```
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Course: ECE596C
Section: T01

Assignment ID: cpp_basics
Assignment Title: C++ Basics

Submission Source: https://github.com/uvic-seng475-2020-05/cpp_basics-JudeOnyia.
git
Commit ID: 5ceed22f6bf97b14db0740bfeccbcd96470460bb

Submitted Files
===============

drwxrwxr-x    4096 2020-05-22 14:30 ./app
-rw-rw-r--    2213 2020-05-22 14:30 ./app/test_random.cpp
-rw-rw-r--    6007 2020-05-22 14:30 ./app/test_rational.cpp
-rw-rw-r--     343 2020-05-22 14:30 ./CMakeLists.txt
-rw-rw-r--     140 2020-05-22 14:30 ./IDENTIFICATION.txt
drwxrwxr-x    4096 2020-05-22 14:30 ./include
drwxrwxr-x    4096 2020-05-22 14:30 ./include/ra
-rw-rw-r--    2377 2020-05-22 14:30 ./include/ra/random.hpp
-rw-rw-r--    6766 2020-05-22 14:30 ./include/ra/rational.hpp
drwxrwxr-x    4096 2020-05-22 14:30 ./lib
-rw-rw-r--    1287 2020-05-22 14:30 ./lib/random.cpp
-rw-rw-r--  391622 2020-05-22 14:30 ./README.pdf

Results
=======

Package          Operation Target           Status
nonprog          generate  ---              OK (0.0s)
random_orig      generate  ---              OK (0.1s)
random_orig      configure ---              OK (0.8s)
random_orig      build     test_random      FAIL (2 0.1s 2L)
random_sane      generate  ---              OK (0.2s)
random_sane      configure ---              OK (0.7s)
random_sane      build     test_random      FAIL (2 0.9s 155L)
rational_orig    generate  ---              OK (0.1s)
rational_orig    configure ---              OK (0.9s)
rational_orig    build     test_rational    FAIL (2 0.1s 2L)
rational_sane    generate  ---              OK (0.2s)
rational_sane    configure ---              OK (0.6s)
rational_sane    build     test_rational    FAIL (2 1.1s 716L)

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
======

Package: nonprog
    Nonprogramming exercises

Package: random_orig
    The code as originally submitted by the student.
Build target: test_random
    Build the test_random program.

Package: random_sane
    Code with modifications to perform API sanity checking.
Build target: test_random
    Build the test_random program.

Package: rational_orig
    The code as originally submitted by the student.
Build target: test_rational
    Build the test_rational program.

Package: rational_sane
    Code with modifications to perform API sanity checking.
Build target: test_rational
    Build the test_rational program.
```

```
1  gmake: *** No rule to make target `test_random'.  Stop.
2  ERROR: build failed to generate executable test_random
```

```
/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake
-S/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ra
ndom_sane/source
-B/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ra
ndom_sane/derived --check-build-system CMakeFiles/Makefile.cmake 0
/usr/bin/gmake  -f CMakeFiles/Makefile2 test_random
gmake[1]: Entering directory
'/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ran
dom_sane/derived'
/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake
-S/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ra
ndom_sane/source
-B/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ra
ndom_sane/derived --check-build-system CMakeFiles/Makefile.cmake 0
/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake -E
cmake_progress_start
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rand
om_sane/derived/CMakeFiles 4
/usr/bin/gmake  -f CMakeFiles/Makefile2 CMakeFiles/test_random.dir/all
gmake[2]: Entering directory
'/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ran
dom_sane/derived'
/usr/bin/gmake  -f CMakeFiles/ra.dir/build.make CMakeFiles/ra.dir/depend
gmake[3]: Entering directory
'/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ran
dom_sane/derived'
cd
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rand
om_sane/derived &&
/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake -E
cmake_depends "Unix Makefiles"
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rand
om_sane/source
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rand
om_sane/source
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rand
om_sane/derived
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rand
om_sane/derived
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rand
om_sane/derived/CMakeFiles/ra.dir/DependInfo.cmake --color=
Scanning dependencies of target ra
gmake[3]: Leaving directory
'/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ran
dom_sane/derived'
/usr/bin/gmake  -f CMakeFiles/ra.dir/build.make CMakeFiles/ra.dir/build
gmake[3]: Entering directory
'/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ran
dom_sane/derived'
[ 25%] Building CXX object CMakeFiles/ra.dir/lib/random.cpp.o
/home/frodo/public/ugls_lab-4.0.70/bin/c++
-I/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ra
ndom_sane/source/include  -pedantic-errors -std=gnu++17 -o
CMakeFiles/ra.dir/lib/random.cpp.o -c
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rand
om_sane/source/lib/random.cpp
[ 50%] Linking CXX static library libra.a
/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake -P
CMakeFiles/ra.dir/cmake_clean_target.cmake
/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake -E
cmake_link_script CMakeFiles/ra.dir/link.txt --verbose=1
/usr/bin/ar qc libra.a  CMakeFiles/ra.dir/lib/random.cpp.o
```

```
/usr/bin/ranlib libra.a
gmake[3]: Leaving directory
`/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ran
dom_sane/derived'
[ 50%] Built target ra
/usr/bin/gmake  -f CMakeFiles/test_random.dir/build.make
CMakeFiles/test_random.dir/depend
gmake[3]: Entering directory
`/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ran
dom_sane/derived'
cd
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rand
om_sane/derived &&
/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake -E
cmake_depends "Unix Makefiles"
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rand
om_sane/source
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rand
om_sane/source
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rand
om_sane/derived
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rand
om_sane/derived
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rand
om_sane/derived/CMakeFiles/test_random.dir/DependInfo.cmake --color=
Scanning dependencies of target test_random
gmake[3]: Leaving directory
`/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ran
dom_sane/derived'
/usr/bin/gmake  -f CMakeFiles/test_random.dir/build.make
CMakeFiles/test_random.dir/build
gmake[3]: Entering directory
`/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ran
dom_sane/derived'
[ 75%] Building CXX object CMakeFiles/test_random.dir/app/test_random.cpp.o
/home/frodo/public/ugls_lab-4.0.70/bin/c++
-I/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ra
ndom_sane/source/include  -pedantic-errors -std=gnu++17 -o
CMakeFiles/test_random.dir/app/test_random.cpp.o -c
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rand
om_sane/source/app/test_random.cpp
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rand
om_sane/source/app/test_random.cpp: In function `int
main()´:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/pac
kage-random_sane/source/app/test_random.cpp:18:8: error: passing `const lcg´ {ak
a `const ra::random::linear_congruential_generator´} as `this´ argument discards
 qualifiers [-fpermissive]
   18 |  cg == cg;
      |        ^~
In file included
 from /tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/packag
e-random_sane/source/app/test_random.cpp:2:
/tmp/assignment_precheck-judeonyia@u
gls5.ece.uvic.ca-18086-eLq0zmKZ/package-random_sane/source/include/ra/random.hpp
:32:8: note:   in call to `bool ra::random::linear_congruential_generator::opera
tor==(const ra::random::linear_congruential_generator&)´
   32 |   bool operator
==(const linear_congruential_generator& obj){
      |        ^~~~~~~~
/tmp/assig
nment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-random_sane/so
```

```
urce/app/test_random.cpp:19:8: error: passing ‘const lcg´ {aka ‘const ra::random
::linear_congruential_generator´} as ‘this´ argument discards qualifiers [-fperm
issive]
   19 |  cg != cg;
      |        ^~
In file included from /tmp/assignme
nt_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-random_sane/sourc
e/app/test_random.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18
086-eLq0zmKZ/package-random_sane/source/include/ra/random.hpp:37:8: note:   in c
all to ‘bool ra::random::linear_congruential_generator::operator!=(const ra::ran
dom::linear_congruential_generator&)´
   37 |   bool operator!=(const linear_con
gruential_generator& obj){
      |        ^~~~~~~~
gmake[3]: *** [CMakeFiles/tes
t_random.dir/app/test_random.cpp.o] Error 1
gmake[3]: Leaving directory ‘/tmp/as
signment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-random_sane
/derived’
gmake[2]: *** [CMakeFiles/test_random.dir/all] Error 2
gmake[2]: Leavi
ng directory ‘/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmK
Z/package-random_sane/derived’
gmake[1]: *** [CMakeFiles/test_random.dir/rule] E
rror 2
gmake[1]: Leaving directory ‘/tmp/assignment_precheck-judeonyia@ugls5.ece
.uvic.ca-18086-eLq0zmKZ/package-random_sane/derived’
gmake: *** [test_random] Er
ror 2
ERROR: build failed to generate executable test_random
```

```
1  gmake: *** No rule to make target `test_rational'.  Stop.
2  ERROR: build failed to generate executable test_rational
```

```
/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake
-S/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ra
tional_sane/source
-B/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ra
tional_sane/derived --check-build-system CMakeFiles/Makefile.cmake 0
/usr/bin/gmake  -f CMakeFiles/Makefile2 test_rational
gmake[1]: Entering directory
'/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rat
ional_sane/derived'
/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake
-S/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ra
tional_sane/source
-B/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ra
tional_sane/derived --check-build-system CMakeFiles/Makefile.cmake 0
/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake -E
cmake_progress_start
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/derived/CMakeFiles 4
/usr/bin/gmake  -f CMakeFiles/Makefile2 CMakeFiles/test_rational.dir/all
gmake[2]: Entering directory
'/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rat
ional_sane/derived'
/usr/bin/gmake  -f CMakeFiles/ra.dir/build.make CMakeFiles/ra.dir/depend
gmake[3]: Entering directory
'/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rat
ional_sane/derived'
cd
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/derived &&
/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake -E
cmake_depends "Unix Makefiles"
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/source
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/source
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/derived
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/derived
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/derived/CMakeFiles/ra.dir/DependInfo.cmake --color=
Scanning dependencies of target ra
gmake[3]: Leaving directory
'/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rat
ional_sane/derived'
/usr/bin/gmake  -f CMakeFiles/ra.dir/build.make CMakeFiles/ra.dir/build
gmake[3]: Entering directory
'/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rat
ional_sane/derived'
[ 25%] Building CXX object CMakeFiles/ra.dir/lib/random.cpp.o
/home/frodo/public/ugls_lab-4.0.70/bin/c++
-I/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ra
tional_sane/source/include  -pedantic-errors -std=gnu++17 -o
CMakeFiles/ra.dir/lib/random.cpp.o -c
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/source/lib/random.cpp
[ 50%] Linking CXX static library libra.a
/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake -P
CMakeFiles/ra.dir/cmake_clean_target.cmake
/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake -E
cmake_link_script CMakeFiles/ra.dir/link.txt --verbose=1
/usr/bin/ar qc libra.a  CMakeFiles/ra.dir/lib/random.cpp.o
```



```
/usr/bin/ranlib libra.a
gmake[3]: Leaving directory
'/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rat
ional_sane/derived'
[ 50%] Built target ra
/usr/bin/gmake  -f CMakeFiles/test_rational.dir/build.make
CMakeFiles/test_rational.dir/depend
gmake[3]: Entering directory
'/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rat
ional_sane/derived'
cd
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/derived &&
/home/frodo/public/ugls_lab-4.0.70/packages/cmake-3.17.1/bin/cmake -E
cmake_depends "Unix Makefiles"
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/source
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/source
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/derived
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/derived
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/derived/CMakeFiles/test_rational.dir/DependInfo.cmake --color=
Scanning dependencies of target test_rational
gmake[3]: Leaving directory
'/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rat
ional_sane/derived'
/usr/bin/gmake  -f CMakeFiles/test_rational.dir/build.make
CMakeFiles/test_rational.dir/build
gmake[3]: Entering directory
'/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rat
ional_sane/derived'
[ 75%] Building CXX object CMakeFiles/test_rational.dir/app/test_rational.cpp.o
/home/frodo/public/ugls_lab-4.0.70/bin/c++
-I/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ra
tional_sane/source/include  -pedantic-errors -std=gnu++17 -o
CMakeFiles/test_rational.dir/app/test_rational.cpp.o -c
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/source/app/test_rational.cpp
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/source/app/test_rational.cpp: In instantiation of 'void do_test()
[with T = short
int]':
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/packa
ge-rational_sane/source/app/test_rational.cpp:86:21:   required from here
/tmp/a
ssignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_s
ane/source/app/test_rational.cpp:35:3: error: passing 'const ra::math::rational<
short int>' as 'this' argument discards qualifiers [-fpermissive]
   35 |   c.tr
uncate();
      |   ^
In file included from /tmp/assignment_precheck-judeonyia@u
gls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/test_rational.c
pp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/packag
e-rational_sane/source/include/ra/rational.hpp:80:12: note:   in call to 'ra::ma
th::rational<T>::int_type ra::math::rational<T>::truncate() [with T = short int;
 ra::math::rational<T>::int_type = short int]'
   80 |   int_type truncate(){
```



```
      |             ^~~~~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-1
8086-eLq0zmKZ/package-rational_sane/source/app/test_rational.cpp:36:3: error: pa
ssing 'const ra::math::rational<short int>' as 'this' argument discards qualifie
rs [-fpermissive]
   36 |   c.is_integer();
      |   ^
In file included from /t
mp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ration
al_sane/source/app/test_rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5
.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/include/ra/rational.hpp
:85:8: note:   in call to 'bool ra::math::rational<T>::is_integer() [with T = sh
ort int]'
   85 |   bool is_integer(){
      |        ^~~~~~~~~~
/tmp/assignment
_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/sourc
e/app/test_rational.cpp:37:3: error: passing 'const ra::math::rational<short int
>' as 'this' argument discards qualifiers [-fpermissive]
   37 |   !c;
      |
 ^~
In file included from /tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-1
8086-eLq0zmKZ/package-rational_sane/source/app/test_rational.cpp:2:
/tmp/assignm
ent_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/so
urce/include/ra/rational.hpp:90:8: note:   in call to 'bool ra::math::rational<T
>::operator!() [with T = short int]'
   90 |   bool operator!(){
      |
^~~~~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/pac
kage-rational_sane/source/app/test_rational.cpp:38:5: error: passing 'const ra::
math::rational<short int>' as 'this' argument discards qualifiers [-fpermissive]

   38 |   c == c;
      |   ~~^~~~
In file included from /tmp/assignment_preche
ck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/t
est_rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-e
LqOzmKZ/package-rational_sane/source/include/ra/rational.hpp:95:8: note:   in ca
ll to 'bool ra::math::rational<T>::operator==(const ra::math::rational<T>&) [wit
h T = short int]'
   95 |   bool operator==(const rational& obj){
      |
 ^~~~~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/pa
ckage-rational_sane/source/app/test_rational.cpp:39:5: error: passing 'const ra:
:math::rational<short int>' as 'this' argument discards qualifiers [-fpermissive
]
   39 |   c != c;
      |   ~~^~~~
In file included from /tmp/assignment_prech
eck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/
test_rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-
eLq0zmKZ/package-rational_sane/source/include/ra/rational.hpp:100:8: note:   in
 call to 'bool ra::math::rational<T>::operator!=(const ra::math::rational<T>&) [w
ith T = short int]'
```



```
  100 |   bool operator!=(const rational& obj){
      |
 ^~~~~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/
package-rational_sane/source/app/test_rational.cpp:40:5: error: passing 'const r
a::math::rational<short int>' as 'this' argument discards qualifiers [-fpermissi
ve]
   40 |   c < c;
      |   ~~^~~
In file included from /tmp/assignment_prech
eck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/
test_rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-
eLq0zmKZ/package-rational_sane/source/include/ra/rational.hpp:105:8: note:   in
 call to 'bool ra::math::rational<T>::operator<(const ra::math::rational<T>&) [wi
th T = short int]'
  105 |   bool operator<(const rational& obj){
      |
 ^~~~~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/pa
ckage-rational_sane/source/app/test_rational.cpp:41:5: error: passing 'const ra:
:math::rational<short int>' as 'this' argument discards qualifiers [-fpermissive
]
   41 |   c > c;
      |   ~~^~~
In file included from /tmp/assignment_prechec
k-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/te
st_rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eL
q0zmKZ/package-rational_sane/source/include/ra/rational.hpp:110:8: note:   in ca
ll to 'bool ra::math::rational<T>::operator>(const ra::math::rational<T>&) [with
 T = short int]'
  110 |   bool operator>(const rational& obj){
      |
~~~~~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/pack
age-rational_sane/source/app/test_rational.cpp:42:5: error: passing 'const ra::m
ath::rational<short int>' as 'this' argument discards qualifiers [-fpermissive]

