Programming Project: Frequencies of Musical Notes with Loops and Arrays
CPSC-298-6 Programming in C++
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Introduction

Loops and arrays provide tremendous power and help you to express programming problems simply. In this assignment, you'll revisit your program to compute the frequencies of musical notes given a reference frequency. This time, you'll compute the frequencies and wavelengths of all the notes from the zero'th to the eighth octave; that is, from note C_0 to note B_8. Even though you're computing more values this time, you'll write far less code.

The Assignment

To compute the frequency of the note in octave **ν** (nu) and half step ***k***, you'll use the following formula. The value **ν** will range from 0 to 8, inclusive, and the value of ***k*** from 0 to 11, inclusive.

$$f_{k,\nu} = f_R \times 2^{(\nu)+ k/12}$$

f_R is the Reference Frequency, in this case 16.35 Hz (cycles per second), the Frequency of the note C in octave 0, the "zero'th octave, (denoted by C_0).
ν is the octave number (which ranges from 0 to 9 for our purposes)
k is the half-step (or semitone number) within the octave, it has values between 0 and 11 inclusive.
$f_{k,\nu}$ is the frequency of the note in octave ν whose half-step within the octave is *k*. [1]

Implement the formula in the form shown. Use the pow() function to compute 2 raised to the **ν** + ***k*** /12. pow() can handle a fractional exponent. Be careful to use floating point division and not integer division when computing **ν** + ***k*** /12.

For the wavelength, use the following formula:

$$W_{k,\nu} = c / f_{k,\nu}$$

where

$W_{k,\nu}$ is the wavelength, c is the speed of sound in air (at room temperature), and $f_{k,\nu}$ is the frequency.

The speed of sound in air at room temperature is (roughly) 345 meters per second (345 m/s) or 34500 centimeters per second. (Remember that there are 100 centimeters in a meter.)

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[1] More technically, it is frequency of equal-tempered interval *k* in octave **ν**. The octaves are named in the order of their appearance on a standard 88-key piano keyboard, beginning with octave 0 (or the "zero'th octave").

You'll also use the following array of strings containing the names of all the notes whose frequencies and wavelengths you'll be displaying.

```
std::string a_strNotes[] = {
                "C0", "C#0", "D0","D#0", "E0", "F0", "F#0", "G0", "G#0", "A0", "A#0", "B0",
                "C1", "C#1", "D1","D#1", "E1", "F1", "F#1", "G1", "G#1", "A1", "A#1", "B1",
                "C2", "C#2", "D2","D#2", "E2", "F2", "F#2", "G2", "G#2", "A2", "A#2", "B2",
                "C3", "C#3", "D3","D#3", "E3", "F3", "F#3", "G3", "G#3", "A3", "A#3", "B3",
                "C4", "C#4", "D4","D#4", "E4", "F4", "F#4", "G4", "G#4", "A4", "A#4", "B4",
                "C5", "C#5", "D5","D#5", "E5", "F5", "F#5", "G5", "G#5", "A5", "A#5", "B5",
                "C6", "C#6", "D6","D#6", "E6", "F6", "F#6", "G6", "G#6", "A6", "A#6", "B6",
                "C7", "C#7", "D7","D#7", "E7", "F7", "F#7", "G7", "G#7", "A7", "A#7", "B7",
                "C8", "C#8", "D8","D#8", "E8", "F8", "F#8", "G8", "G#8", "A8", "A#8", "B8",
        };
```

You'll implement an outer for loop over **v**, which ranges from 0 to 8, inclusive. Inside this loop, you'll implement an inner for loop that iterates over k from 0 to 11, inclusive.

```
const int k_nOctaves = 9;    // Number of octaves to consider
const int k_nHalfTones = 12; // Number of Half-tones in an octave
std::string strNote;

for (int nu = 0; /* ?? */, /* ?? */)
{
        for (int k = 0; /* ?? */, /* ?? */)
        {
                // Calculate frequency (f)
                // ??
                // Calculate wavelength (dWavelengthCentimeters)
                // ??
                // Select name for note (e.g. "C#0") from array (assign to strNote)
                // ?? (Need to compute offset into array based on nu and k)
                 strNote = a_strNotes[? expression in terms of nu and k ?];
                std::cout << "Note: " << strNote << "; nu: " << nu << "; k: " << k
                          << "; frequency: " << f << " Hz; wavelength: "
                          << dWavelengthCentimeters << " cm" << std::endl;
        }
}
```

The question marks, `/* ?? */` , indicate code that you need to complete.

