

18-819F: Introduction to Quantum Computing

47-779/47-785: Quantum Integer Programming & Quantum Machine Learning

Create AWS Braket, Dwave Leap, and IBM Qiskit accounts

Access USRA RIACS Resources

Join CMU Quantum Computing

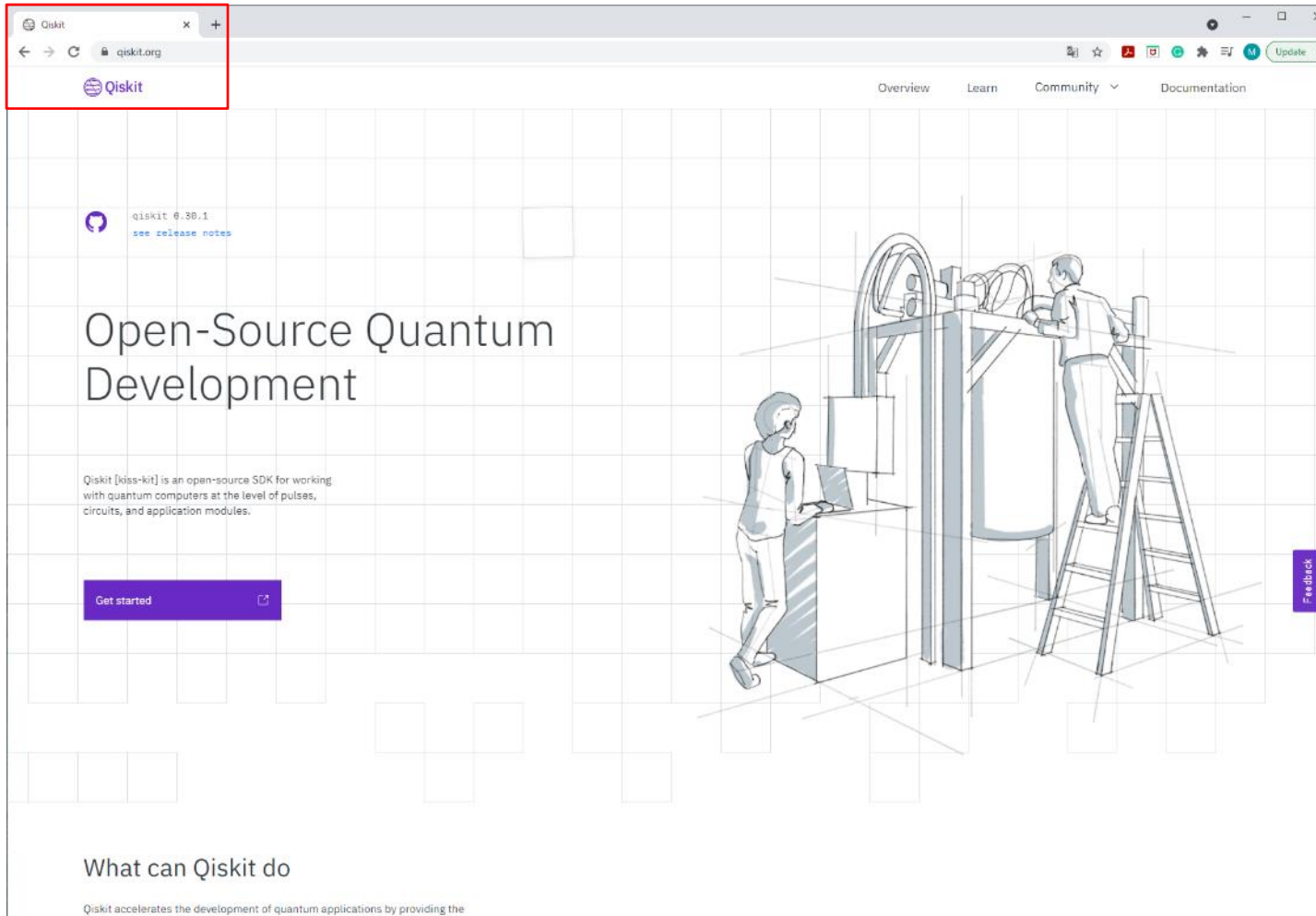
Lecture X

09.28.2022

Agenda

- Create IBM (Qiskit) account
- Create D-Wave (Leap) account
- Create AWS account
- Amazon Bracket
- Accessing USRA resources

Create IBM (Qiskit) account



1- Go to www.qiskit.org

Create IBM (Qiskit) account

Quick Start

When you are looking to start Qiskit, you have two options. You can start Qiskit locally, which is much more secure and private, or you get started with Jupyter Notebooks hosted in IBM Quantum Lab.

Start locally

To install Qiskit locally, you will need [Python 3.6+](#). Although it is not required, we recommend using a [virtual environment with Anaconda](#).

Qiskit Install

Stable (recommended)

Unstable

Operating System

Linux

Mac

Windows

Terminal

```
pip install qiskit
```

copy

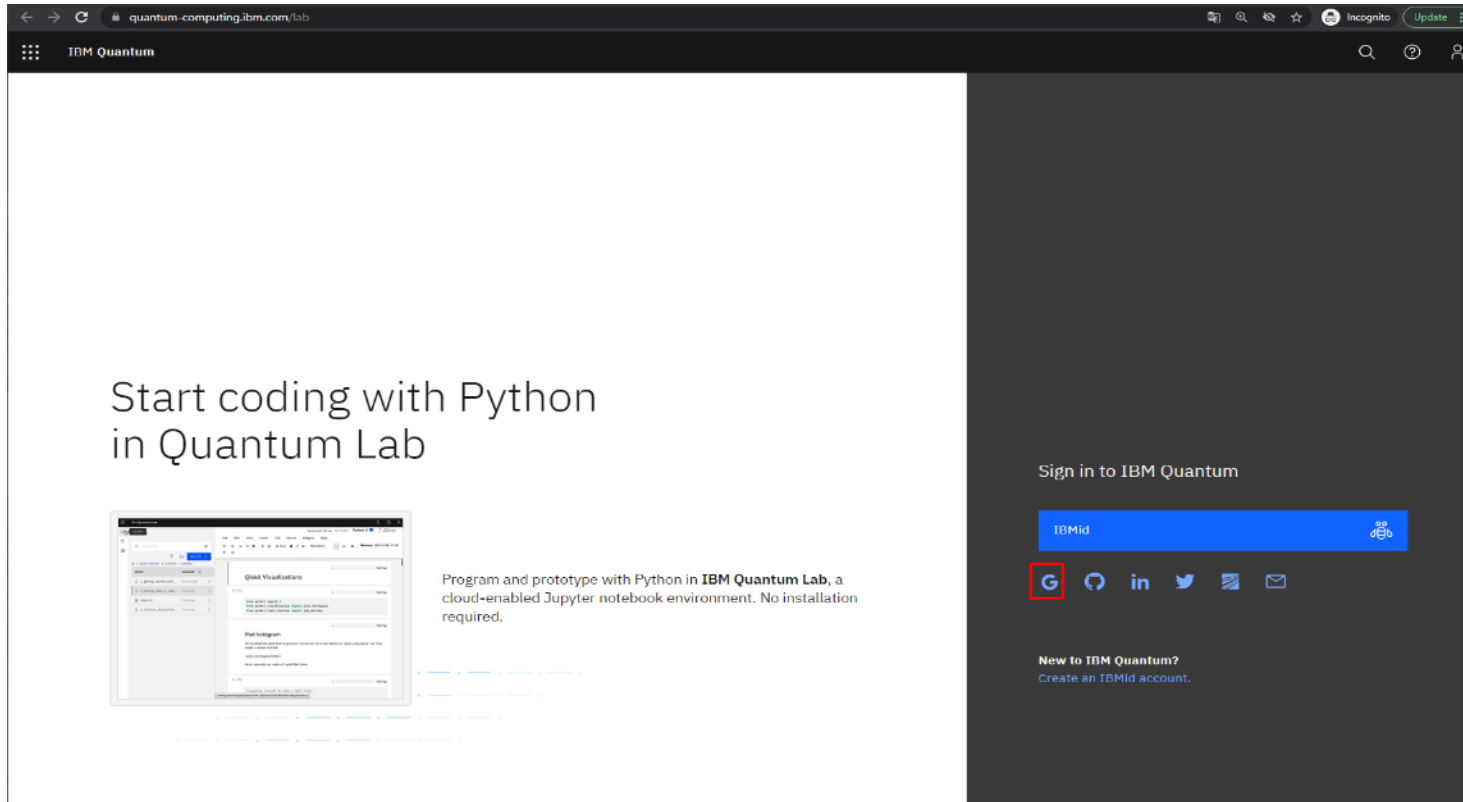
Start Online

Get started in the cloud without installing anything with IBM Quantum Lab.

IBM Quantum Lab

2- Scroll down to Start Online and click where it says “IBM Quantum Lab”.

Create IBM (Qiskit) account



3- If you want to log with your cmu account, click Google's symbol

Create IBM (Qiskit) account

Acceder con Google

Acceder
Ir a [ibm.com](#)

Correo electrónico o teléfono
aaa@andrew.cmu.edu

[¿Olvidaste el correo electrónico?](#)

Para continuar, Google compartirá tu nombre, dirección de correo electrónico, preferencia de idioma y foto de perfil con ibm.com. Antes de usar ibm.com, revisa su [política de privacidad](#) y [condiciones del servicio](#).

[Crear cuenta](#) [Siguiente](#)

Español (Latinoamérica) ▾ Ayuda Privacidad Condiciones

Web Login

AndrewID

Password

[Login](#)

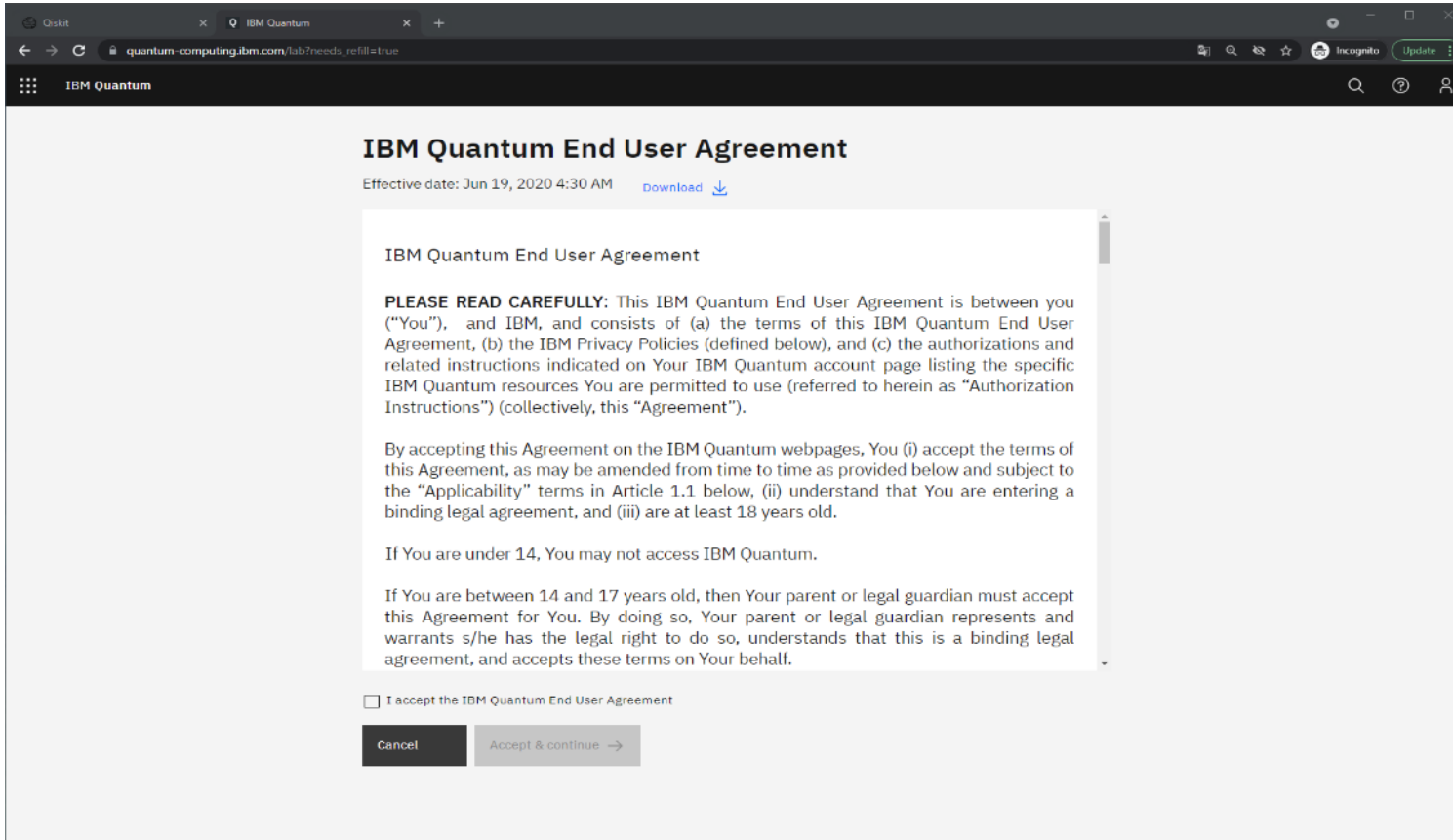


Warning: The URL for this page should begin with <https://login.cmu.edu>.
If it does not, do not fill in any information, and report this site to it-help@cmu.edu.

[About](#) | [Change Password](#) | [Forgot Password?](#)

4- Log with your credentials

Create IBM (Qiskit) account



The screenshot shows a web browser window with the URL `quantum-computing.ibm.com/lab?needs_refill=true`. The page title is "IBM Quantum End User Agreement". Below the title, it says "Effective date: Jun 19, 2020 4:30 AM" and has a "Download" link. The main content area contains the following text:

IBM Quantum End User Agreement

PLEASE READ CAREFULLY: This IBM Quantum End User Agreement is between you ("You"), and IBM, and consists of (a) the terms of this IBM Quantum End User Agreement, (b) the IBM Privacy Policies (defined below), and (c) the authorizations and related instructions indicated on Your IBM Quantum account page listing the specific IBM Quantum resources You are permitted to use (referred to herein as "Authorization Instructions") (collectively, this "Agreement").

By accepting this Agreement on the IBM Quantum webpages, You (i) accept the terms of this Agreement, as may be amended from time to time as provided below and subject to the "Applicability" terms in Article 1.1 below, (ii) understand that You are entering a binding legal agreement, and (iii) are at least 18 years old.

If You are under 14, You may not access IBM Quantum.

If You are between 14 and 17 years old, then Your parent or legal guardian must accept this Agreement for You. By doing so, Your parent or legal guardian represents and warrants s/he has the legal right to do so, understands that this is a binding legal agreement, and accepts these terms on Your behalf.

☐ I accept the IBM Quantum End User Agreement

At the bottom, there are two buttons: "Cancel" and "Accept & continue →".

5- Read the End User Agreement

Create IBM (Qiskit) account

quantum-computing.ibm.com/lab?needs_refill=true

IBM Quantum

Last step! Before you get started,
Tell us a little more about yourself

First name *

Last name *

Your institution *

Carnegie Mellon University

What is your familiarity with quantum?

Select an option

What would you like to use IBM Quantum for?

