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 Course: ECE596C
 Section: T01

Assignment ID: cpp_compile_time
 Assignment Title: Compile-Time Computation

Submission Source: https://github.com/uvic-seng475-2020-05/cpp_compile_time-JudeOnyia.git

Commit ID: 9873843310751781db8f11e9558bb79da4a7f42f

Submitted Files

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```
drwxrwxr-x    4096 2020-06-01 19:27 ./app
-rw-rw-r--    1658 2020-06-01 19:27 ./app/test_biquad_filter.cpp
-rw-rw-r--    2535 2020-06-01 19:27 ./app/test_cexpr_basic_string.cpp
-rw-rw-r--    1170 2020-06-01 19:27 ./app/test_cexpr_math.cpp
-rw-rw-r--     418 2020-06-01 19:27 ./app/test_mandelbrot.cpp
-rw-rw-r--     651 2020-06-01 19:27 ./CMakeLists.txt
-rw-rw-r--     146 2020-06-01 19:27 ./IDENTIFICATION.txt
drwxrwxr-x    4096 2020-06-01 19:27 ./include
drwxrwxr-x    4096 2020-06-01 19:27 ./include/ra
-rw-rw-r--    6019 2020-06-01 19:27 ./include/ra/biquad_filter.hpp
-rw-rw-r--    9615 2020-06-01 19:27 ./include/ra/cexpr_basic_string.hpp
-rw-rw-r--    2999 2020-06-01 19:27 ./include/ra/cexpr_math.hpp
-rw-rw-r--    2633 2020-06-01 19:27 ./include/ra/mandelbrot.hpp
-rw-rw-r--   464306 2020-06-01 19:27 ./README.pdf
```

Results

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Package	Operation	Target	Status
nonprog	generate	---	OK (0.1s)
string_orig	generate	---	OK (0.2s)
string_orig	configure	---	OK (0.9s)
string_orig	build	test_cexpr_basic	OK (0.5s)
string_orig	build	test_mandelbrot	OK (4.7s)
string_sane	generate	---	OK (0.2s)
string_sane	configure	---	OK (0.7s)
string_sane	build	test_cexpr_basic	FAIL (2 0.5s 407L)
string_sane	build	test_mandelbrot	OK (4.9s)
math_orig	generate	---	OK (0.1s)
math_orig	configure	---	OK (0.9s)
math_orig	build	test_cexpr_math	OK (1.9s)
math_orig	build	test_biquad_filt	OK (4.1s)
math_sane	generate	---	OK (0.2s)
math_sane	configure	---	OK (0.7s)
math_sane	build	test_cexpr_math	FAIL (2 5.5s 464L)
math_sane	build	test_biquad_filt	OK (9.1s)

Normally, an operation is indicated as having a status of either "OK" or "FAIL". A status of "?" indicates that the operation could not be performed for some reason (e.g., due to an earlier error or being a manual step). The time (in seconds) required for an operation is denoted by an expression consisting of a number followed by the letter "s" (e.g., "5.0s"). In the case of a test that consists of multiple test cases, the number of

failed test cases and total number of test cases is expressed as a fraction (e.g., "10/50" means 10 test cases failed out of 50 test cases in total). The length (in lines) of the log file generated by an operation is denoted by an expression consisting of a number followed by the letter "L" (e.g., "10L"). To ascertain the reason for the failure of an operation, check the contents of the log file provided.

Legend

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Package: nonprog
Nonprogramming exercises

Package: string_orig
The code as originally submitted by the student.
Build target: test_cexpr_basic_string
Build the test_cexpr_basic_string program.
Build target: test_mandelbrot
Build the test_mandelbrot program.

Package: string_sane
Code with modifications to perform API sanity checking.
Build target: test_cexpr_basic_string
Build the (dummy) test_cexpr_basic_string program.
Build target: test_mandelbrot
Build the (dummy) test_mandelbrot program.

Package: math_orig
The code as originally submitted by the student.
Build target: test_cexpr_math
Build the test_cexpr_math program.
Build target: test_biquad_filter
Build the test_biquad_filter program.

Package: math_sane
Code with modifications to perform API sanity checking.
Build target: test_cexpr_math
Build the (dummy) test_cexpr_math program.
Build target: test_biquad_filter
Build the (dummy) test_biquad_filter program.

Jun 01, 20 19:28	Log: string_sane build test_cexpr_basic_string	Page 1/6
1	/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake	
2	-S/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-st	
3	ring_sane/source	
4	-B/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-st	
5	ring_sane/derived --check-build-system CMakeFiles/Makefile.cmake 0	
6	/usr/bin/gmake -f CMakeFiles/Makefile2 test_cexpr_basic_string	
7	gmake[1]: Entering directory	
8	'/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
9	ing_sane/derived'	
10	/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake	
11	-S/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-st	
12	ring_sane/source	
13	-B/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-st	
14	ring_sane/derived --check-build-system CMakeFiles/Makefile.cmake 0	
15	/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake -E	
16	cmake_progress_start	
17	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
18	ing_sane/derived/CMakeFiles 2	
19	/usr/bin/gmake -f CMakeFiles/Makefile2	
20	CMakeFiles/test_cexpr_basic_string.dir/all	
21	gmake[2]: Entering directory	
22	'/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
23	ing_sane/derived'	
24	/usr/bin/gmake -f CMakeFiles/test_cexpr_basic_string.dir/build.make	
25	CMakeFiles/test_cexpr_basic_string.dir/depend	
26	gmake[3]: Entering directory	
27	'/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
28	ing_sane/derived'	
29	cd	
30	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
31	ing_sane/derived &&	
32	/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake -E	
33	cmake_depends "Unix Makefiles"	
34	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
35	ing_sane/source	
36	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
37	ing_sane/source	
38	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
39	ing_sane/derived	
40	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
41	ing_sane/derived	
42	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
43	ing_sane/derived/CMakeFiles/test_cexpr_basic_string.dir/DependInfo.cmake --color=	
44	Scanning dependencies of target test_cexpr_basic_string	
45	gmake[3]: Leaving directory	
46	'/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
47	ing_sane/derived'	
48	/usr/bin/gmake -f CMakeFiles/test_cexpr_basic_string.dir/build.make	
49	CMakeFiles/test_cexpr_basic_string.dir/build	
50	gmake[3]: Entering directory	
51	'/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
52	ing_sane/derived'	
53	[50%] Building CXX object	
54	CMakeFiles/test_cexpr_basic_string.dir/app/test_cexpr_basic_string.cpp.o	
55	/home/frodo/public/ugls_lab-4.0.70/bin/clang++	
56	-I/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-st	
57	ring_sane/source/include -pedantic-errors -std=gnu++17 -o	
58	CMakeFiles/test_cexpr_basic_string.dir/app/test_cexpr_basic_string.cpp.o -c	
59	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
60	ing_sane/source/app/test_cexpr_basic_string.cpp	
61	clang-10: warning:	
62	-Wl,-rpath,/home/frodo/public/ugls_lab-4.0.70/packages/gcc/lib64: 'linker'	
63	input unused [-Wunused-command-line-argument]	
64	clang-10: warning:	
65	-Wl,-rpath,/home/frodo/public/ugls_lab-4.0.70/packages/clang/lib: 'linker'	
66	input unused [-Wunused-command-line-argument]	
67	clang-10: warning:	
68	-Wl,-rpath,/home/frodo/public/ugls_lab-4.0.70/packages/boost/lib: 'linker'	
69	input unused [-Wunused-command-line-argument]	
70	clang-10: warning:	
71	-Wl,-rpath,/home/frodo/public/ugls_lab-4.0.70/packages/catch/lib64: 'linker'	
72	input unused [-Wunused-command-line-argument]	
73	clang-10: warning:	
74	-Wl,-rpath,/home/frodo/public/ugls_lab-4.0.70/packages/CGAL/lib64: 'linker'	
75	input unused [-Wunused-command-line-argument]	
76	clang-10: warning:	
77	-Wl,-rpath,/home/frodo/public/ugls_lab-4.0.70/packages/jasper/lib64: 'linker'	
78	input unused [-Wunused-command-line-argument]	
79	clang-10: warning:	
80	-Wl,-rpath,/home/frodo/public/ugls_lab-4.0.70/packages/clang/lib64: 'linker'	

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81	input unused [-Wunused-command-line-argument]	
82	clang-10: warning: argument unused during compilation:	
83	'-L/home/frodo/public/ugls_lab-4.0.70/packages/gcc/lib64'	
84	[-Wunused-command-line-argument]	
85	clang-10: warning: argument unused during compilation:	
86	'-L/home/frodo/public/ugls_lab-4.0.70/packages/clang/lib'	
87	[-Wunused-command-line-argument]	
88	clang-10: warning: argument unused during compilation:	
89	'-L/home/frodo/public/ugls_lab-4.0.70/packages/boost/lib'	
90	[-Wunused-command-line-argument]	
91	clang-10: warning: argument unused during compilation:	
92	'-L/home/frodo/public/ugls_lab-4.0.70/packages/catch/lib64'	
93	[-Wunused-command-line-argument]	
94	clang-10: warning: argument unused during compilation:	
95	'-L/home/frodo/public/ugls_lab-4.0.70/packages/CGAL/lib64'	
96	[-Wunused-command-line-argument]	
97	clang-10: warning: argument unused during compilation:	
98	'-L/home/frodo/public/ugls_lab-4.0.70/packages/jasper/lib64'	
99	[-Wunused-command-line-argument]	
100	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
101	ing_sane/source/app/test_cexpr_basic_string.cpp:14:3: warning: expression result	
102	unused [-Wunused-value]	
103	sizeof(string);	
104	^	
105	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
106	ing_sane/source/app/test_cexpr_basic_string.cpp:15:3: warning: expression result	
107	unused [-Wunused-value]	
108	sizeof(typename string::value_type);	
109	^	
110	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
111	ing_sane/source/app/test_cexpr_basic_string.cpp:16:3: warning: expression result	
112	unused [-Wunused-value]	
113	sizeof(typename string::pointer);	
114	^	
115	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
116	ing_sane/source/app/test_cexpr_basic_string.cpp:17:3: warning: expression result	
117	unused [-Wunused-value]	
118	sizeof(typename string::const_pointer);	
119	^	
120	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
121	ing_sane/source/app/test_cexpr_basic_string.cpp:18:3: warning: expression result	
122	unused [-Wunused-value]	
123	sizeof(typename string::reference);	
124	^	
125	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
126	ing_sane/source/app/test_cexpr_basic_string.cpp:19:3: warning: expression result	
127	unused [-Wunused-value]	
128	sizeof(typename string::const_reference);	
129	^	
130	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
131	ing_sane/source/app/test_cexpr_basic_string.cpp:20:3: warning: expression result	
132	unused [-Wunused-value]	
133	sizeof(typename string::iterator);	
134	^	
135	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
136	ing_sane/source/app/test_cexpr_basic_string.cpp:21:3: warning: expression result	
137	unused [-Wunused-value]	
138	sizeof(typename string::const_iterator);	
139	^	
140	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
141	ing_sane/source/app/test_cexpr_basic_string.cpp:14:3: warning: expression result	
142	unused [-Wunused-value]	
143	sizeof(string);	
144	^	
145	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
146	ing_sane/source/app/test_cexpr_basic_string.cpp:111:2: note: in instantiation of	
147	function template specialization 'test_l<char, 128>' requested here	
148	test_l<char, 128>();	
149	^	
150	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
151	ing_sane/source/app/test_cexpr_basic_string.cpp:15:3: warning: expression result	
152	unused [-Wunused-value]	
153	sizeof(typename string::value_type);	
154	^	
155	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
156	ing_sane/source/app/test_cexpr_basic_string.cpp:16:3: warning: expression result	
157	unused [-Wunused-value]	
158	sizeof(typename string::pointer);	
159	^	
160	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	

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161	ng_sane/source/app/test_cexpr_basic_string.cpp:17:3: warning: expression result	
162	unused [-Wunused-value]	
163	sizeof(typename string::const_pointer);	
164	^	
165	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
166	ng_sane/source/app/test_cexpr_basic_string.cpp:18:3: warning: expression result	
167	unused [-Wunused-value]	
168	sizeof(typename string::reference);	
169	^	
170	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
171	ng_sane/source/app/test_cexpr_basic_string.cpp:19:3: warning: expression result	
172	unused [-Wunused-value]	
173	sizeof(typename string::const_reference);	
174	^	
175	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
176	ng_sane/source/app/test_cexpr_basic_string.cpp:20:3: warning: expression result	
177	unused [-Wunused-value]	
178	sizeof(typename string::iterator);	
179	^	
180	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
181	ng_sane/source/app/test_cexpr_basic_string.cpp:21:3: warning: expression result	
182	unused [-Wunused-value]	
183	sizeof(typename string::const_iterator);	
184	^	
185	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
186	ng_sane/source/app/test_cexpr_basic_string.cpp:26:6: error: object of type	
187	'string' (aka 'cexpr_basic_string<char, 1280UL>') cannot be assigned because its	
188	copy assignment operator is implicitly deleted	
189	s3 = s;	
190	^	
191	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
192	ng_sane/source/include/ra/cexpr_basic_string.hpp:44:34: note: explicitly	
193	defaulted function was implicitly deleted here	
194	constexpr cexpr_basic_string& operator=(const	
195	cexpr_basic_string&) = default;	
196	^	
197	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
198	ng_sane/source/include/ra/cexpr_basic_string.hpp:238:21: note: copy assignment	
199	operator of 'cexpr_basic_string<char, 128>' is implicitly deleted because field	
200	'nullChar_' is of const-qualified type 'const	
201	ra::cexpr::cexpr_basic_string<char, 128>::value_type' (aka 'const char')	
202	const value_type nullChar_ = value_type(0);	
203	^	
204	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
205	ng_sane/source/app/test_cexpr_basic_string.cpp:27:6: error: object of type	
206	'string' (aka 'cexpr_basic_string<char, 1280UL>') cannot be assigned because its	
207	copy assignment operator is implicitly deleted	
208	s4 = std::move(s3);	
209	^	
210	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
211	ng_sane/source/include/ra/cexpr_basic_string.hpp:44:34: note: explicitly	
212	defaulted function was implicitly deleted here	
213	constexpr cexpr_basic_string& operator=(const	
214	cexpr_basic_string&) = default;	
215	^	
216	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
217	ng_sane/source/include/ra/cexpr_basic_string.hpp:238:21: note: copy assignment	
218	operator of 'cexpr_basic_string<char, 128>' is implicitly deleted because field	
219	'nullChar_' is of const-qualified type 'const	
220	ra::cexpr::cexpr_basic_string<char, 128>::value_type' (aka 'const char')	
221	const value_type nullChar_ = value_type(0);	
222	^	
223	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
224	ng_sane/source/app/test_cexpr_basic_string.cpp:14:3: warning: expression result	
225	unused [-Wunused-value]	
226	sizeof(string);	
227	^	
228	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
229	ng_sane/source/app/test_cexpr_basic_string.cpp:112:2: note: in instantiation of	
230	function template specialization 'test_1<unsigned char, 255>' requested here	
231	test_1<unsigned char, 255>();	
232	^	
233	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
234	ng_sane/source/app/test_cexpr_basic_string.cpp:15:3: warning: expression result	
235	unused [-Wunused-value]	
236	sizeof(typename string::value_type);	
237	^	
238	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
239	ng_sane/source/app/test_cexpr_basic_string.cpp:16:3: warning: expression result	
240	unused [-Wunused-value]	

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241	sizeof(typename string::pointer);	
242	^	
243	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
244	ng_sane/source/app/test_cexpr_basic_string.cpp:17:3: warning: expression result	
245	unused [-Wunused-value]	
246	sizeof(typename string::const_pointer);	
247	^	
248	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
249	ng_sane/source/app/test_cexpr_basic_string.cpp:18:3: warning: expression result	
250	unused [-Wunused-value]	
251	sizeof(typename string::reference);	
252	^	
253	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
254	ng_sane/source/app/test_cexpr_basic_string.cpp:19:3: warning: expression result	
255	unused [-Wunused-value]	
256	sizeof(typename string::const_reference);	
257	^	
258	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
259	ng_sane/source/app/test_cexpr_basic_string.cpp:20:3: warning: expression result	
260	unused [-Wunused-value]	
261	sizeof(typename string::iterator);	
262	^	
263	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
264	ng_sane/source/app/test_cexpr_basic_string.cpp:21:3: warning: expression result	
265	unused [-Wunused-value]	
266	sizeof(typename string::const_iterator);	
267	^	
268	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
269	ng_sane/source/app/test_cexpr_basic_string.cpp:26:6: error: object of type	
270	'string' (aka 'cexpr_basic_string<unsigned char, 2550UL>') cannot be assigned	
271	because its copy assignment operator is implicitly deleted	
272	s3 = s;	
273	^	
274	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
275	ng_sane/source/include/ra/cexpr_basic_string.hpp:44:34: note: explicitly	
276	defaulted function was implicitly deleted here	
277	constexpr cexpr_basic_string& operator=(const	
278	cexpr_basic_string&) = default;	
279	^	
280	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
281	ng_sane/source/include/ra/cexpr_basic_string.hpp:238:21: note: copy assignment	
282	operator of 'cexpr_basic_string<unsigned char, 255>' is implicitly deleted	
283	because field 'nullChar_' is of const-qualified type 'const	
284	ra::cexpr::cexpr_basic_string<unsigned char, 255>::value_type' (aka 'const	
285	unsigned char')	
286	const value_type nullChar_ = value_type(0);	
287	^	
288	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
289	ng_sane/source/app/test_cexpr_basic_string.cpp:27:6: error: object of type	
290	'string' (aka 'cexpr_basic_string<unsigned char, 2550UL>') cannot be assigned	
291	because its copy assignment operator is implicitly deleted	
292	s4 = std::move(s3);	
293	^	
294	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
295	ng_sane/source/include/ra/cexpr_basic_string.hpp:44:34: note: explicitly	
296	defaulted function was implicitly deleted here	
297	constexpr cexpr_basic_string& operator=(const	
298	cexpr_basic_string&) = default;	
299	^	
300	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
301	ng_sane/source/include/ra/cexpr_basic_string.hpp:238:21: note: copy assignment	
302	operator of 'cexpr_basic_string<unsigned char, 255>' is implicitly deleted	
303	because field 'nullChar_' is of const-qualified type 'const	
304	ra::cexpr::cexpr_basic_string<unsigned char, 255>::value_type' (aka 'const	
305	unsigned char')	
306	const value_type nullChar_ = value_type(0);	
307	^	
308	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
309	ng_sane/source/app/test_cexpr_basic_string.cpp:14:3: warning: expression result	
310	unused [-Wunused-value]	
311	sizeof(string);	
312	^	
313	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
314	ng_sane/source/app/test_cexpr_basic_string.cpp:113:2: note: in instantiation of	
315	function template specialization 'test_1<wchar_t, 64>' requested here	
316	test_1<wchar_t, 64>();	
317	^	
318	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQC/package-stri	
319	ng_sane/source/app/test_cexpr_basic_string.cpp:15:3: warning: expression result	
320	unused [-Wunused-value]	

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321	sizeof(typename string::value_type);	
322	^	
323	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
324	ng_sane/source/app/test_cexpr_basic_string.cpp:16:3: warning: expression result	
325	unused [-Wunused-value]	
326	sizeof(typename string::pointer);	
327	^	
328	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
329	ng_sane/source/app/test_cexpr_basic_string.cpp:17:3: warning: expression result	
330	unused [-Wunused-value]	
331	sizeof(typename string::const_pointer);	
332	^	
333	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
334	ng_sane/source/app/test_cexpr_basic_string.cpp:18:3: warning: expression result	
335	unused [-Wunused-value]	
336	sizeof(typename string::reference);	
337	^	
338	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
339	ng_sane/source/app/test_cexpr_basic_string.cpp:19:3: warning: expression result	
340	unused [-Wunused-value]	
341	sizeof(typename string::const_reference);	
342	^	
343	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
344	ng_sane/source/app/test_cexpr_basic_string.cpp:20:3: warning: expression result	
345	unused [-Wunused-value]	
346	sizeof(typename string::iterator);	
347	^	
348	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
349	ng_sane/source/app/test_cexpr_basic_string.cpp:21:3: warning: expression result	
350	unused [-Wunused-value]	
351	sizeof(typename string::const_iterator);	
352	^	
353	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
354	ng_sane/source/app/test_cexpr_basic_string.cpp:26:6: error: object of type	
355	'string' (aka 'cexpr_basic_string<wchar_t, 640L>') cannot be assigned because	
356	its copy assignment operator is implicitly deleted	
357	s3 = s;	
358		
359	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
360	ng_sane/source/include/ra/cexpr_basic_string.hpp:44:34: note: explicitly	
361	defaulted function was implicitly deleted here	
362	constexpr cexpr_basic_string& operator=(const	
363	cexpr_basic_string&) = default;	
364	^	
365	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
366	ng_sane/source/include/ra/cexpr_basic_string.hpp:238:21: note: copy assignment	
367	operator of 'cexpr_basic_string<wchar_t, 64>' is implicitly deleted because	
368	field 'nullChar' is of const-qualified type 'const	
369	ra::cexpr::cexpr_basic_string<wchar_t, 64>::value_type' (aka 'const wchar_t')	
370	const value_type nullChar_ = value_type(0);	
371	^	
372	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
373	ng_sane/source/app/test_cexpr_basic_string.cpp:27:6: error: object of type	
