



# Quantum Integer Programming

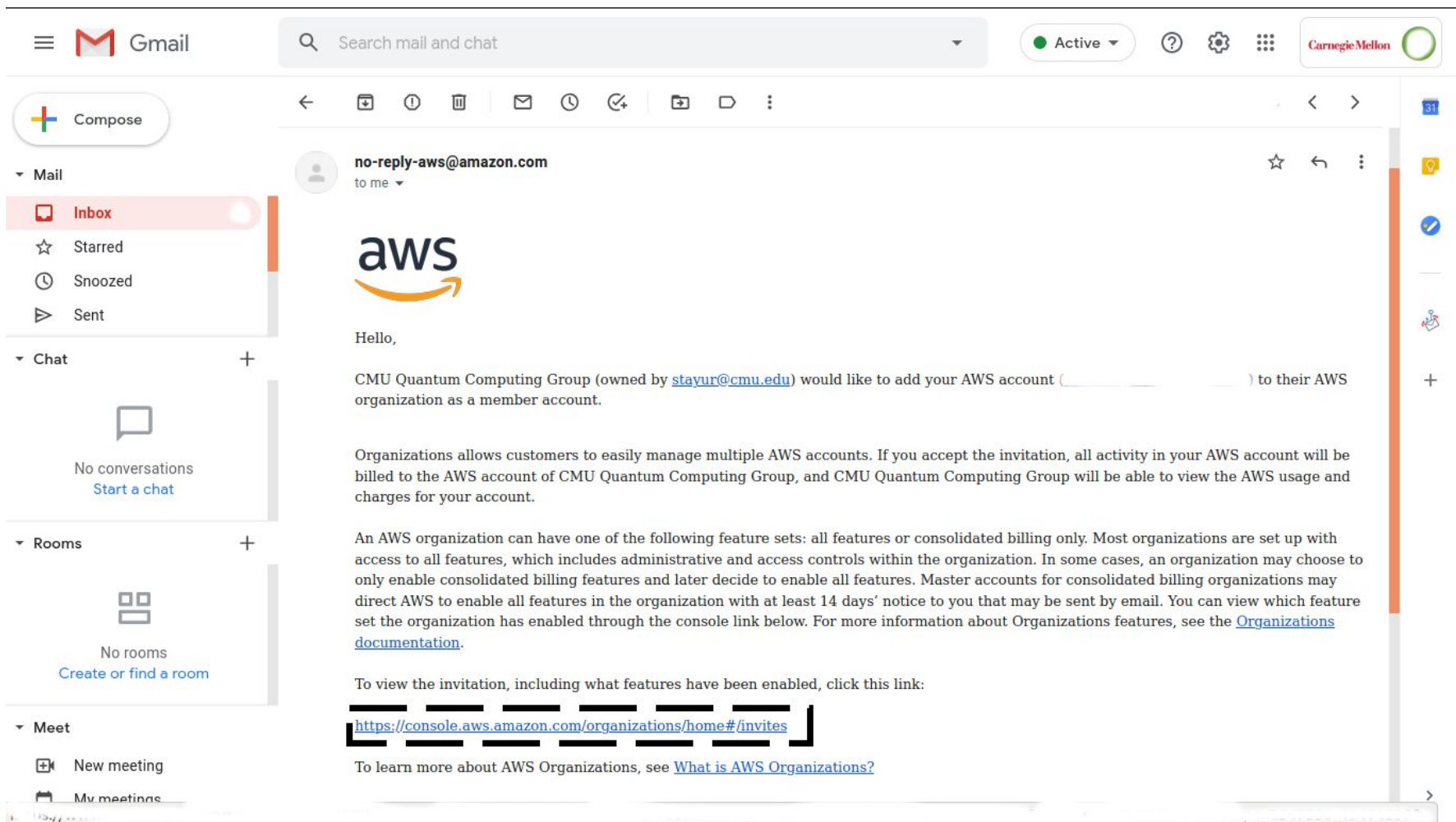
**47-779**

**Create AWS account**

**Join CMU Quantum Computing Group**  
**Amazon Braket**



# Check your email for an invitation and open the invite link in it.



# Sign into your AWS account, if you don't have one, create it.



## 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

New to AWS?

Create a new AWS account

## Build, train, and deploy ML models quickly

Get ML models into production faster with less effort and lower cost with Amazon SageMaker

[Learn more »](#)

aws machine learning



### About Amazon.com Sign In

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**(For those creating a new account):  
Provide email at which you received our  
invitation. Choose password and user id**

aws English ▾

## Create an AWS account

**AWS Accounts Include  
12 Months of Free Tier Access**

Including use of Amazon EC2, Amazon S3, and Amazon DynamoDB  
Visit [aws.amazon.com/free](https://aws.amazon.com/free) for full offer terms

Email address

Password

Confirm password

AWS account name ⓘ

[Continue](#)

[Sign in to an existing AWS account](#)

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**(For those creating a new account): Choose "Professional Account", provide contact information.**

Account type ⓘ

☒ Professional ☐ Personal

Full name

Your Name

Company name

Carnegie Mellon University

Phone number

A Number

Country/Region

United States

Address

5000 Forbes Av.

Apartment, suite, unit, building, floor, etc.

