

# 1 FreeBSD Kernel Development Setup

FreeBSD is an open source, Unix-like, operating system that has been actively developed since 1993. It is provided in several different formats but for our purposes we will set it up within a virtual machine rather than on actual hardware, as modern systems, including laptops, are fast enough to make kernel development and debugging practical in these environments.

There are several virtualization technologies available but we will be using QEMU [qemu.org](https://qemu.org) because it is fast, cross platform, and open source. In our example we will use a graphical system that wraps QEMU, UTM, which is available for MacOS.

When setting up our virtual machine we have several choices to make:

**Architecture** x86 or Apple Silicon (M1, M2, M3 etc.)

**Number of CPUs** At least 2, but usually 1/4 to 1/2 of those available on the system.

**RAM Size** 1G of RAM per CPU selected above

**Hard Disk Size** At least 8G but 16 or 32 is better.

Before starting the installation you will need to download a suitable image from the FreeBSD website [www.freebsd.org](https://www.freebsd.org). You *must* pick an installation image that matched the architecture of your actual hardware, such as the laptop you are running the virtualization on. While QEMU can emulate many architectures you want to be using virtualization, and not emulation. The Downloads page for FreeBSD lists releases in order from most recent to least recently supported. You should always start with the latest release. From the *Installer* column pick the appropriate architecture for your system. If you are using an Intel based system then you will want to select amd64 and if you are using Apple Silicon then select aarch64. You will be presented with a list of images, compressed in xz format, or uncompressed. Select the compressed image of disc1, for example FreeBSD-13.2-RELEASE-arm64-aarch64-disc1.iso.xz. Once the download is complete, uncompress the image with the `unxz` command. You now have an ISO image that can be used by QEMU to install the operating system and its associated tools.

Once the system has rebooted, disconnect the CD/DVD ROM ISO from the Virtual Machine, otherwise the install process will start again. If you wind up at the installer prompt a second time, disconnect the CD/DVD ROM and then reboot the virtual machine again.

## 1.1 Creating a case sensitive volume.

Most Unix-like operating systems are built on case sensitive filesystems. The filesystems on macOS are case preserving but not case sensitive by default and this will be a problem if you try to clone the FreeBSD source repository onto the default volume. With the Disk Utility you can create a case sensitive volume to store your repositories.

Once you have your code cloned into the new volume you can mount the volume over NFS into the FreeBSD VM. You will need to log into the virtual machine to see which IPv4 address it has been assigned. In Figure 55 we see that our VM has an IP address of 192.168.68.2, which means that the macOS host is 192.168.68.1, note this down for later.

On the macOS host we set up a file called `/etc/exports` as shown in Figure 56

We next make sure the NFS daemon is running on the mac host.