374	'string' (aka 'cexpr_basic_string<wchar_t, 640L>') cannot be assigned because	
375	its copy assignment operator is implicitly deleted	
376	s4 = std::move(s3);	
377		
378	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
379	ng_sane/source/include/ra/cexpr_basic_string.hpp:44:34: note: explicitly	
380	defaulted function was implicitly deleted here	
381	constexpr cexpr_basic_string& operator=(const	
382	cexpr_basic_string&) = default;	
383	^	
384	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
385	ng_sane/source/include/ra/cexpr_basic_string.hpp:238:21: note: copy assignment	
386	operator of 'cexpr_basic_string<wchar_t, 64>' is implicitly deleted because	
387	field 'nullChar' is of const-qualified type 'const	
388	ra::cexpr::cexpr_basic_string<wchar_t, 64>::value_type' (aka 'const wchar_t')	
389	const value_type nullChar_ = value_type(0);	
390	^	
391	32 warnings and 6 errors generated.	
392	gmake[3]: ***	
393	[CMakeFiles/test_cexpr_basic_string.dir/app/test_cexpr_basic_string.cpp.o]	
394	Error 1	
395	gmake[3]: Leaving directory	
396	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
397	ing_sane/derived'	
398	gmake[2]: *** [CMakeFiles/test_cexpr_basic_string.dir/all] Error 2	
399	gmake[2]: Leaving directory	
400	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	

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401	ing_sane/derived'	
402	gmake[1]: *** [CMakeFiles/test_cexpr_basic_string.dir/rule] Error 2	
403	gmake[1]: Leaving directory	
404	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-str	
405	ing_sane/derived'	
406	gmake: *** [test_cexpr_basic_string] Error 2	
407	ERROR: build failed to generate executable test_cexpr_basic_string	

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1	/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake	
2	-S/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-ma	
3	th_sane/source	
4	-B/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-ma	
5	th_sane/derived --check-build-system CMakeFiles/Makefile.cmake 0	
6	/usr/bin/gmake -f CMakeFiles/Makefile2 test_cexpr_math	
7	gmake[1]: Entering directory	
8	`/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-mat	
9	h_sane/derived'	
10	/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake	
11	-S/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-ma	
12	th_sane/source	
13	-B/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-ma	
14	th_sane/derived --check-build-system CMakeFiles/Makefile.cmake 0	
15	/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake -E	
16	cmake_progress_start	
17	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
18	_sane/derived/CMakeFiles 2	
19	/usr/bin/gmake -f CMakeFiles/Makefile2 CMakeFiles/test_cexpr_math.dir/all	
20	gmake[2]: Entering directory	
21	`/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-mat	
22	h_sane/derived'	
23	/usr/bin/gmake -f CMakeFiles/test_cexpr_math.dir/build.make	
24	CMakeFiles/test_cexpr_math.dir/depend	
25	gmake[3]: Entering directory	
26	`/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-mat	
27	h_sane/derived'	
28	cd	
29	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
30	_sane/derived 44	
31	/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake -E	
32	cmake_depends "Unix Makefiles"	
33	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
34	_sane/source	
35	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
36	_sane/source	
37	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
38	_sane/derived	
39	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
40	_sane/derived	
41	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
42	_sane/derived/CMakeFiles/test_cexpr_math.dir/DependInfo.cmake --color=	
43	Scanning dependencies of target test_cexpr_math	
44	gmake[3]: Leaving directory	
45	`/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-mat	
46	h_sane/derived'	
47	/usr/bin/gmake -f CMakeFiles/test_cexpr_math.dir/build.make	
48	CMakeFiles/test_cexpr_math.dir/build	
49	gmake[3]: Entering directory	
50	`/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-mat	
51	h_sane/derived'	
52	[50%] Building CXX object	
53	CMakeFiles/test_cexpr_math.dir/app/test_cexpr_math.cpp.o	
54	/home/frodo/public/ugls_lab-4.0.70/bin/clang++	
55	-I/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-ma	
56	th_sane/source/include -pedantic-errors -std=gnu++17 -o	
57	CMakeFiles/test_cexpr_math.dir/app/test_cexpr_math.cpp.o -c	
58	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
59	_sane/source/app/test_cexpr_math.cpp	
60	clang-10: warning:	
61	-Wl,-rpath,/home/frodo/public/ugls_lab-4.0.70/packages/gcc/lib64: 'linker'	
62	input unused [-Wunused-command-line-argument]	
63	clang-10: warning:	
64	-Wl,-rpath,/home/frodo/public/ugls_lab-4.0.70/packages/clang/lib: 'linker'	
65	input unused [-Wunused-command-line-argument]	
66	clang-10: warning:	
67	-Wl,-rpath,/home/frodo/public/ugls_lab-4.0.70/packages/boost/lib: 'linker'	
68	input unused [-Wunused-command-line-argument]	
69	clang-10: warning:	
70	-Wl,-rpath,/home/frodo/public/ugls_lab-4.0.70/packages/catch/lib64: 'linker'	
71	input unused [-Wunused-command-line-argument]	
72	clang-10: warning:	
73	-Wl,-rpath,/home/frodo/public/ugls_lab-4.0.70/packages/CGAL/lib64: 'linker'	
74	input unused [-Wunused-command-line-argument]	
75	clang-10: warning:	
76	-Wl,-rpath,/home/frodo/public/ugls_lab-4.0.70/packages/jasper/lib64: 'linker'	
77	input unused [-Wunused-command-line-argument]	
78	clang-10: warning:	
79	-Wl,-rpath,/home/frodo/public/ugls_lab-4.0.70/packages/clang/lib64: 'linker'	
80	input unused [-Wunused-command-line-argument]	

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81	clang-10: warning: argument unused during compilation:	
82	'-L/home/frodo/public/ugls_lab-4.0.70/packages/gcc/lib64'	
83	[-Wunused-command-line-argument]	
84	clang-10: warning: argument unused during compilation:	
85	'-L/home/frodo/public/ugls_lab-4.0.70/packages/clang/lib'	
86	[-Wunused-command-line-argument]	
87	clang-10: warning: argument unused during compilation:	
88	'-L/home/frodo/public/ugls_lab-4.0.70/packages/boost/lib'	
89	[-Wunused-command-line-argument]	
90	clang-10: warning: argument unused during compilation:	
91	'-L/home/frodo/public/ugls_lab-4.0.70/packages/catch/lib64'	
92	[-Wunused-command-line-argument]	
93	clang-10: warning: argument unused during compilation:	
94	'-L/home/frodo/public/ugls_lab-4.0.70/packages/CGAL/lib64'	
95	[-Wunused-command-line-argument]	
96	clang-10: warning: argument unused during compilation:	
97	'-L/home/frodo/public/ugls_lab-4.0.70/packages/jasper/lib64'	
98	[-Wunused-command-line-argument]	
99	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
100	_sane/source/app/test_cexpr_math.cpp:14:17: error: constexpr variable 'x6' must	
101	be initialized by a constant expression	
102	constexpr auto x6 = rcm::sin(T(5.0));	
103	^	
104	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
105	_sane/source/app/test_cexpr_math.cpp:22:2: note: in instantiation of function	
106	template specialization 'test<float>' requested here	
107	test<float>();	
108	^	
109	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
110	_sane/source/include/ra/cexpr_math.hpp:41:3: note: constexpr evaluation hit	
111	maximum step limit; possible infinite loop?	
112	if(y == 0){	
113	^	
114	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
115	_sane/source/include/ra/cexpr_math.hpp:55:17: note: in call to	
116	'mod(3.484586e-07, 6.283185e+00)'	
117	T reduced_x = mod<T>(x, 2*pi<T>);	
118	^	
119	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
120	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
121	'sin(3.484586e-07)'	
122	(4*cube(sin(reduced_x/3))); result = (3*sin(reduced_x/3)) -	
123	^	
124	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
125	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
126	'sin(1.045376e-06)'	
127	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
128	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
129	'sin(3.136127e-06)'	
130	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
131	_sane/source/include/ra/cexpr_math.hpp:65:17: note: in call to	
132	'sin(9.408382e-06)'	
133	(4*cube(sin(reduced_x/3))); result = (3*sin(reduced_x/3)) -	
134	^	
135	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
136	_sane/source/include/ra/cexpr_math.hpp:65:45: note: (skipping 7 calls in	
137	backtrace; use -fconstexpr-backtrace-limit=0 to see all)	
138	result = (3*sin(reduced_x/3)) -	
139	^	
140	(4*cube(sin(reduced_x/3)));	
141	^	
142	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
143	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
144	'sin(6.172839e-02)'	
145	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
146	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
147	'sin(1.851852e-01)'	
148	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
149	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
150	'sin(5.555555e-01)'	
151	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
152	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
153	'sin(1.666667e+00)'	
154	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
155	_sane/source/app/test_cexpr_math.cpp:14:22: note: in call to 'sin(5.000000e+00)'	
156	constexpr auto x6 = rcm::sin(T(5.0));	
157	^	
158	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
159	_sane/source/app/test_cexpr_math.cpp:16:17: error: constexpr variable 'x8' must	
160		

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161	be initialized by a constant expression	
162	constexpr auto x8 = rcm::tan(T(5.0));	
163	^	
164	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
165	_sane/source/include/ra/cexpr_math.hpp:38:27: note: constexpr evaluation hit	
166	maximum step limit; possible infinite loop?	
167	constexpr T mod(T x, T y){	
168	^	
169	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
170	_sane/source/include/ra/cexpr_math.hpp:55:17: note: in call to	
171	'mod(3.484586e-07, 6.283185e+00)'	
172	^	
173	T reduced_x = mod<T>(x, 2*pi<T>);	
174	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
175	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
176	'sin(3.484586e-07)'	
177	^	
178	(4*cube(sin(reduced_x/3)));	
179	^	
180	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
181	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
182	'sin(1.045376e-06)'	
183	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
184	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
185	'sin(3.136127e-06)'	
186	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
187	_sane/source/include/ra/cexpr_math.hpp:65:17: note: in call to	
188	'sin(9.408382e-06)'	
189	^	
190	(4*cube(sin(reduced_x/3)));	
191	^	
192	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
193	_sane/source/include/ra/cexpr_math.hpp:65:45: note: (skipping 8 calls in	
194	backtrace; use -fconstexpr-backtrace-limit=0 to see all)	
195	^	
196	(4*cube(sin(reduced_x/3)));	
197	^	
198	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
199	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
200	'sin(1.851852e-01)'	
201	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
202	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
203	'sin(5.555556e-01)'	
204	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
205	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
206	'sin(1.666667e+00)'	
207	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
208	_sane/source/include/ra/cexpr_math.hpp:89:9: note: in call to	
209	'sin(5.000000e+00)'	
210	^	
211	T a = sin<T>(x);	
212	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
213	_sane/source/app/test_cexpr_math.cpp:16:22: note: in call to 'tan(5.000000e+00)'	
214	constexpr auto x8 = rcm::tan(T(5.0));	
215	^	
216	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
217	_sane/source/app/test_cexpr_math.cpp:14:17: error: constexpr variable 'x6' must	
218	be initialized by a constant expression	
219	constexpr auto x6 = rcm::sin(T(5.0));	
220	^	
221	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
222	_sane/source/app/test_cexpr_math.cpp:23:21: note: in instantiation of function	
223	template specialization 'test<double>' requested here	
224	test<double>();	
225	^	
226	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
227	_sane/source/include/ra/cexpr_math.hpp:41:13: note: constexpr evaluation hit	
228	maximum step limit; possible infinite loop?	
229	if (y == 0) {	
230	^	
231	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
232	_sane/source/include/ra/cexpr_math.hpp:55:17: note: in call to	
233	'mod(3.484586e-07, 6.283185e+00)'	
234	^	
235	T reduced_x = mod<T>(x, 2*pi<T>);	
236	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
237	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
238	'sin(3.484586e-07)'	
239	^	
240	(4*cube(sin(reduced_x/3)));	

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241	^	
242	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
243	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
244	'sin(1.045376e-06)'	
245	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
246	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
247	'sin(3.136127e-06)'	
248	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
249	_sane/source/include/ra/cexpr_math.hpp:65:17: note: in call to	
250	'sin(9.408382e-06)'	
251	^	
252	(4*cube(sin(reduced_x/3)));	
253	^	
254	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
255	_sane/source/include/ra/cexpr_math.hpp:65:45: note: (skipping 7 calls in	
256	backtrace; use -fconstexpr-backtrace-limit=0 to see all)	
257	^	
258	(4*cube(sin(reduced_x/3)));	
259	^	
260	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
261	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
262	'sin(6.172840e-02)'	
263	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
264	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
265	'sin(1.851852e-01)'	
266	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
267	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
268	'sin(5.555556e-01)'	
269	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
270	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
271	'sin(1.666667e+00)'	
272	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
273	_sane/source/app/test_cexpr_math.cpp:14:22: note: in call to 'sin(5.000000e+00)'	
274	constexpr auto x6 = rcm::sin(T(5.0));	
275	^	
276	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
277	_sane/source/app/test_cexpr_math.cpp:16:17: error: constexpr variable 'x8' must	
278	be initialized by a constant expression	
279	constexpr auto x8 = rcm::tan(T(5.0));	
280	^	
281	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
282	_sane/source/include/ra/cexpr_math.hpp:38:27: note: constexpr evaluation hit	
283	maximum step limit; possible infinite loop?	
284	constexpr T mod(T x, T y){	
285	^	
286	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
287	_sane/source/include/ra/cexpr_math.hpp:55:17: note: in call to	
288	'mod(3.484586e-07, 6.283185e+00)'	
289	^	
290	T reduced_x = mod<T>(x, 2*pi<T>);	
291	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
292	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
293	'sin(3.484586e-07)'	
294	^	
295	(4*cube(sin(reduced_x/3)));	
296	^	
297	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
298	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
299	'sin(1.045376e-06)'	
300	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
301	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
302	'sin(3.136127e-06)'	
303	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
304	_sane/source/include/ra/cexpr_math.hpp:65:17: note: in call to	
305	'sin(9.408382e-06)'	
306	^	
307	(4*cube(sin(reduced_x/3)));	
308	^	
309	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
310	_sane/source/include/ra/cexpr_math.hpp:65:45: note: (skipping 8 calls in	
311	backtrace; use -fconstexpr-backtrace-limit=0 to see all)	
312	^	
313	(4*cube(sin(reduced_x/3)));	
314	^	
315	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
316	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
317	'sin(1.851852e-01)'	
318	/tmp/assignment_precheck-judeonyia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
319	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
320	'sin(5.555556e-01)'	

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321	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
322	_sane/source/include/ra/cexpr_math.hpp:55:45: note: in call to	
323	'sin(1.666667e+00)'	
324	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
325	_sane/source/include/ra/cexpr_math.hpp:89:9: note: in call to	
326	'sin(5.000000e+00)'	
327	^	
328	T a = sin<T>(x);	
329	^	
330	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
331	_sane/source/app/test_cexpr_math.cpp:16:22: note: in call to 'tan(5.000000e+00)'	
332	constexpr auto x8 = rcm::tan(T(5.0));	
333	^	
334	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
335	_sane/source/app/test_cexpr_math.cpp:14:17: error: constexpr variable 'x6' must	
336	be initialized by a constant expression	
337	constexpr auto x6 = rcm::sin(T(5.0));	
338	^	
339	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
340	_sane/source/app/test_cexpr_math.cpp:24:21: note: in instantiation of function	
341	template specialization 'test<long double>' requested here	
342	test<long double>();	
343	^	
344	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
345	_sane/source/include/ra/cexpr_math.hpp:41:3: note: constexpr evaluation hit	
346	maximum step limit; possible infinite loop?	
347	if(y == 0){	
348	^	
349	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
350	_sane/source/include/ra/cexpr_math.hpp:55:17: note: in call to	
351	'mod(3.484586e-07, 6.283185e+00)'	
352	^	
353	T reduced_x = mod<T>(x, 2*pi<T>);	
354	^	
355	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
356	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
357	'sin(3.484586e-07)'	
358	^	
359	result = (3*sin(reduced_x/3)) -	
360	^	
361	(4*cube(sin(reduced_x/3)));	
362	^	
363	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
364	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
365	'sin(1.045376e-06)'	
366	^	
367	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
368	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
369	'sin(3.136127e-06)'	
370	^	
371	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
372	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
373	'sin(9.408382e-06)'	
374	^	
375	result = (3*sin(reduced_x/3)) -	
376	^	
377	(4*cube(sin(reduced_x/3)));	
378	^	
379	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
380	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
381	'sin(6.172840e-02)'	
382	^	
383	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
384	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
385	'sin(5.555556e-01)'	
386	^	
387	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
388	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
389	'sin(1.666667e+00)'	
390	^	
391	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
392	_sane/source/app/test_cexpr_math.cpp:14:22: note: in call to 'tan(5.000000e+00)'	
393	constexpr auto x8 = rcm::tan(T(5.0));	
394	^	
395	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
396	_sane/source/app/test_cexpr_math.cpp:16:17: error: constexpr variable 'x8' must	
397	be initialized by a constant expression	
398	constexpr auto x8 = rcm::tan(T(5.0));	
399	^	
400	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
401	_sane/source/include/ra/cexpr_math.hpp:38:27: note: constexpr evaluation hit	
402	maximum step limit; possible infinite loop?	

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401	constexpr T mod(T x, T y){	
402	^	
403	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
404	_sane/source/include/ra/cexpr_math.hpp:55:17: note: in call to	
405	'mod(3.484586e-07, 6.283185e+00)'	
406	^	
407	T reduced_x = mod<T>(x, 2*pi<T>);	
408	^	
409	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
410	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
411	'sin(3.484586e-07)'	
412	^	
413	result = (3*sin(reduced_x/3)) -	
414	^	
415	(4*cube(sin(reduced_x/3)));	
416	^	
417	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
418	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
419	'sin(1.045376e-06)'	
420	^	
421	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
422	_sane/source/include/ra/cexpr_math.hpp:65:17: note: in call to	
423	'sin(3.136127e-06)'	
424	^	
425	result = (3*sin(reduced_x/3)) -	
426	^	
427	(4*cube(sin(reduced_x/3)));	
428	^	
429	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
430	_sane/source/include/ra/cexpr_math.hpp:65:45: note: (skipping 8 calls in	
431	backtrace; use -fconstexpr-backtrace-limit=0 to see all)	
432	result = (3*sin(reduced_x/3)) -	
433	^	
434	(4*cube(sin(reduced_x/3)));	
435	^	
436	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
437	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
438	'sin(1.851852e-01)'	
439	^	
440	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
441	_sane/source/include/ra/cexpr_math.hpp:65:45: note: in call to	
442	'sin(1.666667e+00)'	
443	^	
444	T a = sin<T>(x);	
445	^	
446	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-math	
447	_sane/source/app/test_cexpr_math.cpp:16:22: note: in call to 'tan(5.000000e+00)'	
448	constexpr auto x8 = rcm::tan(T(5.0));	
449	^	
450	6 errors generated.	
451	gmake[3]: *** [CMakeFiles/test_cexpr_math.dir/app/test_cexpr_math.cpp.o] Error 1	
452	gmake[3]: Leaving directory	
453	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-mat	
454	h_sane/derived'	
455	gmake[2]: *** [CMakeFiles/test_cexpr_math.dir/all] Error 2	
456	gmake[2]: Leaving directory	
457	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-mat	
458	h_sane/derived'	
459	gmake[1]: *** [CMakeFiles/test_cexpr_math.dir/rule] Error 2	
460	gmake[1]: Leaving directory	
461	/tmp/assignment_precheck-judeonia@ugls6.ece.uvic.ca-15563-01WM6NQc/package-mat	
462	h_sane/derived'	
463	gmake: *** [test_cexpr_math] Error 2	
464	ERROR: build failed to generate executable test_cexpr_math	


