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**TANDON SCHOOL
OF ENGINEERING**

FRE6883

Financial Computation

9/2/2023

1



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Leading invention, innovation
and entrepreneurship





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**TANDON SCHOOL
OF ENGINEERING**

Topic 1

Set up AWS Cloud 9 for C++ Development

9/2/2023

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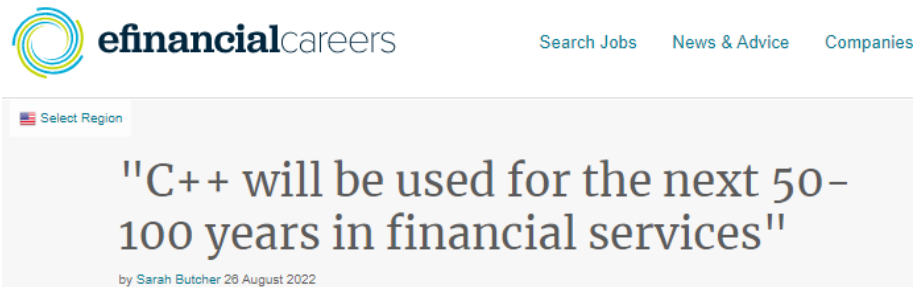


What are prerequisites?

- Have knowledge about derivatives and quantitative methods of option pricing.
- Be aware of elementary programming concepts such as variable declaration and flow control structures such as sequential, looping and conditional statements in general.
- Knowledge in another programming language such as Python is helpful. But it is important not try to fit C/C++ into the language you already know.

Why C++?

- C++ is an industry standard because of its flexibility and performance. It has been the selected language for backend engine in many software applications. C++ is a powerful modern object-oriented language.
- Many 3rd party libraries have been created to integrate market data and conduct complex numerical calculations in C++ applications with high efficiency.
- C++ has been used in creating financial applications which need to process significant amount of historical data and complete complicated computation in real-time.



The Difficulty of Learning C++

- C++ may not be an ideal language for beginners. It provides far more flexibility to programmers often more than required and could be confusing.
- It is very easy to make mistakes and have bugs especially when pointers are used.
- The object-oriented programming concept is not easy to grasp.
- The good news is that once you know C++, learning other programming languages become easier.

Why AWS Cloud9 for C++ Development?

- C++ is very “close to the hardware”, which means that the ways of building financial applications could be different in different computer systems.
- The development environments for C++ applications are different in Windows, MAC, and Linux, which increases the difficulty for students to learn C++.
- Using GNU Compiler Collection (G++) in Linux virtual environment has become standard software development environment for financial industry.
- AWS Cloud9 is a G++ development environment with Linux EC2 instance, and it is almost free.

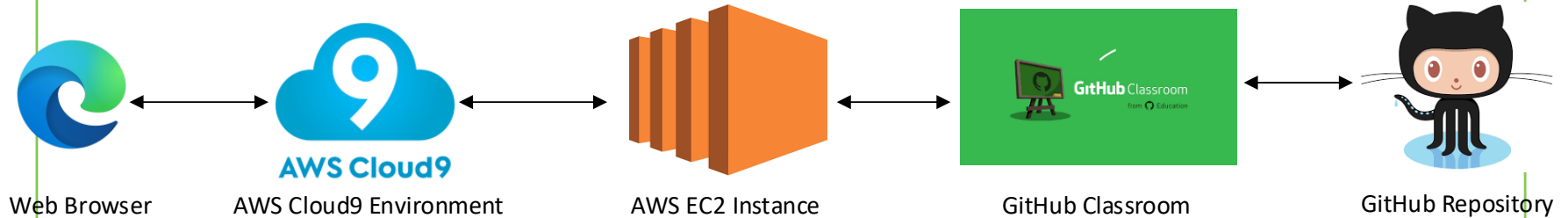
What is AWS Cloud 9?



- AWS Cloud9 is an integrated software development environment (IDE) and could be easily access through a Web browser.
- For using the AWS Cloud9 IDE, running in a web browser on our local computer, to interact with our AWS Cloud9 environment, which is connected to an Amazon EC2 instance. All the source codes will be committed to GitHub remote repository.

<https://docs.aws.amazon.com/cloud9/latest/user-guide/welcome.html>

Our C++ Programming Environment



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Benefits of Using AWS Cloud9

- AWS Cloud9 offers an industry-level development environment to edit, build and run C++ programs and applications. The free-tier is sufficient for our learning purpose.
- Using the AWS Cloud9 IDE, we can:
 - Store our project's files locally on the instance or server.
 - Sync with a remote code repository – We use GitHub as the remote repository.
- Work with a combination of local and cloned files in the environment.
- By storing the environment in the cloud, our projects no longer need to be tied to a single computer or IDE setup, all the students will have a standardized development environment, and make teaching more efficient.

GitHub Classroom

- GitHub Classroom automates repository creation and access control. It offer an integrated platform for distributing starter code from GitHub and managing homework assignments.



GitHub Repository



- GitHub is a website providing cloud-based service store and manage source codes for software applications, as well as track and control changes to the source codes.
 - The lecture source codes, and student's assignments are organized in projects.
 - A GitHub Repository contains all the project's files and each file's revision history.
 - GitHub provides free service for personal usage as well as educational organization.
 - GitHub is one of the world's largest community of software developers, and many employers use GitHub.
 - It will be a big plus for students in finance if the students could show potential employers their GitHub repositories with the history of completed projects.
- <https://docs.github.com/en/repositories/creating-and-managing-repositories/about-repositories>

AWS Cloud 9 Setup

- Create AWS Account
 - **Personal – for your own project**
 - **Basic support – Free**
- Add IAM User to your account
- Sign in as IAM User
- Create AWS Cloud 9 IDE Environment
- Create GitHub account and Join FRE6883 GitHub classroom for homework assignments
- Clone the Homework Assignment 1 to Cloud9 Env

Create AWS Account, <https://aws.amazon.com/>



Explore Free Tier products with a new AWS account.

To learn more, visit aws.amazon.com/free.



Sign up for AWS

Root user email address

Used for account recovery and some administrative functions

AWS account name

Choose a name for your account. You can change this name in your account settings after you sign up.

Verify email address

OR

Sign in to an existing AWS account

Sign up for AWS

Select a support plan

Choose a support plan for your business or personal account. [Compare plans and pricing examples](#). You can change your plan anytime in the AWS Management Console.

☒ Basic support - Free

- Recommended for new users just getting started with AWS
- 24x7 self-service access to AWS resources
- For account and billing issues only
- Access to Personal Health Dashboard & Trusted Advisor



☐ Developer support - From \$29/month

- Recommended for developers experimenting with AWS
- Email access to AWS Support during business hours
- 12 (business)-hour response times



☐ Business support - From \$100/month

- Recommended for running production workloads on AWS
- 24x7 tech support via email, phone, and chat
- 1-hour response times
- Full set of Trusted Advisor best-practice recommendations



Need Enterprise level support?