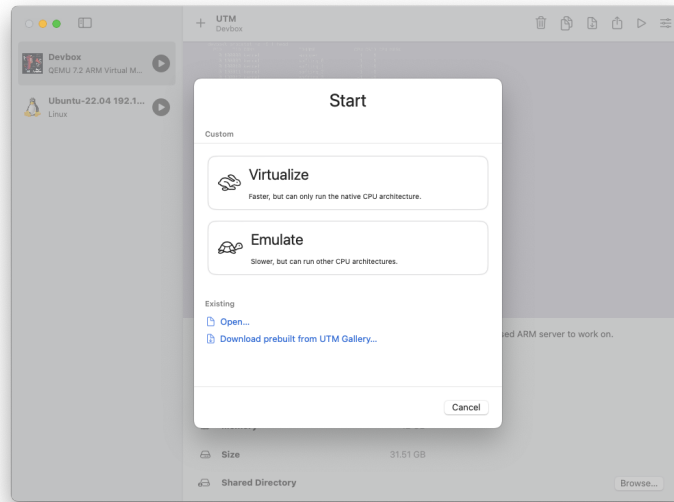


Figure 1: Select Virtualize

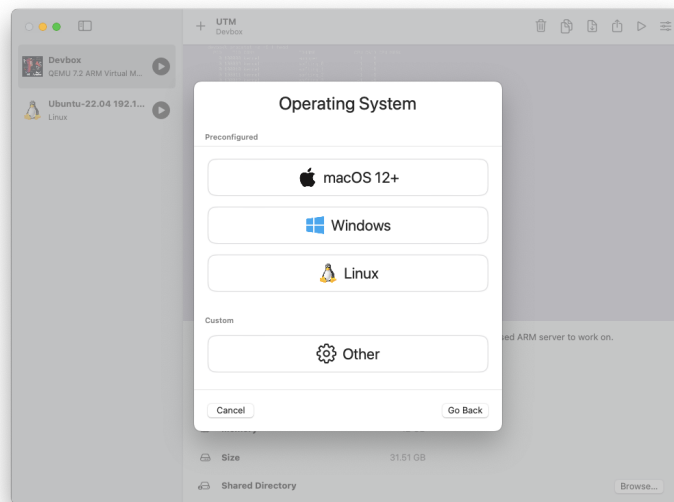


Figure 2: Select Other

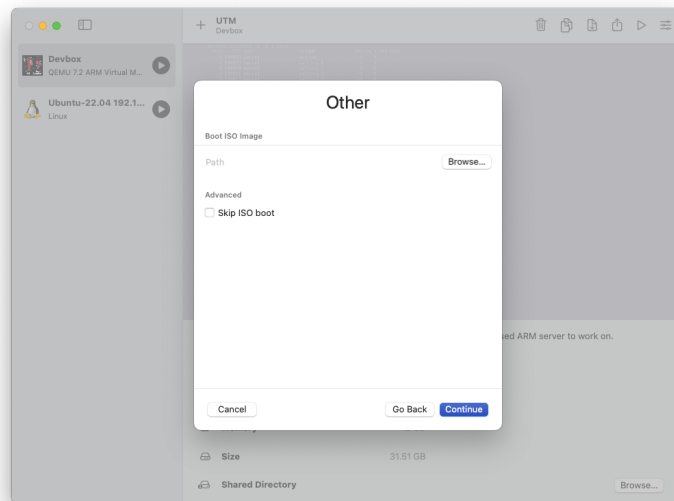


Figure 3: Browe to the ISO

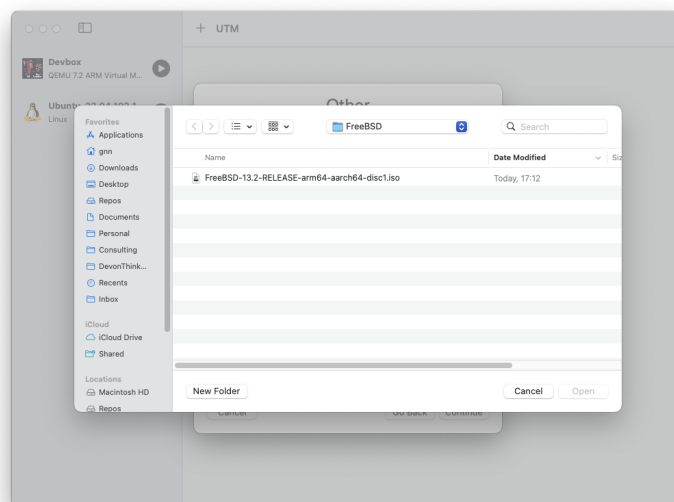