```
1  commit ddd44b41088d6da6abc5b4dde63be21adcc8a2bf
2  Author: JudeOnyia <60678029+JudeOnyia@users.noreply.github.com>
3  Date:   Fri May 29 00:55:23 2020 -0700
4
5      My First Commit
6
7  commit 8b4a82ae0c0c63ccfa2fb34e288cd469e1e087bd
8  Author: JudeOnyia <60678029+JudeOnyia@users.noreply.github.com>
9  Date:   Fri May 29 01:55:51 2020 -0700
10
11     Set up the structure of cexpr_basic_string class
12
13  commit fc4203a5fe1b1fc4d243d6f8972dd860378d44a0
14  Author: Jude Onyia <judeonyia@ugls19.ece.uvic.ca>
15  Date:   Fri May 29 02:12:34 2020 -0700
16
17     Checking Folder from assignment precheck
18
19  commit f5e4a01ac9557e6b06c7349dbc5f7e196efdff4b
20  Author: JudeOnyia <60678029+JudeOnyia@users.noreply.github.com>
21  Date:   Fri May 29 02:16:50 2020 -0700
22
23     Removed Assign Precheck Folder
24
25  commit bfb276218a4abd78411a7355926d1c7dd748b5d
26  Author: Jude Onyia <judeonyia10@gmail.com>
27  Date:   Fri May 29 17:01:36 2020 -0700
28
29     1) Wrote the types and data members of cexpr_basic_string
30     2) Wrote the default constructor
31     3) Wrote the constructor with parameter of string pointer
32     4) Tested
33
34  commit f82e1dc817588636e0b5a8d951a623cba0fcbe66
35  Author: Jude Onyia <judeonyia10@gmail.com>
36  Date:   Sat May 30 00:53:50 2020 -0700
37
38     1) Wrote max size, size and capacity functions
39     2) Wrote data, begin and end functions
40     3) Wrote operator[] overload
41
42  commit 06a99e4cf21d3984ffe77a80ef06e08b3a5fa7ee
43  Author: Jude Onyia <judeonyia10@gmail.com>
44  Date:   Sat May 30 00:57:12 2020 -0700
45
46     Removed swp files
47
48  commit 5fe880a9fb8917e64109972b981a36c701e1a6f0
49  Author: Jude Onyia <judeonyia10@gmail.com>
50  Date:   Sat May 30 18:49:33 2020 -0700
51
52     1) Wrote push_back() and pop_back()
53     2) Wrote append(pointer), append(obj)
54     3) Wrote clear()
55
56  commit 3dfb8efadaaa7367243c3db6c29ace0a4efccf77
57  Author: Jude Onyia <judeonyia10@gmail.com>
58  Date:   Sun May 31 00:27:48 2020 -0700
59
60     1) Wrote Alias for cexpr_basic_string called cexpr_string
61     2) Wrote to_string helper function
62
```