From \$15,000 a month you will receive 15-minute response times and concierge-style experience with an assigned Technical Account Manager. [Learn more](#)

Sign in as Root User for AWS Account Console



Sign in

☒ **Root user**

Account owner that performs tasks requiring unrestricted access. [Learn more](#)

☐ **IAM user**

User within an account that performs daily tasks. [Learn more](#)

Root user email address

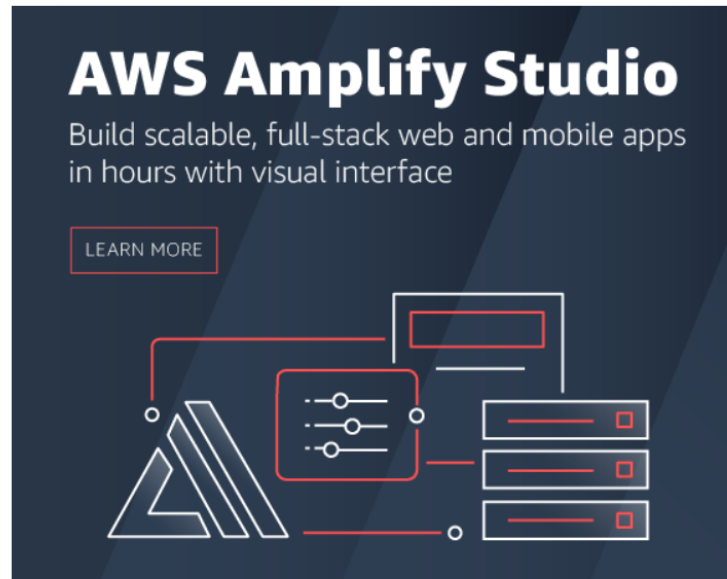
username@example.com




Next

By continuing, you agree to the [AWS Customer Agreement](#) or other agreement for AWS services, and the [Privacy Notice](#). This site uses essential cookies. See our [Cookie Notice](#) for more information.


— New to AWS? —

Create a new AWS account





 Services [Alt+S]  


Console Home [Info](#)

[Reset to default layout](#) [+ Add widgets](#) 

Recently visited [Info](#)


 Cloud9


 IAM


 EC2

[View all services](#)

Welcome to AWS

[Getting started with AWS](#)
Learn the fundamentals and find valuable information to get the most out of AWS.

[Training and certification](#)
Learn from AWS experts and advance your skills and knowledge.

[What's new with AWS?](#)
Discover new AWS services, features, and Regions.

AWS Health [Info](#)

Open issues

0


Past 7 days

Scheduled changes

0

Upcoming and past 7 days

Cost and usage [Info](#)




[Feedback](#) Looking for language selection? Find it in the new [Unified Settings](#)


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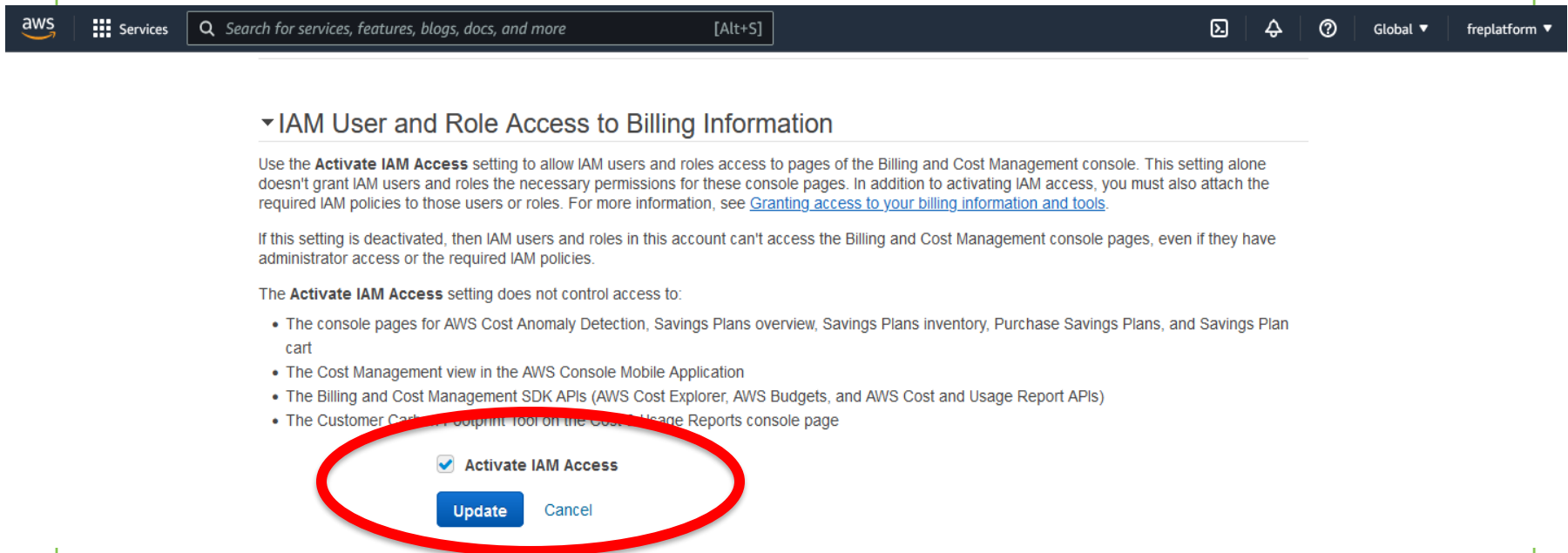
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Create admin IAM user and user group (1)

- Enable access to billing data for the IAM admin user we are going to create.



The screenshot shows the AWS IAM console interface. At the top, there's a navigation bar with the AWS logo, 'Services' link, a search bar, and utility icons. Below this, the page title is 'IAM User and Role Access to Billing Information'. The main content area explains the 'Activate IAM Access' setting, stating it allows IAM users and roles access to Billing and Cost Management console pages. It also lists what this setting does not control access to, such as AWS Cost Anomaly Detection, Savings Plans, and Cost Explorer. At the bottom of the settings section, there is a toggle for 'Activate IAM Access' which is currently checked. This toggle and the 'Update' button are circled in red. The 'Update' button is a blue button with white text.

Click on My Account on the Right-hand top. Click on Edit under “IAM User and Role Access to Billing Information” and check “Activate IAM Access” and click on Update.

