Task 1

1 - Explain the difference between contextualization and orchestration processes.

Contextualization in Docker refers to the process of defining the environment of a Docker container. This is done using a Dockerfile, which contains a set of instructions to build an image. On the other hand, orchestration is the process of managing multiple containers, often across multiple machines. It involves tasks like scaling the application, ensuring fault tolerance, and managing networking between containers.

2 - Explain the followings commands and concepts:

i) Contents of the docker file used in this task.

```
FROM ubuntu:22.04
RUN apt-get update
RUN apt-get -y upgrade
RUN apt-get install sl
ENV PATH="${PATH}:/usr/games/"
CMD ["echo", "Data Engineering-I."]
```

The Dockerfile used in this task is a text file that contains all the commands needed to build a Docker image. It starts from a base Ubuntu 22.04 image, updates the system, installs the `sl` package (which displays animations aimed to correct users who accidentally enter `sl` instead of `ls`), and sets an environment variable to include `/usr/games/` in the PATH. It runs the `echo` command to print the message "Data Engineering-I." to the console when container starts.

ii) Explain the command

```
# docker run -it mycontainer/first:v1 bash
```

- This command starts a new container from the `mycontainer/first:v1` image in interactive mode and runs the 'bash' command in it.

iii) Show the output and explain the following commands:

```
# docker ps
```

```
ubuntu@samir-mehdiyev-a4:~$ docker ps
CONTAINER ID   IMAGE     COMMAND   CREATED   STATUS    PORTS     NAMES
```

It lists all running Docker containers.

```
# docker images
```

```
ubuntu@samir-mehdiyev-a4:~$ docker images
REPOSITORY          TAG       IMAGE ID       CREATED          SIZE
mycontainer/first   v1        30fe335283a9   4 minutes ago    136MB
ubuntu              22.04     3db8720ecbf5   2 weeks ago      77.9MB
```

It lists all Docker images on the host.

```
# docker stats
CONTAINER ID   NAME      CPU %     MEM USAGE / LIMIT   MEM %     NET I/O   BLOCK I/O   PI
DS
```

It displays a live stream of containers resource usage statistics.

3–What is the difference between `docker run`, `docker exec` and `docker build` commands?

- `docker run` creates a new container and starts it.
- `docker exec` runs a command in a running container.
- `docker build` builds an image from a Dockerfile.

4 - Create an account on DockerHub and upload your newly built container to your DockerHub area. (Watch the UI and think: is it uploading the entire image, or just your changes? How is this advantageous?) Briefly explain how DockerHub is used. Make your container publicly available and report the name of your publicly available container.

DockerHub is a cloud-based registry service that allows you to link to code repositories, build your images and test them, stores manually pushed images, and links to Docker Cloud so you can deploy images to your hosts. When you push an image to DockerHub, it uses layering to ensure that only the layers that have changed are pushed, saving bandwidth and time.
My container: samirmehd1yev/samir_a4_1:v1

5 - Explain the difference between `docker build` and `docker-compose` commands.

The `docker build` command is used to build Docker images from a Dockerfile. It allows you to specify the context (the directory containing the Dockerfile) and tag the resulting image with a name and optionally a version.
On the other hand, the `docker-compose` command is used to define and run multi-container Docker applications. It uses a YAML file (named **docker-compose.yml**) to specify the services, networks, and volumes required for your application. It can build, start, stop, and manage multiple containers as a single application stack.

Task 2

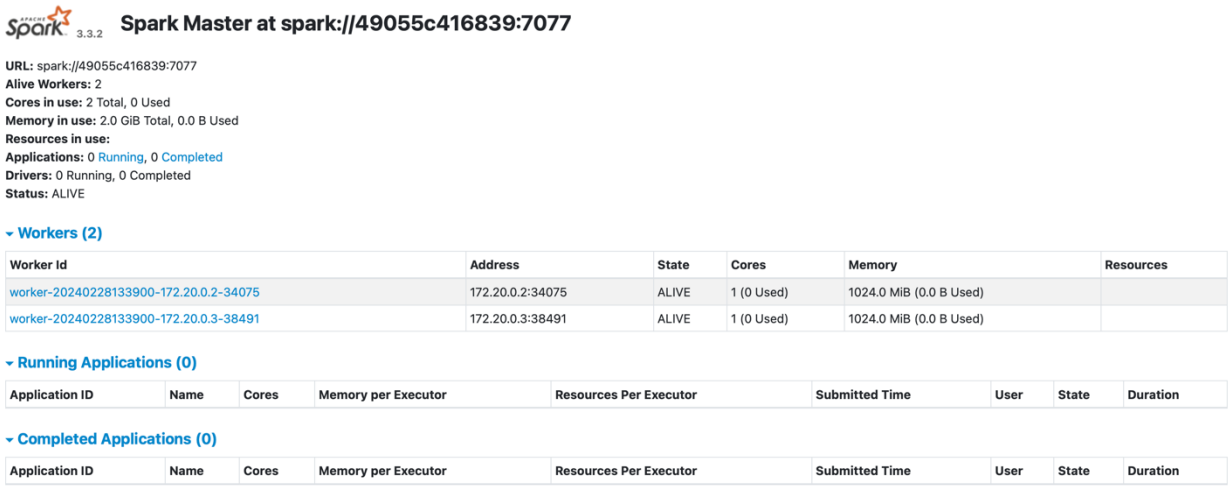
1 – Explain your `docker-compose` configuration file.

```yaml
version: '3.8'
services:
  spark-master:
    image: bitnami/spark:3.3.2
    environment:
      - SPARK_MODE=master
    ports:
      - '8080:8080'
  spark-worker-1:
    image: bitnami/spark:3.3.2
    environment:
      - SPARK_MODE=worker
      - SPARK_MASTER_URL=spark://spark-master:7077
  spark-worker-2:
    image: bitnami/spark:3.3.2
    environment:
      - SPARK_MODE=worker
      - SPARK_MASTER_URL=spark://spark-master:7077
```