```
63 commit ee65da40a2cec5787b274eac9e9539a84f718176
64 Author: JudeOnyia <60678029+JudeOnyia@users.noreply.github.com>
65 Date: Sun May 31 01:26:13 2020 -0700
66
67 Set up for Mandelbrot section
68
69 commit b3b55701af97708b386a6eb79a54d77292b53919
70 Author: Jude Onyia <judeonyia10@gmail.com>
71 Date: Sun May 31 21:07:54 2020 -0700
72
73 1) Wrote basic Mandelbrot hpp and cpp
74 2) Modified to_string function to accomodate clang compiler
75
76 commit 1db2c71fe13c812a0f718986d289ea88d06be7ec
77 Author: Jude Onyia <judeonyia10@gmail.com>
78 Date: Sun May 31 21:26:38 2020 -0700
79
80 1) Printed the mandelbrot to a file called mandelbrot.pnm
81 2) Displayed file on image software. Confirming it is mandelbrot
82
83 commit cf9bcf5545031c9845cbb379ec2911d3bb1b814c
84 Author: Jude Onyia <judeonyia10@gmail.com>
85 Date: Mon Jun 1 01:00:08 2020 -0700
86
87 1) Wrote template variable pi
88 2) Wrote template functions abs,sqr, cube and mod
89
90 commit e52269371567c4f87e4a75clea4650dacde9eba3
91 Author: Jude Onyia <judeonyia10@gmail.com>
92 Date: Mon Jun 1 02:33:02 2020 -0700
93
94 1) Wrote template functions for sin, cos, tan and sqrt
95
96 commit d450669cb83518f16fde276b25d96f3baf63570c
97 Author: Jude Onyia <judeonyia10@gmail.com>
98 Date: Mon Jun 1 14:44:45 2020 -0700
99
100 1) Wrote biquad_filter_coefs class
101 2) Wrote constexpr constructor to initialize parameters
102 3) Wrote constexpr constructor to copy from another obj
103
104 commit 9873843310751781db8f11e9558bb79da4a7f42f
105 Author: Jude Onyia <judeonyia10@gmail.com>
106 Date: Mon Jun 1 17:32:15 2020 -0700
107
108 1) Wrote template functions for lowpass, highpass and bandpass filters
109 2) Wrote template functions for low shelf boost and low shelf cut filters
```

Name: Jude Onyia
Student ID: V00947095
Course: ECE 596C
Due Date: June 5, 2020

Assignment 2: Non – Programming Exercise

8.1)

x?	lvalue
static_cast<std::vector<int>&&>(x)?	Rvalue (xvalue)
x.begin()?	Rvalue (xvalue)
++i?	lvalue
*i?	lvalue
*i += 5?	lvalue
x[0]?	lvalue
++a?	lvalue
a++?	Rvalue (prvalue)
func1(x)?	Rvalue (xvalue)
y = func1(x)?	lvalue

8.24)

Widget b(a);	Copy Constructor	Required with certainty (cannot be elided)
Widget c = a;	Copy Constructor	Required with certainty (cannot be elided)
Widget d(std::move(c));	Move Constructor	Required with certainty (cannot be elided)
Widget e = std::move(d);	Move Constructor	Required with certainty (cannot be elided)
Widget f(make_widget_1());	Move Constructor	Guaranteed to be elided
Widget g(make_widget_2(true));	Move Constructor	May be required (depending on if it can be elided)
c = a;	Copy Assignment	Required with certainty (cannot be elided)
b = std::move(c);	Move Assignment	Required with certainty (cannot be elided)
a = make_widget_1();	Move Assignment	Guaranteed to be elided
a = make_widget_2(true);	Move Assignment	May be required (depending on if it can be elided)
func_1(a);	Copy Constructor	Required with certainty (cannot be elided)
func_1(std::move(a));	Move Constructor	Required with certainty (cannot be elided)
func_1(make_widget_1());	Move Constructor	Guaranteed to be elided
func_2(std::move(b));	Move Constructor	Required with certainty (cannot be elided)

8.25)

Lines marked with ???:	Line of code where a temporary object is created:	Description and explanation:
<i>Line 67: z = x + y;</i>	<i>Line 53: counter(x)</i>	This temporary object is created within operator+. It is needed to store the result of x+=y without changing the value of x.
	<i>Line 67: x+y</i>	This temporary object is created in the main function. It is required in order to hold the return of operator+ before it can be assigned to counter z.
<i>Line 68: z = z + z;</i>	<i>Line 53: counter(x)</i>	This temporary object is created within operator+. It is needed to store the result of x+=y without changing the value of x.
	<i>Line 68: z+z</i>	This temporary object is created in the main function. It is required in order to hold the return of operator+ before it can be assigned to counter z.
<i>Line 69: y = ++z;</i>	N/A	This line does not need a temporary object because the pre-fixed operator++ returns an lvalue reference to the counter z.
<i>Line 70: z = y++;</i>	<i>Line 70: y++</i>	This temporary object is created in the main function. It is required in order to hold the return value of operator++(int) before it can be assigned to counter z.
<i>Line 71: x = z;</i>	N/A	This line does not need a temporary object because the operator= returns an lvalue reference.

8.26)

Some advantages of array-based implementation of a stack are elements stored contiguously in memory, less overhead, and it is more cache friendly. The disadvantage of array-based implementation is it cannot guarantee that each push will take constant time. This is due to the situation where the capacity of the array is full, in this case it would have to copy its entire content to a bigger section of memory before it can push that object.

An advantage of node-based implementation of a stack is that the previously discussed capacity exceeding problem is not evident here. This guarantees the push operation will be done in constant time. Another advantage is that references to objects in the stack are stable (always valid) since the objects they refer to are not forced to be copied or moved somewhere else. Disadvantages of node-based implementation include not storing elements contiguously in memory, per-element overhead, and requires more space than array-based implementation due to the overhead.