   42 |   c <= c;
      |   ~~^~~
In file included from /tmp/assignment_prechec
k-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/te
st_rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eL
q0zmKZ/package-rational_sane/source/include/ra/rational.hpp:115:8: note:   in ca
ll to 'bool ra::math::rational<T>::operator<=(const ra::math::rational<T>&) [wit
h T = short int]'
  115 |   bool operator<=(const rational& obj){
      |
 ^~~~~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/pa
ckage-rational_sane/source/app/test_rational.cpp:43:5: error: passing 'const ra:
:math::rational<short int>' as 'this' argument discards qualifiers [-fpermissive
]
   43 |   c >= c;
      |   ~~^~~
In file included from /tmp/assignment_prech
eck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/
test_rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-
eLq0zmKZ/package-rational_sane/source/include/ra/rational.hpp:120:8: note:   in
```

```
call to ‘bool ra::math::rational<T>::operator>=(const ra::math::rational<T>&) [w
ith T = short int]’
  120 |   bool operator>=(const rational& obj){
      |
   ^~~~~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/
package-rational_sane/source/app/test_rational.cpp: In instantiation of ‘void do
_test() [with T = int]’:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18
086-eLq0zmKZ/package-rational_sane/source/app/test_rational.cpp:87:15:   require
d from here
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/
package-rational_sane/source/app/test_rational.cpp:35:3: error: passing ‘const r
a::math::rational<int>’ as ‘this’ argument discards qualifiers [-fpermissive]