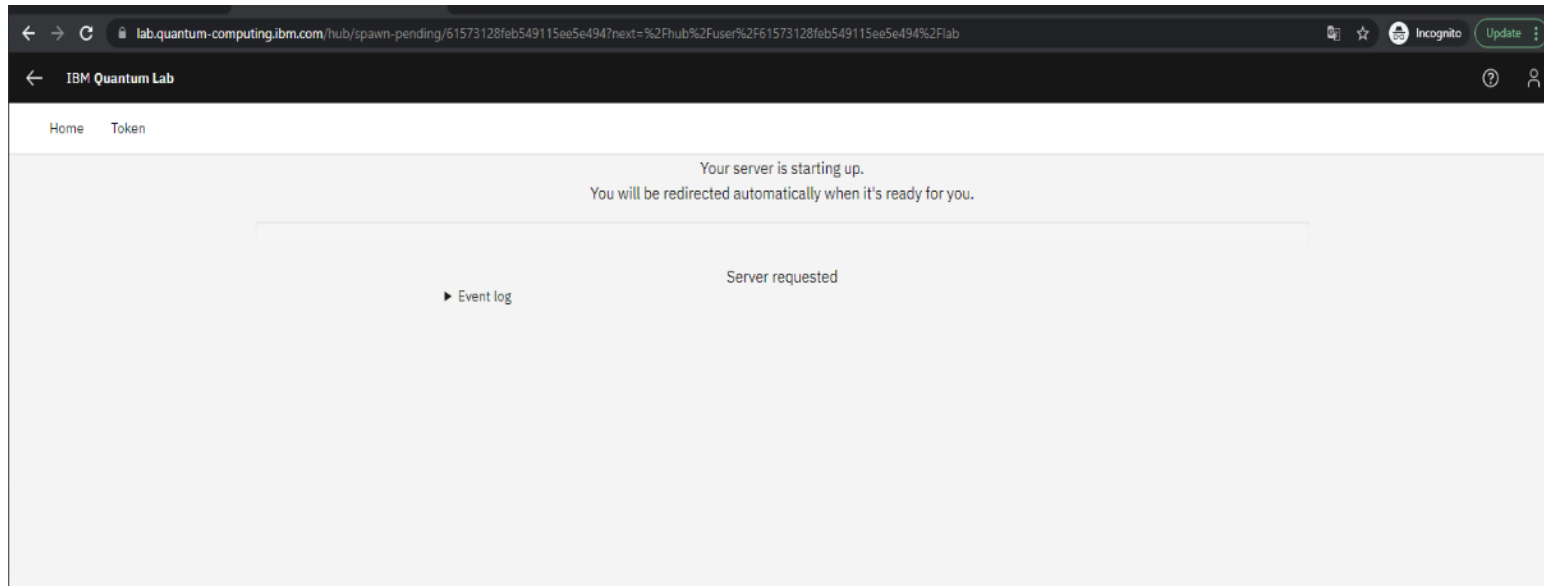
Stay up to date with the latest news and updates by receiving:

- ☐ Product updates and announcements
- ☐ IBM Quantum newsletter
- ☐ Tips about using our tools
- ☐ Requests for feedback to help improve our tools

Cancel Continue →

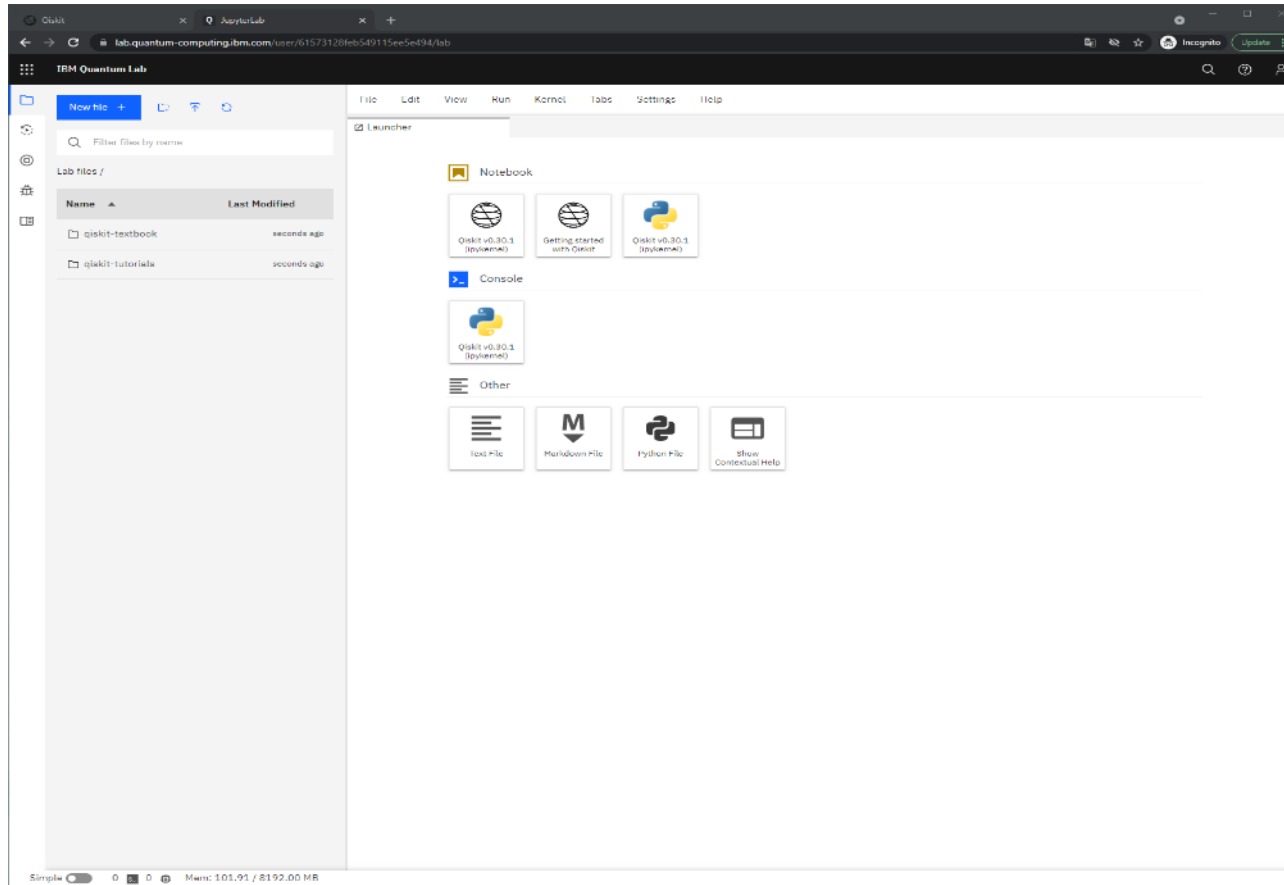
6- Complete the last step

Create IBM (Qiskit) account



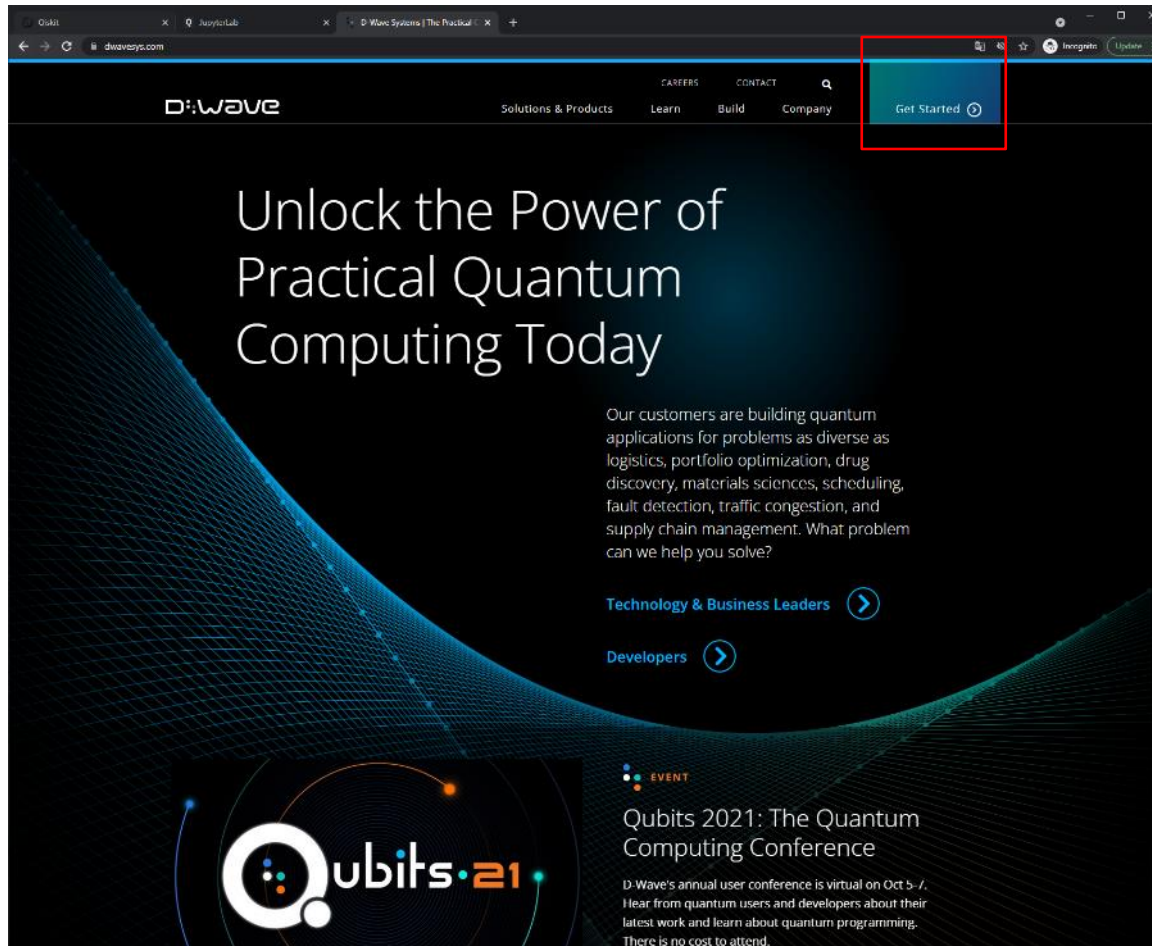
7- Wait while the server is starting up

Create IBM (Qiskit) account



8- Your account should be created successfully!

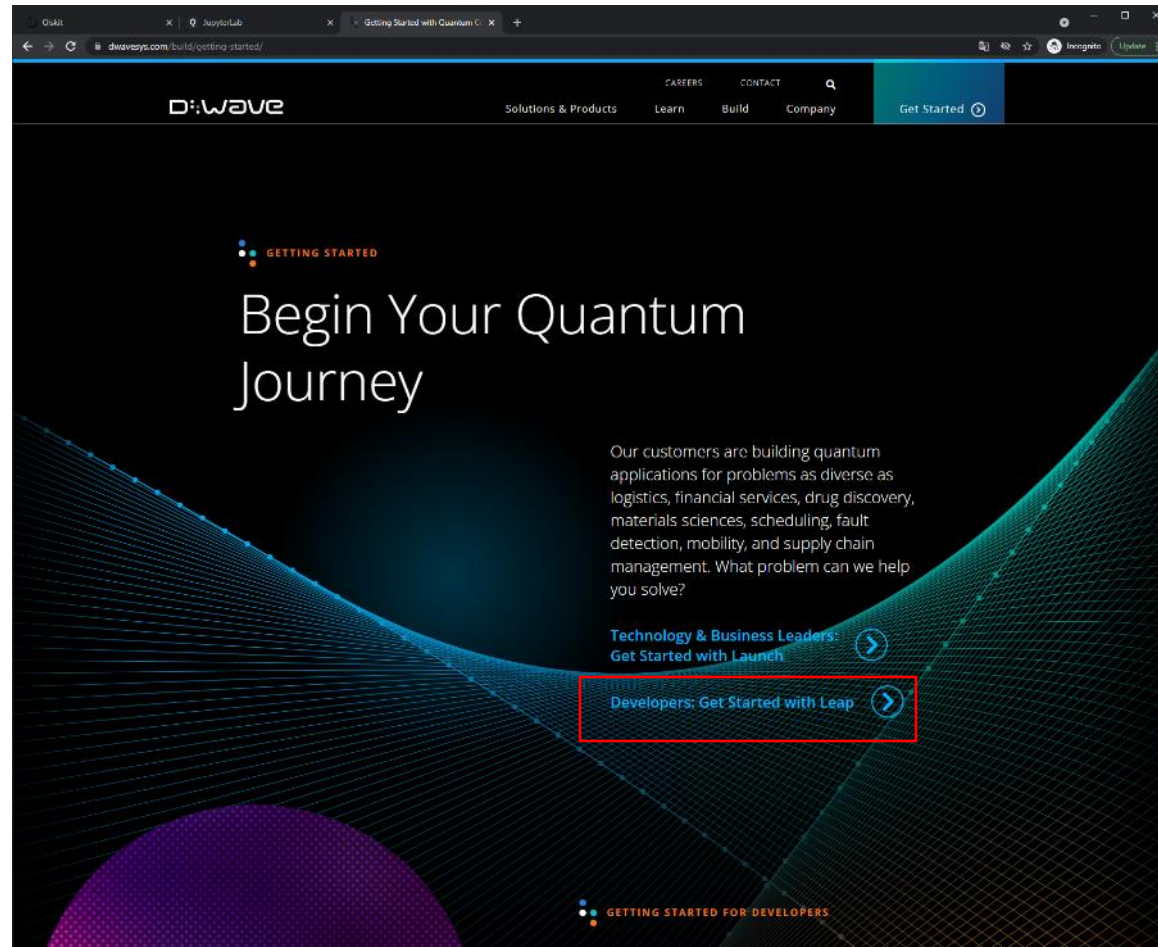
Create D-WAVE (Leap) account



1- Go to dwavesys.com

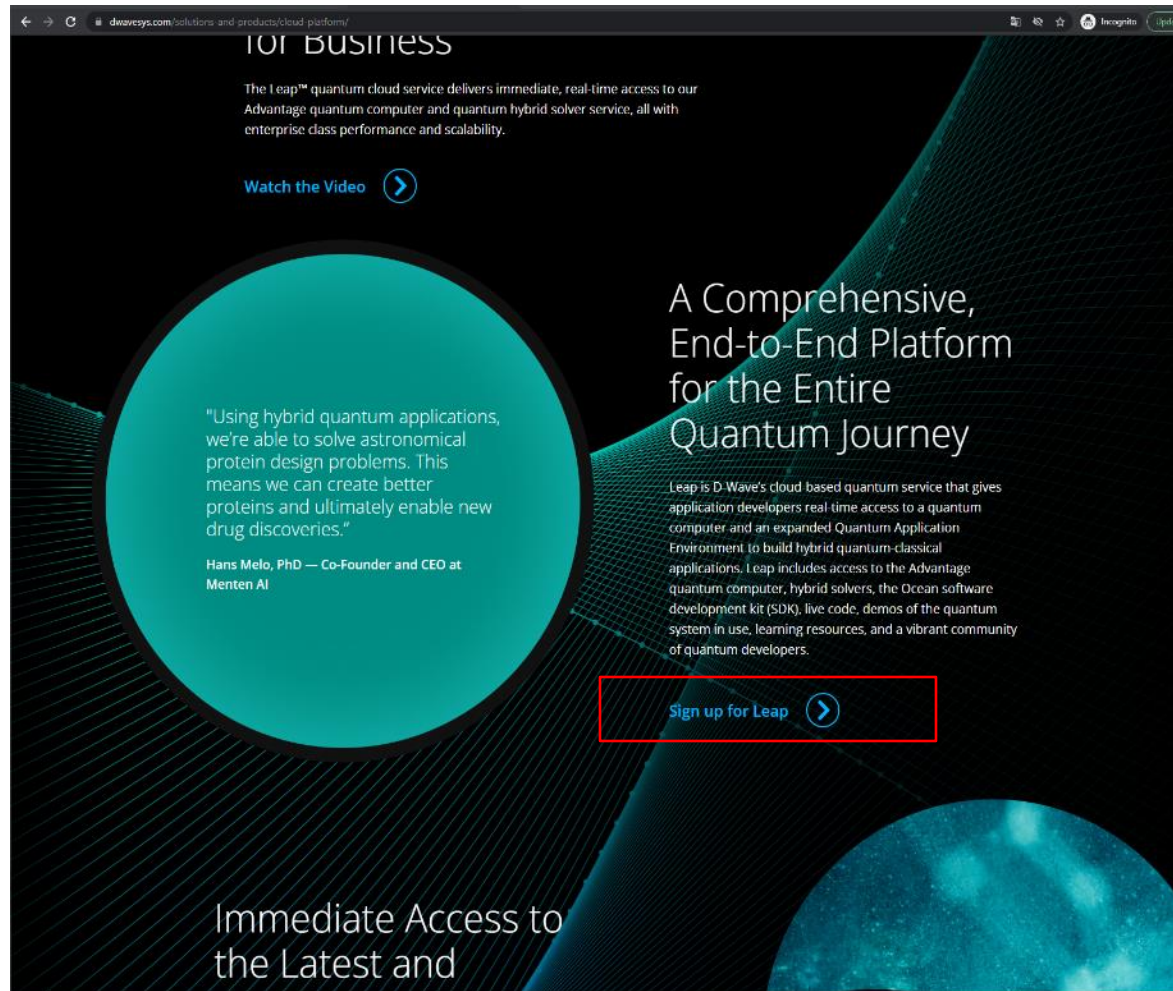
2- Click on “Get Started”

Create D-WAVE (Leap) account



3- Click on “Developers Get Started with Leap”

