)}{2.38440696 - 1} \\
&= 300000\frac{0.005762}{1.38440696} \\
&= 300000(0.004162185) = \$1248.69/mo
\end{aligned}$$

The data should be in a list, *i.e.*, house = [300000,2.9,30] which represents the value of the house, the interest rate and the years. If house = [100000,6.0,30], the monthly payment is about \$599.95. We will call this function Mortgage (house)

This seems easy financially. You can find what the mortgage *actually* costs by finding what you paid for the house and what its original value was:

$$\$1248.69/mo(30\,yr)(12\;mo/yr) - \$300000$$

$$\$449528.40 - \$300000 \approx \$149528.40$$

We will call this function total_paid(house).

**Deliverables for Problem 7**

- round the return values to two decimal places
- Complete the functions.
- The total_paid function must use the Mortgage function. Both take lists described above

## Problem 8: Geometric Series

A geometric series is the sum of an infinite number of terms that have a constant ratio between successive terms. For example,

$$\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+\frac{1}{16} \tag{44}$$

is apparently a geometric series since:

$$\frac{1/4}{1/2}=\frac{1/8}{1/4}=\frac{1/16}{1/8}=\frac{1}{2} \tag{45}$$

Write a function $is\_geo(xlst)$ that takes a list of numbers and returns 1 only if the series is geometric; otherwise 0. If the list has 2 or fewer members, $is\_geo$ returns 0. For example,

$$\begin{aligned}
is_geo([1/2,1/4,1/8,1/16,1/32]) &= 1 && (46)\\
is_geo([1,-3,9,-27]) &= 1 && (47)\\
is_geo([625,125,25]) &= 1 && (48)\\
is_geo([1/2,1/4,1/8,1/16,1/31]) &= 0 && (49)\\
is_geo([1,-3,9,-26]) &= 0 && (50)\\
is_geo([625,125,24]) &= 0 && (51)\\
is_geo([1/2,1/4]) &= 0 && (52)
\end{aligned}$$

**Deliverables for Problem 8**

- Complete the function
- Assume none of the numbers are zero
- If the series has 2 or fewer the function returns 0

# 1 Student Pairs

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