City

Pittsburgh

State / Province or region

PA

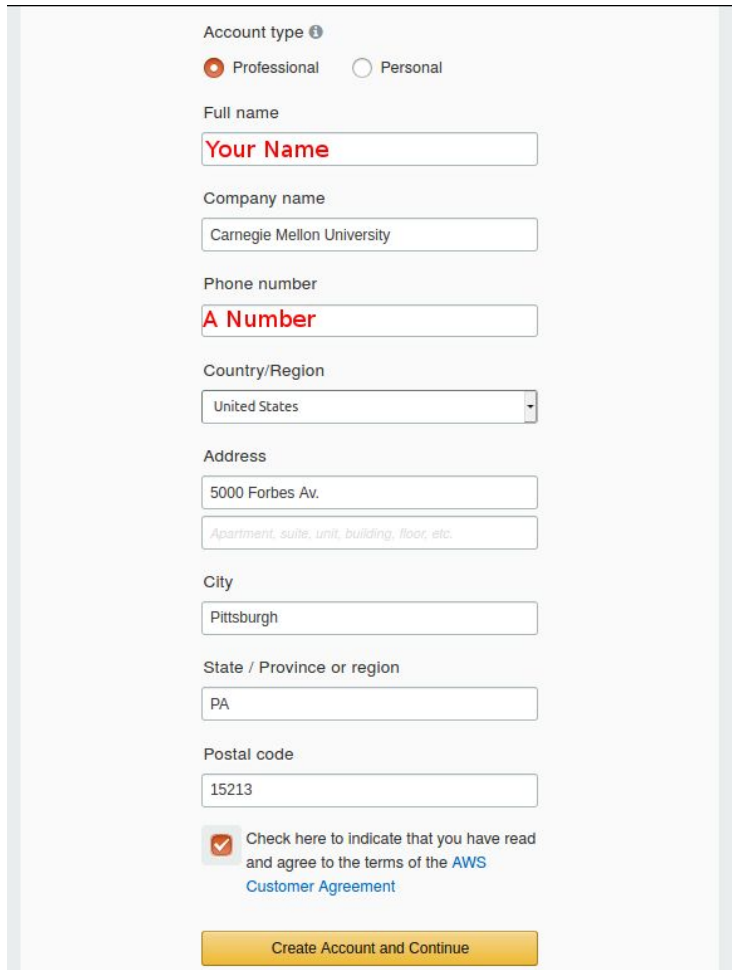
Postal code

15213

☒ Check here to indicate that you have read and agree to the terms of the [AWS Customer Agreement](#)

Create Account and Continue

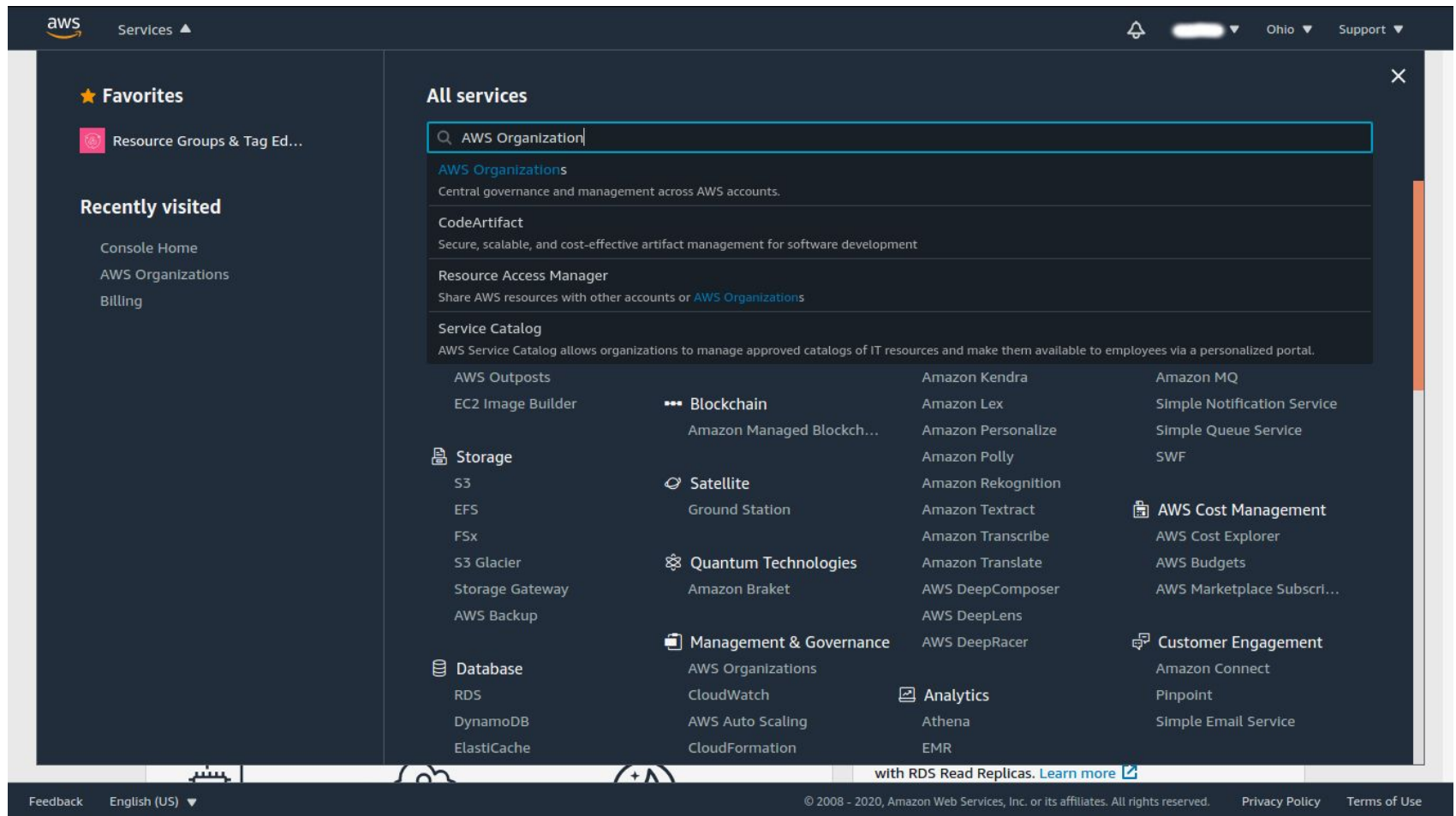
## (For those creating a new account)



The screenshot shows the AWS account creation form. At the top, there is a section for 'Account type' with two radio buttons: 'Professional' (selected) and 'Personal'. Below this are several input fields: 'Full name' with the placeholder 'Your Name', 'Company name' with 'Carnegie Mellon University', 'Phone number' with 'A Number', 'Country/Region' with a dropdown menu showing 'United States', 'Address' with '5000 Forbes Av.' and a sub-field for 'Apartment, suite, unit, building, floor, etc.', 'City' with 'Pittsburgh', 'State / Province or region' with 'PA', and 'Postal code' with '15213'. At the bottom, there is a checkbox labeled 'Check here to indicate that you have read and agree to the terms of the AWS Customer Agreement' which is checked. A yellow button at the very bottom says 'Create Account and Continue'.