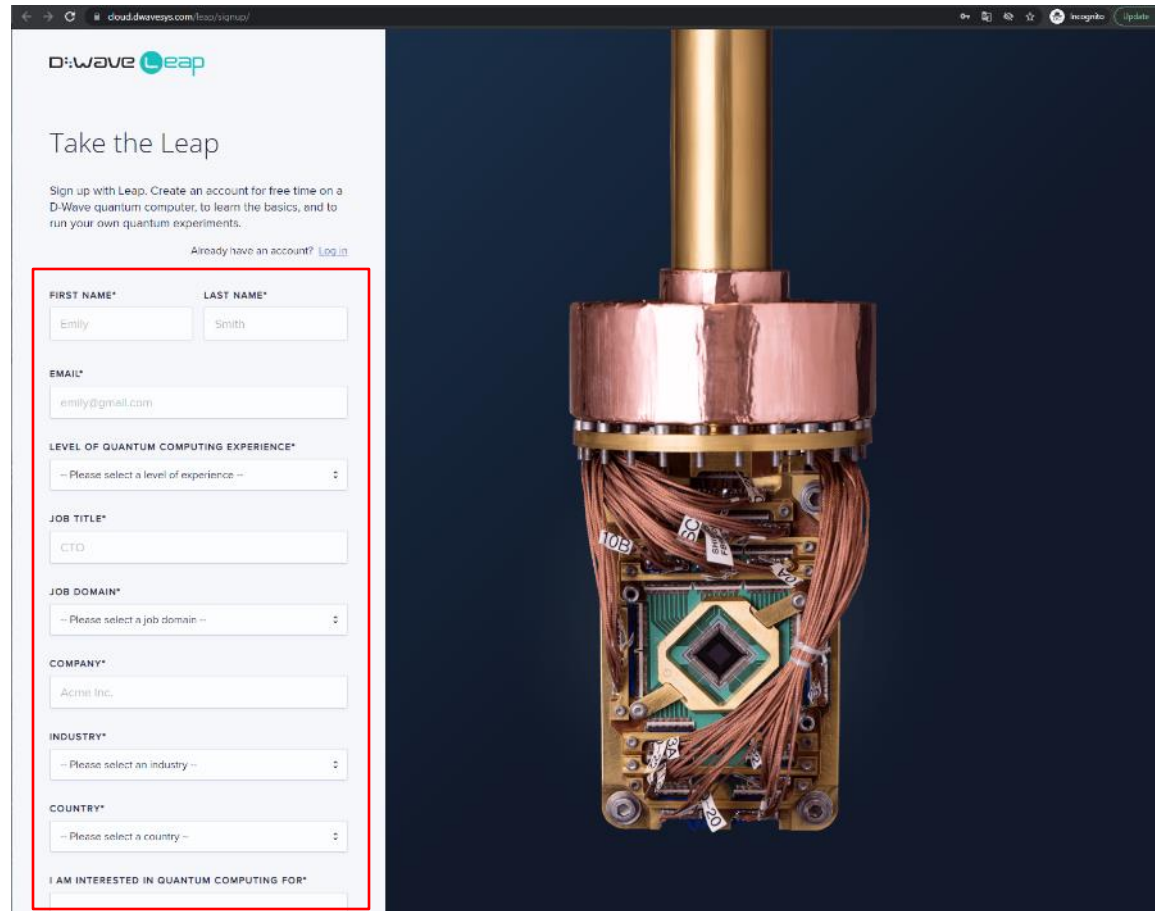
Create D-WAVE (Leap) account



4- Scroll down

5- Click on “Sign up for Leap”

Create D-WAVE (Leap) account



cloud.dwavesys.com/leap/signup/

D-WAVE Leap

Take the Leap

Sign up with Leap. Create an account for free time on a D-Wave quantum computer, to learn the basics, and to run your own quantum experiments.

Already have an account? [Log in](#)

FIRST NAME* **LAST NAME***

Emily Smith

EMAIL*

emily@gmail.com

LEVEL OF QUANTUM COMPUTING EXPERIENCE*

-- Please select a level of experience --

JOB TITLE*

CTO

JOB DOMAIN*

-- Please select a job domain --

COMPANY*

Acme Inc.

INDUSTRY*

-- Please select an industry --

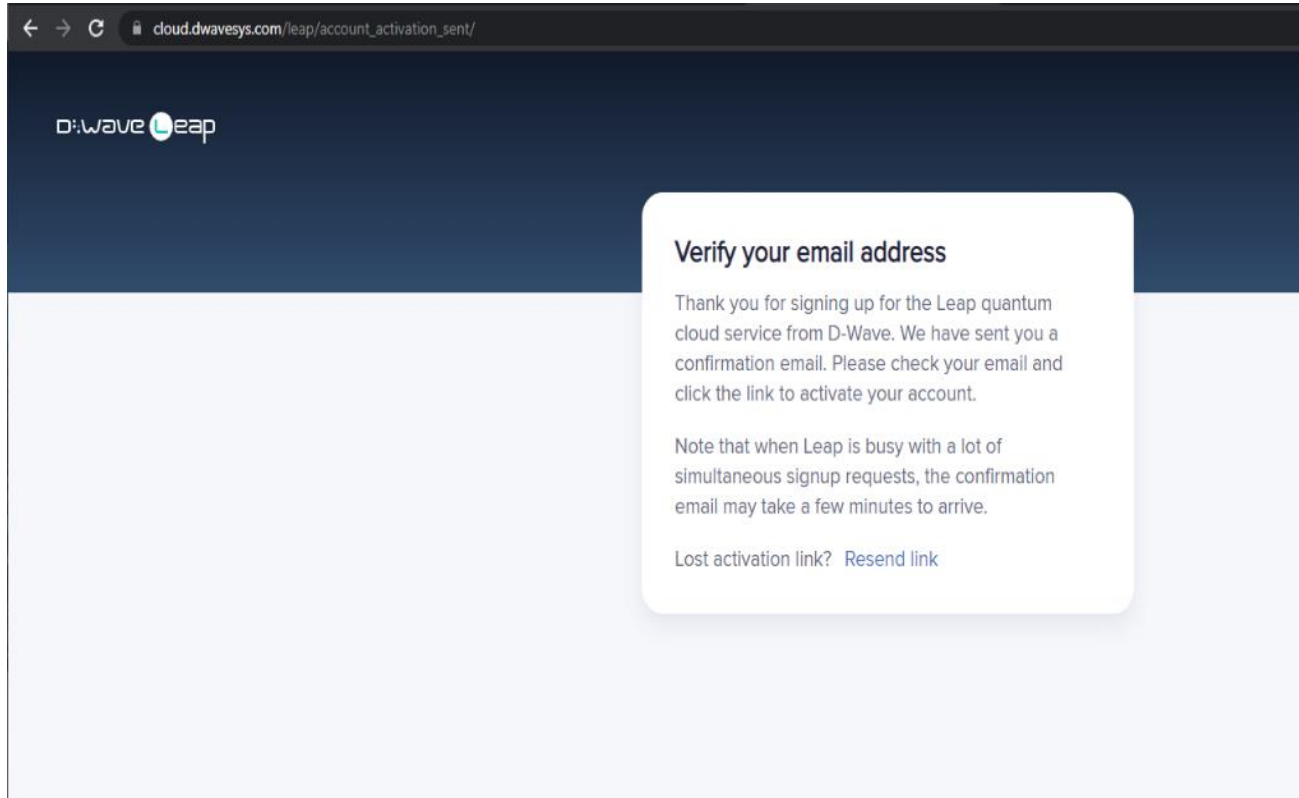
COUNTRY*

-- Please select a country --

I AM INTERESTED IN QUANTUM COMPUTING FOR*

6- Follow the steps

Create D-WAVE (Leap) account



7- Verify your email address

Create D-WAVE (Leap) account

Welcome to Leap - Account Activation External Inbox x



notifications@dwavesys.com

to me ▾

Hi

Welcome to Leap, the only real-time Quantum Application Environment.

At login, you'll find access to demos about quantum computing, the Ocean quantum programming SDK, interactive coding examples, a growing quantum community and, most importantly, free time on an actual D-Wave quantum computer.

The best part, you'll get the jump on a new paradigm in quantum development. And who knows... maybe even design the first quantum killer app.

We're thrilled you're here.

Click below to confirm your registration and get started.

<https://cloud.dwavesys.com/leap/activate/Njk4NTQ/5ui-79c654686ce3c527e92c/>

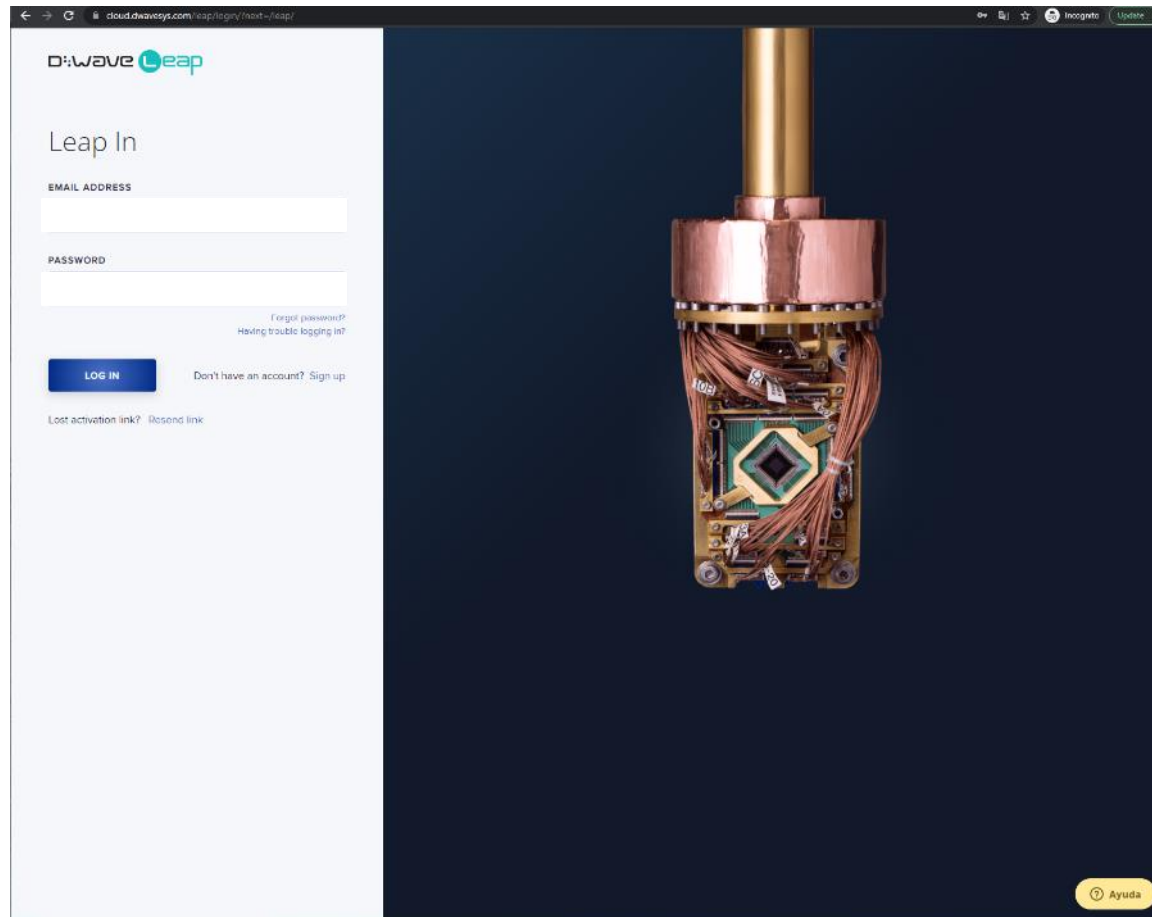
This one-time link expires after three days.

- - -

This is an unmonitored mailbox and unfortunately, this email is an automated notification unable to receive replies. If you have a question or concern, please contact us directly at support@dwavesys.com.

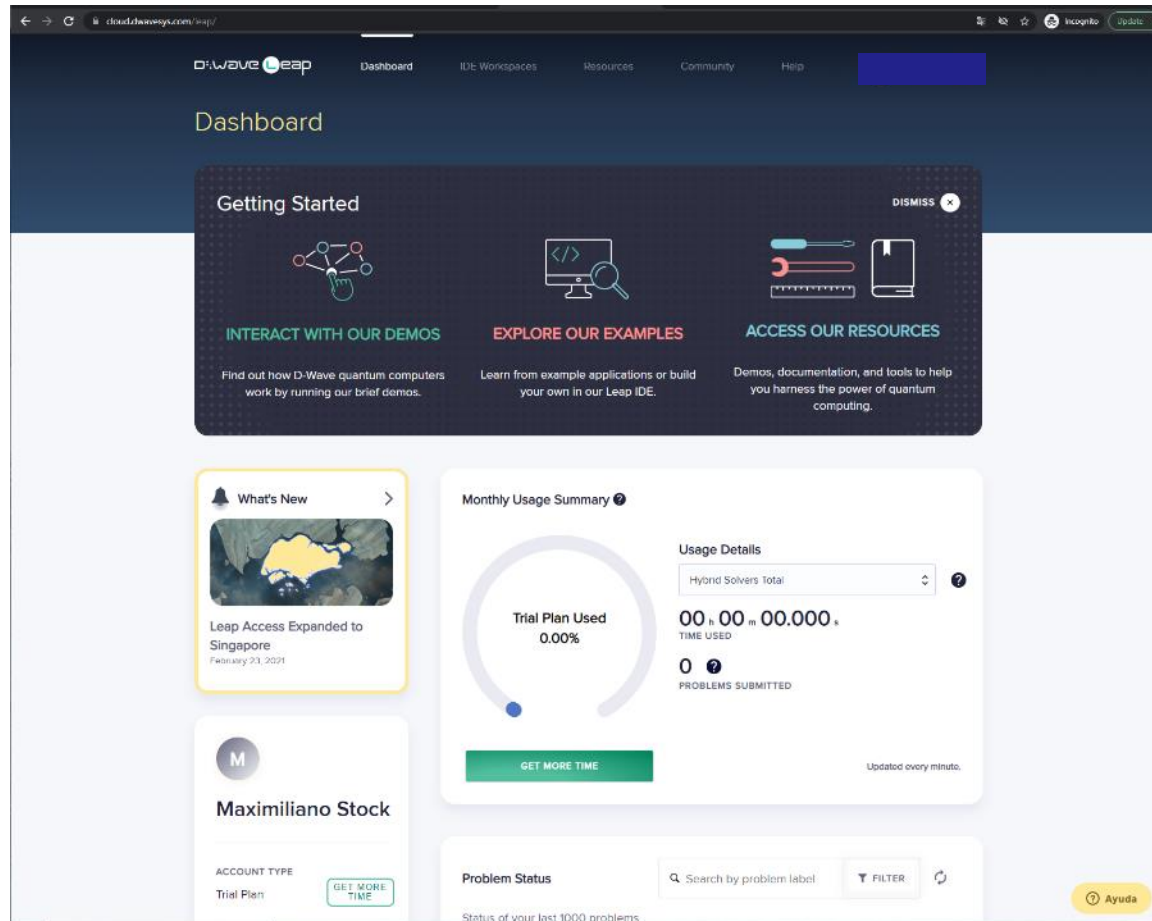
8- Confirm your registration

Create D-WAVE (Leap) account



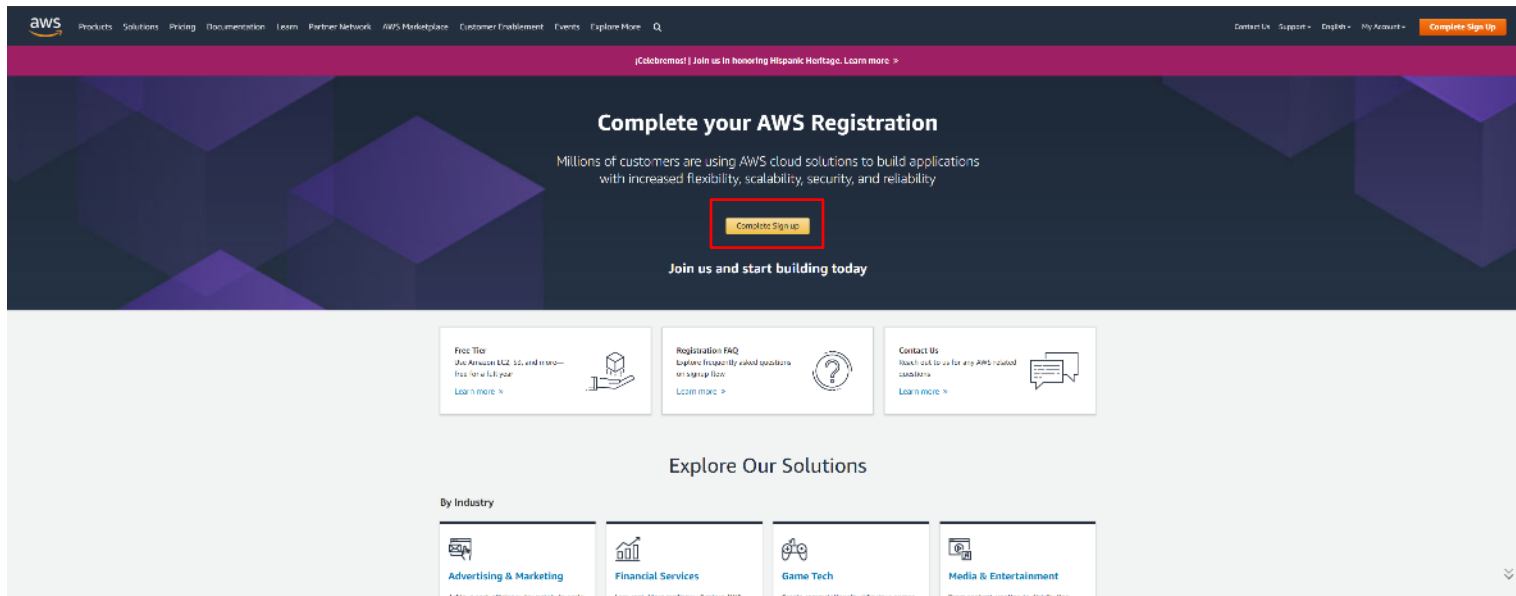
9- Log in

Create D-WAVE (Leap) account




10- Enjoy!