```
1  # Specify Minimum Required Version
2  cmake_minimum_required(VERSION 3.1 FATAL_ERROR)
3
4  # Specify Project and Language
5  project(cpp_compile_time LANGUAGES CXX)
6
7  # For Clang:
8  set(EXTRA_COMPILE_FLAGS "-fconstexpr-steps=100000000")
9  set_source_files_properties(app/test_mandelbrot.cpp PROPERTIES COMPILE_FLAGS ${E
XTRA_COMPILE_FLAGS})
10
11 # Set Include Directory
12 include_directories(include)
13
14 # Add Executable Program
15 add_executable(test_cexpr_basic_string app/test_cexpr_basic_string.cpp)
16 add_executable(test_mandelbrot app/test_mandelbrot.cpp)
17 add_executable(test_cexpr_math app/test_cexpr_math.cpp)
18 add_executable(test_biquad_filter app/test_biquad_filter.cpp)
```

```

1  #ifndef CEXPR
2  #define CEXPR
3  #include <cstddef>
4  #include <stdexcept>
5  #include <string>
6  namespace ra::cexpr{
7      // A basic string class template for use in constexpr contexts
8      template<class T, std::size_t M>
9      class cexpr_basic_string{
10         public:
11             // An unsigned integral type used to represent sizes
12             using size_type = std::size_t;
13
14             // The type of each character in the string (i.e., an alias for
15             // the template parameter T)
16             using value_type = T;
17
18             // The type of a mutating pointer to each character in the string
19             using pointer = T*;
20
21             // The type of a non-mutating pointer to each character in the
22             // string
23             using const_pointer = const T*;
24
25             // The type of a mutating reference to a character in the string
26             using reference = T&;
27
28             // The type of a non-mutating reference to a character in the
29             // string
30             using const_reference = const T&;
31
32             // A mutating iterator type for the elements in the string
33             using iterator = pointer;
34
35             // A non-mutating iterator type for the elements in the string
36             using const_iterator = const_pointer;
37
38             // Creates an empty string (i.e., a string containing no
39             // characters)
40             constexpr cexpr_basic_string() : charArray_{0}, charSize_(0) {}
41
42             // Explicitly default some special members
43             constexpr cexpr_basic_string(const cexpr_basic_string&) = default;
44             constexpr cexpr_basic_string& operator=(const cexpr_basic_string&) =
45             default;
46
47             ~cexpr_basic_string() = default;
48
49             // Creates a string with the contents given by the
50             // null-terminated character array pointed to by s
51             // If the string does not have sufficient capacity to hold
52             // the character data provided, an exception of type
53             // std::runtime_error is thrown
54             constexpr cexpr_basic_string(const value_type* s) : charArray_{0}, c
55             harSize_(0){
56                 while(s[charSize_] != nullChar_){
57                     if(M <= charSize_){
58                         clear();
59                         throw std::runtime_error("String does not have sufficient capacity");
60                     }
61                     else{
62                         charArray_[charSize_] = s[charSize_];

```