 35 |   c.truncate();
    |   ^
In file included from /tmp/assignment_precheck
-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/tes
t_rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq
0zmKZ/package-rational_sane/source/include/ra/rational.hpp:80:12: note:   in cal
l to ‘ra::math::rational<T>::int_type ra::math::rational<T>::truncate() [with T
= int; ra::math::rational<T>::int_type = int]’
   80 |   int_type truncate(){

      |            ^~~~~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-1
8086-eLq0zmKZ/package-rational_sane/source/app/test_rational.cpp:36:3: error: pa
ssing ‘const ra::math::rational<int>’ as ‘this’ argument discards qualifiers [-f
permissive]
   36 |   c.is_integer();
      |   ^
In file included from /tmp/ass
ignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_san
e/source/app/test_rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.u
vic.ca-18086-eLq0zmKZ/package-rational_sane/source/include/ra/rational.hpp:85:8:
 note:   in call to ‘bool ra::math::rational<T>::is_integer() [with T = int]’

 85 |   bool is_integer(){
    |        ^~~~~~~~~~
/tmp/assignment_precheck-ju
deonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/test_r
ational.cpp:37:3: error: passing ‘const ra::math::rational<int>’ as ‘this’ argum
ent discards qualifiers [-fpermissive]
   37 |   !c;
      |   ^~
In file includ
ed from /tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/pack
age-rational_sane/source/app/test_rational.cpp:2:
/tmp/assignment_precheck-judeo
nyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/include/ra/ra
tional.hpp:90:8: note:   in call to ‘bool ra::math::rational<T>::operator!() [wi
th T = int]’
   90 |   bool operator!(){
      |        ^~~~~~~~
/tmp/assignment
_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/sourc
e/app/test_rational.cpp:38:5: error: passing ‘const ra::math::rational<int>’ as
‘this’ argument discards qualifiers [-fpermissive]
   38 |   c == c;
```



```
      |     ~
~^~~~
In file included from /tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca
-18086-eLq0zmKZ/package-rational_sane/source/app/test_rational.cpp:2:
/tmp/assig
nment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/
source/include/ra/rational.hpp:95:8: note:   in call to ‘bool ra::math::rational
<T>::operator==(const ra::math::rational<T>&) [with T = int]’
   95 |   bool ope
rator==(const rational& obj){
      |        ^~~~~~~~
/tmp/assignment_precheck-j
udeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/test_
rational.cpp:39:5: error: passing ‘const ra::math::rational<int>’ as ‘this’ argu
ment discards qualifiers [-fpermissive]
   39 |   c != c;
      |   ~~^~~~
In fi
le included from /tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0
zmKZ/package-rational_sane/source/app/test_rational.cpp:2:
/tmp/assignment_prech
eck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/incl
ude/ra/rational.hpp:100:8: note:   in call to ‘bool ra::math::rational<T>::opera
tor!=(const ra::math::rational<T>&) [with T = int]’
  100 |   bool operator!=(co
nst rational& obj){
      |        ^~~~~~~~
/tmp/assignment_precheck-judeonyia@u
gls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/test_rational.c
pp:40:5: error: passing ‘const ra::math::rational<int>’ as ‘this’ argument disca
rds qualifiers [-fpermissive]
   40 |   c < c;
      |   ~~^~~
In file included
from /tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package
-rational_sane/source/app/test_rational.cpp:2:
/tmp/assignment_precheck-judeonyi
a@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/include/ra/ratio
nal.hpp:105:8: note:   in call to ‘bool ra::math::rational<T>::operator<(const r
a::math::rational<T>&) [with T = int]’
  105 |   bool operator<(const rational&
obj){
      |        ^~~~~~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.
ca-18086-eLq0zmKZ/package-rational_sane/source/app/test_rational.cpp:41:5: error
: passing ‘const ra::math::rational<int>’ as ‘this’ argument discards qualifiers
 [-fpermissive]
   41 |   c > c;
      |   ~~^~~
In file included from /tmp/assi
gnment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane
/source/app/test_rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uv
ic.ca-18086-eLq0zmKZ/package-rational_sane/source/include/ra/rational.hpp:110:8:
 note:   in call to ‘bool ra::math::rational<T>::operator>(const ra::math::ratio
nal<T>&) [with T = int]’
  110 |   bool operator>(const rational& obj){
      |        ^~~~~~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0z
mKZ/package-rational_sane/source/app/test_rational.cpp:42:5: error: passing ‘con
st ra::math::rational<int>’ as ‘this’ argument discards qualifiers [-fpermissive
```



```
]
   42 |   c <= c;
      |   ~~^~~~
In file included from /tmp/assignment_prech
eck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/
test_rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-
eLq0zmKZ/package-rational_sane/source/include/ra/rational.hpp:115:8: note:   in
call to ‘bool ra::math::rational<T>::operator<=(const ra::math::rational<T>&) [w
ith T = int]’
  115 |   bool operator<=(const rational& obj){
      |        ^~
~~~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/packag
e-rational_sane/source/app/test_rational.cpp:43:5: error: passing ‘const ra::mat
h::rational<int>’ as ‘this’ argument discards qualifiers [-fpermissive]
   43 |
  c >= c;
      |   ~~^~~~
In file included from /tmp/assignment_precheck-judeon
yia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/test_ratio
nal.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/p
ackage-rational_sane/source/include/ra/rational.hpp:120:8: note:   in call to ‘b
ool ra::math::rational<T>::operator>=(const ra::math::rational<T>&) [with T = in
t]’
  120 |   bool operator>=(const rational& obj){
      |        ^~~~~~~~
/tmp
/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational
_sane/source/app/test_rational.cpp: In instantiation of ‘void do_test() [with T
= long int]’:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmK
Z/package-rational_sane/source/app/test_rational.cpp:88:16:   required from here

/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rat
ional_sane/source/app/test_rational.cpp:35:3: error: passing ‘const ra::math::ra
tional<long int>’ as ‘this’ argument discards qualifiers [-fpermissive]
   35 |
  c.truncate();
      |   ^
In file included from /tmp/assignment_precheck-judeo
nyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/test_rati
onal.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/
package-rational_sane/source/include/ra/rational.hpp:80:12: note:   in call to ‘
ra::math::rational<T>::int_type ra::math::rational<T>::truncate() [with T = long
 int; ra::math::rational<T>::int_type = long int]’
   80 |   int_type truncate()
{
      |            ^~~~~~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.
ca-18086-eLq0zmKZ/package-rational_sane/source/app/test_rational.cpp:36:3: error
: passing ‘const ra::math::rational<long int>’ as ‘this’ argument discards quali
fiers [-fpermissive]
   36 |   c.is_integer();
      |   ^
In file included from
 /tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rat
ional_sane/source/app/test_rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ug
ls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/include/ra/rational.
```



```
hpp:85:8: note:   in call to ‘bool ra::math::rational<T>::is_integer() [with T =
 long int]’
   85 |   bool is_integer(){
      |        ^~~~~~~~~~
/tmp/assignme
nt_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/sou
rce/app/test_rational.cpp:37:3: error: passing ‘const ra::math::rational<long in
t>’ as ‘this’ argument discards qualifiers [-fpermissive]
   37 |   !c;
      |
  ^~
In file included from /tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-
18086-eLq0zmKZ/package-rational_sane/source/app/test_rational.cpp:2:
/tmp/assign
ment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/s
ource/include/ra/rational.hpp:90:8: note:   in call to ‘bool ra::math::rational<
T>::operator!() [with T = long int]’
   90 |   bool operator!(){
      |
^~~~~~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/pac
kage-rational_sane/source/app/test_rational.cpp:38:5: error: passing ‘const ra::
math::rational<long int>’ as ‘this’ argument discards qualifiers [-fpermissive]

   38 |   c == c;
      |   ~~^~~~
In file included from /tmp/assignment_prechec
k-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/te
st_rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eL
q0zmKZ/package-rational_sane/source/include/ra/rational.hpp:95:8: note:   in cal
l to ‘bool ra::math::rational<T>::operator==(const ra::math::rational<T>&) [with
 T = long int]’
   95 |   bool operator==(const rational& obj){
      |        ^
~~~~~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/pack
age-rational_sane/source/app/test_rational.cpp:39:5: error: passing ‘const ra::m
ath::rational<long int>’ as ‘this’ argument discards qualifiers [-fpermissive]