Create admin IAM user and user group (2)

- Create user group Administrators
 - Search IAM to open IAM Dashboard; Click User Group and then Create Group






Create group

Create a group and select the policies to be attached to the group. Using groups is a best-practice way to manage users' permissions by job functions, AWS service access, or your custom permissions. [Learn more](#)

Group name

Create policy Refresh

Filter policies Search Showing 766 results

	Policy name	Type	Used as	Description
<input checked="" type="checkbox"/>	 AdministratorAccess	Job function	None	Provides full access to AWS services and resources.
<input type="checkbox"/>	 AdministratorAccess-Amp...	AWS managed	None	Grants account administrative permissions while explicitly allow...
<input type="checkbox"/>	 AdministratorAccess-AWS...	AWS managed	None	Grants account administrative permissions. Explicitly allows de...
<input type="checkbox"/>	 AlexaForBusinessDeviceS...	AWS managed	None	Provide device setup access to AlexaForBusiness services
<input type="checkbox"/>	 AlexaForBusinessFullAcc...	AWS managed	None	

Cancel Create group

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Create admin IAM user and user group (3)

- Create your IAM admin user

The screenshot displays the AWS IAM console interface. On the left sidebar, the 'Users' link under 'Access management' is circled in red. The main content area shows the 'Users (1)' page, where the 'Create user' button is also circled in red. The console header includes the AWS logo, 'Services' menu, a search bar with 'IAM' entered, and navigation icons. The left sidebar also features a search bar labeled 'Search IAM' and a 'Dashboard' link.

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[IAM](#) > [Users](#) > Create user

Step 1

Specify user details

Step 2

[Set permissions](#)

Step 3

[Review and create](#)

Step 4

Retrieve password

Specify user details

User details

User name

FRE6883

The user name can have up to 64 characters. Valid characters: A-Z, a-z, 0-9, and + = , . @ _ - (hyphen)

☒ Provide user access to the AWS Management Console - *optional*

If you're providing console access to a person, it's a [best practice](#) to manage their access in IAM Identity Center.



Are you providing console access to a person?

User type

☐ Specify a user in Identity Center - Recommended

We recommend that you use Identity Center to provide console access to a person. With Identity Center, you can centrally manage user access to their AWS accounts and cloud applications.

☒ I want to create an IAM user

We recommend that you create IAM users only if you need to enable programmatic access through access keys, service-specific credentials for AWS CodeCommit or Amazon Keyspaces, or a backup credential for emergency account access.

Console password

☐ Autogenerated password

You can view the password after you create the user.

☒ Custom password

Enter a custom password for the user.

The password you entered does not conform to the account's password policy:

- Must be at least 8 characters long
- Must include at least three of the following mix of character types: uppercase letters (A-Z), lowercase letters (a-z), numbers (0-9), and symbols ! @ # \$ % ^ & * () _ + - (hyphen) = [] { } ' "

☐ Show password☐ Users must create a new password at next sign-in - Recommended

Users automatically get the [IAMUserChangePassword](#) policy to allow them to change their own password.



If you are creating programmatic access through access keys or service-specific credentials for AWS CodeCommit or Amazon Keyspaces, you can generate them after you create this IAM user. [Learn more](#)

Cancel

Next



Set permissions

Add user to an existing group or create a new one. Using groups is a best-practice way to manage user's permissions by job functions. [Learn more](#)

Permissions options

☒ Add user to group

Add user to an existing group, or create a new group. We recommend using groups to manage user permissions by job function.

☐ Copy permissions

Copy all group memberships, attached managed policies, and inline policies from an existing user.

☐ Attach policies directly

Attach a managed policy directly to a user. As a best practice, we recommend attaching policies to a group instead. Then, add the user to the appropriate group.

User groups (1/1)

Refresh

Create group

Search

< 1 >

Settings

<input checked="" type="checkbox"/>	Group name	Users	Attached policies	Created
<input checked="" type="checkbox"/>	administrators	1	AdministratorAccess	2022-08-30 (1 year ago)

► Set permissions boundary - optional

Cancel

Previous

Next

aws

Services

Search for services, features, blogs, docs, and more

[Alt+S]

Global

freplatform

Identity and Access Management (IAM)

Search IAM

Dashboard

Access management

- User groups
- Users**
- Roles
- Policies
- Identity providers
- Account settings

Access reports

- Access analyzer
- Archive rules
- Analyzers
- Settings

Introducing the new Users list experience

We've redesigned the Users list experience to make it easier to use. [Let us know what you think.](#)

The user FRE6883 have been created.

IAM > Users

Users (1) Info

An IAM user is an identity with long-term credentials that is used to interact with AWS in an account.

Find users by username or access key

< 1 >

User nameGroupsLast activityMFAPassword ...Active key age

FRE6883

Administrators

Never


None

6 minutes ago


6 minutes ago

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Sign in as IAM user



Sign in as IAM user

Account ID (12 digits) or account alias

264484317875

IAM user name

FRE6883

Password

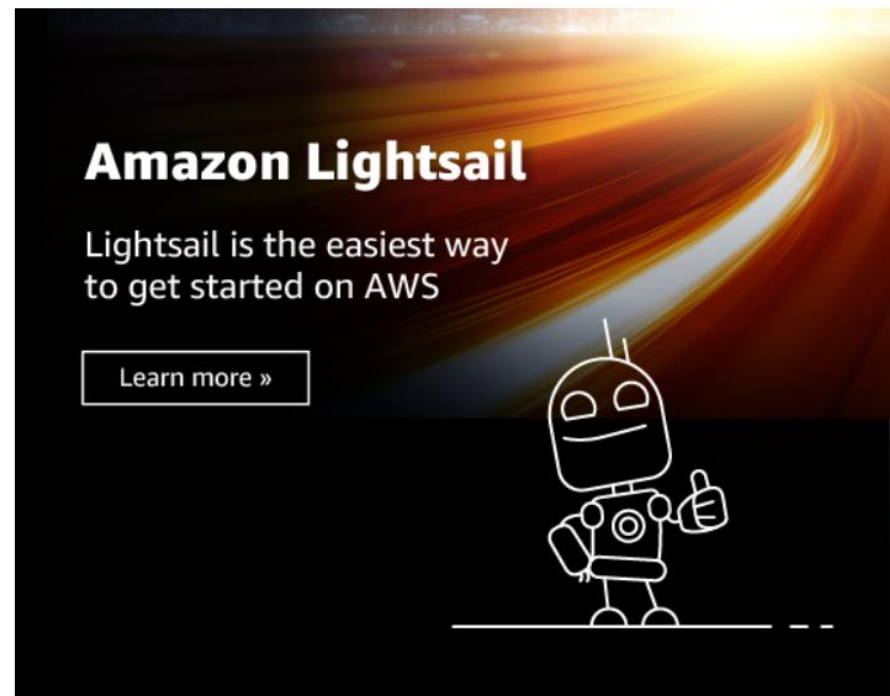
••••••••••

☐ Remember this account

Sign in

[Sign in using root user email](#)

[Forgot password?](#)



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Console Home [Info](#)

Reset to default layout

+ Add widgets

Recently visited [Info](#)