Create AWS account



- 1- Go to <https://aws.amazon.com/>
- 2- Click “Complete sign up”

Create AWS account



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

Next

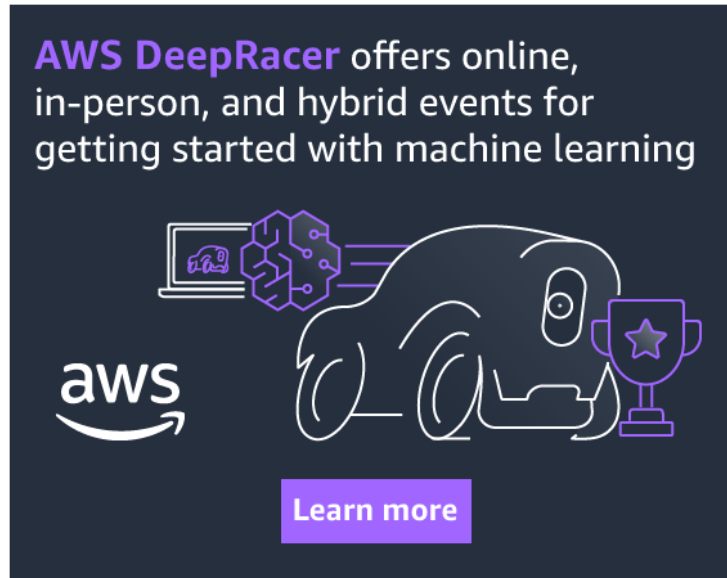
By continuing, you agree to the [AWS Customer Agreement](#) or other agreement for AWS services, and the [Privacy Notice](#). This site uses essential cookies. See our [Cookie Notice](#) for more information.

_____ New to AWS? _____

Create a new AWS account

© 2021, Amazon Web Services, Inc. or its affiliates. All rights reserved.

English ▾



3- Click “Create a new AWS account”

Create AWS account



Explore Free Tier products with a new AWS account.

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



Sign up for AWS

Email address

You will use this email address to sign in to your new AWS account.

Password

Confirm password

AWS account name


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

[Continue \(step 1 of 5\)](#)

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


4- Complete step 1


Create AWS account




Free Tier offers

All AWS accounts can explore 3 different types of free offers, depending on the product used.

**Always free**
Never expires

**12 months free**
Start from initial sign-up date

**Trials**
Start from service activation date

Sign up for AWS

Contact Information


How do you plan to use AWS?

☒ Business - for your work, school, or organization

☐ Personal - for your own projects

Who should we contact about this account?

Full Name

 A full name is required.

Organization name

Phone Number
Enter your country code and your phone number.

Country or Region

Address

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

City

State, Province, or Region

Postal Code


☐ I have read and agree to the terms of the [AWS Customer Agreement](#).

Continue (step 2 of 5)


5- Select “Business – for your work, school, or organization”


6- Complete step 2

Create AWS account



Secure verification





 We will not charge for usage below AWS Free Tier limits. We temporarily hold \$1 USD/EUR as a pending transaction for 3-5 days to verify your identity.



Sign up for AWS

Billing Information

Credit or Debit card number

AWS accepts all major credit and debit cards. To learn more about payment options, review our [FAQ](#)

Expiration date

Cardholder's name

Billing address

☒ Use my contact address

5000 Forbes Av
Pittsburgh Pennsylvania 15213
US

☐ Use a new address

Verify and Continue (step 3 of 5)

You might be redirected to your bank's website to authorize the verification charge.

7- Ignore step 3 and wait for the welcome email from AWS.

Create AWS account



Welcome to Amazon Web Services

Thank you for creating an Amazon Web Services (AWS) account. For the next 12 months, you'll have free access to all AWS services within the limits of the [Free Tier](#).

If you are unable to access AWS Services, please note that some services may take up to 24 hours to fully activate. If you're still unable to access AWS Services after that time, please visit [AWS Support](#).

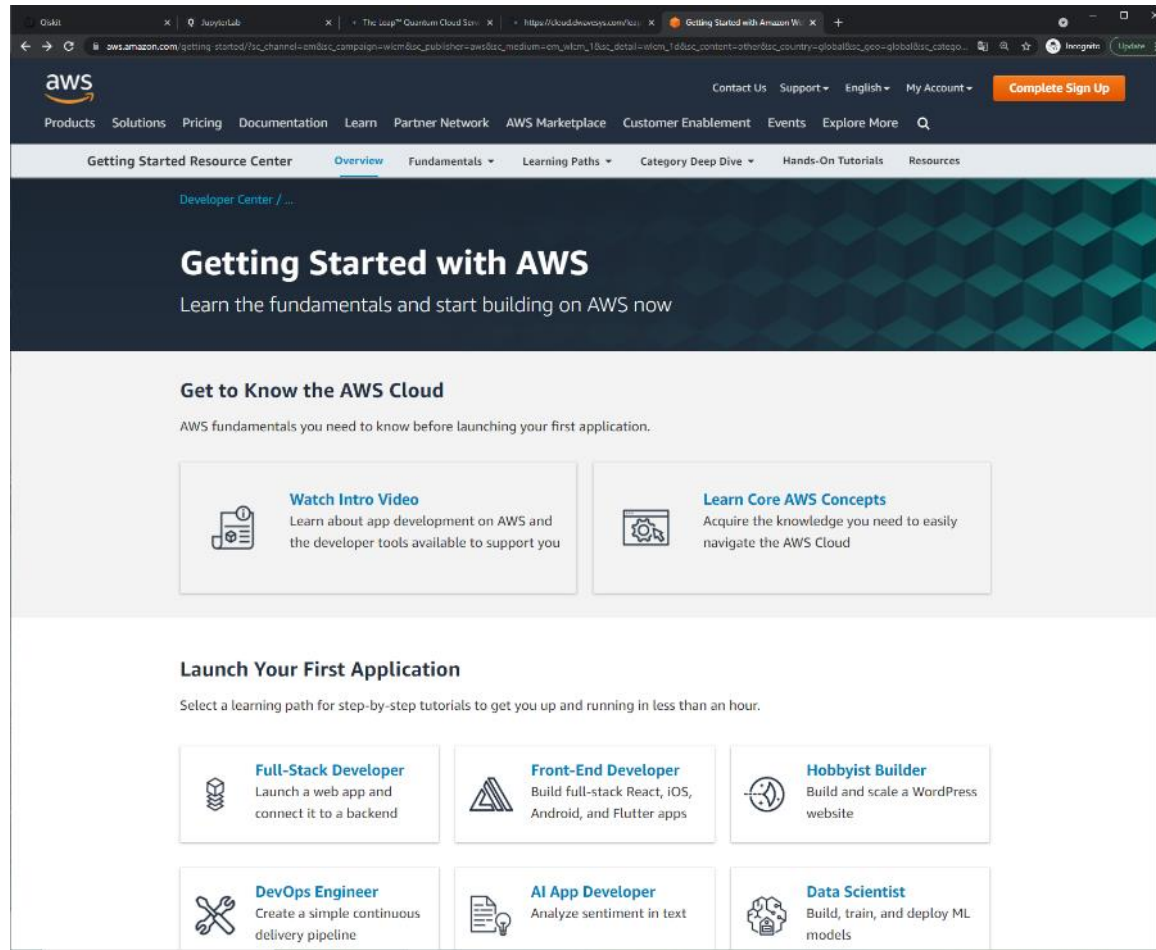
[Getting Started Resources »](#)

Welcome to the AWS community!

—The Amazon Web Services Team

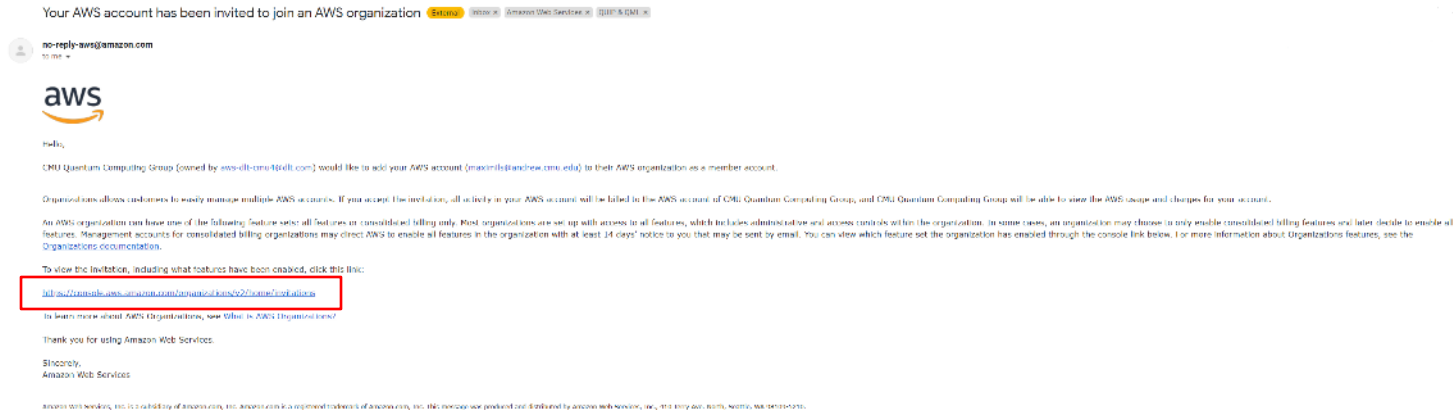
8- Click on “Getting Started Resources”

Create AWS account



9- You should be redirected to aws.amazon.com/getting-started

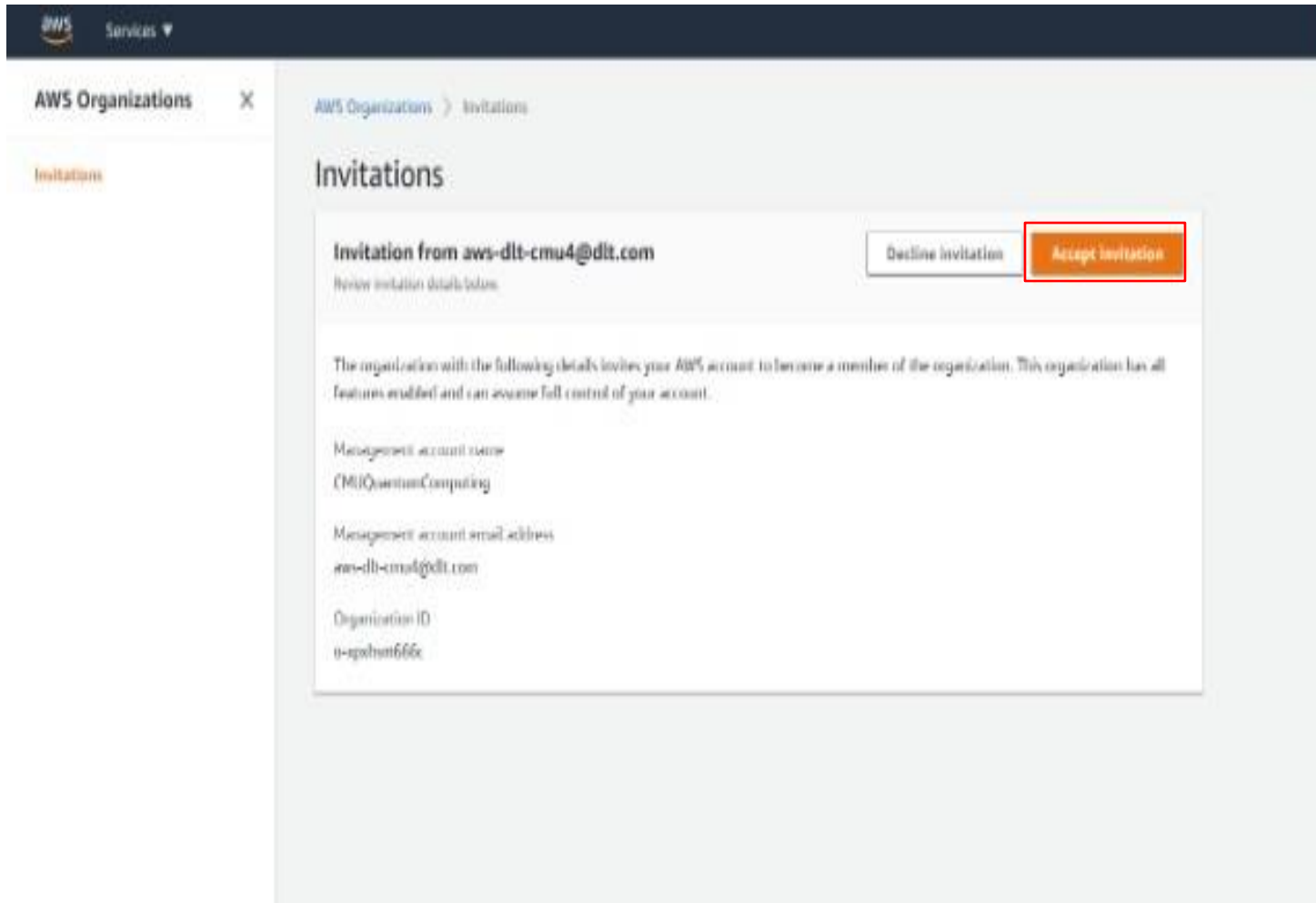
Create AWS account



10- Check your email

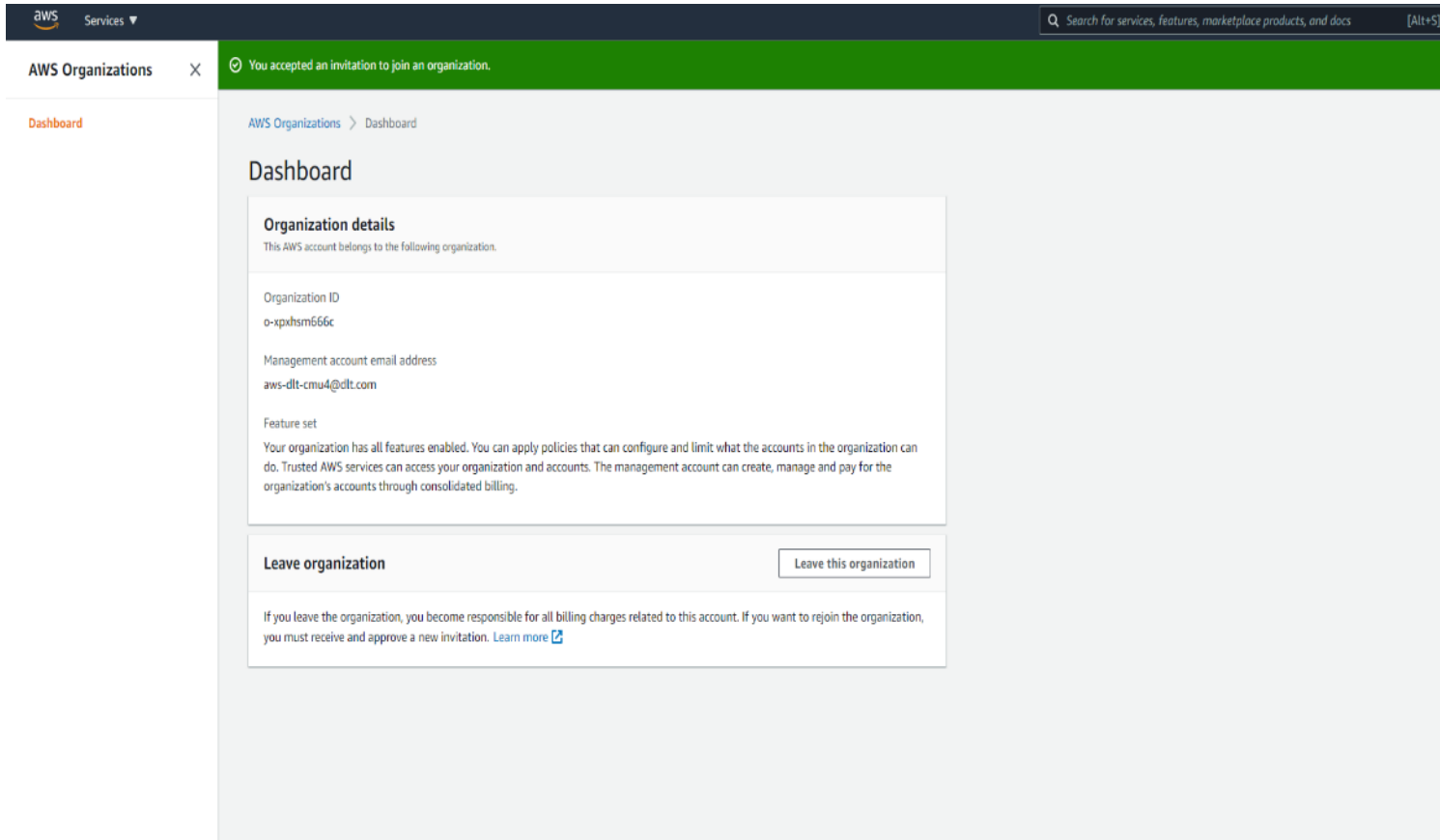
11- Click the link to view the invitation to join an AWS Organization

Create AWS account



12- Accept invitation

Create AWS account



The screenshot shows the AWS Organizations console. At the top, there's a navigation bar with the AWS logo, a 'Services' dropdown, and a search bar. Below this, a green banner indicates 'You accepted an invitation to join an organization.' The left sidebar shows 'AWS Organizations' and 'Dashboard'. The main content area is titled 'Dashboard' and contains two sections: 'Organization details' and 'Leave organization'. The 'Organization details' section shows the Organization ID 'o-xpdxsm666c', the Management account email address 'aws-dlt-cmu4@dlc.com', and a note that all features are enabled. The 'Leave organization' section includes a 'Leave this organization' button and a warning that leaving the organization makes the user responsible for all billing charges.