Figure 4: Select the ISO

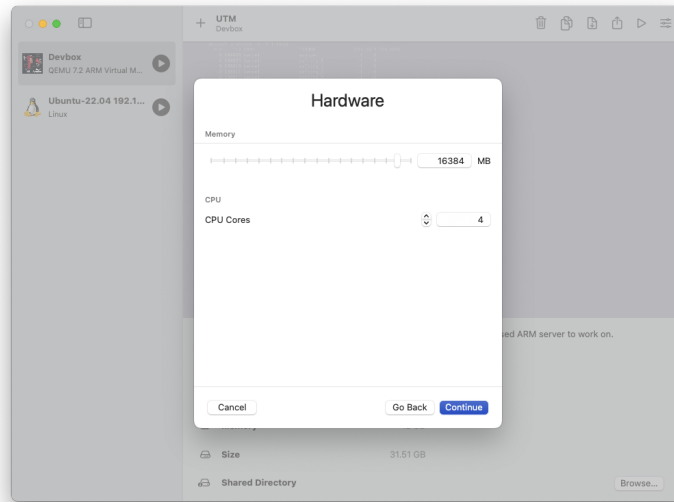


Figure 5: Select 16G of RAM and 4 cores

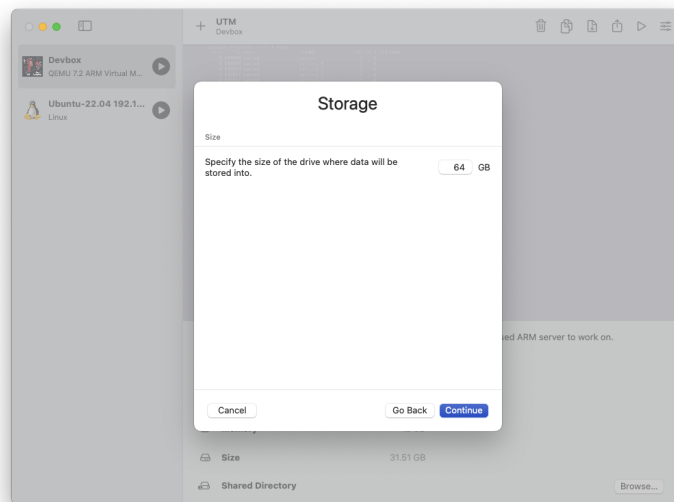


Figure 6: Select the default 64G disk size

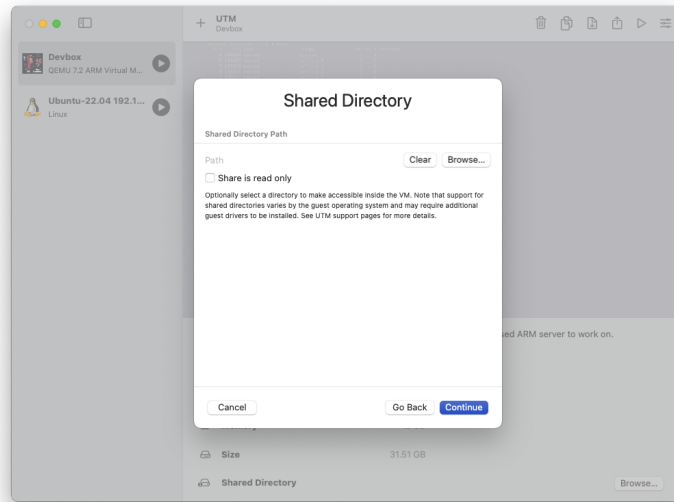


Figure 7: Do not select a Shared Directory