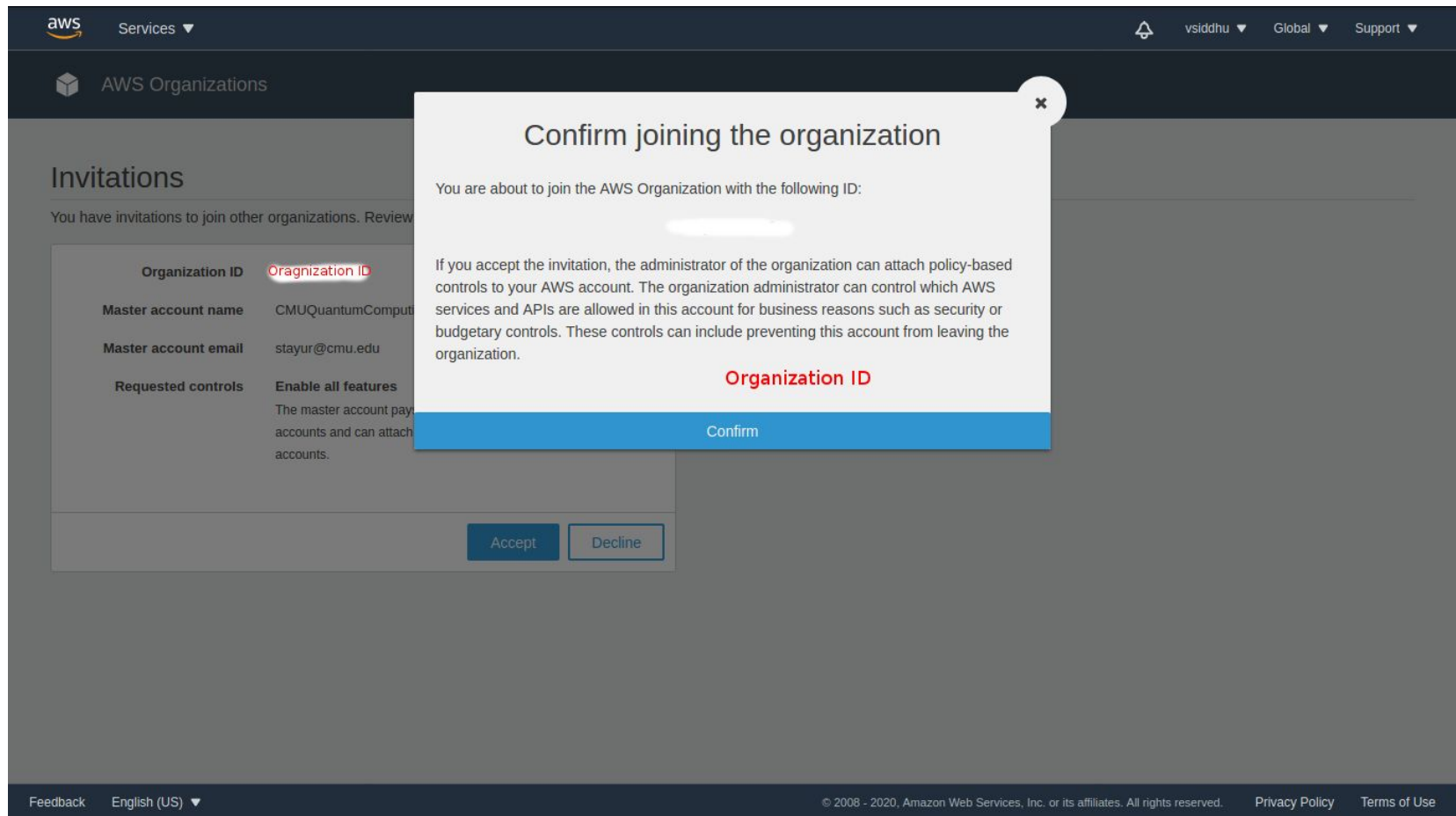
1. Click “Create Account and Continue”. Your account is now created!
2. Ignore if you are asked to enter a payment method.  
**You don’t need to provide credit card details etc.**
3. At the bottom of the page Sign Out and then Sign back in again

Once you have signed into your AWS account. Click on 'Services' on top left and search/open 'AWS Organization'