Cloud9



EC2

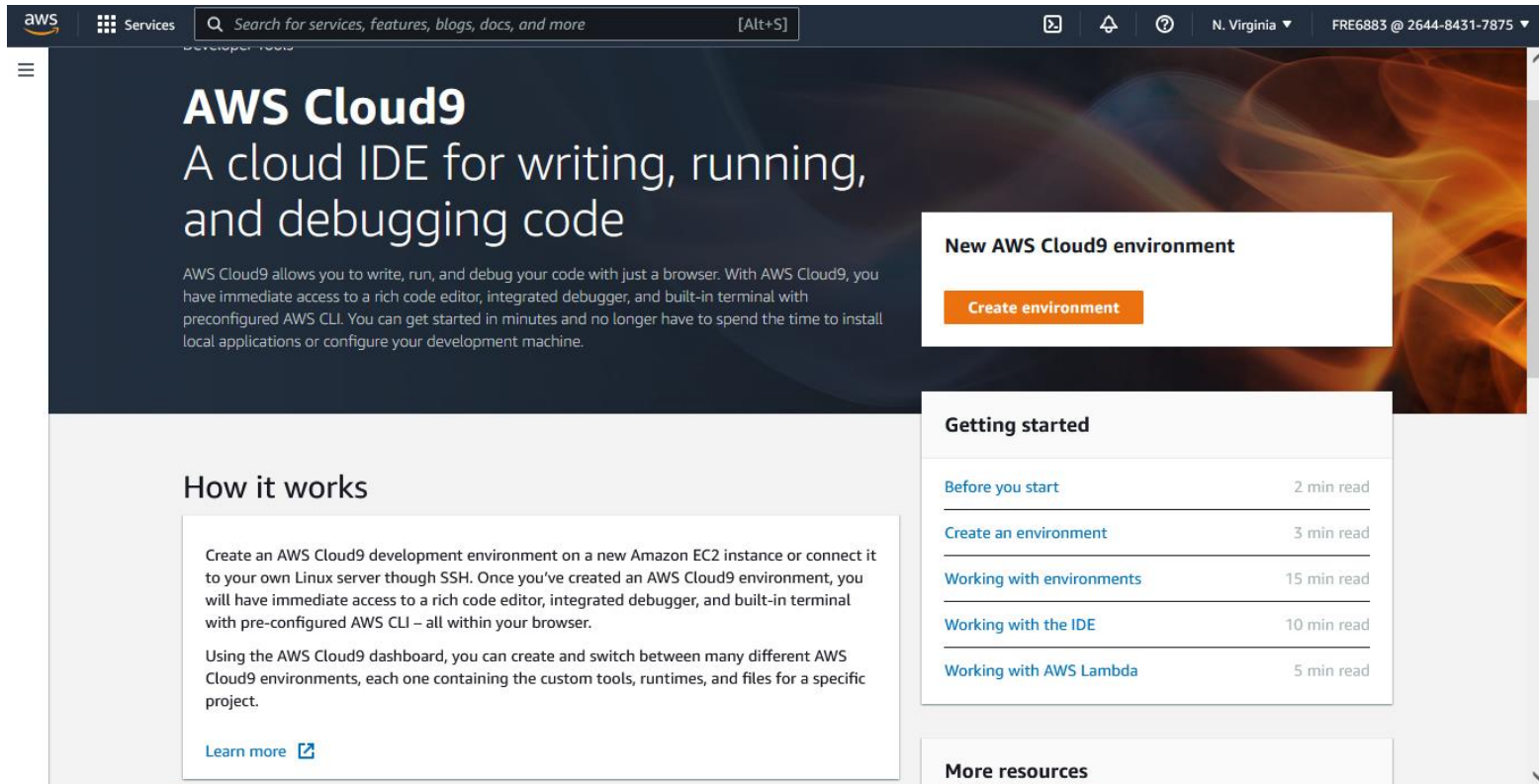


AWS Budgets



IAM

Create AWS Cloud9 C++ coding env



The screenshot shows the AWS Cloud9 console interface. At the top, there's a navigation bar with the AWS logo, 'Services' link, a search bar, and account information (N. Virginia, FRE6883 @ 2644-8431-7875). The main content area has a dark background with the text 'AWS Cloud9' and 'A cloud IDE for writing, running, and debugging code'. Below this, a paragraph explains that AWS Cloud9 allows writing, running, and debugging code with just a browser, providing immediate access to a rich code editor, integrated debugger, and built-in terminal with preconfigured AWS CLI. A 'Create environment' button is prominently displayed. To the right, a 'Getting started' section lists several guides: 'Before you start' (2 min read), 'Create an environment' (3 min read), 'Working with environments' (15 min read), 'Working with the IDE' (10 min read), and 'Working with AWS Lambda' (5 min read). A 'More resources' section is also visible at the bottom right.

AWS Cloud9
A cloud IDE for writing, running, and debugging code

AWS Cloud9 allows you to write, run, and debug your code with just a browser. With AWS Cloud9, you have immediate access to a rich code editor, integrated debugger, and built-in terminal with preconfigured AWS CLI. You can get started in minutes and no longer have to spend the time to install local applications or configure your development machine.

New AWS Cloud9 environment

[Create environment](#)

How it works

Create an AWS Cloud9 development environment on a new Amazon EC2 instance or connect it to your own Linux server through SSH. Once you've created an AWS Cloud9 environment, you will have immediate access to a rich code editor, integrated debugger, and built-in terminal with pre-configured AWS CLI – all within your browser.

Using the AWS Cloud9 dashboard, you can create and switch between many different AWS Cloud9 environments, each one containing the custom tools, runtimes, and files for a specific project.

[Learn more](#)

Getting started

- [Before you start](#) 2 min read
- [Create an environment](#) 3 min read
- [Working with environments](#) 15 min read
- [Working with the IDE](#) 10 min read
- [Working with AWS Lambda](#) 5 min read

More resources

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AWS Cloud9



Your environments

Shared with you

Account environments

How-to guide

AWS Cloud9 > Environments > Create environment

Step 1

Name environment

Step 2

Configure settings

Step 3

Review

Configure settings

Environment settings

Environment type [Info](#)

Run your environment in a new EC2 instance or an existing server. With EC2 instances, you can connect directly through Secure Shell (SSH) or connect via AWS Systems Manager (without opening inbound ports).

- ☒ **Create a new EC2 instance for environment (direct access)**
Launch a new instance in this region that your environment can access directly via SSH.
- ☐ **Create a new no-ingress EC2 instance for environment (access via Systems Manager)**
Launch a new instance in this region that your environment can access through Systems Manager.
- ☐ **Create and run in remote server (SSH connection)**
Configure the secure connection to the remote server for your environment.

Instance type

- ☒ **t2.micro (1 GiB RAM + 1 vCPU)**
Free-tier eligible. Ideal for educational users and exploration.
- ☐ **t3.small (2 GiB RAM + 2 vCPU)**
Recommended for small-sized web projects.
- ☐ **m5.large (8 GiB RAM + 2 vCPU)**
Recommended for production and general-purpose development.
- ☐ **Other instance type**
Select an instance type.

t3.nano

Platform

- ☒ **Amazon Linux 2 (recommended)**
- ☐ Amazon Linux AMI
- ☐ Ubuntu Server 18.04 LTS

Cost-saving setting

Choose a predetermined amount of time to auto-hibernate your environment and prevent unnecessary charges. We recommend a hibernation settings of half an hour of no activity to maximize savings.

After 30 minutes (default)

IAM role

AWS Cloud9 creates a service-linked role for you. This allows AWS Cloud9 to call other AWS services on your behalf. You can delete the role from the AWS IAM console once you no longer have any AWS Cloud9 environments. [Learn more](#)

AWSServiceRoleForAWSCloud9

► Network settings (advanced)

No tags associated with the resource.