```
60         ++charSize_;
61     }
62 }
63
64
65 // Creates a string with the contents specified by the characters
66 // in the iterator range [first, last).
67 // If the string does not have sufficient capacity to hold
68 // the character data provided, an exception of type
69 // std::runtime_error is thrown.
70 constexpr cexpr_basic_string(const_iterator first, const_iterator la
st) : charArray_{0}, charSize_(0){
71     if(M < (last - first)){
72         throw std::runtime_error("String does not have sufficient capacity");
73     }
74     else{
75         for(const_iterator i=first; i < last; ++i){
76             charArray_[charSize_] = *i;
77             ++charSize_;
78         }
79     }
80 }
81
82 // Returns the maximum number of characters that can be held by a
83 // string of this type.
84 // The value returned is the template parameter M
85 static constexpr size_type max_size() { return M; }
86
87 // Returns the maximum number of characters that the string can
88 // hold. The value returned is always the template parameter M
89 constexpr size_type capacity() const { return M; }
90
91 // Returns the number of characters in the string (excluding the
92 // dummy null character)
93 constexpr size_type size() const { return charSize_; }
94
95 // Returns a pointer to the first character in the string
96 // The pointer that is returned is guaranteed to point to a
97 // null-terminated character array
98 // The user of this class shall not alter the dummy null
99 // character stored at data() + size().
100 value_type* data(){
101     return charArray_;
102 }
103 const value_type* data() const {
104     return charArray_;
105 }
106
107 // Returns an iterator referring to the first character in the
108 // string
109 constexpr iterator begin() {
110     return charArray_;
111 }
112 constexpr const_iterator begin() const {
113     return charArray_;
114 }
115
116 // Returns an iterator referring to the fictitious
117 // one-past-the-end character in the string
118 constexpr iterator end(){
119     return (&charArray_[charSize_]);
120 }
```

```
121     constexpr const_iterator end() const {
122         return (&charArray_[charSize_]);
123     }
124
125     // Returns a reference to the i-th character in the string if i
126     // is less than the string size; and returns a reference to the
127     // dummy null character if i equals the string size.
128     // Precondition: The index i is such that i >= 0 and i <= size().
129     constexpr reference operator[](size_type i){
130         if(i<0 || i>charSize_){
131             throw std::domain_error("invalid array access");
132         }
133         else if(i==charSize_){ return charArray_[charSize_]; }
134         else{ return charArray_[i];}
135     }
136     constexpr const_reference operator[](size_type i) const{
137         if(i<0 || i>charSize_){
138             throw std::domain_error("invalid array access");
139         }
140         else if(i==charSize_){ return nullChar_; }
141         else{ return charArray_[i];}
142     }
143
144     // Appends (i.e., adds to the end) a single character to the
145     // string. If the size of the string is equal to the capacity,
146     // the string is not modified and an exception of type
147     // std::runtime_error is thrown.
148     constexpr void push_back(const T& x){
149         if(M <= charSize_){
150             throw std::runtime_error("String does not have sufficient capacity");
151         }
152         else{
153             charArray_[charSize_] = x;
154             ++charSize_;
155         }
156     }
157
158     // Erases the last character in the string.
159     // If the string is empty, an exception of type std::runtime_error
160     // is thrown.
161     constexpr void pop_back(){
162         if(charSize_ == 0){
163             throw std::runtime_error("String does not have sufficient capacity");
164         }
165         else{
166             charArray_[charSize_ - 1] = '\0';
167             --charSize_;
168         }
169     }
170
171     // Appends (i.e., adds to the end) to the string the
172     // null-terminated string pointed to by s.
173     // Precondition: The pointer s must be non-null.
174     // If the string has insufficient capacity to hold the new value
175     // resulting from the append operation, the string is not modified
176     // and an exception of type std::runtime_error is thrown.
177     constexpr cexpr_basic_string& append(const value_type* s){
178         size_type addSize = 0;
179         if(s == nullptr) {
180             throw std::runtime_error("Null pointer");
181         }
182         else{
```



```

183         while(s[addToSize] != nullChar_){
184             if(M <= (charSize_+addToSize)){
185                 charSize_ += addToSize;
186                 for(size_type i=0; i<addToSize; ++i){
187                     pop_back();
188                 }
189                 addToSize = 0;
190                 throw std::runtime_error("String does not have sufficient capacit
y");
191                 break;
192             }
193             else{
194                 charArray_[charSize_ + addToSize] = s[addToSize];
195                 ++addToSize;
196             }
197         }
198         charSize_ += addToSize;
199     }
200     return *this;
201 }
202
203 // Appends (i.e., adds to the end) to the string another
204 // cexpr_basic_string with the same character type (but
205 // possibly a different maximum size).
206 // If the string has insufficient capacity to hold the new value
207 // resulting from the append operation, the string is not modified
208 // and an exception of type std::runtime_error is thrown.
209 template<size_type OtherM>
210 constexpr cexpr_basic_string& append(const cexpr_basic_string<value_
type, OtherM>& other){
211     size_type addToSize = 0;
212     if(M < (charSize_ + other.size())){
213         throw std::runtime_error("String does not have sufficient capacity");
214     }
215     else{
216         for(size_type i=0; i<other.size(); ++i){
217             charArray_[charSize_ + i] = other[i];
218             ++addToSize;
219         }
220         charSize_ += addToSize;
221     }
222     return *this;
223 }
224
225 // Erases all of the characters in the string, yielding an empty
226 // string.
227 constexpr void clear(){
228     for(size_type i=0; i<charSize_; ++i){
229         charArray_[i] = '\0';
230     }
231     charSize_ = 0;
232 }
233
234 private:
235     value_type charArray_[M+1];
236     size_type charSize_;
237     const value_type nullChar_ = value_type(0);
238 };
239
240 template<std::size_t M>
241 using cexpr_string = cexpr_basic_string<char, M>;

```

```
243
244     constexpr char digit_to_char(std::size_t num){
245         char mychar = '0';
246         switch(num) {
247             case std::size_t(0) : mychar = '0'; break;
248             case std::size_t(1) : mychar = '1'; break;
249             case std::size_t(2) : mychar = '2'; break;
250             case std::size_t(3) : mychar = '3'; break;
251             case std::size_t(4) : mychar = '4'; break;
252             case std::size_t(5) : mychar = '5'; break;
253             case std::size_t(6) : mychar = '6'; break;
254             case std::size_t(7) : mychar = '7'; break;
255             case std::size_t(8) : mychar = '8'; break;
256             case std::size_t(9) : mychar = '9'; break;
257             default: mychar = '0';
258         }
259         return mychar;
260     }
261
262     constexpr std::size_t to_string(std::size_t n, char* buffer, std::size_t size
, char** end){
263         std::size_t ite = 0;
264         char temp_buf = 0;
265         //char theArray[size_const] = {0};
266         //char theArray_backwards[size] = {0};
267         while(n!=0){
268             buffer[ite] = digit_to_char(n % std::size_t(10));
269             n = n / std::size_t(10);
270             ++ite;
271             if(ite > size){
272                 throw std::runtime_error("String does not have sufficient capacity");
273                 break;
274             }
275         }
276         if(ite <= size){
277             for(std::size_t i=0; i<(ite/2); ++i){
278                 temp_buf = buffer[i];
279                 buffer[i] = buffer[ite-1-i];
280                 buffer[ite-1-i] = temp_buf;
281             }
282             //buffer = theArray;
283             if(end != nullptr){
284                 *end = &buffer[ite];
285             }
286         }
287         return ite;
288     }
289     /*constexpr std::size_t to_string(std::size_t n, char* buffer, std::size_t s
ize, char** end){
290         const size_t size_const = size;
291         cexpr_string<size_const> obj;
292         std::string n_str = std::to_string(n);
293         if(n_str.size() > size_const){
294             throw std::runtime_error("String does not have sufficient capacity")
;
295         }
296         else{
297             for(size_t i=0; i<n_str.size(); ++i){
298                 obj.push_back(n_str[i]);
299             }
300             buffer = obj.data();
301             if(end != nullptr){
```

```
302             *end = obj.data() + obj.size();
303         }
304     }
305     return (obj.size());
306 }*/
307 }
308 #endif
```

```

1  #ifndef Mymandelbrot
2  #define Mymandelbrot
3  #include "ra/cexpr_basic_string.hpp"
4  #include <cstdint>
5
6  namespace ra::fractal {
7      // Function to compute mandelbrot
8      constexpr ra::cexpr::cexpr_string<1100000> mandelbrotComputation(const std::
size_t W, const std::size_t H){
9          ra::cexpr::cexpr_string<1100000> obj;
10         char W_str[10] = {0};
11         std::size_t W_str_size = 0;
12         char H_str[10] = {0};
13         std::size_t H_str_size = 0;
14
15         double c0 = 0.0;
16         double c1 = 0.0;
17         double zn_c0 = 0.0;
18         double zn_c0_next = 0.0;
19         double zn_c1 = 0.0;
20         double zn_c1_next = 0.0;
21         std::size_t n = 0;
22         bool outOfBound = false;
23
24         double a0 = -1.6;
25         double a1 = -1.1;
26         double b0 = 0.6;
27         double b1 = 1.1;
28         double mult_c0 = (b0-a0)/(W-1);
29         double mult_c1 = (b1-a1)/(H-1);
30
31         obj.push_back('P');
32         obj.push_back('l');
33         obj.push_back(' ');
34         W_str_size = ra::cexpr::to_string(W,W_str,10,nullptr);
35         for(std::size_t i=0; i<W_str_size; ++i){
36             obj.push_back(W_str[i]);
37         }
38         obj.push_back(' ');
39         H_str_size = ra::cexpr::to_string(H,H_str,10,nullptr);
40         for(std::size_t i=0; i<H_str_size; ++i){
41             obj.push_back(H_str[i]);
42         }
43         obj.push_back('\n');
44
45
46         for(std::size_t l=0; l<H; ++l){
47             c1 = a1 + ( (double)(H-1-l) * mult_c1 );
48             for(std::size_t k=0; k<W; ++k){
49                 c0 = a0 + ( (double)k * mult_c0 );
50                 while(n < 16){
51                     zn_c0_next = (zn_c0*zn_c0)-(zn_c1*zn_c1) + c0;
52                     zn_c1_next = (2.0*zn_c0*zn_c1) + c1;
53                     zn_c0 = zn_c0_next;
54                     zn_c1 = zn_c1_next;
55                     if( ((zn_c0*zn_c0)+(zn_c1*zn_c1)) > 4.0 ){
56                         outOfBound = true;
57                         break;
58                     }
59                     ++n;
60                 }
61                 if(outOfBound == false){

```

```
62         obj.push_back('1');
63     }
64     else{
65         obj.push_back('0');
66     }
67     outOfBound = false;
68     n = 0;
69     zn_c0 = 0.0;
70     zn_c1 = 0.0;
71 }
72 obj.push_back('\n');
73 }
74
75 //obj.push_back('P');
76 //obj.push_back('1');
77 //obj.push_back(' ');
78 //W_str_size = ra::cexpr::to_string(W,W_str,10,nullptr);
79 //for(std::size_t i=0; i<W_str_size; ++i){
80     //obj.push_back(W_str[i]);
81 //}
82 //obj.push_back(' ');
83 //H_str_size = ra::cexpr::to_string(H,H_str,10,nullptr);
84 //for(std::size_t i=0; i<H_str_size; ++i){
85     //obj.push_back(H_str[i]);
86 //}
87 //obj.push_back('\n');
88
89 return obj;
90
91 }
92
93 // A variable template for a string that represents an image depicting
94 // the Mandelbrot set. The image has width W and height H.
95 // This object must be of type cexpr_string<M> for some appropriate M.
96 // The string is a binary image encoded in the text-based bitmap PNM
97 // format.
98 // The values of W and H must be such that W >= 2 and H >= 2.
99 template<std::size_t W, std::size_t H>
100 constexpr auto mandelbrot = mandelbrotComputation(W,H);
101 }
102 #endif
```