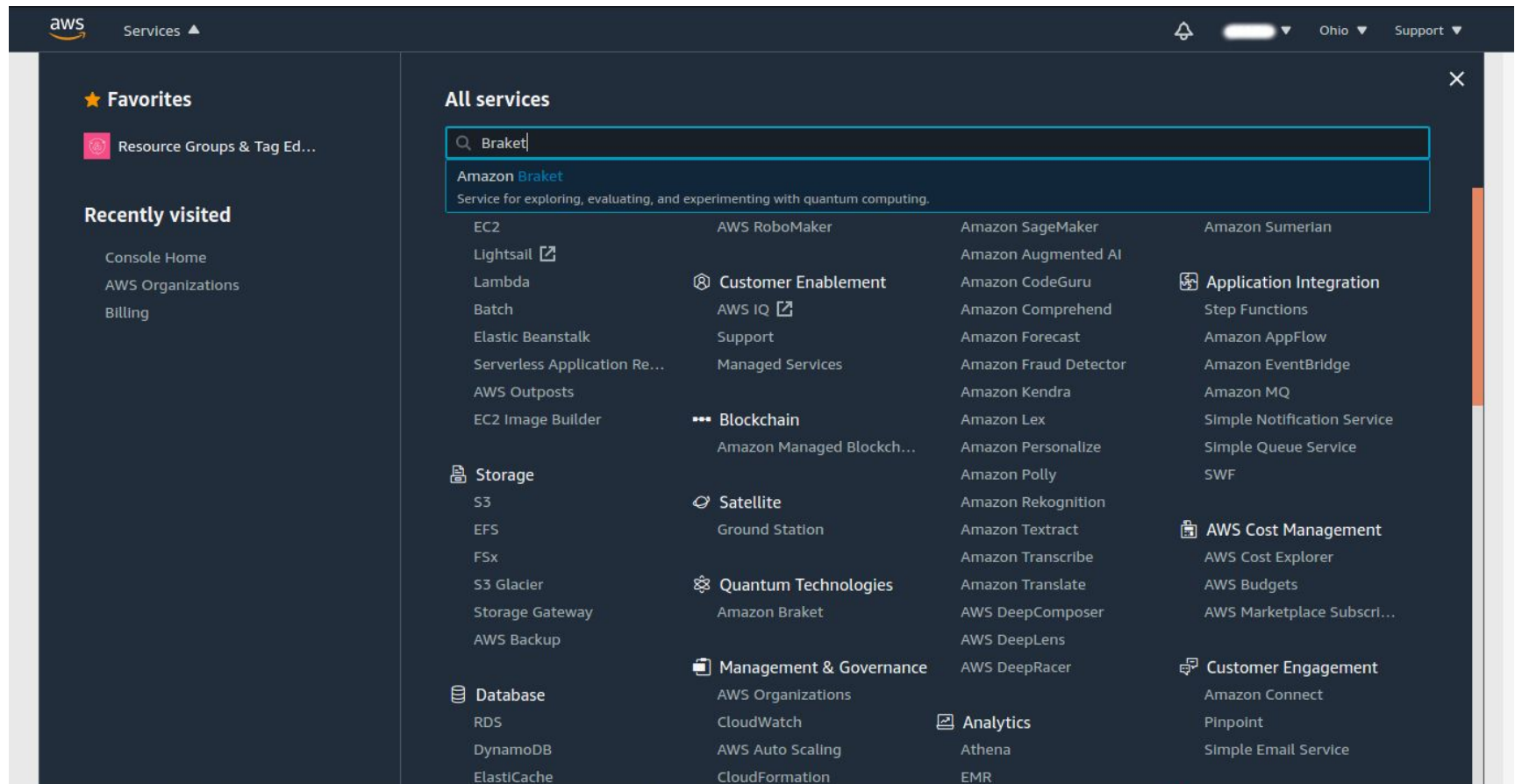


# Accept and Confirm our invitation from CMUQuantumComputing

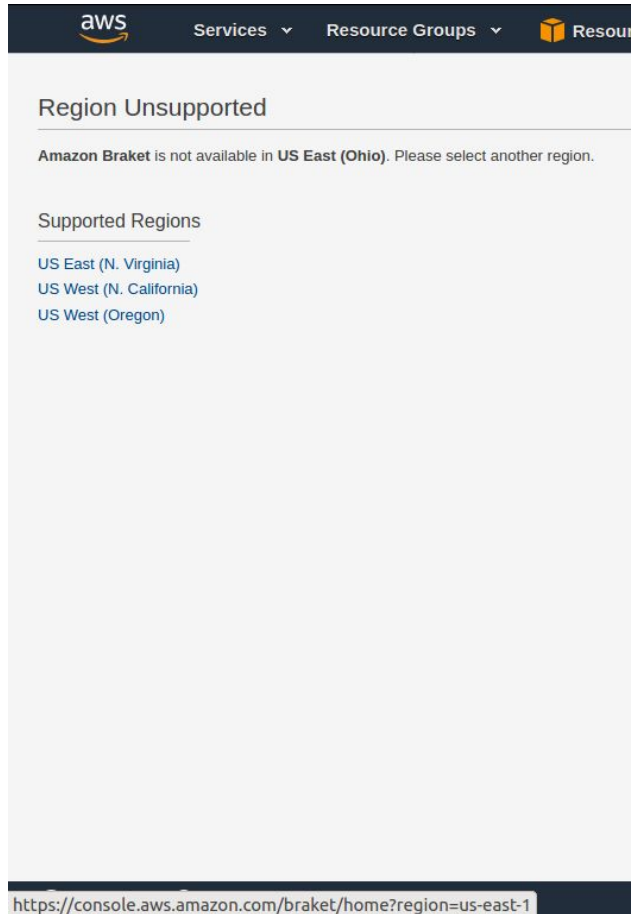




# Go back to “Services”, find and open Amazon Braket



# Open Amazon Braket



Upon opening the Amazon Braket service, the website may say it is unavailable in your location. If so, change to a suitable location, for instance *US East (N. Virginia)*

# Start Amazon Braket. Locate home page with various machines and simulators.

The screenshot displays the Amazon Braket console interface. The top navigation bar includes the AWS logo, 'Services', a notification bell, a user profile, 'N. Virginia' region, and 'Support'. The left sidebar contains 'Amazon Braket' with a close button, and a menu with 'Devices', 'Notebooks', 'Tasks', and 'Announcements'. The main content area is titled 'Amazon Braket > Devices' and features a section for 'Quantum Processing Units (QPUs)'. This section lists three QPUs: D-Wave — DW\_2000Q\_6, IonQ, and Rigetti — Aspen-8. Each QPU card provides details on its type, qubit count, status, region, and next available time. Below the QPUs is a 'Simulators' section, which currently shows 'Amazon Web Services — SV1'.

QPU Name	Type	Qubits	Status	Region	Next available
D-Wave — DW_2000Q_6	Quantum Annealer based on superconducting qubits	2048	ONLINE	us-west-2	AVAILABLE NOW
IonQ	Universal gate-model QPU based on trapped ions	11	ONLINE	us-east-1	14:53:21
Rigetti — Aspen-8	Universal gate-model QPU based on superconducting qubits	31	ONLINE	us-west-1	16:53:21

Simulator Name	Type	Qubits	Status
Amazon Web Services — SV1	Braket SV1 Simulator		

# Go straight to notebooks on the left pane.

The screenshot displays the Amazon Braket console interface. On the left, a sidebar contains navigation links: 'Devices', 'Notebooks' (highlighted with an orange border), 'Tasks', and 'Announcements'. The main content area is titled 'Amazon Braket > Notebooks'. It features a 'Notebooks (0)' header with a refresh icon, an 'Actions' dropdown, and a prominent orange 'Create notebook instance' button. Below this is a search bar labeled 'Search notebooks' and a filter box showing 'Name contains: amazon-braket-' with a 'Clear all' button. A table header is visible with columns: 'Name', 'Instance', 'Creation time', 'Status', and 'URL'. The table body is empty, displaying a 'No Notebooks' message and a 'Create notebook' button. The footer includes 'Feedback', 'English (US)', copyright information for 2008-2020 Amazon Web Services, and links to 'Privacy Policy' and 'Terms of Use'.