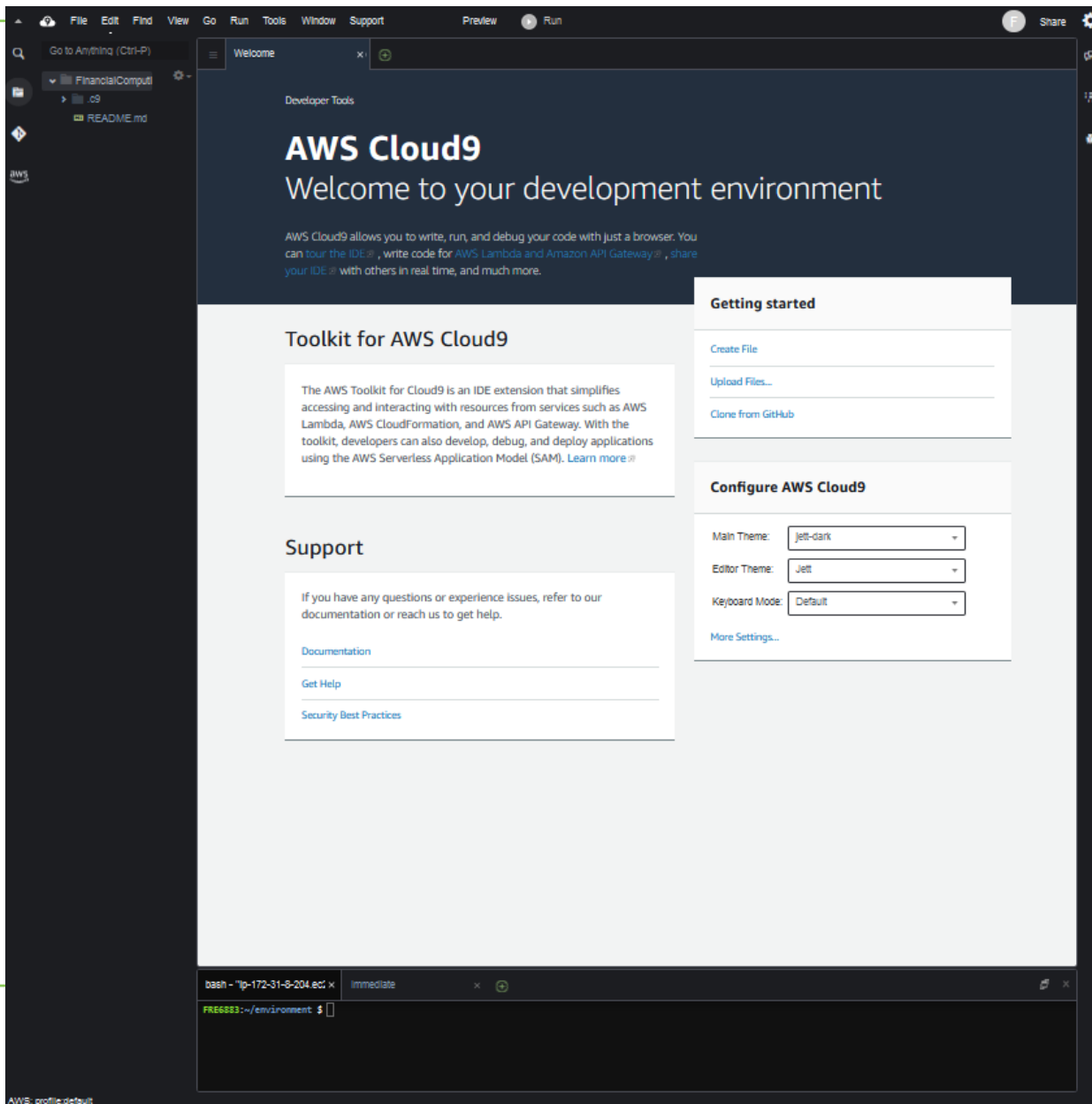
Add new tag

You can add 50 more tags.

Cancel

Previous step

Next step



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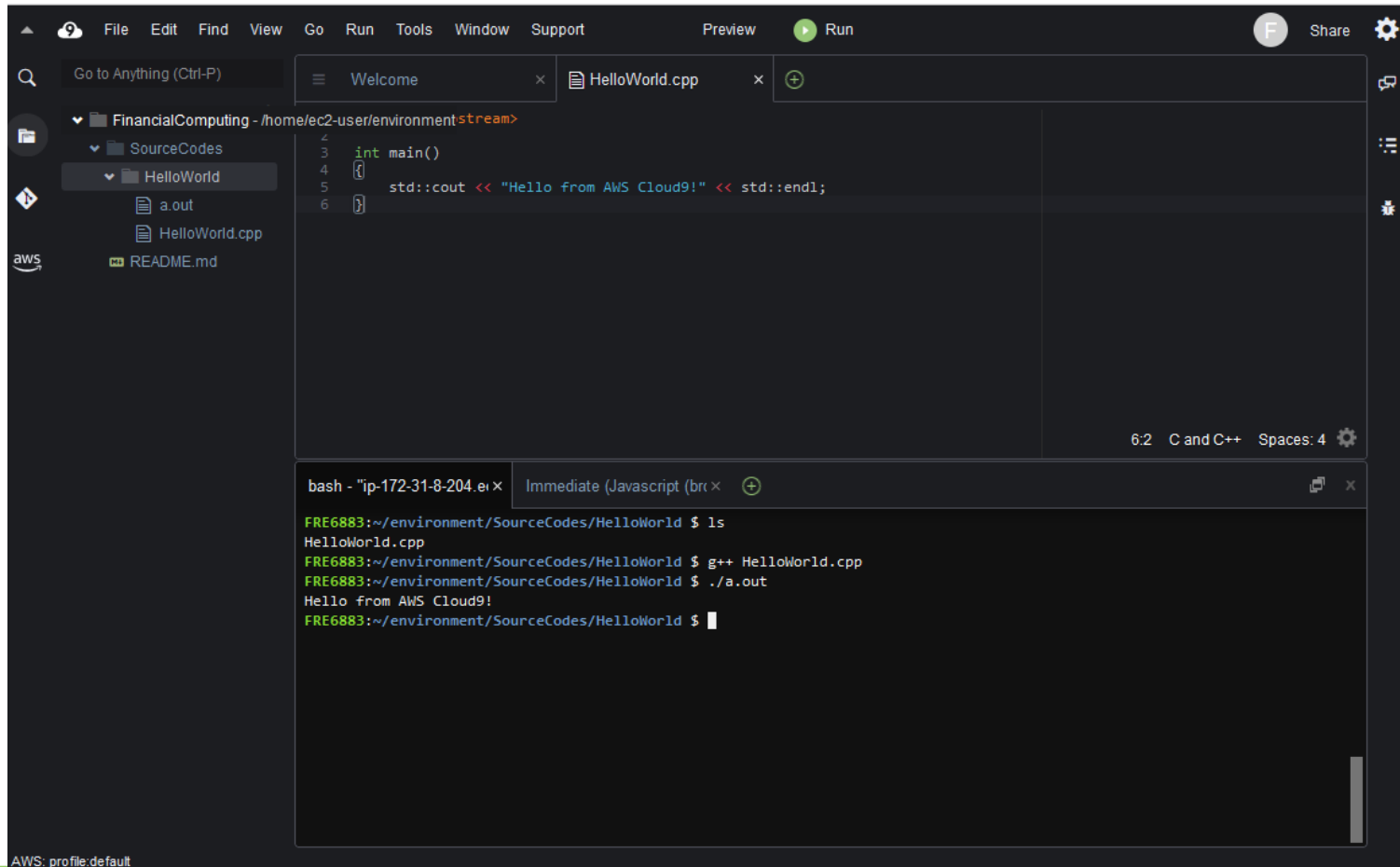
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Your 1st C++ Program: HelloWorld