The Docker Compose configuration file is a YAML file that defines services, networks, and volumes. Each service represents a container that is part of your application. In the context of a Spark cluster:

- The `version` field specifies the version of Docker Compose file format to be used.
- Under `services`, three services are defined: `spark-master`, `spark-worker-1`, and `spark-worker-2`. Each service uses the `bitnami/spark:3.3.2` Docker image which is the most popular spark image in the docker hub.
- The `spark-master` service runs in `master` mode, as specified by the `SPARK_MODE=master` environment variable.
- The `spark-worker-1` and `spark-worker-2` services run in `worker` mode, as specified by the `SPARK_MODE=worker` environment variable. They connect to the master node via the `SPARK_MASTER_URL=spark://spark-master:7077` environment variable.
- The master node's web UI is accessible on port 8080 of the host machine, as specified by the `ports:` configuration.

Here is the web UI of final result, it is accessible via floating ip of vm on port 8080, or in local via localhost:8080.



2 – What is the format of the `docker-compose` compatible configuration file?
The Docker Compose configuration file is written in YAML (YAML Ain't Markup Language). It starts with a version number, followed by services, networks, and volumes. Each service represents a container and has its own configuration such as build context, environment variables, ports, volumes, etc.

3 - What are the limitations of `docker-compose`?
While Docker Compose is a powerful tool, it has some limitations:

- It's primarily designed for development and testing environments. For production environments, tools like Docker Swarm or Kubernetes are more suitable.
- Docker Compose does not support auto-scaling of services.
- It does not provide a built-in mechanism for rolling updates.
- Docker Compose runs on a single host. If you need to orchestrate containers over multiple hosts, you'll need a tool like Docker Swarm or Kubernetes.
- It does not have built-in service discovery. Services communicate with each other through links or shared networks, but there's no DNS-based service discovery like in Docker Swarm or Kubernetes.

Task 3

Write a short essay on the role of runtime orchestration and contextualization for large scale distributed applications. Briefly discuss the features and design philosophy of at least four relevant frameworks. In Task 2, you have orchestrated a multi-container Spark cluster using `docker-compose`. Discuss how the features of frameworks like Kubernetes and Docker Swarm can improve your current solution for providing a Spark cluster. The expected length of the easy will be one A4 page 11 pt Arial.

The increasing complexity of large-scale distributed applications necessitates robust solutions for runtime orchestration and contextualization. Runtime orchestration automates the complex processes of deploying, scaling, and managing containerized applications across diverse infrastructure environments. Contextualization adds intelligence by dynamically adapting configuration, monitoring, and deployment strategies based on the application's specific needs, environmental factors, and user-provided data. Here is the key orchestration frameworks and their design philosophies:

1. **Docker Compose:** A powerful tool for defining and running multi-container applications, Docker Compose is often a cornerstone of distributed application development. Its focus on clear YAML-based configuration and modeling inter-container dependencies simplifies the local development and testing of distributed systems before deployment to more complex environments.

2. **Kubernetes:** Designed for vast, production-grade deployments, Kubernetes emphasizes comprehensive resource management, sophisticated service discovery, and robust self-healing capabilities. Its declarative configuration model, driven by the concept of desired state, promotes infrastructure as code and streamlines continuous delivery practices.

3. **Docker Swarm:** Integrated within the Docker ecosystem, Swarm prioritizes simplicity and operational ease. It offers core orchestration features like service discovery, load balancing, and scaling, making it particularly well-suited for smaller-scale deployments or teams seeking a streamlined, Docker-centric experience.

4. **Apache Mesos:** A mature and battle-tested cluster manager, Mesos excels at fine-grained resource allocation and a flexible two-level scheduling mechanism. This empowers it to handle diverse workloads, including big data frameworks, microservices, and traditional applications. Frameworks like Marathon or Chronos can be built on top of Mesos for customized orchestration.

While Docker Compose effectively establishes a functional multi-container Spark cluster as demonstrated in Task 2, production scenarios often demand the advanced capabilities of frameworks like Kubernetes and Docker Swarm:

- **Resilience and Fault Tolerance:** Both Kubernetes and Swarm introduce robust self-healing mechanisms. They automatically detect and restart failed containers or even entire nodes, safeguarding the Spark cluster's availability in the face of unexpected issues.
- **Dynamic Autoscaling:** To optimize resource usage and ensure performance under load, these frameworks can automatically add or remove Spark worker nodes based on real-time demand. This avoids both underprovisioning (which slows down jobs) and overprovisioning (which wastes resources).
- **Streamlined Operations and Deployment:** The declarative approaches of Kubernetes and Swarm drastically simplify cluster updates, rollbacks, and versioning. This aligns well with continuous delivery pipelines, promoting greater agility in deploying new Spark features or configurations.
- **Centralized Monitoring and Observability:** These platforms often integrate monitoring and logging solutions, providing a holistic view of the Spark cluster's health, resource usage, and potential bottlenecks. This empowers administrators to proactively address issues and optimize performance.

Runtime orchestration and contextualization are indispensable for managing the complexity of modern distributed applications at scale. While Docker Compose serves as an excellent tool for development and testing, frameworks like Kubernetes and Docker Swarm provide the advanced features necessary for resilient, scalable, and efficiently managed production deployments. By harnessing the power of these orchestration platforms, organizations can ensure the smooth and efficient operation of their distributed systems, even under demanding workloads.