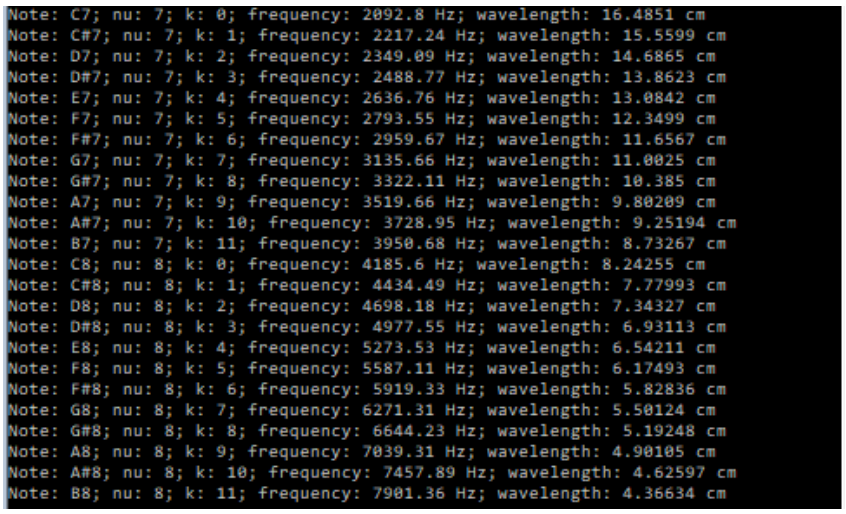
Within the inner for loop you'll print the name of the note, the values of nu (**v**) and k, and the computed frequency and wavelength of the note. You can use setw() and other methods to improve the appearance of the output if you'd like.

When printing out the name of the note, such as "C#0", you'll need to access the array element within the a_strNotes array correspond to nu (**v**) and k. In the code fragment above, strNote is a string variable that is assigned to the appropriate element within array a_strNotes. But which one? The solution involves k_nHalfTones and may look similar to the following, where *o* and *O* represent two different numeric operators such +, -, * and /. The question mark represents something else - a mystery you'll need to solve.

strNote = a_strNotes[? *o* nu *O* k];