- In your Cloud9 env, create a new folder, and name it as ***HelloWorld***
- Create a new file Using ***New File from Template and then C++ file***
- Save the file as ***HelloWorld.cpp*** in the folder HelloWorld.
- On the command line, type the following3 commands:
 - ***cd HelloWorld***
 - ***g++ HelloWorld.cpp***
 - ***./a.out***

Your 1st C++ Program: HelloWorld (Continued)



The screenshot displays the AWS Cloud9 IDE interface. The top menu bar includes File, Edit, Find, View, Go, Run, Tools, Window, Support, Preview, and Run. The left sidebar shows a file explorer with the following structure:

- FinancialComputing - /home/ec2-user/environment:stream>
 - SourceCodes
 - HelloWorld
 - a.out
 - HelloWorld.cpp
 - README.md

The main editor window shows the `HelloWorld.cpp` file with the following code:

```
1 // HelloWorld.cpp
2
3 int main()
4 {
5     std::cout << "Hello from AWS Cloud9!" << std::endl;
6 }
```

The bottom panel shows the terminal output for the command `bash - "ip-172-31-8-204.ec2" Immediate (Javascript (br...))`:

```
FRE6883:~/environment/SourceCodes/HelloWorld $ ls
HelloWorld.cpp
FRE6883:~/environment/SourceCodes/HelloWorld $ g++ HelloWorld.cpp
FRE6883:~/environment/SourceCodes/HelloWorld $ ./a.out
Hello from AWS Cloud9!
FRE6883:~/environment/SourceCodes/HelloWorld $
```

The status bar at the bottom left indicates "AWS: profile: default".

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Create GitHub account

github.com



Sign up

Let's build from here, together.

The complete developer platform to build, scale, and
deliver secure software.

Sign up for GitHub

83+ million

Developers

4+ million

Organizations

200+ million

Repositories

90%

Fortune 100


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Create GitHub Personal Access Token (PAT)

- Login your GitHub account, click your name at the right top corner and then settings
- Click Developer settings on the bottom of left panel.
- Click Personal access tokens and Select Tokens.
- Click Generate new token (Classic)
- For the new token, make sure select the following:
 - *admin:repo_hook, delete_repo, repo*

Create GitHub PAT (Continued)

 GitHub Apps

 OAuth Apps

 Personal access tokens

New personal access token

Personal access tokens function like ordinary OAuth access tokens. They can be used instead of a password for Git over HTTPS, or can be used to [authenticate to the API over Basic Authentication](#).

Note

AWS Cloud9

What's this token for?

Expiration *

No expiration ▾

The token will never expire!

GitHub strongly recommends that you set an expiration date for your token to help keep your information secure. [Learn more](#)

Select scopes

Scopes define the access for personal tokens. [Read more about OAuth scopes](#).

☒ repo

Full control of private repositories

☐ repo:status

Access commit status



Create GitHub PAT (Continued)

- **Make sure copy/paste your PAT token and save it somewhere as you will not be able to see it anymore.**
- **The PAT token will be used for clone the Git repository into your AWS Cloud9 and push your homework from Cloud9 to GitHub.**

GitHub Apps

OAuth Apps

Personal access tokens

Personal access tokens

Generate new token

Revoke all

Tokens you have generated that can be used to access the [GitHub API](#).

AWSCloud9 — *admin:repo_hook, delete_repo,* Last used within the last week

Delete

repo

⚠ This token has no expiration date.

Personal access tokens function like ordinary OAuth access tokens. They can be used instead of a password for Git over HTTPS, or can be used to [authenticate to the API over Basic Authentication](#).

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Join FRE6883 GitHub Classroom

- Login into your GitHub account and Join FRE6883 classroom via the following links:
 - **Students in Tuesday Session:**
 - <https://classroom.github.com/a/NAcVtKky>
 - **Students in Saturday Session:**
 - <https://classroom.github.com/a/u79tQ6Dn>
 - Associate your name with your GitHub Account (**Double Check to make sure select right name from the roster**)
- Click Accept this Assignment
- Click the assignment repository such as the following:

Homework Assignment Repository

FRE6883-Fall2023-TuesdayEvenings

Accept the assignment —

FRE6883_Homework_Assignment_1

Once you accept this assignment, you will be granted access to the `fre6883-homework-assignment-1-stangny` repository in the **FRE6883** organization on GitHub.

Accept this assignment

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Homework Assignment Repository (Continue)



You accepted the assignment, **FRE6883_Homework_Assignment_1**.
We're configuring your repository now. This may take a few minutes to complete. Refresh this page to see updates.

 Your assignment is due by **Sep 19, 2023, 18:00 EDT**

Note: You may receive an email invitation to join [FRE6883](#) on your behalf. No further action is necessary.

Homework Assignment Repository (Continue)




You're ready to go!

You accepted the assignment, **FRE6883_Homework_Assignment_1**.

Your assignment repository has been created:

 <https://github.com/FRE6883/fre6883-homework-assignment-1-stangny>

We've configured the repository associated with this assignment ([update](#)).

 Your assignment is due by **Sep 19, 2023, 18:00 EDT**

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Note: You may receive an email invitation to join [FRE6883](#) on your behalf. No further action is necessary.