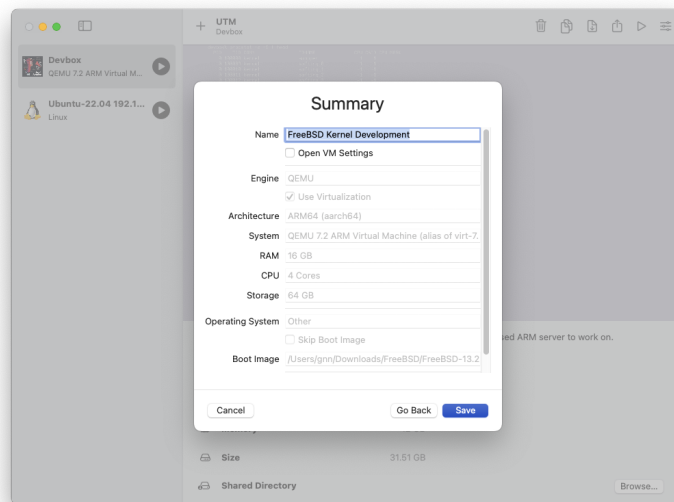


Figure 8: Name your Virtual Machine

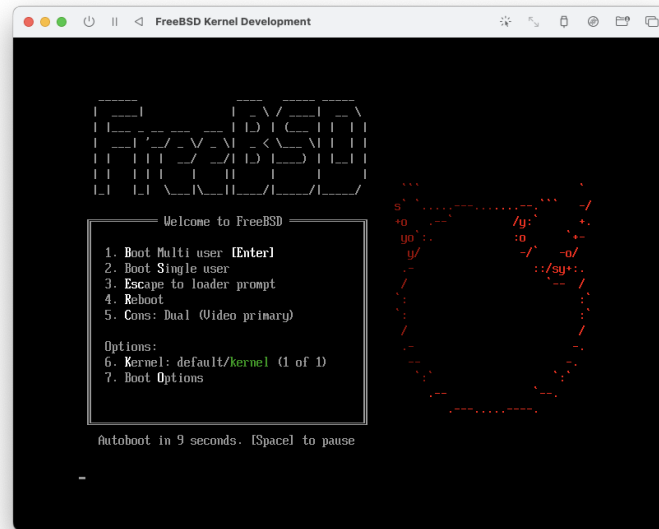


Figure 9: FreeBSD Installer Boot Screen

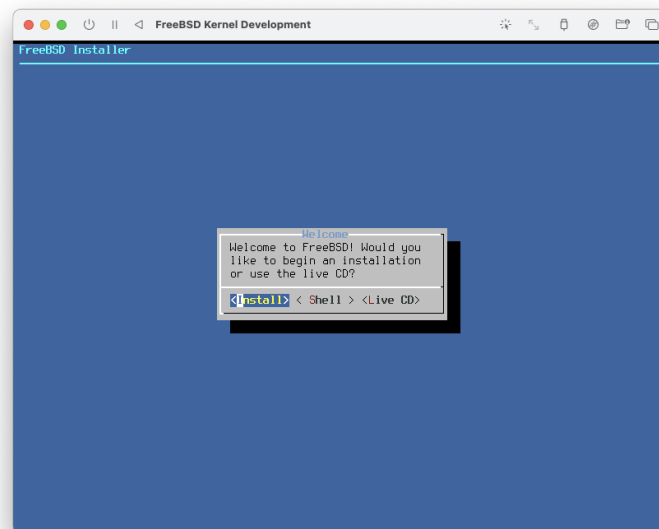


Figure 10: Select the Install option.