```
1  #ifndef CexprMath
2  #define CexprMath
3  #include<boost/math/constants/constants.hpp>
4
5  namespace ra::cexpr_math {
6      // The math constant pi.
7      // The type T is a floating-point type.
8      template<class T>
9      constexpr T pi = boost::math::constants::pi<T>();
10
11     // Returns the absolute value of x.
12     // The type T is a floating-point type.
13     template<class T>
14     constexpr T abs(T x){
15         return (x < 0)? (-x) : x;
16     }
17
18     // Returns the square of x.
19     // The type T is a floating-point type.
20     template<class T>
21     constexpr T sqr(T x){
22         return (x * x);
23     }
24
25     // Returns the cube of x.
26     // The type T is a floating-point type.
27     template<class T>
28     constexpr T cube(T x){
29         return (x * x * x);
30     }
31
32     // Returns the remainder after division when x is divided by y.
33     // In particular, x - n y is returned where n is the result obtained by
34     // dividing x by y and then rounding (to an integer value) toward zero.
35     // If y is zero, an exception of type std::overflow_error is thrown.
36     // The type T is a floating-point type.
37     template<class T>
38     constexpr T mod(T x, T y){
39         long long n = 0;
40         T remainder = 0;
41         if(y == 0){
42             throw std::overflow_error("zero modulus");
43         }
44         n = (long long)(x / y);
45         remainder = x - ( (T)n * y );
46         return remainder;
47     }
48
49     // Returns the sine of x.
50     // Note that a particular algorithm must be used to implement this
51     // function.
52     // The type T is a floating-point type.
53     template<class T>
54     constexpr T sin(T x){
55         T reduced_x = mod<T>(x, 2*pi<T>);
56         T result = 0;
57         if(reduced_x < 0){
58             result = -1 * sin(abs(reduced_x));
59         }
60         else{
61             if(x <= 0.000001){
62                 result = x;
```

```
63         }
64         else{
65             result = (3*sin(reduced_x/3)) - (4*cube(sin(reduced_x/3)));
66         }
67     }
68     return result;
69 }
70
71 // Returns the cosine of x.
72 // Note that a particular algorithm must be used to implement this
73 // function.
74 // The type T is a floating-point type.
75 template<class T>
76 constexpr T cos(T x){
77     return (sin<T>( x + (pi<T>/2) ));
78 }
79
80 // Returns the tangent of x.
81 // Note that a particular algorithm must be used to implement this
82 // function.
83 // If the tangent of x is infinite, an exception of type
84 // std::overflow_error is thrown.
85 // The type T is a floating-point type.
86 template<class T>
87 constexpr T tan(T x){
88     T result = 0;
89     T a = sin<T>(x);
90     T b = cos<T>(x);
91     if(b == 0){
92         throw std::overflow_error("infinite tangent");
93     }
94     else{
95         result = a / b;
96     }
97     return result;
98 }
99
100 // Returns the square root of x.
101 // If x is negative, an exception of type std::domain_error is thrown.
102 // Note that a particular algorithm must be used to implement this
103 // function.
104 // The type T is a floating-point type.
105 template<class T>
106 constexpr T sqrt(T x){
107     T ep = std::numeric_limits<T>::epsilon();
108     T result = x;
109     T result_next = x;
110     if(x < 0){
111         throw std::domain_error("square root of negative number");
112     }
113     else{
114         do{
115             result = result_next;
116             result_next = result - ( (sqr<T>(result)-x) / (2*result) );
117         } while(abs<T>(result_next - result) > ep);
118     }
119     return result;
120 }
121 }
122 #endif
```

```

1  #ifndef BiquadFilter
2  #define BiquadFilter
3  #include "ra/cexpr_math.hpp"
4
5  namespace ra::biquad {
6      // Biquad filter coefficients class.
7      template<class Real>
8      struct biquad_filter_coefs{
9          // The real number type used to represent the filter coefficients.
10         using real = Real;
11
12         // Creates a set of filter coefficients where the coefficients
13         // a0, a1, a2, b0, b1, and b2 are initialized to a0_, a1_, a2_,
14         // b0_, b1_, and b2_, respectively.
15         constexpr biquad_filter_coefs(real a0_, real a1_, real a2_, real b0_, re
16         al b1_, real b2_) : a0(a0_), a1(a1_), a2(a2_), b0(b0_), b1(b1_), b2(b2_){}
17
18         // Creates a set of filter coefficients by copying from another set.
19         // Since Real and OtherReal need not be the same, this constructor
20         // can be used to convert between filter coefficients of different
21         // types.
22         template<class OtherReal>
23         constexpr biquad_filter_coefs(const biquad_filter_coefs<OtherReal>& coef
24         s) : a0(coefs.a0), a1(coefs.a1), a2(coefs.a2), b0(coefs.b0), b1(coefs.b1), b2(co
25         efs.b2){}
26
27         // The filter coefficients a0, a1, a2, b0, b1, and b2.
28         real a0;
29         real a1;
30         real a2;
31         real b0;
32         real b1;
33         real b2;
34     };
35
36     // Returns the coefficients for a biquad lowpass filter with normalized
37     // cutoff frequency f and Q factor q, where f in [0,1] and q > 0.
38     // The filter coefficients are always normalized such that the
39     // coefficient b0 is 1.
40     // The type Real is a floating-point type.
41     // All real arithmetic should be performed with the Real type.
42     template<class Real>
43     constexpr biquad_filter_coefs<Real> lowpass(Real f, Real q){
44         Real pi_ = ra::cexpr_math::pi<Real>;
45         Real sig_ = ra::cexpr_math::tan<Real>(f*pi_/2.0);
46         Real a0 = ra::cexpr_math::sqr<Real>(sig_);
47         Real a1 = 2.0 * a0;
48         Real a2 = a0;
49         Real b0 = a0 + (sig_ / q) + 1.0;
50         Real b1 = 2.0 * (a0 - 1.0);
51         Real b2 = a0 - (sig_ / q) + 1.0;
52
53         a0=a0/b0; a1=a1/b0; a2=a2/b0; b1=b1/b0; b2=b2/b0;
54         biquad_filter_coefs<Real> obj(a0,a1,a2,1.0,b1,b2);
55         return obj;
56     }
57
58     // Returns the coefficients for a biquad highpass filter with
59     // normalized cutoff frequency f and Q factor q, where f in [0,1]
60     // and q > 0.
61     // The filter coefficients are always normalized such that the
62     // coefficient b0 is 1.

```



```

60 // The type Real is a floating-point type.
61 // All real arithmetic should be performed with the Real type.
62 template<class Real>
63 constexpr biquad_filter_coefs<Real> highpass(Real f, Real q){
64     Real pi_ = ra::cexpr_math::pi<Real>;
65     Real sig_ = ra::cexpr_math::tan<Real>(f*pi_/2.0);
66     Real sig_sqr = ra::cexpr_math::sqr<Real>(sig_);
67     Real a0 = 1.0;
68     Real a1 = -2.0;
69     Real a2 = 1.0;
70     Real b0 = sig_sqr + (sig_/q) + 1.0;
71     Real b1 = 2.0 * (sig_sqr - 1.0);
72     Real b2 = sig_sqr - (sig_/q) + 1.0;
73
74     a0=a0/b0; a1=a1/b0; a2=a2/b0; b1=b1/b0; b2=b2/b0;
75     biquad_filter_coefs<Real> obj(a0,a1,a2,1.0,b1,b2);
76     return obj;
77 }
78
79 // Returns the coefficients for a biquad bandpass filter with
80 // normalized cutoff frequency f and Q factor q, where f in [0,1]
81 // and q > 0.
82 // The filter coefficients are always normalized such that the
83 // coefficient b0 is 1.
84 // The type Real is a floating-point type.
85 // All real arithmetic should be performed with the Real type.
86 template<class Real>
87 constexpr biquad_filter_coefs<Real> bandpass(Real f, Real q){
88     Real pi_ = ra::cexpr_math::pi<Real>;
89     Real sig_ = ra::cexpr_math::tan<Real>(f*pi_/2.0);
90     Real sig_sqr = ra::cexpr_math::sqr<Real>(sig_);
91     Real a0 = sig_ / q;
92     Real a1 = 0.0;
93     Real a2 = -a0;
94     Real b0 = sig_sqr + (sig_/q) + 1.0;
95     Real b1 = 2.0 * (sig_sqr - 1.0);
96     Real b2 = sig_sqr - (sig_/q) + 1.0;
97
98     a0=a0/b0; a1=a1/b0; a2=a2/b0; b1=b1/b0; b2=b2/b0;
99     biquad_filter_coefs<Real> obj(a0,a1,a2,1.0,b1,b2);
100    return obj;
101 }
102
103 // Returns the coefficients for a biquad low-frequency shelving
104 // boost filter with normalized cutoff frequency f and gain-control
105 // parameter a, where f in [0,1] and a >= 0.
106 // For a gain in dB of G (where G > 0), choose a = 10 ^ (G / 20).
107 // The filter coefficients are always normalized such that the
108 // coefficient b0 is 1.
109 // The type Real is a floating-point type.
110 // All real arithmetic should be performed with the Real type.
111 template<class Real>
112 constexpr biquad_filter_coefs<Real> lowshelf_boost(Real f, Real a){
113     Real pi_ = ra::cexpr_math::pi<Real>;
114     Real sig_ = ra::cexpr_math::tan<Real>(f*pi_/2.0);
115     Real sig_sqr = ra::cexpr_math::sqr<Real>(sig_);
116     Real sqrt_2a = ra::cexpr_math::sqrt<Real>(2.0 * a);
117     Real sqrt_2 = ra::cexpr_math::sqrt<Real>(2.0);
118     Real a0 = (a * sig_sqr) + (sqrt_2a * sig_) + 1.0;
119     Real a1 = 2.0 * ((a*sig_sqr) - 1.0);
120     Real a2 = (a * sig_sqr) - (sqrt_2a * sig_) + 1.0;
121     Real b0 = sig_sqr + (sqrt_2 * sig_) + 1.0;

```