# Create a Notebook instance

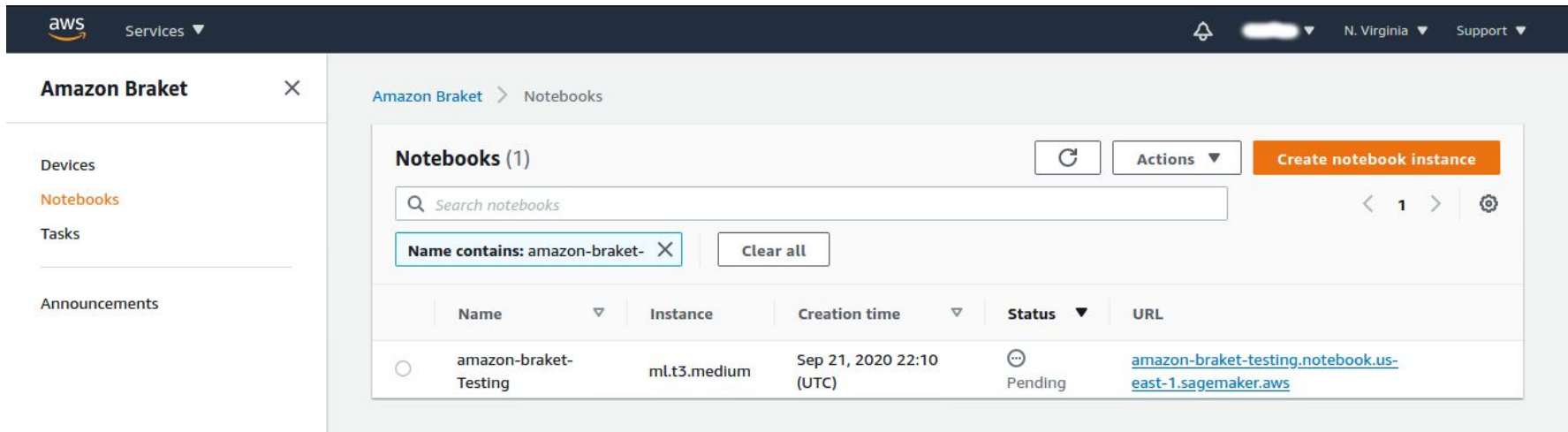
The screenshot shows the AWS Amazon Braket console interface for creating a new notebook instance. The left sidebar contains navigation links for 'Devices', 'Notebooks', 'Tasks', and 'Announcements'. The main content area is titled 'Create notebook instance' and includes a brief description of Amazon Braket. Below this, there are several sections for configuration:

- Notebook Instance settings:**
  - Notebook instance name:** A text input field containing 'amazon-braket-Testing'. A note below states: 'Maximum of 49 alphanumeric characters. Can include hyphens (-), but not spaces. Must be unique within your account in an AWS Region.'
  - Notebook instance type:** A dropdown menu currently set to 'ml.t3.medium'. A note below states: 'Instance types comprise varying combinations of CPU, GPU, memory for building, running your quantum tasks.'
- Additional settings:** A section header for further configuration options.
- Permissions and encryption:**
  - IAM role:** A dropdown menu set to 'Create a new role'. A blue informational box explains: 'Passing an IAM role gives Amazon SageMaker permission to perform actions in other AWS services on your behalf. Creating a role here will grant permissions described by the AmazonBraketFullAccess IAM policy to the role you create.'
  - Root access — optional:** Two radio buttons: 'Enable - Give users root access to the notebook' (selected) and 'Disable - Don't give users root access to the notebook'.
  - Encryption key — optional:** A dropdown menu set to 'No custom encryption key'. A note states: 'Encrypt your notebook data. Choose an existing KMS key or enter a key ARN.'
- Network — optional:** A section header for network configuration.

At the bottom right, there are two buttons: 'Cancel' and 'Create notebook instance'.

To create Notebook instance provide a name and click “Create Notebook Instance”

# Check status of Notebook



The screenshot shows the AWS Amazon Braket console. On the left, there is a sidebar with navigation options: Amazon Braket (selected), Devices, Notebooks, Tasks, and Announcements. The main content area is titled 'Amazon Braket > Notebooks'. It displays a list of notebooks under the heading 'Notebooks (1)'. There is a search bar and a filter 'Name contains: amazon-braket-' with a 'Clear all' button. A table lists the notebook details:

	Name	Instance	Creation time	Status	URL
<input type="radio"/>	amazon-braket-Testing	ml.t3.medium	Sep 21, 2020 22:10 (UTC)	Pending	<a href="https://amazon-braket-testing.notebook.us-east-1.sagemaker.aws">amazon-braket-testing.notebook.us-east-1.sagemaker.aws</a>

Buttons for 'Create notebook instance' and 'Actions' are visible at the top right of the notebook list.

It takes a short amount of time for the notebooks to get created. During this time feel free to check out the Devices available to you by clicking on the “Devices” in the left tab.

# The Devices Page: Click on each device to see what is under the hood.

The screenshot displays the Amazon Braket console interface. On the left is a sidebar with navigation links: Amazon Braket, Devices (selected), Notebooks, Tasks, and Announcements. The main content area is titled 'Amazon Braket > Devices' and is divided into two sections: 'Quantum Processing Units (QPUs)' and 'Simulators'.

**Quantum Processing Units (QPUs)**

Device	Description	Qubits	Status	Region	Next available
D-Wave — DW_2000Q_6	Quantum Annealer based on superconducting qubits	2048	ONLINE	us-west-2	AVAILABLE NOW
IonQ	Universal gate-model QPU based on trapped ions	11	ONLINE	us-east-1	14:53:21
Rigetti — Aspen-8	Universal gate-model QPU based on superconducting qubits	31	ONLINE	us-west-1	16:53:21

**Simulators**

Device	Description	Qubits	Status
Amazon Web Services — SV1	Braket SV1 Simulator		

The footer of the console shows 'Feedback', 'English (US)', and copyright information for Amazon Web Services, Inc. (© 2008 - 2020).

# D-Wave. Note the Device ARN, it may be useful in your Notebooks

The screenshot shows the AWS Amazon Braket console interface. On the left is a navigation sidebar with links for Devices, Notebooks, Tasks, and Announcements. The main content area displays the details for the 'D-Wave — DW\_2000Q\_6' device. It includes a description of the quantum annealing approach, the Chimera architecture, and a table of device specifications. The 'Device ARN' is highlighted with a red rectangular box.