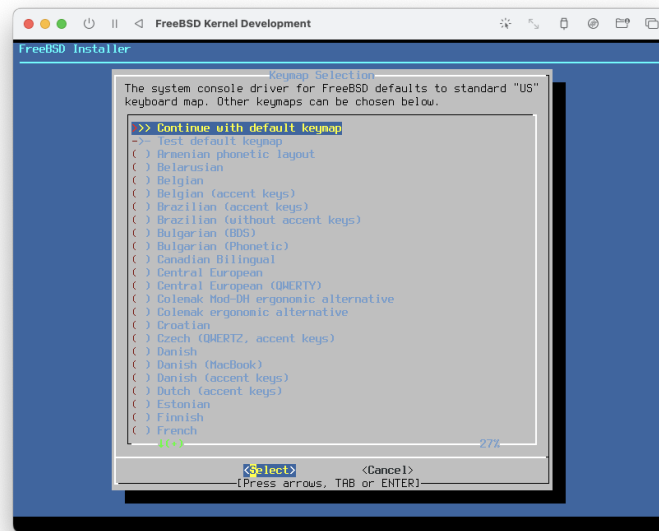


Figure 11: Continued with the default keymap

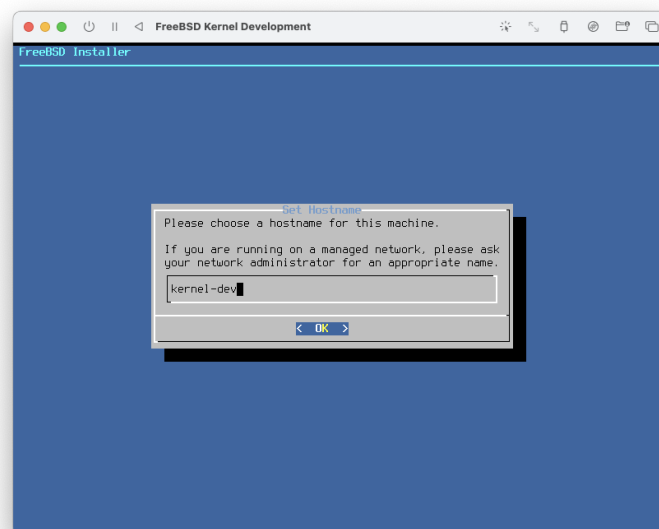


Figure 12: Name your host: kernel-dev

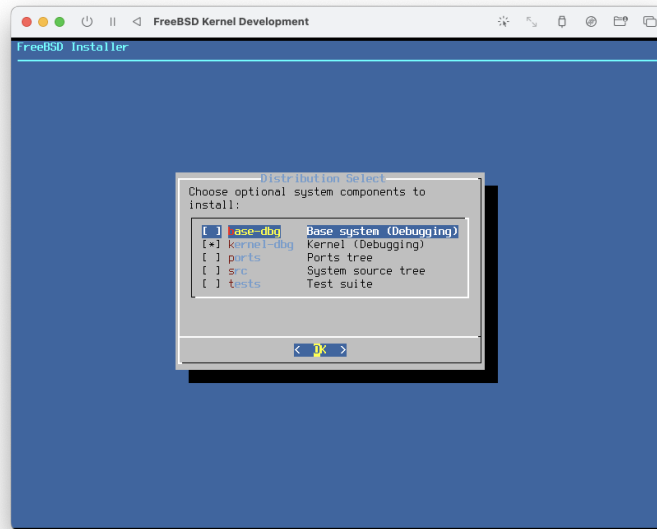


Figure 13: Go with the defaults

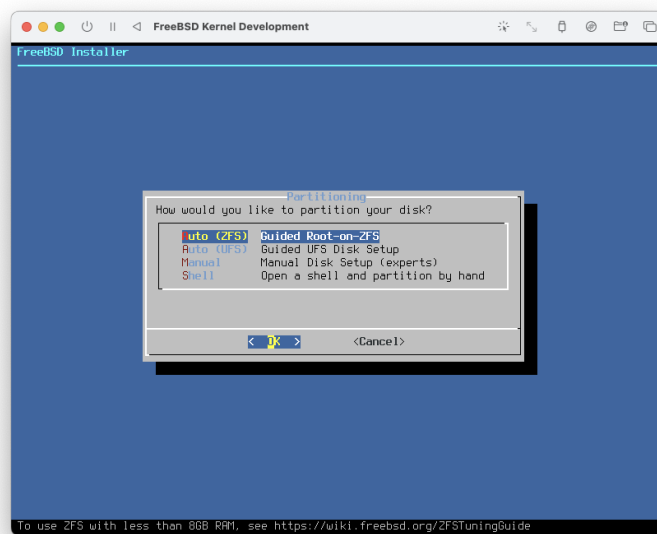


Figure 14: Select ZFS as your filesystem