```
122     Real b1 = 2.0 * (sig_sqr - 1.0);
123     Real b2 = sig_sqr - (sqrt_2 * sig_) + 1.0;
124
125     a0=a0/b0; a1=a1/b0; a2=a2/b0; b1=b1/b0; b2=b2/b0;
126     biquad_filter_coefs<Real> obj(a0,a1,a2,1.0,b1,b2);
127     return obj;
128 }
129
130 // Returns the coefficients for a biquad low-frequency shelving
131 // cut filter with normalized cutoff frequency f and gain-control
132 // parameter a, where f in [0,1] and a >= 0.
133 // For a gain in dB of G (where G < 0), choose a = 10 ^ (-G / 20).
134 // The filter coefficients are always normalized such that the
135 // coefficient b0 is 1.
136 // The type Real is a floating-point type.
137 // All real arithmetic should be performed with the Real type.
138 template<class Real>
139 constexpr biquad_filter_coefs<Real> lowshelf_cut(Real f, Real a){
140     Real pi_ = ra::cexpr_math::pi<Real>;
141     Real sig_ = ra::cexpr_math::tan<Real>(f*pi_/2.0);
142     Real sig_sqr = ra::cexpr_math::sqr<Real>(sig_);
143     Real sqrt_2a = ra::cexpr_math::sqrt<Real>(2.0 * a);
144     Real sqrt_2 = ra::cexpr_math::sqrt<Real>(2.0);
145     Real a0 = sig_sqr + (sqrt_2 * sig_) + 1.0;
146     Real a1 = 2.0 * (sig_sqr - 1.0);
147     Real a2 = sig_sqr - (sqrt_2 * sig_) + 1.0;
148     Real b0 = (a * sig_sqr) + (sqrt_2a * sig_) + 1.0;
149     Real b1 = 2.0 * ((a*sig_sqr) - 1.0);
150     Real b2 = (a * sig_sqr) - (sqrt_2a * sig_) + 1.0;
151
152     a0=a0/b0; a1=a1/b0; a2=a2/b0; b1=b1/b0; b2=b2/b0;
153     biquad_filter_coefs<Real> obj(a0,a1,a2,1.0,b1,b2);
154     return obj;
155 }
156
157 }
158 #endif
159
```

```
1  #include "ra/cexpr_basic_string.hpp"
2  #include <iostream>
3  #include <cstddef>
4
5  int main() {
6
7      using std::cout;
8      using std::endl;
9      // Test default constructor
10     ra::cexpr::cexpr_basic_string<char,10> obj_A;
11     const unsigned char s[] = {'j','u','d','e','\0'};
12     // Test constructor with single pointer
13     ra::cexpr::cexpr_basic_string<unsigned char,20> obj_B(s);
14     cout << "obj_B = " << obj_B[0] << obj_B[1] << obj_B[2] << obj_B[3] << endl;
15     cout << "max size: " << obj_B.max_size() << endl;
16     cout << "capacity: " << obj_B.capacity() << endl;
17     cout << "size: " << obj_B.size() << endl;
18     constexpr unsigned char j[] = {'o','n','y','i','a','\0'};
19     // Test constructor with pointers to first and one past last
20     constexpr ra::cexpr::cexpr_basic_string<unsigned char,6> obj_C(&j[0], &j[5])
;
21     // Test member function data()
22     const unsigned char* t = obj_C.data();
23     for(std::size_t i=0; i<obj_C.size(); ++i){
24         cout<< *t;
25         ++t;
26     }
27     cout << endl;
28     // Test prevention of pointer (from data()) to change null terminator
29     ra::cexpr::cexpr_basic_string<unsigned char,6> obj_D(obj_C);
30     unsigned char* tt = obj_D.data();
31     for(std::size_t i=0; i<=obj_D.size(); ++i){
32         cout<< *tt;
33         ++tt;
34     }
35     cout << endl;
36     tt = obj_D.end();
37     *tt = 'w';
38     --tt;
39     *tt = 'g';
40     tt = obj_D.begin();
41     for(std::size_t i=0; i<=obj_D.size(); ++i){
42         cout<< *tt;
43         ++tt;
44     }
45     cout << endl;
46     // Test push_back(), pop_back() and append()
47     cout << "obj_B.size(): "<< obj_B.size() << endl;
48     obj_B.push_back('c');
49     cout << "obj_B.size(): "<< obj_B.size() << endl;
50     cout << "obj_C.size(): "<< obj_C.size() << endl;
51     cout << "obj_B.capacity(): "<< obj_B.capacity() << endl;
52     obj_B.append(obj_C);
53     cout << "obj_B.size(): "<< obj_B.size() << endl;
54     for(std::size_t i=0; i<=obj_B.size(); ++i){
55         cout << obj_B[i];
56     }
57     cout << endl;
58     obj_B.pop_back();
59     cout << "Pop_back: ";
60     for(std::size_t i=0; i<=obj_B.size(); ++i){
61         cout << obj_B[i];
```

```
62     }
63     cout << endl;
64     obj_B.append(s);
65     cout << "Append s: ";
66     for(std::size_t i=0; i<=obj_B.size(); ++i){
67         cout << obj_B[i];
68     }
69     cout << endl;
70     // Test clear()
71     obj_B.clear();
72     cout << "obj_B.clear. Then obj_B.size(): "<< obj_B.size() << endl;
73     // Test to_string()
74     //std::size_t n = 596;
75     char* buffer = obj_A.begin();
76     //constexpr std::size_t size = 10;
77     char okay = 'a';
78     char* ptr_okay = &okay;
79     char** end = &ptr_okay;
80     cout<<"To String"<<endl;
81     cout<<"size: "<<(ra::cexpr::to_string(596,buffer,obj_A.capacity(),end))<<endl;
82     cout<<"string: "<<buffer<<endl;
83     cout<<"Before end: "<<(*((*end)-1))<<endl;
84     cout<<"end: "<<(**end)<<endl;
85     return 0;
86 }
87
```

```
1  #include<fstream>
2  #include<iostream>
3  #include"ra/mandelbrot.hpp"
4
5  int main(){
6      // Force the image (in PNM format) to be computed at compile time.
7      constexpr auto s = ra::fractal::mandelbrot<256, 256>;
8
9      std::ofstream outfile;
10     outfile.open("mandelbrot.pnm");
11
12     // Output the image (in PNM format).
13     outfile << s.begin() << std::endl;
14     outfile.close();
15     std::cout <<"Written to mandelbrot.pnm"<<std::endl;
16     return 0;
17 }
```

```
1  #include<iostream>
2  #include"ra/cexpr_math.hpp"
3
4  int main () {
5      using std::cout;
6      using std::endl;
7      constexpr long double pi_ = ra::cexpr_math::pi<long double>;
8      cout <<"Pi= "<<pi_<<endl;
9      constexpr float var_A = 23.75;
10     constexpr float var_B = -98.22;
11     cout <<"abs(23.75)= "<<ra::cexpr_math::abs<float>(var_A)<<endl;
12     cout <<"abs(-98.22)= "<<ra::cexpr_math::abs<float>(var_B)<<endl;
13     cout <<"sqr(23.75)= "<<ra::cexpr_math::sqr<float>(var_A)<<endl;
14     cout <<"cube(-98.22)= "<<ra::cexpr_math::cube<float>(var_B)<<endl;
15     cout <<"mod(-6.8*pi_,2*pi_)= "<<ra::cexpr_math::mod<long double>(-6.8*pi_,2*pi_)<
16     <endl;
17     cout <<"sin(-5000*pi_/26)= "<<ra::cexpr_math::sin<long double>(-5000*pi_/26)<<end
18     l;
19     cout <<"sin(4*pi_/3)= "<<ra::cexpr_math::sin<long double>(4*pi_/3)<<endl;
20     cout <<"cos(-5000*pi_/26)= "<<ra::cexpr_math::cos<long double>(-5000*pi_/26)<<en
21     dl;
22     cout <<"cos(4*pi_/3)= "<<ra::cexpr_math::cos<long double>(4*pi_/3)<<endl;
23     cout <<"tan(-5000*pi_/26)= "<<ra::cexpr_math::tan<long double>(-5000*pi_/26)<<end
24     l;
25     cout <<"tan(4*pi_/3)= "<<ra::cexpr_math::tan<long double>(4*pi_/3)<<endl;
26     cout <<"sqrt(1377)= "<<ra::cexpr_math::sqrt<long double>(1377)<<endl;
27
28     return 0;
29 }
```

```
1  #include<iostream>
2  #include"ra/biquad_filter.hpp"
3
4  int main () {
5      using std::cout;
6      using std::endl;
7      constexpr ra::biquad::biquad_filter_coefs<long double> obj_A(23.6,12.0,2.9,1
9.0,34.8,134.5);
8      constexpr ra::biquad::biquad_filter_coefs<float> obj_B(obj_A);
9      cout<<"obj_A(23.6,12.0,2.9,19.0,34.8,134.5): "<<obj_A.a0<<" "<<obj_A.a1<<" "<<obj_A.a2<<"
"<<obj_A.b0<<" "<<obj_A.b1<<" "<<obj_A.b2<<endl;
10     cout<<"obj_B(obj_A): "<<obj_B.a0<<" "<<obj_B.a1<<" "<<obj_B.a2<<" "<<obj_B.b0<<" "
<<obj_B.b1<<" "<<obj_B.b2<<endl;
11     constexpr ra::biquad::biquad_filter_coefs<long double> obj_lp(ra::biquad::lo
wpass(0.33,0.7071));
12     constexpr ra::biquad::biquad_filter_coefs<long double> obj_hp(ra::biquad::hi
ghpass(0.67,0.7071));
13     constexpr ra::biquad::biquad_filter_coefs<long double> obj_bp(ra::biquad::ba
ndpass(0.56,0.7071));
14     constexpr ra::biquad::biquad_filter_coefs<long double> obj_boost(ra::biquad:
:lowshelf_boost(0.33,1.77827941)); //Gain of 5
15     constexpr ra::biquad::biquad_filter_coefs<long double> obj_cut(ra::biquad::l
owshelf_cut(0.33,2.818382931)); //Gain of -9
16     cout<<"lp: "<<obj_lp.a0<<" "<<obj_lp.a1<<" "<<obj_lp.a2<<" "<<obj_lp.b0<<" "<<ob
j_lp.b1<<" "<<obj_lp.b2<<endl;
17     cout<<"hp: "<<obj_hp.a0<<" "<<obj_hp.a1<<" "<<obj_hp.a2<<" "<<obj_hp.b0<<" "<<o
bj_hp.b1<<" "<<obj_hp.b2<<endl;
18     cout<<"bp: "<<obj_bp.a0<<" "<<obj_bp.a1<<" "<<obj_bp.a2<<" "<<obj_bp.b0<<" "<<o
bj_bp.b1<<" "<<obj_bp.b2<<endl;
19     cout<<"boost: "<<obj_boost.a0<<" "<<obj_boost.a1<<" "<<obj_boost.a2<<" "<<obj_bo
ost.b0<<" "<<obj_boost.b1<<" "<<obj_boost.b2<<endl;
20     cout<<"cut: "<<obj_cut.a0<<" "<<obj_cut.a1<<" "<<obj_cut.a2<<" "<<obj_cut.b0<<"
"<<obj_cut.b1<<" "<<obj_cut.b2<<endl;
21
22
23     return 0;
24 }
```