Organization details
This AWS account belongs to the following organization.

Organization ID
o-xpdxsm666c

Management account email address
aws-dlt-cmu4@dlc.com

Feature set
Your organization has all features enabled. You can apply policies that can configure and limit what the accounts in the organization can do. Trusted AWS services can access your organization and accounts. The management account can create, manage and pay for the organization's accounts through consolidated billing.

Leave organization [Leave this organization](#)

If you leave the organization, you become responsible for all billing charges related to this account. If you want to rejoin the organization, you must receive and approve a new invitation. [Learn more](#)

13- Enjoy!

Amazon Braket

The screenshot shows the Amazon Braket website. At the top, the AWS logo is on the left, and navigation links for Products, Solutions, Pricing, Documentation, Learn, Partner Network, AWS Marketplace, Customer Enablement, Events, and Explore More are in the center. On the right, there are links for Contact Us, Support, English, and a highlighted 'Account' dropdown menu with a 'Complete Sign Up' button. Below the navigation bar, a blue banner features the text 'Free AWS Training: Focus on the cloud skills most relevant to you—choose from 500+ digital courses across 30+ AWS solutions'. The main content area has a dark background with the heading 'Amazon Braket' and the subtext 'Accelerate quantum computing research'. A prominent orange button says 'Get Started with Amazon Braket'. To the right, a box offers '1 free hour of simulation time per month for a year with AWS Free Tier'. Below this, three columns describe the service: 'Easily work with different types of quantum computers and circuit simulators using a consistent set of development tools.', 'Build quantum projects on a trusted cloud with simple pricing and management controls for both quantum and classical workloads.', and 'Innovate quickly with expert guidance and tech support, or collaborate with consultants in the Amazon Quantum Solutions Lab.' The 'How it works' section follows, with a subtext: 'Amazon Braket is a fully managed quantum computing service designed to help speed up scientific research and software development for quantum computing.' It includes a diagram with five steps: 1. Amazon Braket (Get started with quantum computing), 2. Build (Build your quantum algorithms on managed Jupyter notebooks or in your own development environment), 3. Test (Test your algorithms on a local simulator or a choice of fully managed high-performance simulators), 4. Run (Run your algorithms on your choice of different quantum computers. Combine classical and quantum computing resources for hybrid algorithms), and 5. Analyze (Analyze results after your algorithm has completed).

- 1- Go to <https://aws.amazon.com/es/braket/>
- 2- Complete Sign up

Amazon Braket



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

© 2021, Amazon Web Services, Inc. or its affiliates. All rights reserved.

English ▼



Security check

Type the characters seen in the image below



Submit


© 2021, Amazon Web Services, Inc. or its affiliates. All rights reserved.

English ▼



3- Sign up

Amazon Braket




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](#)

Complete sign up

4- Complete Sign up

Amazon Bracket



Congratulations!

Thank you for signing up with AWS.

We are activating your account, which should take a few minutes. You will receive an email when this is complete.

[Go to the AWS Management Console](#)

[Sign up for another account](#) or [Contact Sales](#)

5- Go to the AWS Management Console

As an additional step, tell us more about yourself

We would love to learn more about your preferences so that we can provide recommendations catered to your role and interests.

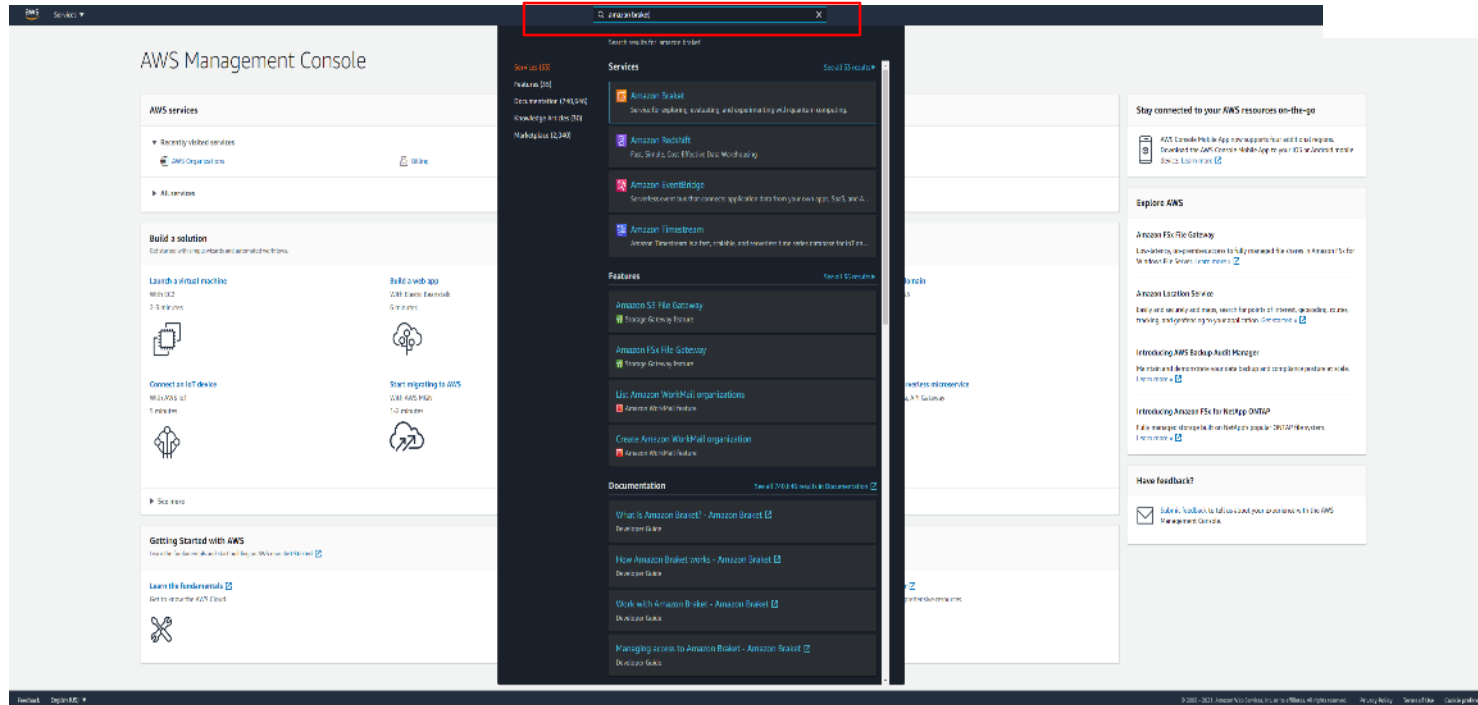
My role is: [select role](#) ▼

I am interested in: [select area](#) ▼

☐ Yes, I'd like Amazon Web Services (AWS) to share the latest news about AWS services and related offerings with me by email, post or telephone.

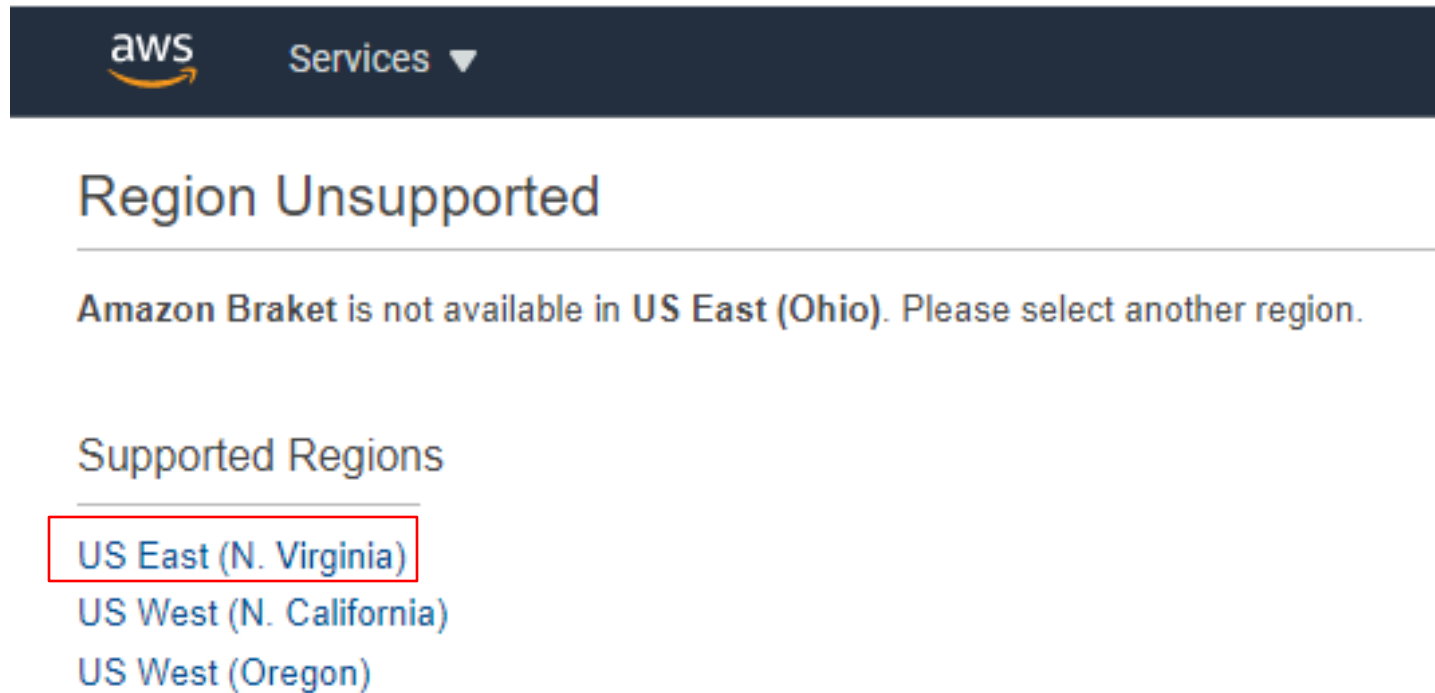
You may unsubscribe from receiving AWS news and offers at any time by following the instructions in the communications received. AWS handles your information as described in the [AWS Privacy Notice](#).

Amazon Braket



6- Search for Amazon Braket

Amazon Braket



7- 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)*

Amazon Braket

Getting started with Amazon Braket

Amazon Braket provides a development environment to design quantum algorithms, test them on quantum simulators, and run them on a quantum computer. To successfully configure and enable Amazon Braket, you need to use an account that has the AmazonBraketFullAccess. You, or your AWS admin, can attach the policy to your role, user, or group using the IAM console. [Learn more](#)

Choose your data storage

Amazon Braket stores results from your algorithms in any Amazon S3 bucket starting with "amazon-braket-". To get you started, we can create a new bucket for you, or you choose to name your bucket, or select from a list of existing valid buckets.

☒ Create new
☐ Specify new
☐ Select existing

Account permissions

Amazon Braket creates a service-linked role in your account. The role **allows Amazon Braket to access AWS resources** on your behalf. The following permissions policy is attached to the role when you enable Amazon Braket. [Learn more](#)

Terms & conditions

If you use Amazon Braket to access quantum computing hardware operated by one of the third-party hardware providers listed [here](#) (each a "Hardware Provider"), you: (1) acknowledge that the Content you provide in connection with your use of Amazon Braket may be processed by the Hardware Provider outside of facilities operated by AWS; and (2) authorize AWS to transfer such Content to the Hardware Provider for processing.

☐ I have read and accepted the above terms & conditions.

Enable Amazon Braket

- 8- Accept terms & conditions
- 9- Enable Amazon Braket

Amazon Braket

The screenshot displays the Amazon Braket console interface. On the left, there is a sidebar with navigation options: Amazon Braket, Devices, 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)

- D-Wave — Advantage_system1.1**: Quantum Annealer based on superconducting qubits. Qubits: 5760, Status: ONLINE, Region: us-west-2, Next available: AVAILABLE NOW.
- D-Wave — DW_2000Q_6**: Quantum Annealer based on superconducting qubits. Qubits: 2048, Status: ONLINE, Region: us-west-2, Next available: AVAILABLE NOW.
- IonQ**: Universal gate-model QPU based on trapped ions. Qubits: 11, Status: ONLINE, Region: us-east-1, Next available: 1 day 21:46:25.
- Rigetti — Aspen-8**: Universal gate-model QPU based on superconducting qubits. Qubits: 31, Status: RETIRED, Region: us-west-1, Next available: UNAVAILABLE.
- Rigetti — Aspen-9**: Universal gate-model QPU based on superconducting qubits. Qubits: 32, Status: ONLINE, Region: us-west-1, Next available: AVAILABLE NOW.

Simulators

- Amazon Web Services — SV1**: Amazon Braket state vector simulator. Qubits: 34, Status: ONLINE, Region: us-east-1, us-west-1, us-west-2, Next available: AVAILABLE NOW.
- Amazon Web Services — TN1**: Amazon Braket tensor network simulator. Qubits: 50, Status: ONLINE, Region: us-east-1, us-west-2, Next available: AVAILABLE NOW.
- Amazon Web Services — DM1**: Amazon Braket density matrix simulator. Qubits: 17, Status: ONLINE, Region: us-east-1, us-west-1, us-west-2, Next available: AVAILABLE NOW.

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

Amazon Braket

The screenshot shows the Amazon Braket console interface. On the left is a navigation pane with links for Devices, Notebooks (highlighted), 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 'Create notebook instance' button. Below this is a search bar labeled 'Search notebooks' and a filter box that says 'Name contains: amazon-braket-' with a 'Clear all' button. A table with columns 'Name', 'Instance', 'Creation time', 'Status', and 'URL' is shown, but it is empty. A message states 'No Notebooks' and 'Use Jupyter Notebooks to create quantum programs in an interactive coding environment.' with a 'Create notebook' button. The footer includes 'Feedback', 'English (US)', copyright information, and links to 'Privacy Policy' and 'Terms of Use'.

11- Go straight to notebooks on the left pane.

Amazon Braket

The screenshot shows the 'Create notebook instance' page in the Amazon Braket console. The left sidebar contains navigation links for 'Amazon Braket', '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 two main sections: 'Notebook instance settings' and 'Permissions and encryption'. In the 'Notebook instance settings' section, the 'Notebook instance name' is set to 'amazon-braket-Testing' and the 'Notebook instance type' is set to 'ml.t3.medium'. The 'Permissions and encryption' section shows the 'IAM role' set to 'Create a new role' and 'Root access' set to 'Enable - Give users root access to the notebook'. There is also an option for 'Encryption key' set to 'No custom encryption key'. At the bottom right, there are 'Cancel' and 'Create notebook instance' buttons.

aws Services ▾

Amazon Braket ×

Devices
Notebooks
Tasks
Announcements

Create notebook instance

Amazon Braket provide fully managed notebook instances that run Jupyter. The notebook instances come preinstalled with the Amazon Braket SDK and include tutorials and example algorithms. Amazon Braket notebooks are based on SageMaker Notebook instances. [Learn more](#)

Notebook instance settings

Notebook instance name
amazon-braket-Testing
Maximum of 49 alphanumeric characters. Can include hyphens (-), but not spaces. Must be unique within your account in an AWS Region.