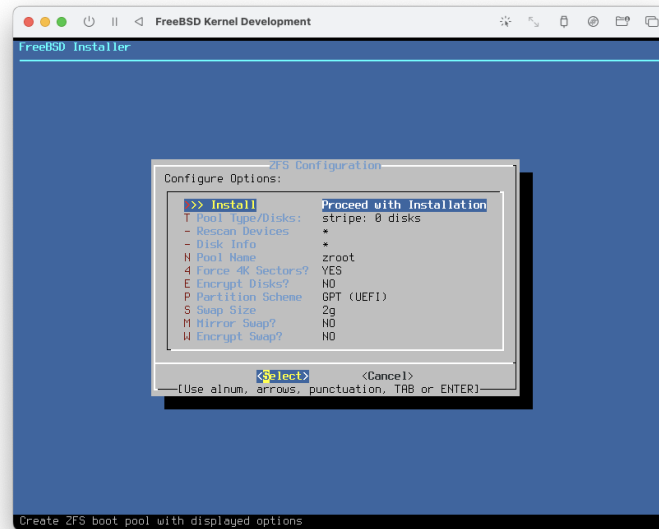


Figure 15: The ZFS default are sufficient.

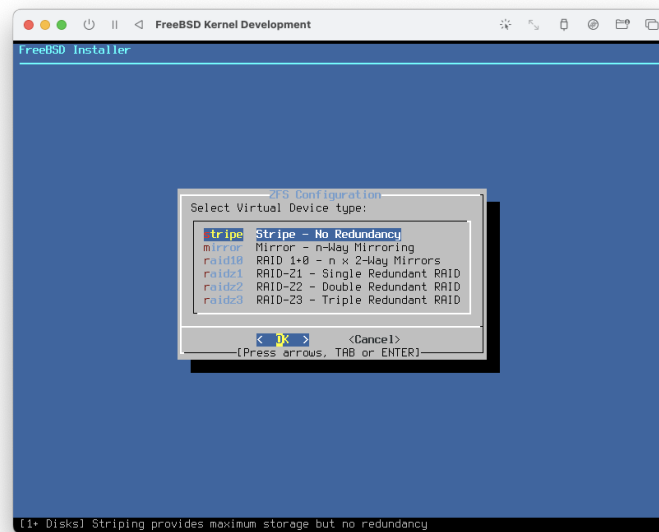


Figure 16: Stripe is all you can do with one disk

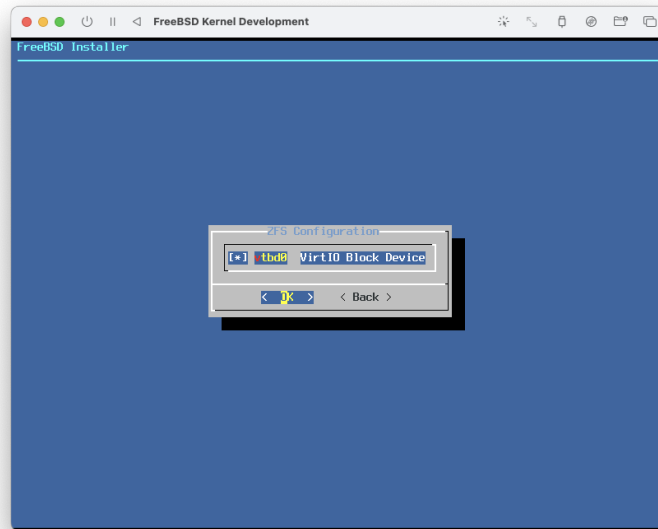


Figure 17: There is only one disk, select it.

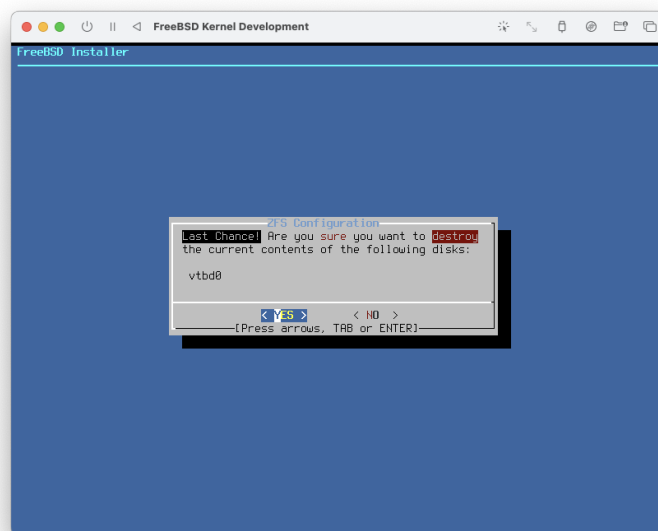


Figure 18: Last chance, select YES.