**Amazon Braket** ×

**D-Wave — DW\_2000Q\_6**

**Quantum Annealer based on superconducting qubits**

D-Waves approach is quantum annealing, which harnesses the natural evolution of quantum states.

Each D-Wave QPU is a lattice of tiny metal loops, each of which is a qubit or a coupler. Below temperatures of 9.2 kelvin, these loops become superconductors and exhibit quantum-mechanical effects. The D-Wave 2000Q QPU has 2000 qubits and 6000 couplers. To reach this scale, it uses 128,000 Josephson Junctions, by far the most complex superconducting integrated circuit ever built. The qubits in the D-Wave 2000Q interconnect in an architecture known as Chimera.

The QPU architecture is critical to translating a QUBO or Ising objective function into a format that a D-Wave system can solve. Such binary objective functions can be represented as graphs; these in turn can be mapped to the QPU.

The Chimera architecture comprises sets of connected unit cells, each with four horizontal qubits connected to four vertical qubits via couplers. Unit cells are tiled vertically and horizontally with adjacent qubits connected, creating a lattice of sparsely connected qubits. The notation CN refers to a Chimera graph consisting of an N x N grid of unit cells. The D-Wave 2000Q QPU supports a C16 Chimera graph: its qubits are logically mapped into a 16 x 16 matrix of unit cells of 8 qubits.

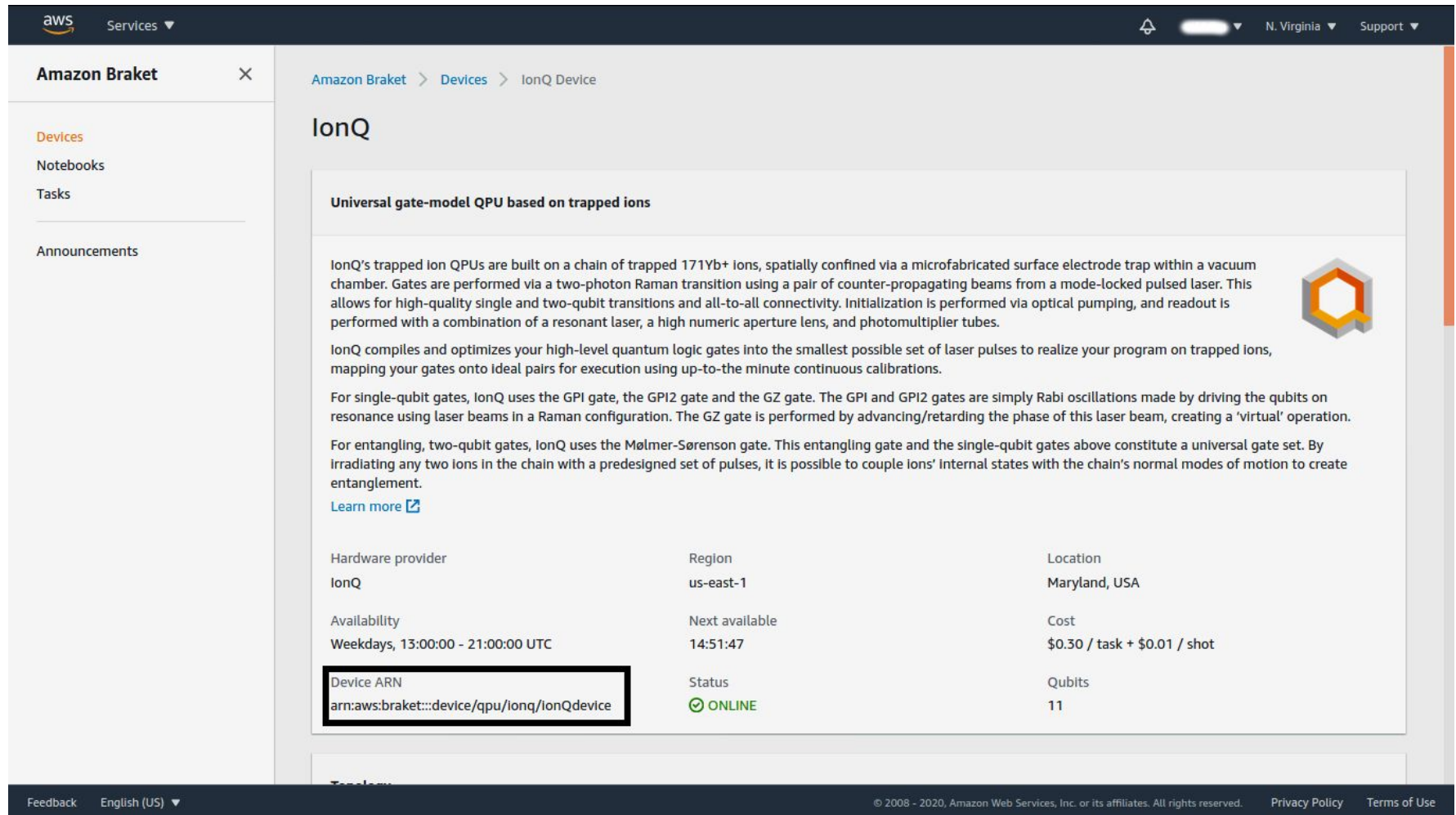
[Learn more](#)

Hardware provider	Region	Location
D-Wave	us-west-2	British Columbia, Canada
Availability	Next available	Cost
Everyday, 00:00:00 - 23:59:59 UTC	✅ AVAILABLE NOW	\$0.30 / task + \$0.00019 / shot
Device ARN	Status	Qubits
arn:aws:braket:::device/qpu/d-wave/DW_2000Q_6	✅ ONLINE	2048

Feedback English (US) ▼ © 2008 - 2020, Amazon Web Services, Inc. or its affiliates. All rights reserved. Privacy Policy Terms of Use



# IonQ. Note the Device ARN, it may be useful in your Notebooks



The screenshot shows the Amazon Braket console interface. On the left is a navigation sidebar with links for Devices, Notebooks, Tasks, and Announcements. The main content area displays the 'IonQ' device page. At the top of this page is a breadcrumb trail: 'Amazon Braket > Devices > IonQ Device'. Below this is the title 'IonQ' and a subtitle 'Universal gate-model QPU based on trapped ions'. A detailed paragraph describes the hardware and operation of the device. Below the text is a table with specifications:

Hardware provider	Region	Location
IonQ	us-east-1	Maryland, USA
Availability	Next available	Cost
Weekdays, 13:00:00 - 21:00:00 UTC	14:51:47	\$0.30 / task + \$0.01 / shot
Device ARN	Status	Qubits
arn:aws:braket:::device/qpu/ionq/ionqdevice	ONLINE	11

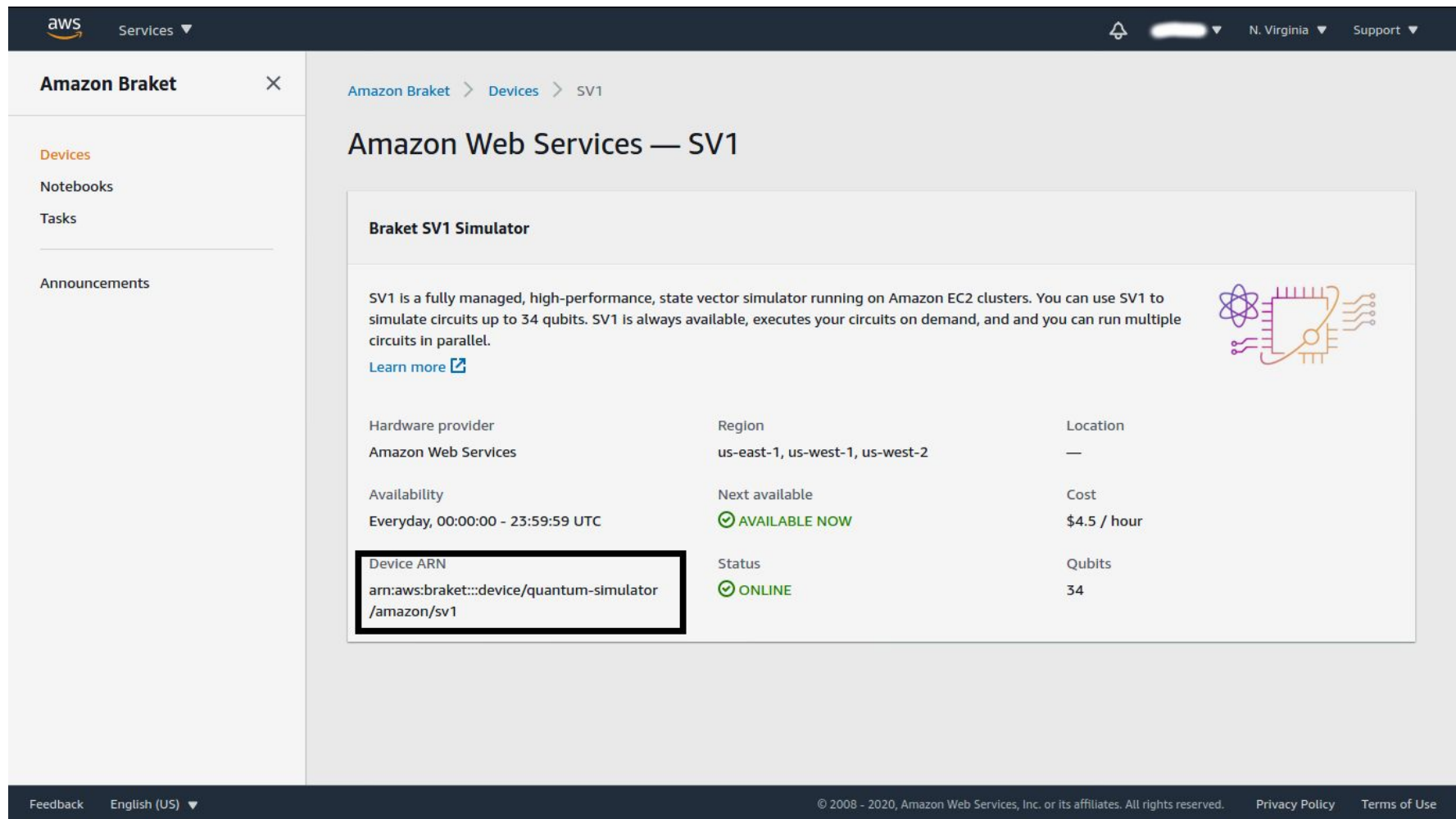
The 'Device ARN' row is highlighted with a red rectangular box. At the bottom of the console page, there is a footer with 'Feedback', 'English (US)', and copyright information for Amazon Web Services, Inc. (2008-2020).

# Rigetti. Note the Device ARN, it may be useful in your Notebooks

The screenshot shows the Amazon Braket console interface. On the left is a navigation sidebar with links for Devices, Notebooks, Tasks, and Announcements. The main content area is titled 'Rigetti — Aspen-8'. It contains a description of the device as a 'Universal gate-model QPU based on superconducting qubits' and the Rigetti logo. Below the text is a table with device specifications. The 'Device ARN' field is highlighted with a black box, showing the value 'arn:aws:braket:::device/qpu/rigetti/Aspen-8'. The bottom of the console shows a footer with copyright information and links to Privacy Policy and Terms of Use.

Hardware provider	Region	Location
Rigetti	us-west-1	California, USA
Availability	Next available	Cost
Everyday, 15:00:00 - 19:00:00 UTC	16:51:23	\$0.30 / task + \$0.00035 / shot
Device ARN	Status	Qubits
arn:aws:braket:::device/qpu/rigetti/Aspen-8	ONLINE	31