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Homework Assignment Repository (continued)

🔒 FRE6883 / fre6883_homework_assignment_1-stangny Private

👁 Watch 1

🍴 Fork 0

★ Star 0

<> Code

🔍 Issues

🔗 Pull requests

🎬 Actions

📁 Projects

🛡 Security

📈 Insights

⚙ Settings

🔗 main

🔗 1 branch

🏷 0 tags

Go to file

Add file

Code

About



fre6883_homework_assignment_1-stangny created by GitHub Classroom

📖 Readme

★ 0 stars

👁 1 watching

🍴 0 forks

Releases

No releases published

[Create a new release](#)

Packages

No packages published

[Publish your first package](#)

Languages



🤖 github-classroom[bot] Initial commit 2284244 5 minutes ago ⌚ 1 commit

📄 BinomialTreeModel.cpp	Initial commit	5 minutes ago
📄 BinomialTreeModel.h	Initial commit	5 minutes ago
📄 Makefile	Initial commit	5 minutes ago
📄 Option01.cpp	Initial commit	5 minutes ago
📄 Option01.h	Initial commit	5 minutes ago
📄 OptionPricer01.cpp	Initial commit	5 minutes ago
📄 README.md	Initial commit	5 minutes ago

README.md



Homework_Assignment 1

Clone GitHub Homework Repository to Cloud9

From your Homework Assignment Repository, click Code and copy the HTTPS link:

The screenshot shows a GitHub repository page for 'FRE6883 / fre6883_homework_assignment_1-stangny'. The repository is private and has 1 watch, 0 forks, and 0 stars. The 'Code' button is highlighted, and the dropdown menu is open, showing the 'Clone' option with the HTTPS link: `https://github.com/FRE6883/fre6883_homework_assignment_1-stangny`. The repository contains files like 'BinomialTreeM...', 'Makefile', 'Option01.cpp', 'Option01.h', 'OptionPricer01....', and 'README.md'. The 'About' section on the right indicates the repository was created by GitHub Classroom and has 1 watching and 0 forks. The 'Releases' section shows no releases published.

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Clone Homework Repo to Cloud9 (continued)

- Sign in your AWS Cloud9 as the IAM user:



Sign in as IAM user

Account ID (12 digits) or account alias

447345693773

IAM user name

stangny

Password

.....

☐ Remember this account

Sign in

[Sign in using root user email](#)

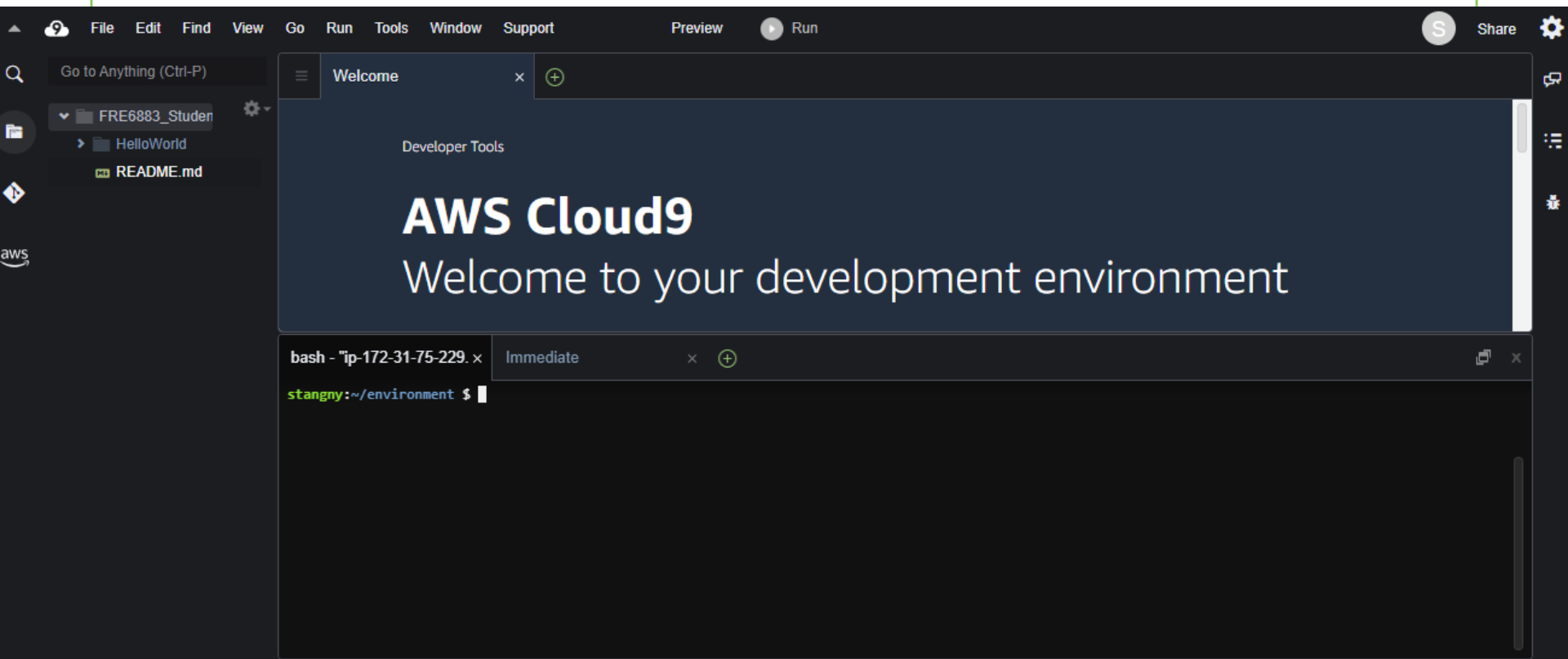
[Forgot password?](#)

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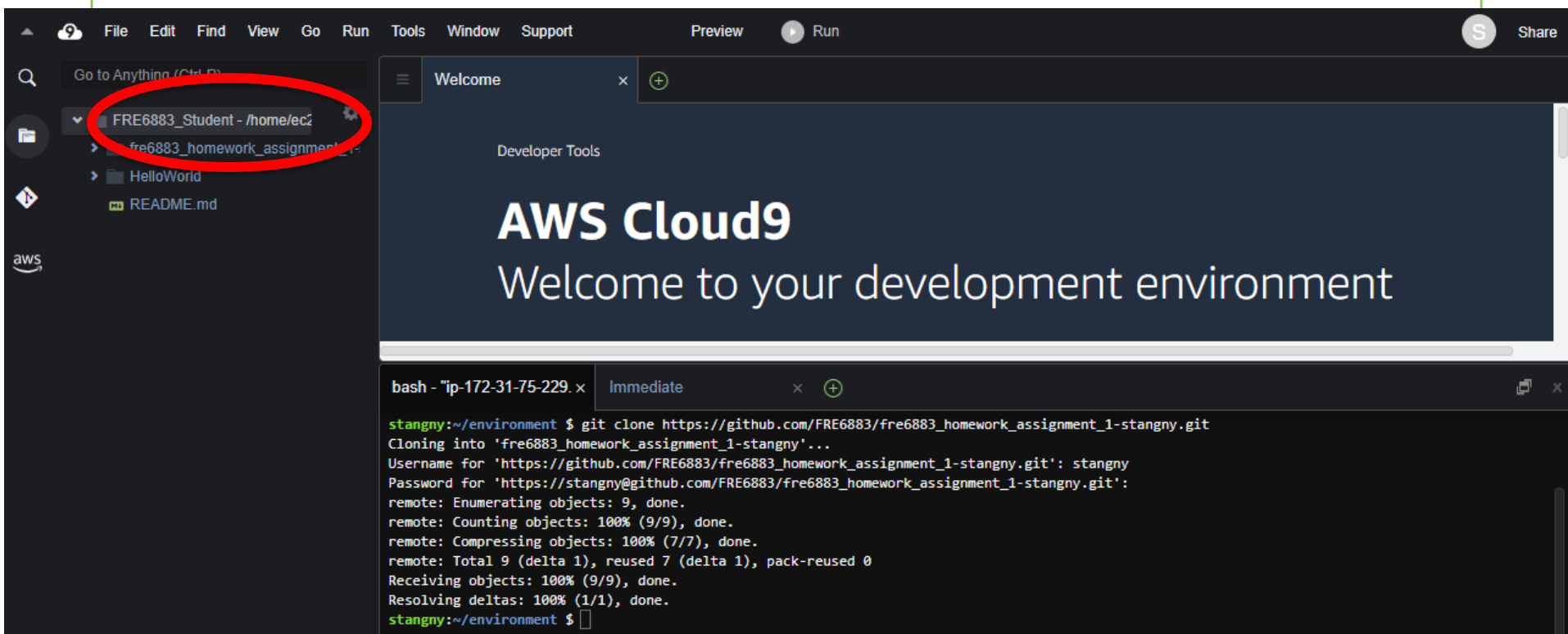
Clone Homework Repo to Cloud9 (continued)