The output of the program will appear similar to the following

```
Note: C0; nu: 0; k: 0; frequency: 16.35 Hz; wavelength: 2110.09 cm
Note: C#0; nu: 0; k: 1; frequency: 17.3222 Hz; wavelength: 1991.66 cm
Note: D0; nu: 0; k: 2; frequency: 18.3523 Hz; wavelength: 1879.88 cm
Note: D#0; nu: 0; k: 3; frequency: 19.4435 Hz; wavelength: 1774.37 cm
Note: E0; nu: 0; k: 4; frequency: 20.5997 Hz; wavelength: 1674.78 cm
Note: F0; nu: 0; k: 5; frequency: 21.8246 Hz; wavelength: 1580.78 cm
Note: F#0; nu: 0; k: 6; frequency: 23.1224 Hz; wavelength: 1492.06 cm
Note: G0; nu: 0; k: 7; frequency: 24.4973 Hz; wavelength: 1408.32 cm
Note: G#0; nu: 0; k: 8; frequency: 25.954 Hz; wavelength: 1329.27 cm
Note: A0; nu: 0; k: 9; frequency: 27.4973 Hz; wavelength: 1254.67 cm
Note: A#0; nu: 0; k: 10; frequency: 29.1324 Hz; wavelength: 1184.25 cm
Note: B0; nu: 0; k: 11; frequency: 30.8647 Hz; wavelength: 1117.78 cm
Note: C1; nu: 1; k: 0; frequency: 32.7 Hz; wavelength: 1055.05 cm
Note: C#1; nu: 1; k: 1; frequency: 34.6444 Hz; wavelength: 995.831 cm
Note: D1; nu: 1; k: 2; frequency: 36.7045 Hz; wavelength: 939.939 cm
Note: D#1; nu: 1; k: 3; frequency: 38.8871 Hz; wavelength: 887.184 cm
Note: E1; nu: 1; k: 4; frequency: 41.1994 Hz; wavelength: 837.39 cm
Note: F1; nu: 1; k: 5; frequency: 43.6493 Hz; wavelength: 790.391 cm
Note: F#1; nu: 1; k: 6; frequency: 46.2448 Hz; wavelength: 746.03 cm
Note: G1; nu: 1; k: 7; frequency: 48.9946 Hz; wavelength: 704.159 cm
Note: G#1; nu: 1; k: 8; frequency: 51.908 Hz; wavelength: 664.637 cm
Note: A1; nu: 1; k: 9; frequency: 54.9946 Hz; wavelength: 627.334 cm
Note: A#1; nu: 1; k: 10; frequency: 58.2648 Hz; wavelength: 592.124 cm
Note: B1; nu: 1; k: 11; frequency: 61.7294 Hz; wavelength: 558.891 cm
Note: C2; nu: 2; k: 0; frequency: 65.4 Hz; wavelength: 527.523 cm
Note: C#2; nu: 2; k: 1; frequency: 69.2889 Hz; wavelength: 497.915 cm
Note: D2; nu: 2; k: 2; frequency: 73.409 Hz; wavelength: 469.97 cm
Note: D#2; nu: 2; k: 3; frequency: 77.7741 Hz; wavelength: 443.592 cm
Note: E2; nu: 2; k: 4; frequency: 82.3988 Hz; wavelength: 418.695 cm
Note: F2; nu: 2; k: 5; frequency: 87.2985 Hz; wavelength: 395.196 cm
Note: F#2; nu: 2; k: 6; frequency: 92.4896 Hz; wavelength: 373.015 cm
Note: G2; nu: 2; k: 7; frequency: 97.9893 Hz; wavelength: 352.079 cm
Note: G#2; nu: 2; k: 8; frequency: 103.816 Hz; wavelength: 332.319 cm
Note: A2; nu: 2; k: 9; frequency: 109.989 Hz; wavelength: 313.667 cm
Note: A#2; nu: 2; k: 10; frequency: 116.53 Hz; wavelength: 296.062 cm
Note: B2; nu: 2; k: 11; frequency: 123.459 Hz; wavelength: 279.446 cm
Note: C3; nu: 3; k: 0; frequency: 130.8 Hz; wavelength: 263.761 cm
Note: C#3; nu: 3; k: 1; frequency: 138.578 Hz; wavelength: 248.958 cm
Note: D3; nu: 3; k: 2; frequency: 146.818 Hz; wavelength: 234.985 cm
Note: D#3; nu: 3; k: 3; frequency: 155.548 Hz; wavelength: 221.796 cm
Note: E3; nu: 3; k: 4; frequency: 164.798 Hz; wavelength: 209.348 cm
Note: F3; nu: 3; k: 5; frequency: 174.597 Hz; wavelength: 197.598 cm
Note: F#3; nu: 3; k: 6; frequency: 184.979 Hz; wavelength: 186.508 cm
Note: G3; nu: 3; k: 7; frequency: 195.979 Hz; wavelength: 176.04 cm
Note: G#3; nu: 3; k: 8; frequency: 207.632 Hz; wavelength: 166.159 cm
Note: A3; nu: 3; k: 9; frequency: 219.979 Hz; wavelength: 156.834 cm
Note: A#3; nu: 3; k: 10; frequency: 233.059 Hz; wavelength: 148.031 cm
Note: B3; nu: 3; k: 11; frequency: 246.918 Hz; wavelength: 139.723 cm
Note: C4; nu: 4; k: 0; frequency: 261.6 Hz; wavelength: 131.881 cm
Note: C#4; nu: 4; k: 1; frequency: 277.156 Hz; wavelength: 124.479 cm
Note: D4; nu: 4; k: 2; frequency: 293.636 Hz; wavelength: 117.492 cm
Note: D#4; nu: 4; k: 3; frequency: 311.097 Hz; wavelength: 110.898 cm
Note: E4; nu: 4; k: 4; frequency: 329.595 Hz; wavelength: 104.674 cm
Note: F4; nu: 4; k: 5; frequency: 349.194 Hz; wavelength: 98.7989 cm
Note: F#4; nu: 4; k: 6; frequency: 369.958 Hz; wavelength: 93.2538 cm
Note: G4; nu: 4; k: 7; frequency: 391.957 Hz; wavelength: 88.0198 cm
Note: G#4; nu: 4; k: 8; frequency: 415.264 Hz; wavelength: 83.0797 cm
Note: A4; nu: 4; k: 9; frequency: 439.957 Hz; wavelength: 78.4168 cm
Note: A#4; nu: 4; k: 10; frequency: 466.118 Hz; wavelength: 74.0156 cm
Note: B4; nu: 4; k: 11; frequency: 493.835 Hz; wavelength: 69.8614 cm
Note: C5; nu: 5; k: 0; frequency: 523.2 Hz; wavelength: 65.9404 cm
Note: C#5; nu: 5; k: 1; frequency: 554.311 Hz; wavelength: 62.2394 cm
Note: D5; nu: 5; k: 2; frequency: 587.272 Hz; wavelength: 58.7462 cm
Note: D#5; nu: 5; k: 3; frequency: 622.193 Hz; wavelength: 55.449 cm
Note: E5; nu: 5; k: 4; frequency: 659.191 Hz; wavelength: 52.3369 cm
Note: F5; nu: 5; k: 5; frequency: 698.388 Hz; wavelength: 49.3995 cm
Note: F#5; nu: 5; k: 6; frequency: 739.917 Hz; wavelength: 46.6269 cm
Note: G5; nu: 5; k: 7; frequency: 783.914 Hz; wavelength: 44.0099 cm
Note: G#5; nu: 5; k: 8; frequency: 830.528 Hz; wavelength: 41.5398 cm
Note: A5; nu: 5; k: 9; frequency: 879.914 Hz; wavelength: 39.2084 cm
Note: A#5; nu: 5; k: 10; frequency: 932.236 Hz; wavelength: 37.0078 cm
Note: B5; nu: 5; k: 11; frequency: 987.67 Hz; wavelength: 34.9307 cm
Note: C6; nu: 6; k: 0; frequency: 1046.4 Hz; wavelength: 32.9702 cm
Note: C#6; nu: 6; k: 1; frequency: 1108.62 Hz; wavelength: 31.1197 cm
Note: D6; nu: 6; k: 2; frequency: 1174.54 Hz; wavelength: 29.3731 cm
Note: D#6; nu: 6; k: 3; frequency: 1244.39 Hz; wavelength: 27.7245 cm
Note: E6; nu: 6; k: 4; frequency: 1318.38 Hz; wavelength: 26.1685 cm
Note: F6; nu: 6; k: 5; frequency: 1396.78 Hz; wavelength: 24.6997 cm
Note: F#6; nu: 6; k: 6; frequency: 1479.83 Hz; wavelength: 23.3134 cm
Note: G6; nu: 6; k: 7; frequency: 1567.83 Hz; wavelength: 22.005 cm
Note: G#6; nu: 6; k: 8; frequency: 1661.06 Hz; wavelength: 20.7699 cm
Note: A6; nu: 6; k: 9; frequency: 1759.83 Hz; wavelength: 19.6042 cm
Note: A#6; nu: 6; k: 10; frequency: 1864.47 Hz; wavelength: 18.5039 cm
Note: B6; nu: 6; k: 11; frequency: 1975.34 Hz; wavelength: 17.4653 cm
```