Notebook instance type
Instance types comprise varying combinations of CPU, GPU, memory for building, running your quantum tasks
ml.t3.medium ▾

► Additional settings

Permissions and encryption

IAM role
Create a new role ▾

ⓘ 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
☒ Enable - Give users root access to the notebook
☐ Disable - Don't give users root access to the notebook
Lifecycle configurations always have root access

Encryption key — optional
Encrypt your notebook data. Choose an existing KMS key or enter a key ARN.
No custom encryption key ▾

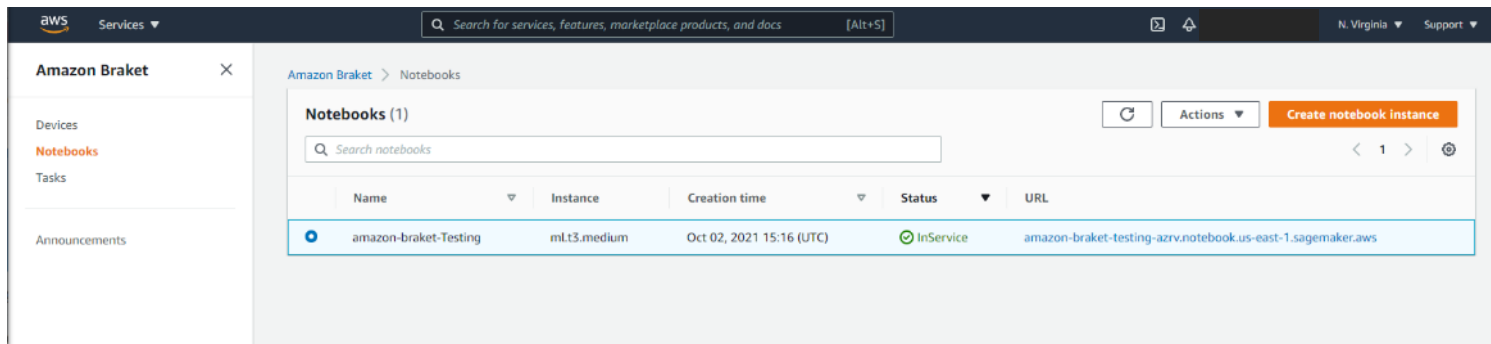
► Network — optional

Cancel Create notebook instance

Feedback English (US) ▾

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

Amazon Braket



13- Check status of Notebook. 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 “Devices” in the left tab.

Amazon Braket

The screenshot displays the Amazon Braket console interface. The top navigation bar includes the AWS logo, a search bar, and regional settings for N. Virginia. The left sidebar shows navigation options: Amazon Braket, Devices, 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 Name	Qubits	Status	Region	Next available
D-Wave — Advantage_system4.1	5760	ONLINE	us-west-2	AVAILABLE NOW
D-Wave — Advantage_system1.1	5760	ONLINE	us-west-2	AVAILABLE NOW
D-Wave — DW_2000Q_6	2048	ONLINE	us-west-2	AVAILABLE NOW
IonQ	11	ONLINE	us-east-1	AVAILABLE NOW
Rigetti — Aspen-8	31	RETIRED	us-west-1	UNAVAILABLE
Rigetti — Aspen-9	32	ONLINE	us-west-1	19:04:13

Simulators

Simulator Name	Qubits	Status	Region	Next available
Amazon Web Services — SV1	34	ONLINE	us-east-1, us-west-1, us-west-2	AVAILABLE NOW
Amazon Web Services — TN1	50	ONLINE	us-east-1, us-west-2	AVAILABLE NOW
Amazon Web Services — DM1	17	ONLINE	us-east-1, us-west-1, us-west-2	AVAILABLE NOW

The bottom of the console shows a footer with 'Feedback', 'English (US)', and copyright information for Amazon Web Services, Inc. (2009 - 2021).

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

Amazon Braket

The screenshot shows the Amazon Braket console interface. The left sidebar contains navigation links for Devices, Notebooks, Tasks, and Announcements. The main content area displays the details for the D-Wave Advantage_system4.1 device. The device is a Quantum Annealer based on superconducting qubits. The console provides information about the hardware provider (D-Wave), region (us-west-2), location (British Columbia, Canada), availability (Everyday, 00:00:00 - 23:59:59 UTC), cost (\$0.30 / task + \$0.00019 / shot), and status (ONLINE). The Device ARN is highlighted with a red box and is: `arn:aws:braket::device/qpu/d-wave/Advantage_system4`. Below this, the topology is shown as a JSON object:

```
{
  "type": "pegasus",
  "shape": {
    "x": 16
  }
}
```

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

Amazon Braket

Amazon Braket

Search for services, features, marketplace products, and docs [Alt+5]

N. Virginia Support

Amazon Braket > Devices > IonQ Device

IonQ

Universal gate-model QPU based on trapped ions

IonQ's trapped ion QPUs are built on a chain of trapped 171Yb^+ ions, spatially confined via a microfabricated surface electrode trap within a vacuum chamber. Gates are performed via a two-photon Raman transition using a pair of counter-propagating beams from a mode-locked pulsed laser. This allows for high-quality single and two-qubit transitions and all-to-all connectivity. Initialization is performed via optical pumping, and readout is performed with a combination of a resonant laser, a high numeric aperture lens, and photomultiplier tubes.

IonQ compiles and optimizes your high-level quantum logic gates into the smallest possible set of laser pulses to realize your program on trapped ions, mapping your gates onto ideal pairs for execution using up-to-the minute continuous calibrations.

For single-qubit gates, IonQ uses the GPI gate, the GPI2 gate and the GZ gate. The GPI and GPI2 gates are simply Rabi oscillations made by driving the qubits on resonance using laser beams in a Raman configuration. The GZ gate is performed by advancing/retarding the phase of this laser beam, creating a 'virtual' operation.

For entangling, two-qubit gates, IonQ uses the Mølmer-Sørensen gate. This entangling gate and the single-qubit gates above constitute a universal gate set. By irradiating any two ions in the chain with a predesigned set of pulses, it is possible to couple ions' internal states with the chain's normal modes of motion to create entanglement.

[More about this device](#)

Hardware provider IonQ	Region us-east-1	Location Maryland, USA
Availability Weekdays, 13:00:00 - 02:00:00 UTC	Next available AVAILABLE NOW	Cost \$0.30 / task + \$0.01 / shot
Device ARN arn:aws:braket::device/qpu/ionq/ionqdevice	Status ONLINE	Qubits 11

Topology

Calibration

Last updated: Sep 21, 2021 13:00 (UTC)

Feedback English (US)

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

Amazon Braket

Rigetti — Aspen-9

Universal gate-model QPU based on superconducting qubits

Rigetti quantum processors are universal, gate-model machines based on all-tunable superconducting qubits.

Just like the Rigetti Aspen-8 chip, the Aspen-9 chip features tileable lattices of alternating fixed-frequency and tunable superconducting qubits within a scalable 32-qubit node technology. Distinguishing characteristics include direct coupling between one qubit and its three nearest neighbors; fast gate times for multiple entangling gate families; rapid sampling via active register reset; and parametric control.

The Aspen chip topology is octagonal with 3-fold (2-fold for edges) connectivity and features both CZ and XY entangling gates that allow developers to optimize programs for performance and minimize circuit depth. Rigetti's optimizing qubit compiler transforms abstract quantum algorithms into this set of native gates and produces optimal circuit implementations to be carried out on a Rigetti QPU. These gates offer fast (60ns and 160ns) 1Q and 2Q gate times and program execution rates within qubit coherence times measuring ~20µs.

Universal gate-based quantum computers powered by superconducting qubits provide users with both fine grained control and efficient variational feedback loops to explore problem spaces in chemical simulation, combinatorial optimization, and machine learning.

[More about this device](#)

Hardware provider Rigetti	Region us-west-1	Location California, USA
Availability Everyday, 15:00:00 - 19:00:00 UTC	Next available 19:00:10	Cost \$0.30 / task + \$0.00035 / shot
Device ARN arn:aws:braket::device/qpu/rigetti/Aspen-9	Status ONLINE	Qubits 32

Topology

Calibration

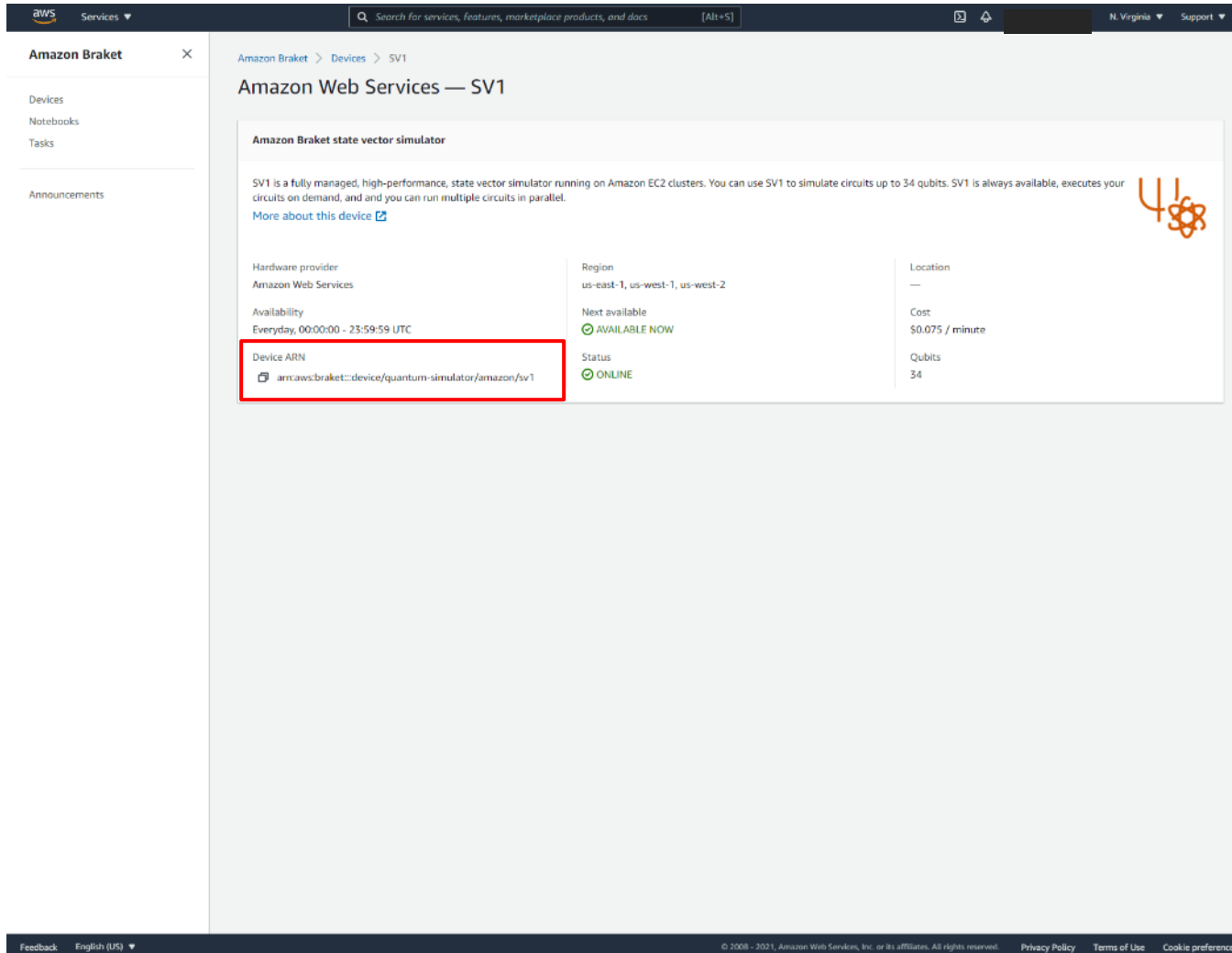
Last updated: Oct 12, 2021 19:58 (UTC)

Qubit

Qubit	T1 (µs)	T2 (µs)	Fidelity (RB) (%)	Fidelity (simultaneous RB) (%)	Readout fidelity (%)	Active reset fidelity (%)
0	27.661	12.521	99.900 ± 0.009	99.612 ± 0.027	97.000	99.850
1	35.419	10.563	97.817 ± 0.120	96.277 ± 0.623	85.800	97.200
2	24.699	4.462	99.759 ± 0.021	99.512 ± 0.027	93.700	99.650

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

Amazon Braket



The screenshot shows the Amazon Braket console interface. The left sidebar contains navigation links for Amazon Braket, Devices, Notebooks, Tasks, and Announcements. The main content area displays the 'Amazon Braket state vector simulator' details for the 'SV1' device. A red box highlights the 'Device ARN' field, which contains the value 'arn:aws:braket::device/quantum-simulator/amazon/sv1'. Other details shown include the hardware provider (Amazon Web Services), region (us-east-1, us-west-1, us-west-2), location (—), next available status (AVAILABLE NOW), cost (\$0.075 / minute), status (ONLINE), and qubits (34).

Hardware provider	Region	Location
Amazon Web Services	us-east-1, us-west-1, us-west-2	—

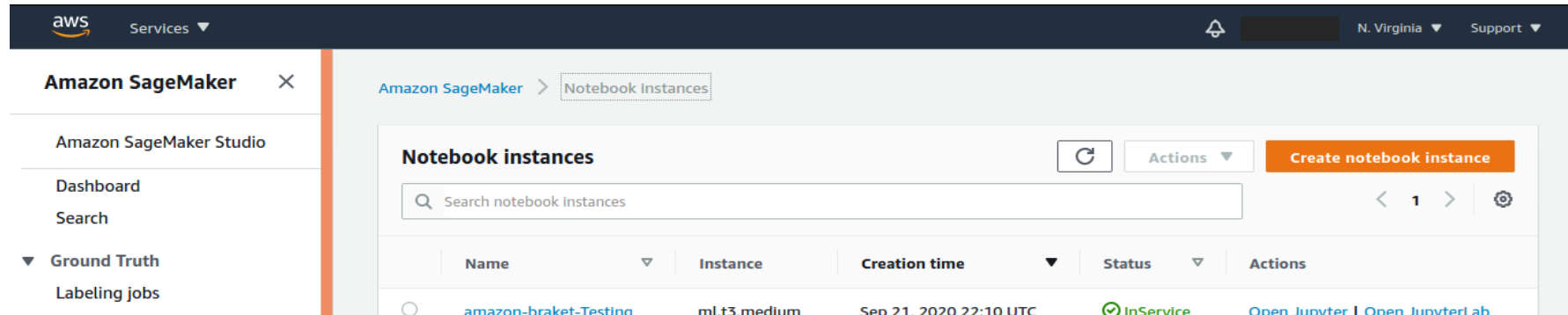
Availability	Next available	Cost
Everyday, 00:00:00 - 23:59:59 UTC	AVAILABLE NOW	\$0.075 / minute

Device ARN	Status	Qubits
arn:aws:braket::device/quantum-simulator/amazon/sv1	ONLINE	34

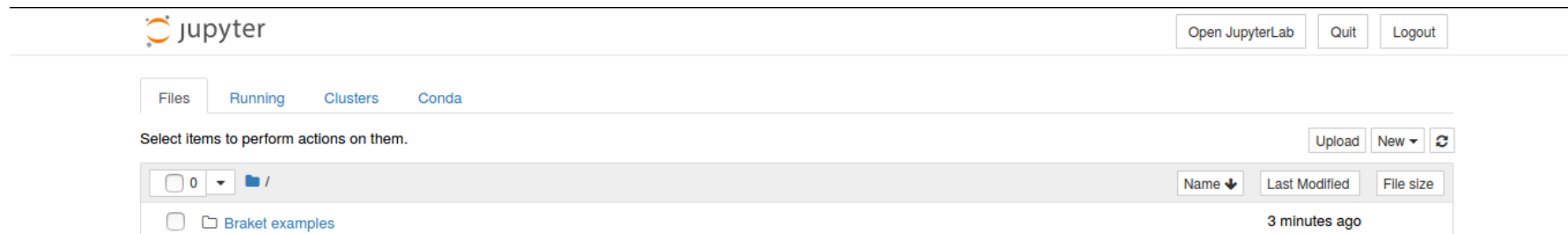
18- Braket Simulator. Note the Device ARN, it may be useful in your Notebooks

Go back to Notebooks tab

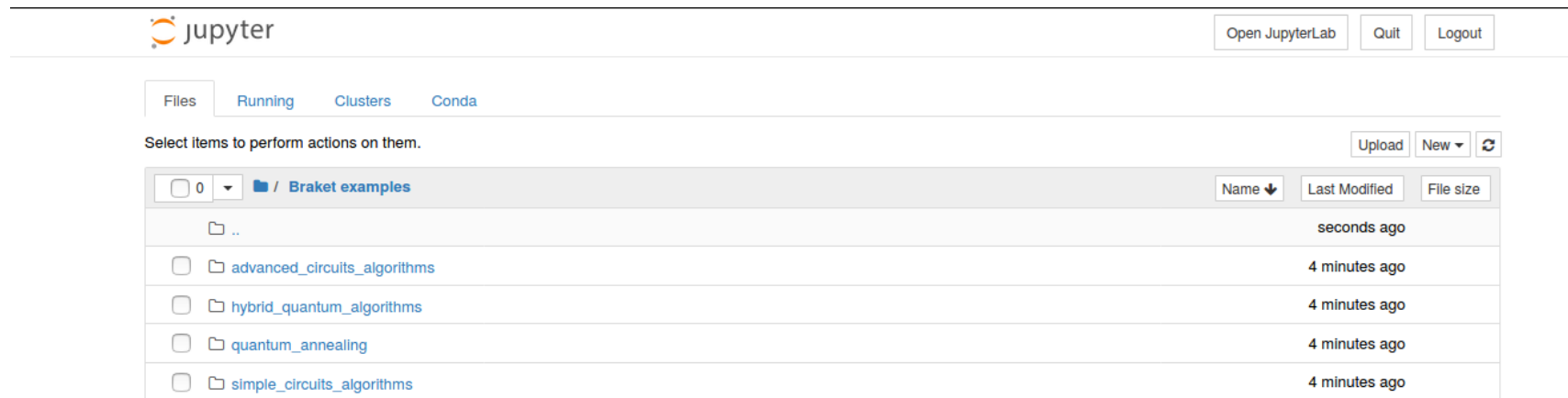
19. Your Notebook may be green i.e. “In Service”



20. Under Actions, click on the notebook



Open Bracket Examples



Explore the set of notebooks provided by Amazon Braket.