- Start your Cloud9 Env:



Clone Homework Repo to Cloud9 (continued)

- Clone the Homework Repo using the HTTPS link you copied such as:
- **git clone https://github.com/FRE6883/fre6883_homework_assignment_1-stangny.git**
- Enter your GitHub username and **your PAT** as the password



```
bash - "ip-172-31-75-229." x Immediate x +
stangny:~/environment $ git clone https://github.com/FRE6883/fre6883_homework_assignment_1-stangny.git
Cloning into 'fre6883_homework_assignment_1-stangny'...
Username for 'https://github.com/FRE6883/fre6883_homework_assignment_1-stangny.git': stangny
Password for 'https://stangny@github.com/FRE6883/fre6883_homework_assignment_1-stangny.git':
remote: Enumerating objects: 9, done.
remote: Counting objects: 100% (9/9), done.
remote: Compressing objects: 100% (7/7), done.
remote: Total 9 (delta 1), reused 7 (delta 1), pack-reused 0
Receiving objects: 100% (9/9), done.
Resolving deltas: 100% (1/1), done.
stangny:~/environment $
```

Verify homework source codes in your Cloud9

The screenshot displays the Cloud9 IDE interface. The top menu bar includes File, Edit, Find, View, Go, Run, Tools, Window, Support, Preview, and a Run button. The left sidebar shows a file explorer for the project 'FRE6883_Student - /home/ec2'. The file 'Option01.cpp' is highlighted with a red circle. The main editor window shows the code for 'Option01.cpp', which includes headers for 'Option01.h', 'BinomialTreeModel.h', and standard C++ libraries. The code defines a namespace 'fre' and a function 'PriceByCRR'. The bottom terminal window shows the execution of 'ls' and 'ls -l' commands in the directory '/environment/fre6883_homework_assignment_1-stangny'.

```
#include "Option01.h"
#include "BinomialTreeModel.h"
#include <iostream>
#include <cmath>
using namespace std;

namespace fre {
    double PriceByCRR(double S0, double U, double D, double R, unsigned int N, double K)
    {
        double q = RiskNeutProb(U, D, R);
        double Price[N];
        for (unsigned int i = 0; i < sizeof(Price) / sizeof(Price[0]); i++)
            Price[i] = 0.0;
        for (unsigned int i = 0; i <= N; i++)
```

```
bash - "ip-172-31-75-229.x" Immediate
Resolving deltas: 100% (1/1), done.
stangny:~/environment $ cd fre6883_homework_assignment_1-stangny/
stangny:~/environment/fre6883_homework_assignment_1-stangny (main) $ ls
BinomialTreeModel.cpp BinomialTreeModel.h Makefile Option01.cpp Option01.h OptionPricer01.cpp README.md
stangny:~/environment/fre6883_homework_assignment_1-stangny (main) $ ls -l
total 28
-rw-rw-r-- 1 ec2-user ec2-user 2040 Aug 31 20:06 BinomialTreeModel.cpp
-rw-rw-r-- 1 ec2-user ec2-user 480 Aug 31 20:06 BinomialTreeModel.h
-rw-rw-r-- 1 ec2-user ec2-user 534 Aug 31 20:06 Makefile
-rw-rw-r-- 1 ec2-user ec2-user 879 Aug 31 20:06 Option01.cpp
-rw-rw-r-- 1 ec2-user ec2-user 211 Aug 31 20:06 Option01.h
-rw-rw-r-- 1 ec2-user ec2-user 516 Aug 31 20:06 OptionPricer01.cpp
-rw-rw-r-- 1 ec2-user ec2-user 24 Aug 31 20:06 README.md
stangny:~/environment/fre6883_homework_assignment_1-stangny (main) $
```

Compile, Build and Run

The screenshot displays a C++ development environment with a file explorer on the left, a code editor in the center, and a terminal at the bottom. The file explorer shows a project named 'FRE6883_Student' with a subdirectory 'fre6883_homework_assignment_1-' containing files like 'BinomialTreeModel.cpp', 'BinomialTreeModel.h', 'BinomialTreeModel.o', 'Makefile', 'Option01.cpp', 'Option01.h', 'Option01.o', 'OptionPricer01', 'OptionPricer01.cpp', 'OptionPricer01.o', and 'README.md'. The code editor shows the content of 'Option01.cpp', which includes headers for 'Option01.h', 'BinomialTreeModel.h', and standard C++ libraries, and defines a namespace 'fre' with a function 'PriceByCRR'. The terminal window, titled '/OptionPricer01 - "ip-172 x"', shows the output of the 'make' command, which compiles the source files into object files and then links them into an executable. The final output of the program is 'European call option price = 21.68'. A red oval highlights the compilation and linking steps in the terminal output.

```
1 #include "Option01.h"
2 #include "BinomialTreeModel.h"
3 #include <iostream>
4 #include <cmath>
5 using namespace std;
6
7 namespace fre {
8     double PriceByCRR(double S0, double U, double D, double R, unsigned int N, double K)
9     {
10         double q = RiskNeutProb(U, D, R);
11         double Price[N];
12         for (unsigned int i = 0; i < sizeof(Price) / sizeof(Price[0]); i++)
13             Price[i] = 0.0;
14
15         for (unsigned int i = 0; i <= N; i++)
```

```
stangny:~/environment/fre6883_homework_assignment_1-stangny (main) $ make
g++ -Wall -ggdb3 -std=c++11 -c OptionPricer01.cpp
g++ -Wall -ggdb3 -std=c++11 -c BinomialTreeModel.cpp
g++ -Wall -ggdb3 -std=c++11 -c Option01.cpp
g++ -Wall -ggdb3 -std=c++11 -o OptionPricer01 OptionPricer01.o BinomialTreeModel.o Option01.o
stangny:~/environment/fre6883_homework_assignment_1-stangny (main) $ ./OptionPricer01
European call option price = 21.68
stangny:~/environment/fre6883_homework_assignment_1-stangny (main) $
```