  39 |   c != c;
     |   ~~^~~~
In file included from /tmp/assignment_precheck
-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/tes
t_rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq
0zmKZ/package-rational_sane/source/include/ra/rational.hpp:100:8: note:   in cal
l to ‘bool ra::math::rational<T>::operator!=(const ra::math::rational<T>&) [with
 T = long int]’
  100 |   bool operator!=(const rational& obj){
      |        ^
~~~~~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/pack
age-rational_sane/source/app/test_rational.cpp:40:5: error: passing ‘const ra::m
ath::rational<long int>’ as ‘this’ argument discards qualifiers [-fpermissive]

  40 |   c < c;
     |   ~~^~~
In file included from /tmp/assignment_precheck-j
udeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/test_
rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0z
```

```
mK/package-rational_sane/source/include/ra/rational.hpp:105:8: note:   in call
to 'bool ra::math::rational<T>::operator<(const ra::math::rational<T>&) [with T
= long int]'
  105 |   bool operator<(const rational& obj){
      |        ^~~~
~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-
rational_sane/source/app/test_rational.cpp:41:5: error: passing 'const ra::math:
:rational<long int>' as 'this' argument discards qualifiers [-fpermissive]
   41
 |   c > c;
      |     ~~^~~
In file included from /tmp/assignment_precheck-judeo
nyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/test_rati
onal.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/
package-rational_sane/source/include/ra/rational.hpp:110:8: note:   in call to '
bool ra::math::rational<T>::operator>(const ra::math::rational<T>&) [with T = lo
ng int]'
  110 |   bool operator>(const rational& obj){
      |        ^~~~~~~~

/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/source/app/test_rational.cpp:42:5: error: passing 'const ra::math::rat
ional<long int>' as 'this' argument discards qualifiers [-fpermissive]
   42 |
 c <= c;
      |     ~~^~~~
In file included from /tmp/assignment_precheck-judeony
ia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/test_ration
al.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/pa
ckage-rational_sane/source/include/ra/rational.hpp:115:8: note:   in call to 'bo
ol ra::math::rational<T>::operator<=(const ra::math::rational<T>&) [with T = lon
g int]'
  115 |   bool operator<=(const rational& obj){
      |        ^~~~~~~

/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/source/app/test_rational.cpp:43:5: error: passing 'const ra::math::rat
ional<long int>' as 'this' argument discards qualifiers [-fpermissive]
   43 |
 c >= c;
      |     ~~^~~~
In file included from /tmp/assignment_precheck-judeony
ia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/test_ration
al.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/pa
ckage-rational_sane/source/include/ra/rational.hpp:120:8: note:   in call to 'bo
ol ra::math::rational<T>::operator>=(const ra::math::rational<T>&) [with T = lon
g int]'
  120 |   bool operator>=(const rational& obj){
      |        ^~~~~~~

/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rati
onal_sane/source/app/test_rational.cpp: In instantiation of 'void do_test() [wit
h T = long long int]':
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-1808
6-eLq0zmKZ/package-rational_sane/source/app/test_rational.cpp:89:21:   required
from here
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/pa
ckage-rational_sane/source/app/test_rational.cpp:35:3: error: passing 'const ra:
```



```
:math::rational<long long int>' as 'this' argument discards qualifiers [-fpermis
sive]
   35 |   c.truncate();
      |   ^
In file included from /tmp/assignment_
precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source
/app/test_rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-1
8086-eLq0zmKZ/package-rational_sane/source/include/ra/rational.hpp:80:12: note:
  in call to 'ra::math::rational<T>::int_type ra::math::rational<T>::truncate()
[with T = long long int; ra::math::rational<T>::int_type = long long int]'
   80
 |   int_type truncate(){
      |            ^~~~~~~
/tmp/assignment_precheck-j
udeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/test_
rational.cpp:36:3: error: passing 'const ra::math::rational<long long int>' as '
this' argument discards qualifiers [-fpermissive]
   36 |   c.is_integer();

  |   ^
In file included from /tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.
ca-18086-eLq0zmKZ/package-rational_sane/source/app/test_rational.cpp:2:
/tmp/ass
ignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_san
e/source/include/ra/rational.hpp:85:8: note:   in call to 'bool ra::math::ration
al<T>::is_integer() [with T = long long int]'
   85 |   bool is_integer(){

 |        ^~~~~~~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-
eLq0zmKZ/package-rational_sane/source/app/test_rational.cpp:37:3: error: passing
 'const ra::math::rational<long long int>' as 'this' argument discards qualifier
s [-fpermissive]
   37 |   !c;
      |   ^~
In file included from /tmp/assignmen
t_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/sour
ce/app/test_rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca
-18086-eLq0zmKZ/package-rational_sane/source/include/ra/rational.hpp:90:8: note:
  in call to 'bool ra::math::rational<T>::operator!() [with T = long long int]'

   90 |   bool operator!(){
      |        ^~~~~~~
/tmp/assignment_precheck-ju
deonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/test_r
ational.cpp:38:5: error: passing 'const ra::math::rational<long long int>' as 't
his' argument discards qualifiers [-fpermissive]
   38 |   c == c;
      |   ~~^
~~~
In file included from /tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-1
8086-eLq0zmKZ/package-rational_sane/source/app/test_rational.cpp:2:
/tmp/assignm
ent_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/so
urce/include/ra/rational.hpp:95:8: note:   in call to 'bool ra::math::rational<T
>::operator==(const ra::math::rational<T>&) [with T = long long int]'
   95 |
bool operator==(const rational& obj){
      |        ^~~~~~~
/tmp/assignment_pr
```



```
echeck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/a
pp/test_rational.cpp:39:5: error: passing 'const ra::math::rational<long long in
t>' as 'this' argument discards qualifiers [-fpermissive]
   39 |   c != c;

  |   ~~^~~~
In file included from /tmp/assignment_precheck-judeonyia@ugls5.ece.
uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/test_rational.cpp:2:
/tm
p/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rationa
l_sane/source/include/ra/rational.hpp:100:8: note:   in call to 'bool ra::math::
rational<T>::operator!=(const ra::math::rational<T>&) [with T = long long int]'

  100 |   bool operator!=(const rational& obj){
      |        ^~~~~~~
/tmp/ass
ignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_san
e/source/app/test_rational.cpp:40:5: error: passing 'const ra::math::rational<lo
ng long int>' as 'this' argument discards qualifiers [-fpermissive]
   40 |   c
< c;
      |   ~~^~~
In file included from /tmp/assignment_precheck-judeonyia@ug
ls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/test_rational.cp
p:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package
-rational_sane/source/include/ra/rational.hpp:105:8: note:   in call to 'bool ra
::math::rational<T>::operator<(const ra::math::rational<T>&) [with T = long long
 int]'
  105 |   bool operator<(const rational& obj){
      |        ^~~~~~~
/t
mp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-ration
al_sane/source/app/test_rational.cpp:41:5: error: passing 'const ra::math::ratio
nal<long long int>' as 'this' argument discards qualifiers [-fpermissive]
   41
|   c > c;
      |     ~~^~~
In file included from /tmp/assignment_precheck-judeon
yia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/test_ratio
nal.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/p
ackage-rational_sane/source/include/ra/rational.hpp:110:8: note:   in call to 'b
ool ra::math::rational<T>::operator>(const ra::math::rational<T>&) [with T = lon
g long int]'
  110 |   bool operator>(const rational& obj){
      |        ^~~~~
~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-
rational_sane/source/app/test_rational.cpp:42:5: error: passing 'const ra::math:
:rational<long long int>' as 'this' argument discards qualifiers [-fpermissive]

   42 |   c <= c;
      |   ~~^~~~
In file included from /tmp/assignment_prechec
k-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/source/app/te
st_rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eL
q0zmKZ/package-rational_sane/source/include/ra/rational.hpp:115:8: note:   in ca
ll to 'bool ra::math::rational<T>::operator<=(const ra::math::rational<T>&) [wit
h T = long long int]'
  115 |   bool operator<=(const rational& obj){
```



```
      |
      ^~~~~~~
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmK
Z/package-rational_sane/source/app/test_rational.cpp:43:5: error: passing 'const
 ra::math::rational<long long int>' as 'this' argument discards qualifiers [-fpe
rmissive]
   43 |   c >= c;
      |   ~~^~~
In file included from /tmp/assignme
nt_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/sou
rce/app/test_rational.cpp:2:
/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.c
a-18086-eLq0zmKZ/package-rational_sane/source/include/ra/rational.hpp:120:8: not
e:   in call to 'bool ra::math::rational<T>::operator>=(const ra::math::rational
<T>&) [with T = long long int]'
  120 |   bool operator>=(const rational& obj){

      |        ^~~~~~~
gmake[3]: *** [CMakeFiles/test_rational.dir/app/test_rat
ional.cpp.o] Error 1
gmake[3]: Leaving directory '/tmp/assignment_precheck-judeo
nyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_sane/derived'
gmake[2]: *
** [CMakeFiles/test_rational.dir/all] Error 2
gmake[2]: Leaving directory '/tmp/
assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-eLq0zmKZ/package-rational_
sane/derived'
gmake[1]: *** [CMakeFiles/test_rational.dir/rule] Error 2
gmake[1]
: Leaving directory '/tmp/assignment_precheck-judeonyia@ugls5.ece.uvic.ca-18086-
eLq0zmKZ/package-rational_sane/derived'
gmake: *** [test_rational] Error 2
ERROR
: build failed to generate executable test_rational
```

```
commit b985c965a338d89c78c23abef0753310181f7f60
Author: JudeOnyia <60678029+JudeOnyia@users.noreply.github.com>
Date:   Sat May 16 21:50:59 2020 -0700

    First commit. Added IDENTIFICATION text file

commit 4ff2d9e74af1f94ec6313fc01c20c8c8e3e27d16
Author: Jude Onyia <judeonyia10@gmail.com>
Date:   Mon May 18 13:12:36 2020 -0700