The exact values for the frequencies and wavelengths are given in Appendix A.

What might have taken a page of code to write on the original assignment, can now be done in just a few lines, and it covers all of the notes now too.

Appendix: Table of Musical Notes and their Frequencies

Note	Frequency (Hz)	Wavelength (cm)
C_0	16.35	2109.89
$C^{\#}_0/D^{b}_0$	17.32	1991.47
D_0	18.35	1879.69
$D^{\#}_0/E^{b}_0$	19.45	1774.20
E_0	20.60	1674.62
F_0	21.83	1580.63
$F^{\#}_0/G^{b}_0$	23.12	1491.91
G_0	24.50	1408.18
$G^{\#}_0/A^{b}_0$	25.96	1329.14
A_0	27.50	1254.55
$A^{\#}_0/B^{b}_0$	29.14	1184.13
B_0	30.87	1117.67
C_1	32.70	1054.94
$C^{\#}_1/D^{b}_1$	34.65	995.73
D_1	36.71	939.85
$D^{\#}_1/E^{b}_1$	38.89	887.10
E_1	41.20	837.31
F_1	43.65	790.31
$F^{\#}_1/G^{b}_1$	46.25	745.96
G_1	49.00	704.09
$G^{\#}_1/A^{b}_1$	51.91	664.57
A_1	55.00	627.27