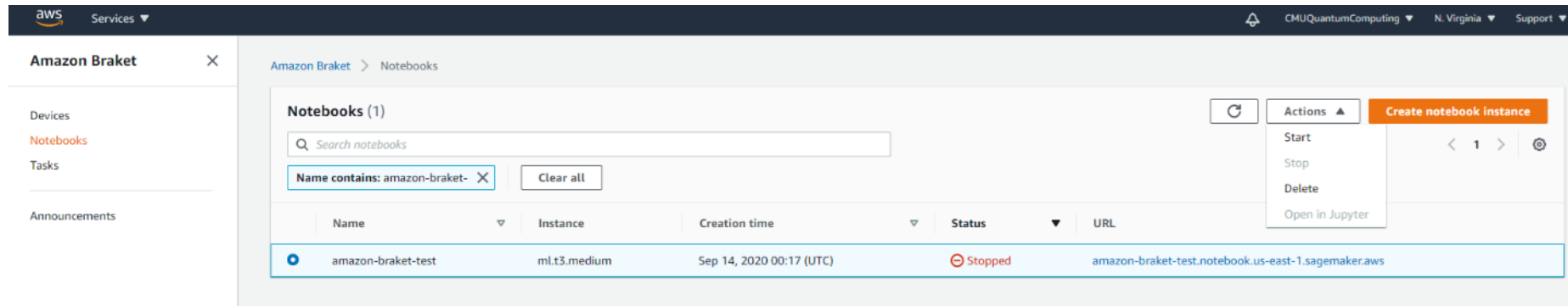
The results are preloaded. You can execute the code yourself, keep in mind that it costs money!
First simulate classically and then use the quantum devices (preferably DWave, Rigetti and IonQ in that order)

Make sure to Stop your notebooks before you Log Out!

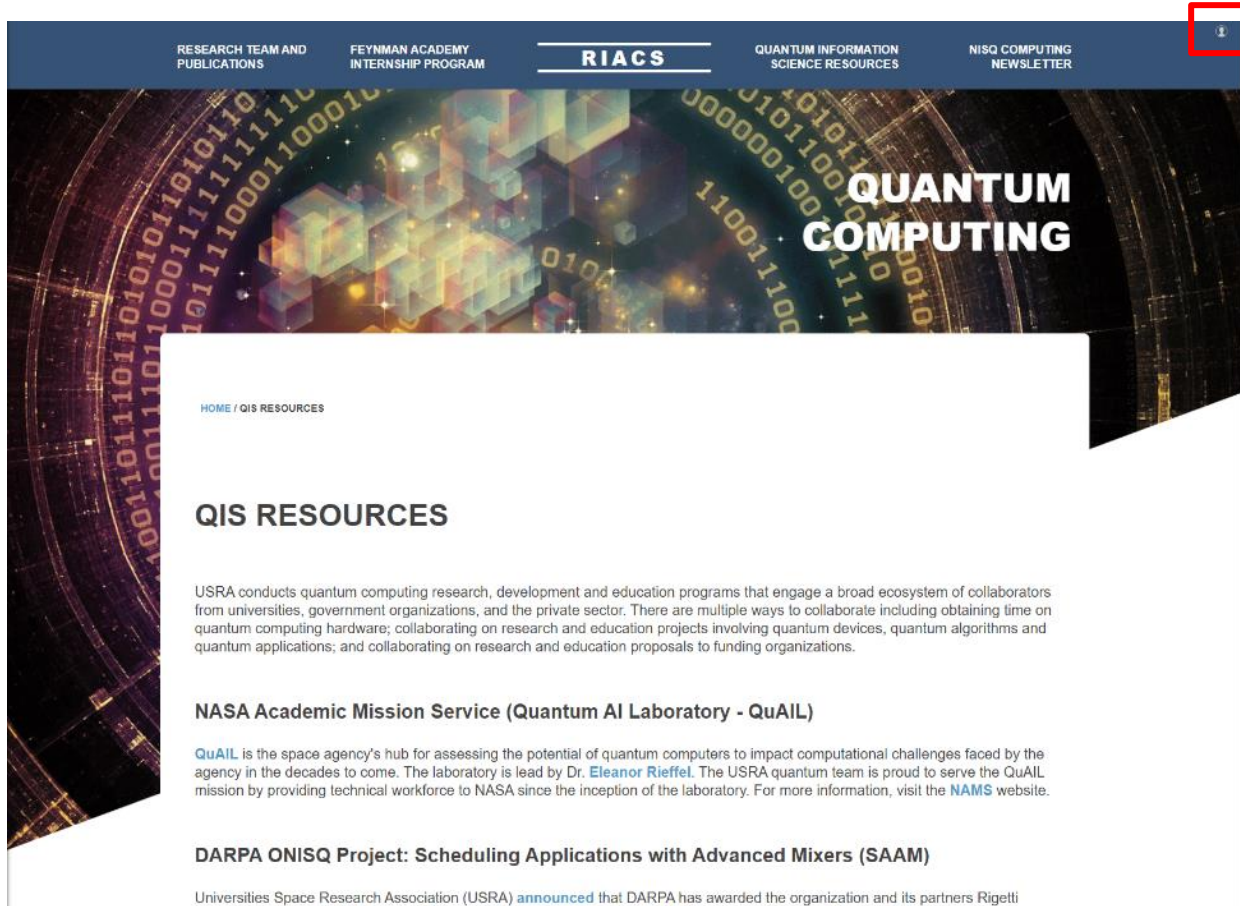
Play Around.

You are ALL SET Here!

- Don't remember to stop the instances after you are done exploring them. Leaving them open costs money and we have limited resources!

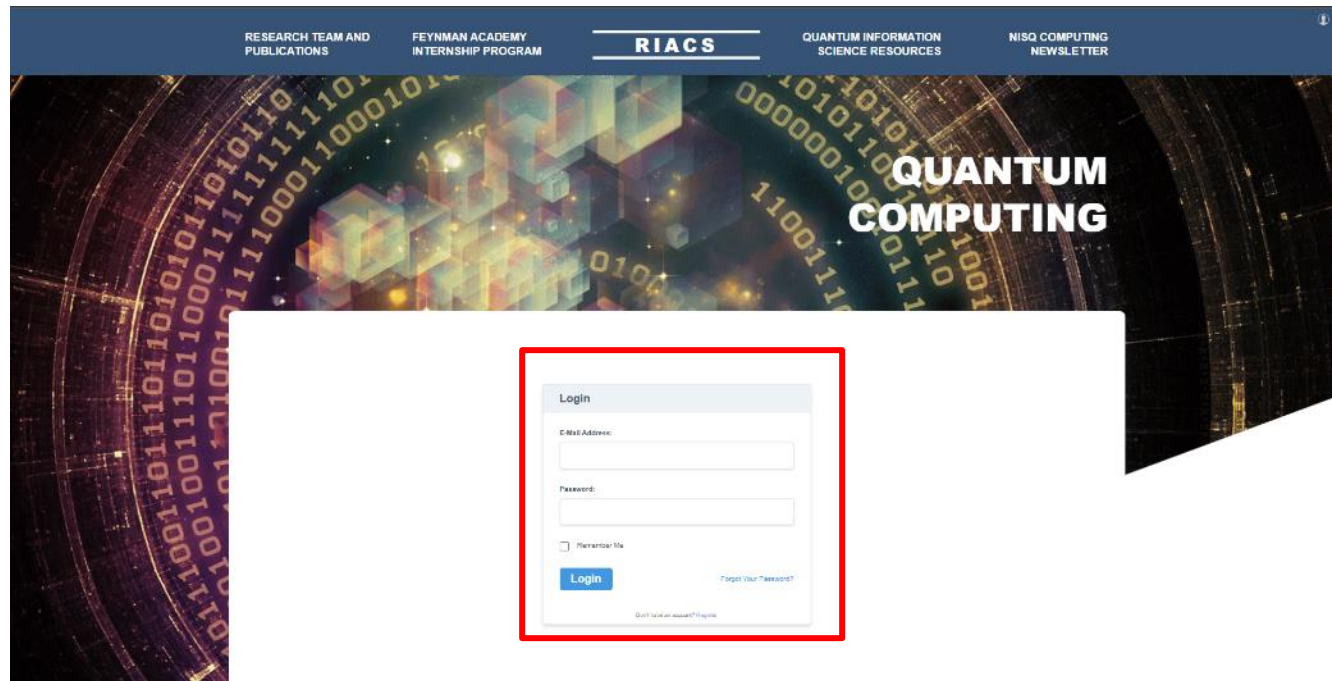


Accessing USRA resources



1. Go to <https://riacs.usra.edu/quantum/qisprogram>
2. Click on “log in”

Accessing USRA resources



3. Log in with the next credentials:
Username: AFRLguest@AFRL
Password: USRApass1

Accessing USRA resources



DARPA ONISQ Project: Scheduling Applications with Advanced Mixers (SAAM)

Universities Space Research Association (USRA) [announced](#) that DARPA has awarded the organization and its partners Rigetti Computing and the NASA Quantum Artificial Intelligence Laboratory (QuAIL) to work as a team to advance the state of art in quantum optimization. USRA, as the prime contractor of the award, will manage the collaboration.

The collaboration will focus on developing a superconducting quantum processor, hardware aware software and custom algorithms that take direct advantage of the hardware advances to solve scheduling and asset allocation problems. In addition, the team will design methods for benchmarking the hardware against classical computers to determine quantum advantage.

In particular, the work will target scheduling problems whose complexity goes beyond what has been done so far with the quantum approximate optimization algorithm (QAOA). USRA's Research Institute for Advanced Computer Science (RIACS) has been working on quantum algorithms for planning and scheduling for NASA QuAIL since 2012. RIACS as the prime contractor will manage the collaboration between NASA QuAIL and Rigetti Computing.

The grant is a part of the DARPA Optimization with Noisy Intermediate-Scale Quantum program (ONISQ). The goal of this program is to establish that quantum information processing using NISQ devices has a quantitative advantage for solving real-world combinatorial optimization problems using the QAOA method.

NSF SpecEES Project: Advancing the Wireless Spectral Frontier with Quantum-Enabled Computational Techniques (QENeTs)

This project running 2019-2021 is investigating a multitude of new communications receiver decoding algorithms that are amenable to be used in hybrid setting with NISQ quantum computers. The designed methods will be tested on real hardware and benchmarked against the best known classical approaches. In addition to spectral efficiency, the project will also consider how quantum-enabled techniques can improve the energy efficiency of massive multiple-input/multiple-output (MIMO) algorithms. More info on the [project website](#).

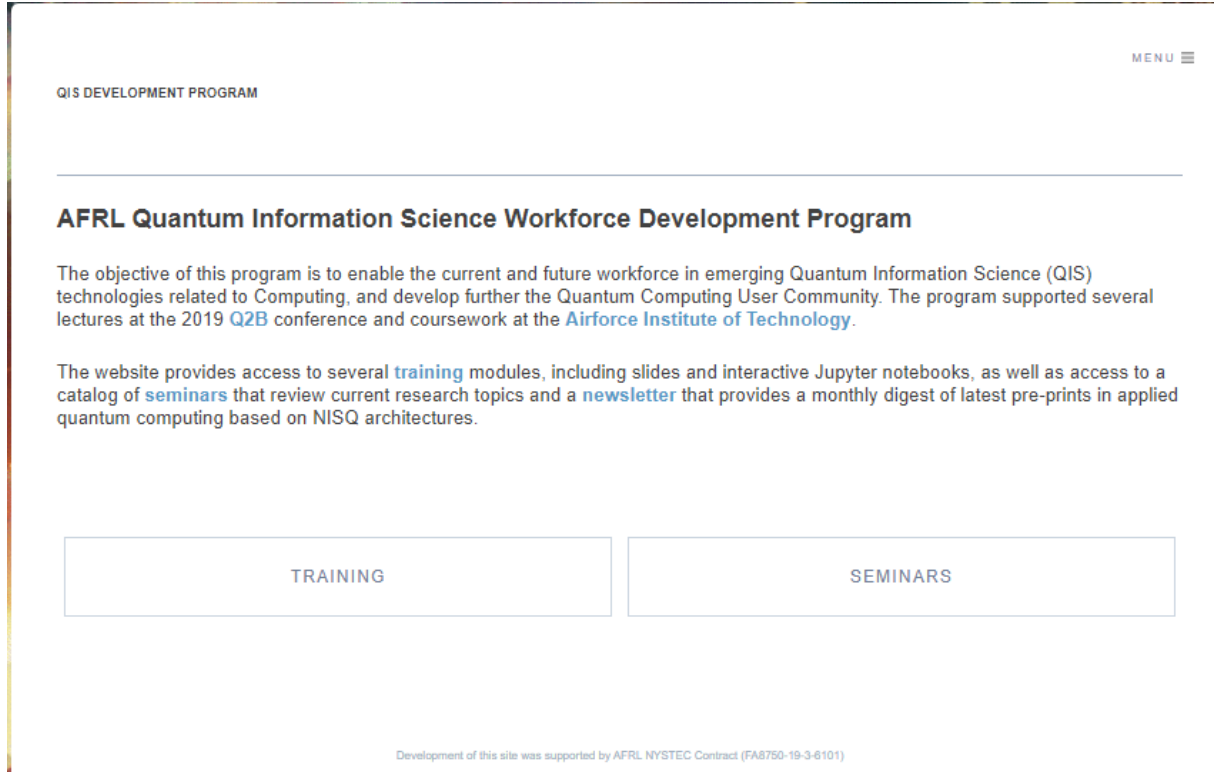
NSF Expeditions in Computing Project: Coherent Ising Machines

USRA has received a subaward from NSF, in team with Stanford, Caltech and Cornell University, to work on the prestigious 5-year program Expeditions in Computing. Collaborators include NASA QuAIL, NTT, NII and Microsoft. This Expeditions award exploits unconventional computing architectures, called Coherent Ising Machines (CIMs), to solve a class of optimization problems. CIMs provide a platform to test ideas for computer engineering in the post-Moore's Law era. Next-generation CIMs also hold great promise to drive substantial practical advances in artificial intelligence (AI) capabilities in multiple fields. In addition, the unconventional memory format used by these machines may establish a pathway towards novel quantum information technologies. More info on [NSF press release](#) and [Project Website](#).