    B-1 part a to part e (detailed description below)
    1) Set up the files to contain the linear_congruential_generator class
    2) Created the type member, int_type
    3) Created the constructor
    4) Created the static member function, default_seed
    5) Created data members, a_, c_, m_ and s_
    6) Created static data member, seed_

commit 7eca19d8d2e76ce9cd63378701749c9bb635e3bf
Author: Jude Onyia <judeonyia10@gmail.com>
Date:   Mon May 18 13:51:49 2020 -0700

    Moved class definition from hpp file to cpp file, fixed the
    static function default_seed, and removed static variable seed_.

commit 6c3e60a42aad47c86ffe70982d73c3d5a64a958e
Author: Jude Onyia <judeonyia10@gmail.com>
Date:   Mon May 18 15:26:42 2020 -0700

    B-1 part f to part i (detailed description below)
    1) created the multiplier, increment and modulus functions
    2) created the seed function to restart the sequence generation process
    3) add a member data to indicate how many next positions should be
       discarded in the generated sequence. This defaults to zero
    4) created the discard function to set the discard member data
    5) overloaded the operator() function to advance the generator to the
       next position, and skip positions that are to be discarded

commit 9c8bd027d1dc11a56e090004d1ba352b4367890d
Author: Jude Onyia <judeonyia10@gmail.com>
Date:   Mon May 18 19:16:06 2020 -0700

    B-1 part m to part o (detailed description below)
    1) created the min and max member functions
    2) overloaded the equality and inequality operators
    3) provided a stream inserter (non member function)
    4) enveloped the class and stream inserter with namespace ra::random

commit 26b588789ebd411370795830191f65b188d68c3e
Author: Jude Onyia <judeonyia10@gmail.com>
Date:   Tue May 19 01:14:59 2020 -0700

    Attempt on test code for lcg class.

commit 3d58a7f5c52fe5f1cac773182784a3bba2a349e3
Author: JudeOnyia <60678029+JudeOnyia@users.noreply.github.com>
Date:   Tue May 19 01:41:40 2020 -0700

    Fixed the random.hpp file to have the proper declarations, and
    modifies the random.cpp file to have definitions of some member functions
    and the non-member function (operator<<).
```

```
commit 9793c850025d636b22bc0b4fc20624eab8dd0f13
Author: Jude Onyia <judeonyia10@gmail.com>
Date:   Tue May 19 02:13:19 2020 -0700

    Some error correction made of random.hpp and the test_random.cpp

commit ed7deaa5cea91373489078fd2cd3a38a5d18f16c
Author: JudeOnyia <60678029+JudeOnyia@users.noreply.github.com>
Date:   Tue May 19 19:47:55 2020 -0700

    Corrected the definition of the seed member function and the operator()

commit b78d4a953eeabfd9cc5cf3e5866afb36e2d2378b
Author: JudeOnyia <60678029+JudeOnyia@users.noreply.github.com>
Date:   Tue May 19 20:04:24 2020 -0700

    Moved the constructor and the stream inserter definitions back to the header
 file

commit 27cd751979710a2e089c05cedc0f1df4332eac70
Author: Jude Onyia <judeonyia10@gmail.com>
Date:   Tue May 19 20:49:00 2020 -0700

    Code Finally Builds. Moved stream inserter definition back to
    random.cpp, removed the const prefix in stream inserter.

commit af187b18f31b16877d39b41292d52ce67087077e
Author: Jude Onyia <judeonyia10@gmail.com>
Date:   Wed May 20 01:58:14 2020 -0700

    Completed draft of the test of every member and non member function

commit 2d6841b73b55efdf874307fa8e8d7ec305e31d0c
Author: Jude Onyia <judeonyia10@gmail.com>
Date:   Wed May 20 02:21:52 2020 -0700

    Moved constructor to random.cpp

commit e76162cfa44cc606be634bb1f86470d3de21128a
Author: Jude Onyia <judeonyia10@gmail.com>
Date:   Wed May 20 15:44:11 2020 -0700

    Began B2 Parts a to h (detailed below)
    1) created the template class rational
    2) created the default constructor
    3) created the two parameter constructor
    4) created the numerator and denominator member functions

commit 56ef8368c9372dd7fc68ff3d3c6a54d3a4ea97f4
Author: Jude Onyia <judeonyia10@gmail.com>
Date:   Wed May 20 17:04:06 2020 -0700

    Wrote set up for compound assignment operators

commit 336f8371c02d5d8c31f0e09d20fbac69f6cd4d05
Author: Jude Onyia <judeonyia10@gmail.com>
Date:   Wed May 20 18:18:27 2020 -0700

    1) Created the truncation function
    2) Wrote test for the default constructor
    3) Wrote test for constructor with single argument
    4) Wrote test for constructor with 2 arguments
```

```
124      5) Wrote test for truncation function
125
126  commit a3443247cb741d1417acf72568bdbf6b0fd88c4c
127  Author: Jude Onyia <judeonyia10@gmail.com>
128  Date:   Wed May 20 19:20:23 2020 -0700
129
130      1) Wrote is_integer function
131      2) Tested is_integer function
132
133  commit 5259695fc4569c708380890aff19c477f40c2b1a
134  Author: Jude Onyia <judeonyia10@gmail.com>
135  Date:   Wed May 20 19:40:18 2020 -0700
136
137      1) Wrote operator oveload for Not(!) operator
138      2) Tested Not(!) operator overload
139
140  commit 81dea77023c36e9e44073e4a565c44f661c16674
141  Author: Jude Onyia <judeonyia10@gmail.com>
142  Date:   Wed May 20 20:11:56 2020 -0700
143
144      1) Wrote the Equality(==) and Inequality(!=) operator overloads
145      2) Tested these operator overloads
146
147  commit 1b9e521fe3e52ec3ae9281ecce871b470fa79c02
148  Author: Jude Onyia <judeonyia10@gmail.com>
149  Date:   Wed May 20 21:04:59 2020 -0700
150
151      1) Wrote the operator overloads for: <, >, <=, >=
152      2) Tested these opertor overloads
153
154  commit 944cd522cd5ede4c7ac8faa1b9530669cbed38ae
155  Author: Jude Onyia <judeonyia10@gmail.com>
156  Date:   Wed May 20 23:31:28 2020 -0700
157
158      1) Wrote code for maintaining reduced form of rational number
159      2) Wrote code for ensuring that denominator is not negative
160      3) Tested both code
161
162  commit 0e547c08ff83c80e76d4ca9ca9761317ba487486
163  Author: Jude Onyia <judeonyia10@gmail.com>
164  Date:   Wed May 20 23:59:36 2020 -0700
165
166      1) Wrote condition for when the denominator is zero
167      2) Tested this condition
168
169  commit 34d8990468b542e4574f8c13a36dc4dc55b7294a
170  Author: Jude Onyia <judeonyia10@gmail.com>
171  Date:   Thu May 21 00:52:45 2020 -0700
172
173      1) Fixed the truncation function
174      2) Wrote operator oveload for prefix increment and decrement
175      3) Tested operato oveloads
176
177  commit e9433fdab5c078db150a3b6a98a86f3df3701b9e
178  Author: Jude Onyia <judeonyia10@gmail.com>
179  Date:   Thu May 21 01:06:11 2020 -0700
180
181      1) Wrote operator overload of postfix increment and decrement
182      2) Tested these operator oveloads
183
184  commit e010f2b773d186879550d3bfe3f7f4c980737195
185  Author: Jude Onyia <judeonyia10@gmail.com>
```

```
Date:   Thu May 21 17:27:22 2020 -0700

    1) Wrote code to turn the numerator and denominator to be whole numbers
       if they weren't.
    2) wrote operator overloads for (+=),(-=),(*=),and (/=)
    3) Tested these operators

commit e0548c8d558cd4ada2bd90c01f6cdee196e84d08
Author: Jude Onyia <judeonyia10@gmail.com>
Date:   Thu May 21 19:21:53 2020 -0700

    1) Wrote non-member operator overloads Unary plus(+) and minus(-)
    2) Tested these overloads

commit d445a44110bbe92770b9e072335b7b5233153fbf
Author: Jude Onyia <judeonyia10@gmail.com>
Date:   Thu May 21 20:23:09 2020 -0700

    1) Wrote the code for operator oveload of binary add, sub, mult, div
    2) Tested these overloads

commit 9938166711a7217237a7db89686466edd839e740
Author: Jude Onyia <judeonyia10@gmail.com>
Date:   Thu May 21 23:25:53 2020 -0700

    1) Wrote Stream Inserter overload and Stream Extractor overload
    2) Tested both overloads

commit 1bcd8abbd4501751ea170a67def4f3d1e4c2f202
Author: Jude Onyia <judeonyia10@gmail.com>
Date:   Fri May 22 00:21:46 2020 -0700

    Make sure both the random and rational classes had const correctness

commit ced72293aad6b851b297ed027b22cde116a1aa57
Author: JudeOnyia <60678029+JudeOnyia@users.noreply.github.com>
Date:   Fri May 22 01:44:33 2020 -0700

    Added Fake README.pdf just to test assignment precheck

commit d00bca51cb1849ae3f839288912b9c879f2566a3
Author: JudeOnyia <60678029+JudeOnyia@users.noreply.github.com>
Date:   Fri May 22 14:04:42 2020 -0700