$A^{\#}_1/B^{b}_1$	58.27	592.07
B_1	61.74	558.84
C_2	65.41	527.47
$C^{\#}_2/D^{b}_2$	69.30	497.87
D_2	73.42	469.92
$D^{\#}_2/E^{b}_2$	77.78	443.55
E_2	82.41	418.65
F_2	87.31	395.16
$F^{\#}_2/G^{b}_2$	92.50	372.98
G_2	98.00	352.04
$G^{\#}_2/A^{b}_2$	103.83	332.29
A_2	110.00	313.64
$A^{\#}_2/B^{b}_2$	116.54	296.03
B_2	123.47	279.42
C_3	130.81	263.74
$C^{\#}_3/D^{b}_3$	138.59	248.93
D_3	146.83	234.96
$D^{\#}_3/E^{b}_3$	155.56	221.77
E_3	164.81	209.33
F_3	174.61	197.58
$F^{\#}_3/G^{b}_3$	185.00	186.49
G_3	196.00	176.02
$G^{\#}_3/A^{b}_3$	207.65	166.14

A_3	220.00	156.82
$A^{\#}_3/B^{b}_3$	233.08	148.02
B_3	246.94	139.71
C_4	261.63	131.87
$C^{\#}_4/D^{b}_4$	277.18	124.47
D_4	293.66	117.48
$D^{\#}_4/E^{b}_4$	311.13	110.89
E_4	329.63	104.66
F_4	349.23	98.79
$F^{\#}_4/G^{b}_4$	369.99	93.24
G_4	392.00	88.01
$G^{\#}_4/A^{b}_4$	415.30	83.07
A_4	440.00	78.41
$A^{\#}_4/B^{b}_4$	466.16	74.01
B_4	493.88	69.85
C_5	523.25	65.93
$C^{\#}_5/D^{b}_5$	554.37	62.23
D_5	587.33	58.74
$D^{\#}_5/E^{b}_5$	622.25	55.44
E_5	659.25	52.33
F_5	698.46	49.39
$F^{\#}_5/G^{b}_5$	739.99	46.62
G_5	783.99	44.01

$G^{\#}_5/A^{b}_5$	830.61	41.54
A_5	880.00	39.20
$A^{\#}_5/B^{b}_5$	932.33	37.00
B_5	987.77	34.93
C_6	1046.50	32.97
$C^{\#}_6/D^{b}_6$	1108.73	31.12
D_6	1174.66	29.37
$D^{\#}_6/E^{b}_6$	1244.51	27.72
E_6	1318.51	26.17
F_6	1396.91	24.70
$F^{\#}_6/G^{b}_6$	1479.98	23.31
G_6	1567.98	22.00
$G^{\#}_6/A^{b}_6$	1661.22	20.77
A_6	1760.00	19.60
$A^{\#}_6/B^{b}_6$	1864.66	18.50
B_6	1975.53	17.46
C_7	2093.00	16.48
$C^{\#}_7/D^{b}_7$	2217.46	15.56
D_7	2349.32	14.69
$D^{\#}_7/E^{b}_7$	2489.02	13.86
E_7	2637.02	13.08
F_7	2793.83	12.35
$F^{\#}_7/G^{b}_7$	2959.96	11.66

G_7	3135.96	11.00
$G^{\#}_7/A^{b}_7$	3322.44	10.38
A_7	3520.00	9.80
$A^{\#}_7/B^{b}_7$	3729.31	9.25
B_7	3951.07	8.73
C_8	4186.01	8.24
$C^{\#}_8/D^{b}_8$	4434.92	7.78
D_8	4698.63	7.34
$D^{\#}_8/E^{b}_8$	4978.03	6.93
E_8	5274.04	6.54
F_8	5587.65	6.17
$F^{\#}_8/G^{b}_8$	5919.91	5.83
G_8	6271.93	5.50
$G^{\#}_8/A^{b}_8$	6644.88	5.19
A_8	7040.00	4.90
$A^{\#}_8/B^{b}_8$	7458.62	4.63
B_8	7902.13	4.37