[Program Modules](#)

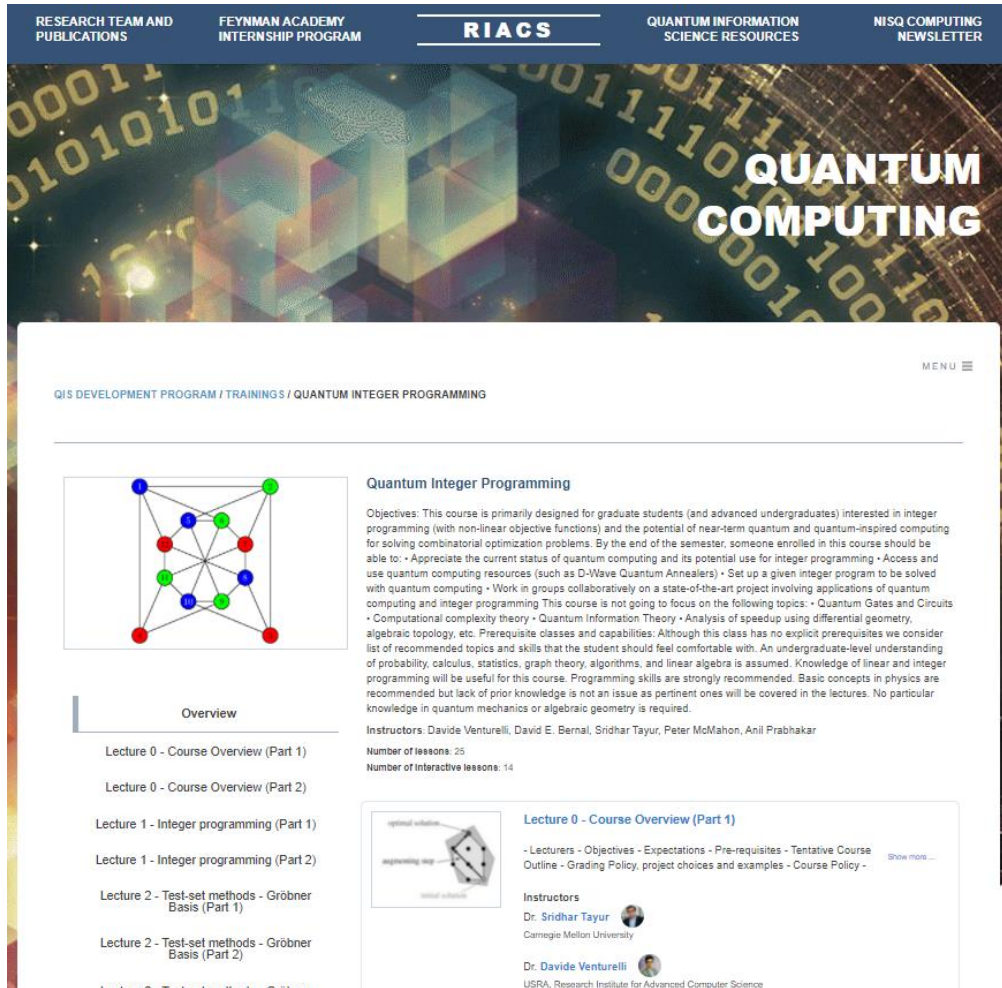
4. Go back to <https://riacs.usra.edu/quantum/qisprogram>
5. Click on Program Modules

Accessing USRA resources



There are plenty of seminars and training available to you!

Accessing USRA resources



The screenshot shows the RIACS Quantum Computing website. The header includes links for Research Team and Publications, Feynman Academy Internship Program, RIACS, Quantum Information Science Resources, and NISQ Computing Newsletter. The main banner features the text "QUANTUM COMPUTING" over a background of binary code and 3D cubes. Below the banner, the page title is "QIS DEVELOPMENT PROGRAM / TRAININGS / QUANTUM INTEGER PROGRAMMING". The main content area is titled "Quantum Integer Programming" and includes a diagram of a graph with nodes and edges. The text describes the course objectives, prerequisites, and instructors. A sidebar on the left lists the course overview and individual lectures.

Quantum Integer Programming

Objectives: This course is primarily designed for graduate students (and advanced undergraduates) interested in integer programming (with non-linear objective functions) and the potential of near-term quantum and quantum-inspired computing for solving combinatorial optimization problems. By the end of the semester, someone enrolled in this course should be able to:

- Appreciate the current status of quantum computing and its potential use for integer programming
- Access and use quantum computing resources (such as D-Wave Quantum Annealers)
- Set up a given integer program to be solved with quantum computing
- Work in groups collaboratively on a state-of-the-art project involving applications of quantum computing and integer programming

This course is not going to focus on the following topics:

- Quantum Gates and Circuits
- Computational complexity theory
- Quantum Information Theory
- Analysis of speedup using differential geometry, algebraic topology, etc.

Prerequisite classes and capabilities: Although this class has no explicit prerequisites we consider list of recommended topics and skills that the student should feel comfortable with. An undergraduate-level understanding of probability, calculus, statistics, graph theory, algorithms, and linear algebra is assumed. Knowledge of linear and integer programming will be useful for this course. Programming skills are strongly recommended. Basic concepts in physics are recommended but lack of prior knowledge is not an issue as pertinent ones will be covered in the lectures. No particular knowledge in quantum mechanics or algebraic geometry is required.

Instructors: Davide Venturelli, David E. Bernal, Sridhar Tayur, Peter McMahon, Anil Prabhakar

Number of lessons: 25
Number of interactive lessons: 14

Lecture 0 - Course Overview (Part 1)

- Lecture 0 - Course Overview (Part 2)
- Lecture 1 - Integer programming (Part 1)
- Lecture 1 - Integer programming (Part 2)
- Lecture 2 - Test-set methods - Gröbner Basis (Part 1)
- Lecture 2 - Test-set methods - Gröbner Basis (Part 2)
- Lecture 3 - Test-set methods - Gröbner

Lecture 0 - Course Overview (Part 1)

- Lecturers - Objectives - Expectations - Pre-requisites - Tentative Course Outline - Grading Policy, project choices and examples - Course Policy - [Show more...](#)

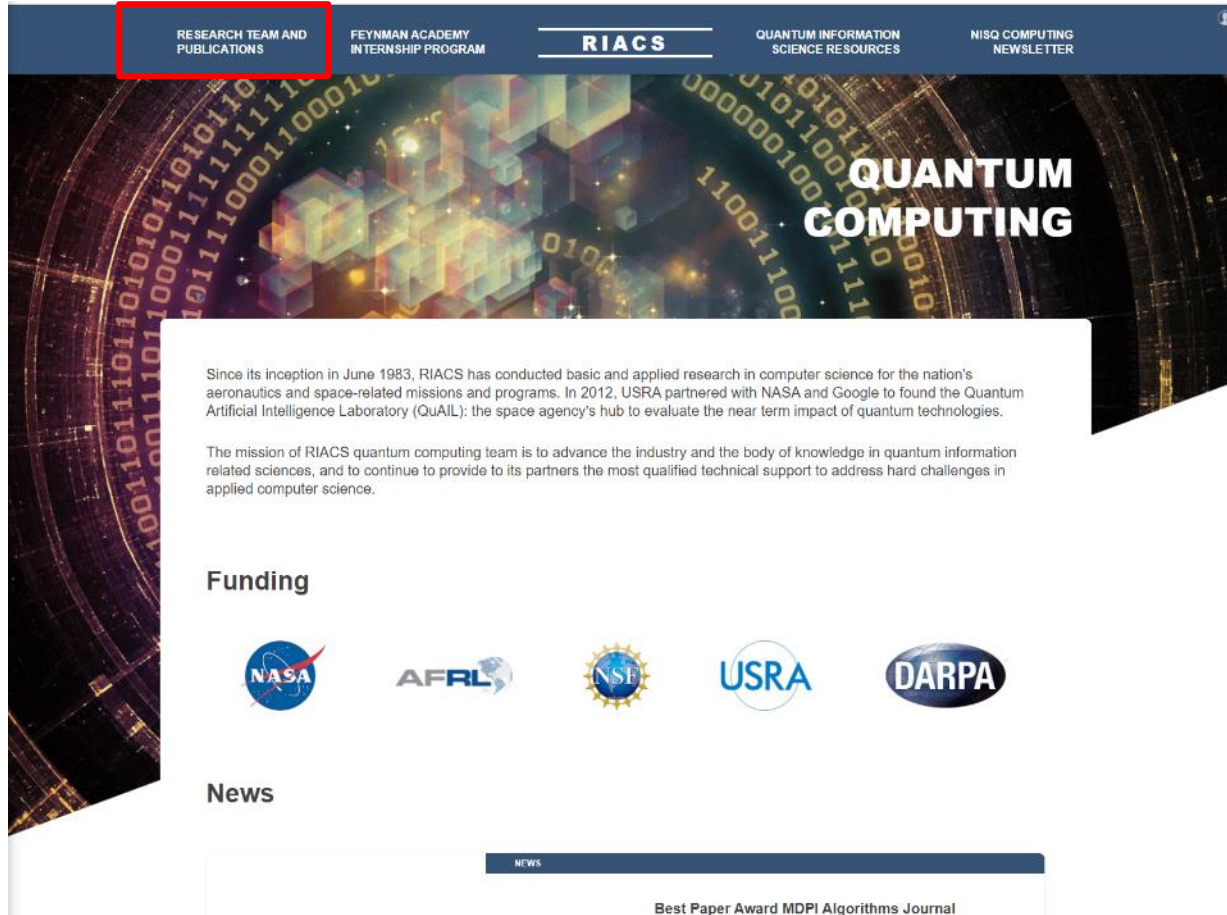
Instructors

Dr. Sridhar Tayur
Carnegie Mellon University

Dr. Davide Venturelli
USRA, Research Institute for Advanced Computer Science

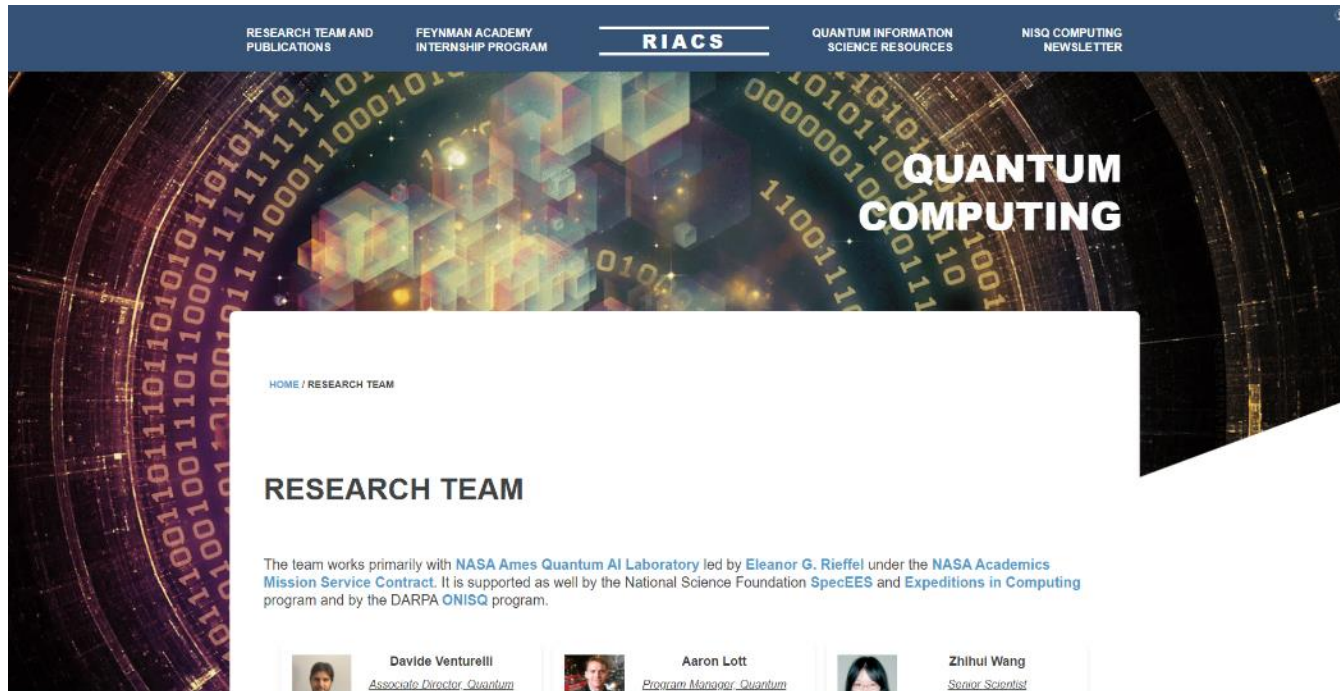
Including last years edited videos, codes, and notes!

Accessing USRA resources



Extra: Go to “Research Team and Publications”

Accessing USRA resources



Scroll down to

Quantum Integer Programming (QuIP) 47-779:
Lecture Notes

Accessing USRA resources

arXiv preprint arXiv:2103.07036, 2021-03-12 Jeffrey Marshall, Gianni Mossi, Eleanor G Rieffel

Quantum-accelerated constraint programming

arXiv preprint arXiv:2103.04502, 2021-03-08 Kyle EC Booth, Bryan O'Gorman, Jeffrey Marshall, Stuart Hadfield, Eleanor Rieffel

Entanglement across separate silicon dies in a modular superconducting qubit device

arXiv preprint arXiv:2102.13293, 2021-02-26 Alysson Gold, JP Paquette, Anna Stockklauser, Matthew J Reagor, M Sohaib Alam, Andrew Bestwick, Nicolas Didier, Ani Nersisyan, Feyza Oruc, Armin Razavi et al.

Quantum Annealing for Large MIMO Downlink Vector Perturbation Precoding

arXiv preprint arXiv:2102.12540, 2021-02-24 Srikar Kasi, Abhishek Kumar Singh, Davide Venturelli, Kyle Jamieson

Information scrambling in computationally complex quantum circuits

arXiv preprint arXiv:2101.08870, 2021-01-21 Xiao Mi, Pedram Roushan, Chris Quintana, Salvatore Mandra, Jeffrey Marshall, Charles Neill, Frank Arute, Kunal Arya, Juan Atalaya, Ryan Babbush et al.

Quantum Integer Programming (QuIP) 47-779: Lecture Notes

arXiv preprint arXiv:2012.11382, 2020-12-17 David E Bernal, Sridhar Tayur, Davide Venturelli

Quantum annealing speedup of embedded problems via suppression of Griffiths singularities

Physical Review B, 2020-12-10 Sergey Knysh, Eugeniu Plamadeala, Davide Venturelli

Classical symmetries and QAOA

arXiv preprint arXiv:2012.04713, 2020-12-08 Ruslan Shaydulin, Stuart Hadfield, Tad Hogg, Ilya Safro

Quantum algorithms with local particle number conservation: noise effects and error correction

arXiv preprint arXiv:2011.06873, 2020-11-13 Michael Streif, Martin Leib, Filip Wudarski, Eleanor Rieffel, Zhihui Wang

Augmented fidelities for single-qubit gates

Physical Review A, 2020-11-12 Filip Wudarski, Jeffrey Marshall, Andre Petukhov, Eleanor Rieffel

Click on

Quantum Integer Programming (QuIP) 47-779:
Lecture Notes

Accessing USRA resources

Cornell University

arXiv.org > quant-ph > arXiv:2012.11382

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Quantum Physics

[Submitted on 17 Dec 2020 (v1), last revised 11 Jan 2021 (this version, v2)]

Quantum Integer Programming (QIP) 47-779: Lecture Notes

David E. Bernal, Sridhar Tayur, Davide Venturelli

This lecture series on Quantum Integer Programming (QIP) — created by Professor Sridhar Tayur, David E. Bernal, and Dr. Davide Venturelli, a collaboration between CMU and USRA, with the support from Amazon Braket during Fall 2020 — is intended for students and researchers interested in Integer Programming and the potential of near term quantum and quantum-inspired computing in solving optimization problems. Originally created for Tepper School of Business course 47-779 (at CMU), these were also used for the course IDS640 (at IIT-Madras, by Professors Anil Prabhakar and Prathiba Mandayam) whose students (listed at the beginning of each lecture) were scribes. Dr. Vikeesh Siddhu, post-doc in CMU Quantum Computing Group, assisted during the lectures, student projects, and with proof-reading this scribe. Through these lectures one will learn to formulate a problem and map it to a Quadratic Unconstrained Binary Optimization (QUBO) problem, understand various mapping and techniques like the Ising model, Grover Augmented Multispeed Algorithm (GAMA), Simulated or Quantum Annealing and QAOA, and ideas on how to solve these Integer problems using these quantum and classical methods.

Comments: The course website (with lecture videos and Google Colab notebooks): <https://bernalde.github.io/QIP/>

Subjects: Quantum Physics (quant-ph)

Cite as: arXiv:2012.11382 [quant-ph]

(or [arXiv:2012.11382v2](https://arxiv.org/abs/2012.11382v2) [quant-ph] for this version)

Submission history

From: David E. Bernal Bernal [view email]

[v1] Thu 17 Dec 2020 19:56:06 UTC (4,180 KB)

[v2] Mon 11 Jan 2021 21:29:49 UTC (4,180 KB)

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arXiv:2012.11382v2 [quant-ph] 11 Jan 2021

Quantum Integer Programming (QIP) 47-779: Lecture Notes

David E. Bernal, Sridhar Tayur, Davide Venturelli

Fall 2020

Abstract

This lecture series on Quantum Integer Programming (QIP) — created by Professor Sridhar Tayur, David E. Bernal and Dr. Davide Venturelli, a collaboration between CMU and USRA, with the support from Amazon Braket during Fall 2020 — is intended for students and researchers interested in Integer Programming and the potential of near term quantum and quantum inspired computing in solving optimization problems.

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The course website (with lecture videos and colab notebooks): <https://bernalde.github.io/QIP/>

Keywords: Ising model, Integer Programming, Computational Algebraic Geometry, Grover Basis, Quantum Annealing, Simulated Annealing, Combinatorial Optimization, Graph coloring, discrete nonlinear optimization.

TEPPER

You will see the arXiv preprint with the scribed notes from 2020 Quantum Integer Programming.