    Added the right README.pdf

commit 5ceed22f6bf97b14db0740bfeccbcd96470460bb
Author: Jude Onyia <judeonyia10@gmail.com>
Date:   Fri May 22 14:17:39 2020 -0700

    Removed the exception in stream extractor of rational.hpp
```

Name: Jude Onyia

Student ID: V00947095

Course: ECE 596C

Due Date: May 22, 2020

Assignment 1: Non – Programming Exercise

8.8 a)

If the tree is balanced and we assume worst case, the asymptotic time complexity of the function is the height of the balanced tree, which is **O(log n)**.

8.8 b)

If the tree is not balanced, assuming worst case of the search for a node with the value and worst case of the imbalance of the tree, the asymptotic time complexity is **O(n)**.

8.9 a)

The source code performs a sequential accumulative sum of the lower triangle of the matrix. From inspecting the source code, it is evident that the elements included in the accumulation consist of half of the matrix excluding the primary diagonal elements (i.e. a(0,0), a(1,1), etc.), plus the primary diagonal elements. Since the code loops over these elements, the asymptotic time complexity is $O(\frac{n^2-n}{2}+n)$, this can be reduced to $\mathbf{O(n^2)}$.

8.9 b)

Since the allocation of memory for the variables created in this function are not dependent on n, assuming the maximum value of type int is greater than n, then the asymptotic space complexity of the function is **O(1)**.

8.10 a)

The asymptotic time complexity of reverse_array_1 is $O(\frac{n}{2})$, this can be reduced to **O(n)**. Assuming the maximum value of type int is greater than n, the asymptotic space complexity is **O(1)**.

8.10 b)

The asymptotic time complexity of reverse_array_2 is **O(n)**. The space complexity is **O(n)** because a vector of size n is created. The assumption here is also that the maximum value of type int is great than n.

8.10 c)

Based on asymptotic complexity analysis, both have the same time complexity, however, reverse_array_1 has a space complexity of O(1) while reverse_array_2 has O(n). Therefore, reverse_array_1 is preferable.

8.12)

We would need to calculate the overall speedup of the program when each of the three parts are optimized.

A) If part A is optimized, the overall speedup of the program is:

$$S_o = \frac{1}{(1 - f_e) + \frac{f_e}{S_e}} = \frac{1}{(1 - 0.05) + \frac{0.05}{10}} = 1.0471$$

B) If part B is optimized, the overall speedup of the program is:

$$S_o = \frac{1}{(1 - f_e) + \frac{f_e}{S_e}} = \frac{1}{(1 - 0.5) + \frac{0.5}{1.05}} = 1.0244$$

C) If part C is optimized, the overall speedup of the program is:

$$S_o = \frac{1}{(1 - f_e) + \frac{f_e}{S_e}} = \frac{1}{(1 - 0.1) + \frac{0.1}{3}} = 1.0714$$

Based on the above calculations, the choice that would yield the most speedup is optimizing part C, therefore, part C should be optimized.

8.13 a)

If we assume the worst case of all bits having the value 1 (or even just the most significant bit having the value 1), the while loops will iterate until the most significant bit of value 1 has been checked. Hence, it will iterate for the bit-length of the integer. The number of bits of the integer is $\log_2(n)$, rounded up. Therefore, the asymptotic time complexity is **O(log n)**. The asymptotic space complexity is **O(1)** because if the number of bits used for n is changed, the only memory affected is that of n.

8.13 b)

The code below is an implementation of the algorithm derived from [1].

```
unsigned int hamming_2(unsigned int n){
    unsigned int total_bit_num = sizeof(int) * CHAR_BITS; // Number of bits in n
    unsigned int partition_1 = (~(unsigned int)0) / 3; // Binary 01010101
    unsigned int partition_2 = (~(unsigned int)0) / 5; // Binary 00110011
    unsigned int partition_4 = (~(unsigned int)0) / 17; // Binary 00001111

    n -= (n >> 1) & partition_1;  //Count the ones of each 2 bits and
                                  //replace those 2 bits with result
```

```
    n = (n & partition_2) + ((n >> 2) & partition_2); //Count the ones of each 4 bits
                                                      //and replace those 4 bits with result
    n = (n + (n >> 4)) & partition_4; // Count the ones of each 8 bits and
                                      //replace those 8 bits with result

    if(total_bit_num > 8)  n += n >>  8; //move result of each 16 bits into lowest 8 bits
    if(total_bit_num > 16) n += n >> 16; //move result of each 32 bits into lowest 8 bits
    if(total_bit_num > 32) n += n >> 32; //move result of each 64 bits into lowest 8 bits
    return n & 0x7F; // bit AND with decimal number 127 will keep the 8 bits
}
```

The advantage of the algorithm is that it's asymptotic time complexity is **O(1)**, less than hamming_1's complexity of O(log n). The disadvantage is that it requires more space in memory than hamming_1.

8.13 c)

The reasoning behind using asymptotic complexity is to have a sense of the effect of problem size on the performance of the program as the problem size increases to relatively huge amount. The asymptotic analysis is necessary to calculate the rate of program's performance and memory requirement as the problem size increases.

Reference

[1] Joel Yliluoma, WP2 - Nifty Revised, without multipliations, Bit-counting algorithms, 2013. https://bisqwit.iki.fi/source/misc/bitcounting/

```
1  # Specify Minimum Required Version
2  cmake_minimum_required(VERSION 3.1 FATAL_ERROR)
3
4  # Specify Project and Language
5  project(random_and_rational LANGUAGES CXX)
6
7  # Set Include Directory
8  include_directories(include)
9
10 # Add Executable Program
11 add_executable(random app/test_random.cpp lib/random.cpp)
12 add_executable(rational app/test_rational.cpp)
```

```
1  #ifndef random_hpp
2  #define random_hpp
3  #include <iostream>
4  namespace ra::random{
5      class linear_congruential_generator {
6      public:
7          typedef unsigned long long int int_type; // type member
8          static int_type default_seed(){ return (int_type)1;} // Function to retu
   rn default seed of one for all objects
9
10         // Constructor that initializes the multiplier, increment and modulus. S
   eed is optional argument.
11         linear_congruential_generator(int_type a, int_type c, int_type m, int_ty
   pe s = default_seed());
12
13         const int_type multiplier() const { return a_;} // Function to return mu
   ltiplier value
14         const int_type increment() const { return c_;} // Function to return inc
   rement value
15         const int_type modulus() const { return m_;} // Function to return modul
   us value
16         const int_type position() const { return x_;} // Function to return the
   current position in the sequence
17
18         // Function to restarts the sequence generation process with a new seed
   value
19         void seed(int_type s);
20
21         // Operator to advance the generator to the next position in the sequenc
   e
22         // with consideration to the number of positions to be discarded
23         int_type operator()();
24
25         // Function to discard the next n numbers in the generated sequence
26         void discard(unsigned long long n){ n_ = n; }
27
28         const int_type min() const { return c_==(int_type)0? (int_type)1 : (int_
   type)0; } // Function to get the smallest value
29         const int_type max() const { return m_-(int_type)1; } // Funtion to get
   the largest value in sequence
30
31         // Operator to test two linear_congruential_generator objects for equali
   ty
32         bool operator==(const linear_congruential_generator& obj){
33             return (a_==obj.multiplier() && c_==obj.increment()  && m_==obj.modu
   lus()  && x_==obj.position());
34         }
35
36         // Operator to test two linear_congruential_generator objects for inequa
   lity
37         bool operator!=(const linear_congruential_generator& obj){
38                 return !(a_==obj.multiplier() && c_==obj.increment()  && m_==obj
   .modulus()  && x_==obj.position());
39         }
40
41
42     private:
43         int_type a_; // multiplier
44         int_type c_; // increment
45         int_type m_; // modulus
46         int_type x_; // current position in the generated sequence
47         unsigned long long n_ = (unsigned long long)0; // number of positions to
```

```
     discard in the sequence
48      };
49
50      // Stream inserter
51      std::ostream& operator<<(std::ostream& outStream, const linear_congruential_
    generator& objA);
52  }
53  #endif
```

```cpp
#include <iostream>
#include "ra/random.hpp"

namespace ra::random {
        typedef linear_congruential_generator::int_type int_type;

        // Constructor that initializes the multiplier, increment and modulus. Seed is optional argument.
        linear_congruential_generator::linear_congruential_generator(int_type a, int_type c, int_type m, int_type s){
            a_ = a;
            c_ = c;
            m_ = m;
            if( (c_ % m_)==(int_type)0 && (s % m_)==(int_type)0 ) x_ = (int_type)1;
            else x_ = s;
        }

        // Function to restarts the sequence generation process with a new seed value
        void linear_congruential_generator::seed(int_type s){
            if( (c_ % m_)==(int_type)0 && (s % m_)==(int_type)0 ) x_ = (int_type)1;
            else x_ = s;
            n_ = (unsigned long long)0;
        }

        // Operator to advance the generator to the next position in the sequence
        // with consideration to the number of positions to be discarded
        int_type linear_congruential_generator::operator()(){
            ++n_;
            do{
                x_ = (a_ * x_ + c_) % m_;
                --n_;
            } while(n_);
            return x_;
        }