# Braket Simulator. Note the Device ARN, it may be useful in your Notebooks



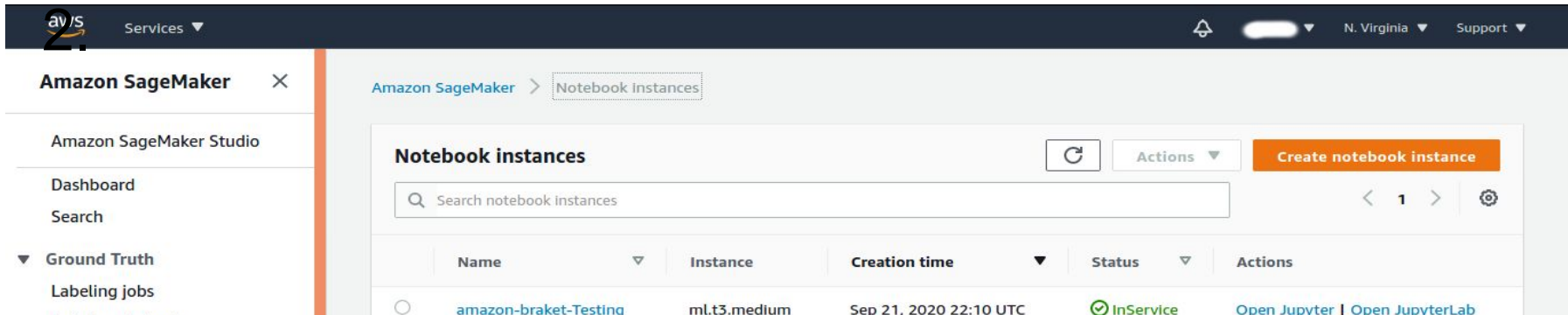
The screenshot shows the Amazon Braket console interface. On the left is a navigation sidebar with links for Devices, Notebooks, Tasks, and Announcements. The main content area is titled 'Amazon Web Services — SV1'. Below this, there's a section for the 'Braket SV1 Simulator'. A paragraph describes SV1 as a fully managed, high-performance, state vector simulator. To the right of this text is an icon representing a quantum circuit. Below the text is a 'Learn more' link. A table-like structure displays key information about the simulator:

Hardware provider	Region	Location
Amazon Web Services	us-east-1, us-west-1, us-west-2	—
Availability	Next available	Cost
Everyday, 00:00:00 - 23:59:59 UTC	🟢 AVAILABLE NOW	\$4.5 / hour
Device ARN	Status	Qubits
arn:aws:braket::device/quantum-simulator/amazon/sv1	🟢 ONLINE	34

The 'Device ARN' is highlighted with a black rectangular box. The footer of the console shows 'Feedback', 'English (US)', and copyright information for 2008-2020.

# Go back to Notebooks tab

## 1. Your Notebook may be green i.e. “In Service”



The screenshot shows the Amazon SageMaker console. The left sidebar has a search bar and a list of services including Amazon SageMaker Studio, Dashboard, Search, Ground Truth, and Labeling jobs. The main content area is titled 'Notebook instances' and features a search bar, a 'Create notebook instance' button, and a table of instances. The table has columns for Name, Instance, Creation time, Status, and Actions. One instance is listed: 'amazon-braket-Testing' with instance type 'ml.t3.medium', created on 'Sep 21, 2020 22:10 UTC', and status 'InService'. The 'InService' status is highlighted in green. The 'Actions' column for this instance contains links for 'Open Jupyter' and 'Open JupyterLab'.

Name	Instance	Creation time	Status	Actions
amazon-braket-Testing	ml.t3.medium	Sep 21, 2020 22:10 UTC	InService	<a href="#">Open Jupyter</a>   <a href="#">Open JupyterLab</a>

## 2. Under Actions, click on the notebook



The screenshot shows the JupyterLab interface. At the top, there's a header with the Jupyter logo and buttons for 'Open JupyterLab', 'Quit', and 'Logout'. Below the header, there are tabs for 'Files', 'Running', 'Clusters', and 'Conda'. The 'Running' tab is active. Below the tabs, there's a section titled 'Select items to perform actions on them.' with a search bar and a list of items. The list shows a folder named 'Braket examples' with a '3 minutes ago' timestamp. To the right of the list, there are buttons for 'Upload', 'New', and a refresh icon. Below the list, there are columns for 'Name', 'Last Modified', and 'File size'.





# Open Bracket Examples

The screenshot shows the JupyterLab interface. At the top, there's a header with the 'jupyter' logo and buttons for 'Open JupyterLab', 'Quit', and 'Logout'. Below the header, there's a navigation bar with tabs for 'Files', 'Running', 'Clusters', and 'Conda'. The 'Files' tab is active, showing a file browser. At the top of the file browser, there's a prompt 'Select items to perform actions on them.' and buttons for 'Upload', 'New', and a refresh icon. Below this, there's a table of files and directories. The table has columns for 'Name', 'Last Modified', and 'File size'. The first row is a directory named 'Braket examples'. Below it, there are four sub-directories: 'advanced\_circuits\_algorithms', 'hybrid\_quantum\_algorithms', 'quantum\_annealing', and 'simple\_circuits\_algorithms'. Each directory has a checkbox to its left and a timestamp '4 minutes ago' to its right.

	Name	Last Modified	File size
<input type="checkbox"/>	/ Braket examples		
<input type="checkbox"/>	..	seconds ago	
<input type="checkbox"/>	advanced_circuits_algorithms	4 minutes ago	
<input type="checkbox"/>	hybrid_quantum_algorithms	4 minutes ago	
<input type="checkbox"/>	quantum_annealing	4 minutes ago	
<input type="checkbox"/>	simple_circuits_algorithms	4 minutes ago	

Explore the set of notebooks provided by Amazon Braket.

The results are preloaded. You can execute the code yourself, keep in mind that that consumes our credits!



# Make sure to Stop your notebooks before you Log Out!

## Play Around.

## You are ALL SET Here!

We will be covering during this class

- quantum\_annealing/D-Wave\_anatomy.ipynb
- hybrid\_quantum\_algorithms/QAOA.ipynb

The screenshot shows the Amazon Braket console interface. On the left is a sidebar with navigation links: Amazon Braket, Devices, Notebooks, Tasks, and Announcements. The main panel is titled 'Amazon Braket > Notebooks'. It features a search bar, a filter 'Name contains: amazon-braket-' with a 'Clear all' button, and a table of notebooks. The table has columns for Name, Instance, Creation time, Status, and URL. One notebook is listed: 'amazon-braket-test' on 'ml.t3.medium' instance, created on 'Sep 14, 2020 00:17 (UTC)', with a status of 'Stopped' and URL 'amazon-braket-test.notebook.us-east-1.sagemaker.aws'. An 'Actions' menu is open, showing options: Start, Stop, Delete, and Open in Jupyter. A 'Create notebook instance' button is also visible.

Name	Instance	Creation time	Status	URL
amazon-braket-test	ml.t3.medium	Sep 14, 2020 00:17 (UTC)	Stopped	amazon-braket-test.notebook.us-east-1.sagemaker.aws