        // Stream inserter
        std::ostream& operator<<(std::ostream& outStream, const linear_congruential_generator& objA){
            outStream << objA.multiplier() << " " << objA.increment() << " " << objA.modulus() << " " << objA.position();
            return outStream;
        }


}
```

```cpp
#include "ra/random.hpp"
#include <iostream>
#include <random>

int main(){

    typedef ra::random::linear_congruential_generator::int_type int_type;
    using std::cout;
    using std::endl;

    // Test class against linear congruential engine in standard library
    // Test constructor with no seed input
    // Test the operator() and the operator<<
    ra::random::linear_congruential_generator obj_mine(14,5,29);
    std::linear_congruential_engine<std::uint_fast32_t,14,5,29> obj_theirs;
    obj_mine();
    obj_theirs();
    cout << "lc generator object: " << obj_mine << endl;
    cout << "lc engine current state: " << obj_theirs << endl;

    // Compare their minimum and maximum
    cout << "lc generator min value: " << obj_mine.min() << endl;
    cout << "lc engine min value: " << obj_theirs.min() << endl;
    cout << "lc generator max value: " << obj_mine.max() << endl;
    cout << "lc engine max value: " << obj_theirs.max() << endl;

    // Test constructor with seed input
    // Test seed() member function
    // Test operator== and operator!=
    ra::random::linear_congruential_generator obj_mine_A(97,41,300,77);
    cout << "lc generator object (seed must be 77): " << obj_mine_A << endl;
    obj_mine_A.seed(259);
    cout << "lc generator object (seed change to 259): " << obj_mine_A << endl;
    obj_mine_A.seed(77);
    ra::random::linear_congruential_generator obj_mine_B(97,41,300,77);
    ra::random::linear_congruential_generator obj_mine_C(20,58,300,77);
    cout << "lc generator equality check (Must be true): " << (obj_mine_A==obj_mine_B) << endl;
    cout << "lc generator equality check (Must be false): " << (obj_mine_A==obj_mine_C) << endl
;
    cout << "lc generator inequality check (Must be false): " << (obj_mine_A!=obj_mine_B) << end
l;
    cout << "lc generator inequality check (Must be true): " << (obj_mine_A!=obj_mine_C) << end
l;

    // Test the discard member function
    for(int i=0; i<90; ++i){
        obj_mine_A();
    }
    obj_mine_B.discard(90);
    cout << "lc generator discard function check (Must be true): " << (obj_mine_A()==obj_mine_B()
) << endl;

    // Test condition when increment and seed are both zero
    ra::random::linear_congruential_generator obj_mine_D(20,0,300,0);
    cout << "lc generator seed (Must be 1): " << obj_mine_D << endl;

    return 0;



}
```

```
1  #ifndef rational_hpp
2  #define rational_hpp
3  #include <iostream>
4  #include <algorithm>
5  #include <string>
6  #include <sstream>
7  namespace ra::math{
8  template<class T>
9  class rational {
10     public:
11         typedef T int_type;
12
13         // Function to reduce the form of the rational number
14         void reduce_form(){
15             long long the_gcd = std::__gcd((long long)n_,(long long)d_);
16             n_ = (int_type)( (long long)n_ / the_gcd ); // Also make numerator a
    whole number;
17             d_ = (int_type)( (long long)d_ / the_gcd ); // Also make denominator
    a whole number
18         }
19
20         // Function to Prevent denominator from having zero or negative value
21         void denominator_handle(){
22             if(d_ == (int_type)0){
23                 n_ = std::numeric_limits<int_type>::max();
24                 d_ = (int_type)1;
25             }
26             if(d_ < (int_type)0) { d_ = d_ * (int_type)(-1); n_ = n_ * (int_type
    )(-1); }
27         }
28
29         // Default constructor sets rational number to 0
30         rational(){
31             n_ = (int_type)0;
32             d_ = (int_type)1;
33         }
34
35         // Constructor to specify numerator and denominator values
36         rational(int_type n, int_type d = (int_type)1){
37             n_ = n;
38             d_ = d;
39             reduce_form();
40             denominator_handle();
41         }
42
43         const int_type numerator() const { return n_; } // Function to return th
    e numerator value
44         const int_type denominator() const { return d_; } // Function to return
    the denominator value
45
46         // Operator for compound addition (+=)
47         rational& operator+=(const rational& obj){
48             n_ = (n_ * obj.denominator()) + (obj.numerator() * d_);
49             d_ = d_ * obj.denominator();
50             reduce_form();
51             return *this;
52         }
53
54         // Operator for compound subtraction (-=)
55         rational& operator-=(const rational& obj){
56             n_ = (n_ * obj.denominator()) - (obj.numerator() * d_);
57             d_ = d_ * obj.denominator();
```

```
58              reduce_form();
59              return *this;
60          }
61
62          // Operator for compound multiplication (*=)
63          rational& operator*=(const rational& obj){
64              n_ = n_ * obj.numerator();
65              d_ = d_ * obj.denominator();
66              reduce_form();
67              return *this;
68          }
69
70          // Operator for compound division (/=)
71          rational& operator/=(const rational& obj){
72              n_ = n_ * obj.denominator();
73              d_ = d_ * obj.numerator();
74              reduce_form();
75              denominator_handle();
76              return *this;
77          }
78
79          // Function for rounding the rational number towards zero (discard fract
    ional part)
80          int_type truncate(){
81              return (int_type)((long long)(n_ / d_));
82          }
83
84          // Function to check if rational number is an integer
85          bool is_integer(){
86              return ( d_==(int_type)1 );
87          }
88
89          // Operator to check if a rational number is zero (!)
90          bool operator!(){
91              return (n_==(int_type)0);
92          }
93
94          // Operator to check equality of rational numbers (==)
95          bool operator==(const rational& obj){
96              return ( (n_/d_) == (obj.numerator()/obj.denominator()) );
97          }
98
99          // Operator to check inequality of rational numbers (!=)
100         bool operator!=(const rational& obj){
101             return ( (n_/d_) != (obj.numerator()/obj.denominator()) );
102         }
103
104         // Operator to check less than of rational numbers (<)
105         bool operator<(const rational& obj){
106             return ( (n_/d_) < (obj.numerator()/obj.denominator()) );
107         }
108
109         // Operator to check greater than of rational numbers (>)
110         bool operator>(const rational& obj){
111             return ( (n_/d_) > (obj.numerator()/obj.denominator()) );
112         }
113
114         // Operator to check less than or equals to of rational numbers (<=)
115         bool operator<=(const rational& obj){
116             return ( (n_/d_) <= (obj.numerator()/obj.denominator()) );
117         }
118
```

```
119         // Operator to check greater than or equals to of rational numbers (>=)
120         bool operator>=(const rational& obj){
121             return ( (n_/d_) >= (obj.numerator()/obj.denominator()) );
122         }
123 
124         // Operator to perform prefix increment (++obj)
125         rational& operator++(){
126             n_ = n_ + d_;
127             return *this;
128         }
129 
130         // Operator to perform prefix and decrement (--obj)
131         rational& operator--(){
132             n_ = n_ - d_;
133             return *this;
134         }
135 
136         // Operator to perform postfix increment (obj++)
137         rational operator++(int){
138             rational<int_type> obj_copy(n_,d_);
139             n_ = n_ + d_;
140             return obj_copy;
141         }
142 
143         // Operator to perform postfix decrement (obj--)
144         rational operator--(int){
145             rational<int_type> obj_copy(n_,d_);
146             n_ = n_ - d_;
147             return obj_copy;
148         }
149 
150     private:
151         int_type n_; // Numerator
152         int_type d_; // Denominator
153 };
154 
155 // Operator to perform Unary plus (+)
156 template<class int_type>
157 rational<int_type> operator+(const rational<int_type>& obj){
158     return rational<int_type>(+(obj.numerator()),obj.denominator());
159 }
160 
161 // Operator to perform Unary minus (-)
162 template<class int_type>
163 rational<int_type> operator-(const rational<int_type>& obj){
164     return rational<int_type>(-(obj.numerator()),obj.denominator());
165 }
166 
167 // Operator to perform Binary addition (+)
168 template<class int_type>
169 rational<int_type> operator+(const rational<int_type>& obj_A, const rational<int
    _type>& obj_B){
170     int_type n_result = (obj_A.numerator() * obj_B.denominator()) + (obj_A.denom
    inator() * obj_B.numerator());
171     int_type d_result = obj_A.denominator() * obj_B.denominator();
172     return rational<int_type>(n_result,d_result);
173 }
174 
175 // Operator to perform Binary subtraction (-)
176 template<class int_type>
177 rational<int_type> operator-(const rational<int_type>& obj_A, const rational<int
    _type>& obj_B){
```

```
178     int_type n_result = (obj_A.numerator() * obj_B.denominator()) - (obj_A.denom
    inator() * obj_B.numerator());
179     int_type d_result = obj_A.denominator() * obj_B.denominator();
180     return rational<int_type>(n_result,d_result);
181 }
182
183 // Operator to perform Binary multiplication (*)
184 template<class int_type>
185 rational<int_type> operator*(const rational<int_type>& obj_A, const rational<int
    _type>& obj_B){
186     int_type n_result = obj_A.numerator() * obj_B.numerator();
187     int_type d_result = obj_A.denominator() * obj_B.denominator();
188     return rational<int_type>(n_result,d_result);
189 }
190
191 // Operator to perform Binary division (/)
192 template<class int_type>
193 rational<int_type> operator/(const rational<int_type>& obj_A, const rational<int
    _type>& obj_B){
194     int_type n_result = obj_A.numerator() * obj_B.denominator();
195     int_type d_result = obj_A.denominator() * obj_B.numerator();
196     return rational<int_type>(n_result,d_result);
197 }
198
199 // Stream Inserter
200 template<class int_type>
201 std::ostream& operator<<(std::ostream& outStream, const rational<int_type>& obj)
    {
202     outStream << obj.numerator() << "/" << obj.denominator();
203     return outStream;
204 }
205
206 // Stream Extractor
207 template<class int_type>
208 std::istream& operator>>(std::istream& inStream, rational<int_type>& obj){
209     std::string the_input;
210     std::getline(inStream,the_input);
211     std::istringstream iss(the_input);
212     std::string n, d;
213     std::getline(iss,n,'/');
214     std::getline(iss,d);
215     long long n_l = std::stoll(n);
216     long long d_l = std::stoll(d);
217     if((std::to_string(n_l) + '/' + std::to_string(d_l))!=the_input){
218         inStream.setstate(std::ios_base::failbit);
219     }
220     obj = rational<int_type>((int_type)n_l,(int_type)d_l);
221     return inStream;
222 }
223
224
225
226 }
227 #endif
```

```cpp
#include "ra/rational.hpp"
#include <iostream>

#include <string>
#include <sstream>

int main(){
    using std::cout;
    using std::endl;

    ra::math::rational<double> obj_A;
    cout << "1) Test default constructor" << endl;
    cout << "  Numerator: " << obj_A.numerator() << endl;
    cout << "  Denominator: " << obj_A.denominator() << endl << endl;

    ra::math::rational<float> obj_B(-56);
    cout << "2) Test constructor with single parameter" << endl;
    cout << "  Numerator: " << obj_B.numerator() << endl;
    cout << "  Denominator: " << obj_B.denominator() << endl << endl;

    ra::math::rational<double> obj_C(31488,117);
    cout << "3) Test constructor with double parameter and trunction function" << endl;
    cout << "  Numerator: " << obj_C.numerator() << endl;
    cout << "  Denominator: " << obj_C.denominator() << endl;
    cout << "  Truncated value: " << obj_C.truncate() << endl << endl;

    ra::math::rational<double> obj_D(48,-4);
    cout << "4) Test is_integer function" << endl;
    cout << "  Numerator: " << obj_D.numerator() << endl;
    cout << "  Denominator: " << obj_D.denominator() << endl;
    cout << "  is_integer: " << obj_D.is_integer() << endl;
    cout << "  Numerator: " << obj_C.numerator() << endl;
    cout << "  Denominator: " << obj_C.denominator() << endl;
    cout << "  is_integer: " << obj_C.is_integer() << endl << endl;

    ra::math::rational<double> obj_E(0,-4);
    cout << "5) Test the Not(!) operator" << endl;
    cout << "  Numerator: " << obj_E.numerator() << endl;
    cout << "  Not(!) operator: " << !obj_E << endl;
    cout << "  Numerator: " << obj_D.numerator() << endl;
    cout << "  Not(!) operator: " << !obj_D << endl << endl;

    ra::math::rational<double> obj_F(-12);
    cout << "6) Test Equality(==) operator" << endl;
    cout << "  Must be true: " << (obj_D==obj_F) << endl;
    cout << "  Must be false: " << (obj_F==obj_C) << endl << endl;

    cout << "7) Test Inequality(!=) operator" << endl;
    cout << "  Must be true: " << (obj_C!=obj_F) << endl;
    cout << "  Must be false: " << (obj_F!=obj_D) << endl << endl;

    cout << "8) Test Less than(<) operator" << endl;
    cout << "  Must be true: " << (obj_F<obj_C) << endl;
    cout << "  Must be false: " << (obj_E<obj_F) << endl;
    cout << "  Must be false: " << (obj_F<obj_D) << endl << endl;

    cout << "9) Test Greater than(>) operator" << endl;
    cout << "  Must be false: " << (obj_F>obj_C) << endl;
    cout << "  Must be true: " << (obj_E>obj_F) << endl;
    cout << "  Must be false: " << (obj_F>obj_D) << endl << endl;

    cout << "10) Test Less than or equals to(<=) operator" << endl;
```

```
63      cout << "  Must be true: " << (obj_F<=obj_C) << endl;
64      cout << "  Must be false: " << (obj_E<=obj_F) << endl;
65      cout << "  Must be true: " << (obj_F<=obj_D) << endl << endl;
66
67      cout << "11) Test Greater than or equals to(>=) operator" << endl;
68      cout << "  Must be false: " << (obj_F>=obj_C) << endl;
69      cout << "  Must be true: " << (obj_E>=obj_F) << endl;
70      cout << "  Must be true: " << (obj_F>=obj_D) << endl << endl;
71
72      cout << "12) Test Reduced form and negative denominator" << endl;
73      cout << "  obj_C(31488,117): " << obj_C.numerator() << "," << obj_C.denominator()
     << endl;
74      cout << "  obj_D(48,-4): " << obj_D.numerator() << "," << obj_D.denominator() <<
     endl << endl;
75
76      ra::math::rational<double> obj_G(-9,0);
77      cout << "13) Test Condition when denominator is zero" << endl;
78      cout << "  obj_G(-9,0): " << obj_G.numerator() << "," << obj_G.denominator() <<
    endl << endl;
79
80      cout << "14) Test Prefix Increment(++obj) and Decrement(--obj) operators" << endl;
81      cout << "  obj_D: " << obj_D.numerator() << "," << obj_D.denominator() << endl
    ;
82      cout << "  increment: " << (++obj_D).numerator() << "," << obj_D.denominator()
    << endl;
83      cout << "  decrement: " << (--obj_D).numerator() << "," << obj_D.denominator()
    << endl << endl;
84
85      cout << "15) Test Postfix Increment(obj++) and Decrement(obj--) operators" << endl;
86      cout << "  obj_D: " << obj_D.numerator() << "," << obj_D.denominator() << endl
    ;
87      cout << "  increment: " << (obj_D++).numerator() << "," << obj_D.denominator()
    << endl;
88      cout << "  See change after: " << obj_D.numerator() << "," << obj_D.denominator()
    << endl;
89      cout << "  decrement: " << (obj_D--).numerator() << "," << obj_D.denominator()
    << endl;
90      cout << "  See change after: " << obj_D.numerator() << "," << obj_D.denominator()
    << endl << endl;
91
92      ra::math::rational<double> obj_H(-9.776,1.33);
93      cout << "16) Test case where a decimal points is used for the numerator and denominator " << endl;
94      cout << "  obj_H: " << obj_H.numerator() << "," << obj_H.denominator() << endl
     << endl;
95
96      ra::math::rational<float> obj_I(8,10);
97      ra::math::rational<float> obj_J(1,5);
98      ra::math::rational<float> obj_K(2,3);
99      cout << "17) Test Operator(+=) and (-=) and (*=) and (/=)" << endl;
100     cout << "  (8/10) += (1/5): " << (obj_I+=obj_J).numerator() << "/" << obj_I.denomi
    nator() << endl;
101     cout << "  (prev ans) -= (2/3): " << (obj_I-=obj_K).numerator() << "/" << obj_I.deno
    minator() << endl;
102     cout << "  (prev ans) *= (2/3): " << (obj_I*=obj_K).numerator() << "/" << obj_I.deno
    minator() << endl;
103     cout << "  (prev ans) /= (1/5): " << (obj_I/=obj_J).numerator() << "/" << obj_I.deno
    minator() << endl << endl;
104
105     cout << "18) Test Unary minus(-) and Unary plus(+)" << endl;
106     cout << "  obj_H: " << obj_H.numerator() << "," << obj_H.denominator() << endl
    ;
107     cout << "  Unary Plus: " << (+obj_H).numerator() << "/" << obj_H.denominator() <
```

```
    < endl;
108     cout << "  Unary Minus: " << (-obj_H).numerator() << "/" << obj_H.denominator()
    << endl;
109
110     cout << "19) Test Binary operators (+), (-), (*), and (/)" << endl;
111     cout <<"   "<<obj_I<<" + "<<obj_J<< " = " <<(obj_I+obj_J)<<endl;
112     cout <<"   "<<obj_I<<" - "<<obj_J<< " = " <<(obj_I-obj_J)<<endl;
113     cout <<"   "<<obj_I<<" * "<<obj_J<< " = " <<(obj_I*obj_J)<<endl;
114     cout <<"   "<<obj_I<<" / "<<obj_J<< " = " <<(obj_I/obj_J)<<endl<<endl;
115
116     cout << "20) Test Stream extractor" << endl;
117     std::cin >> obj_K;
118     cout << obj_K << endl;
119
120
121
122
123     return 0;
124 }
```