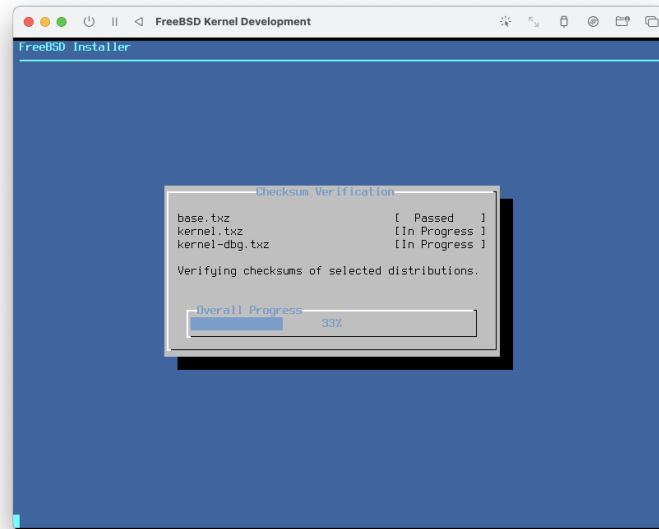


Figure 19: Installing

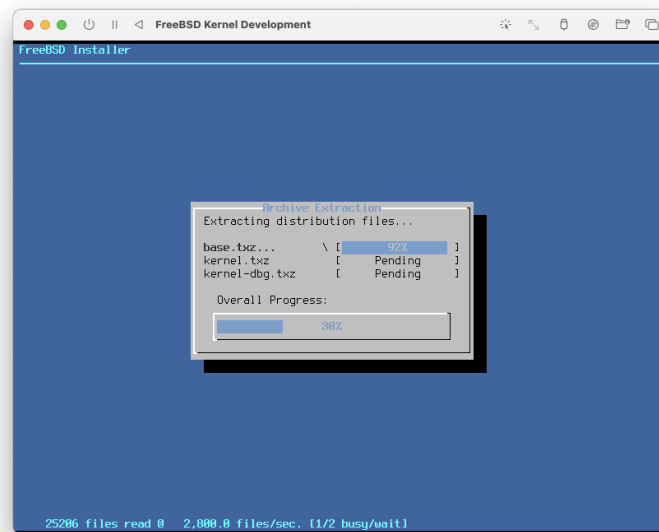


Figure 20: Extracting files

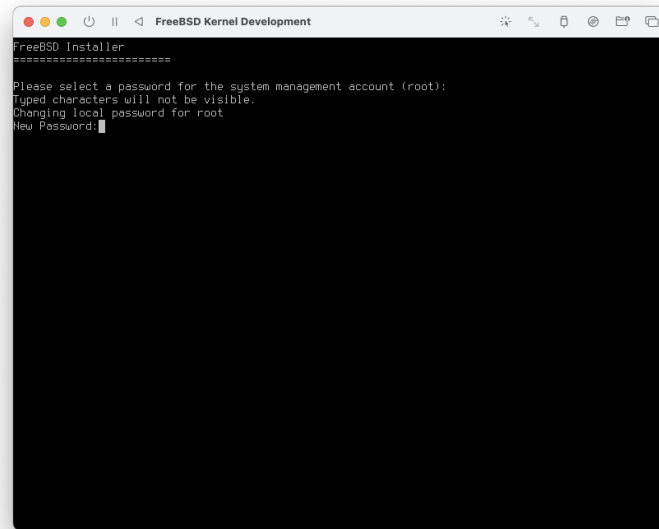


Figure 21: Select a root password

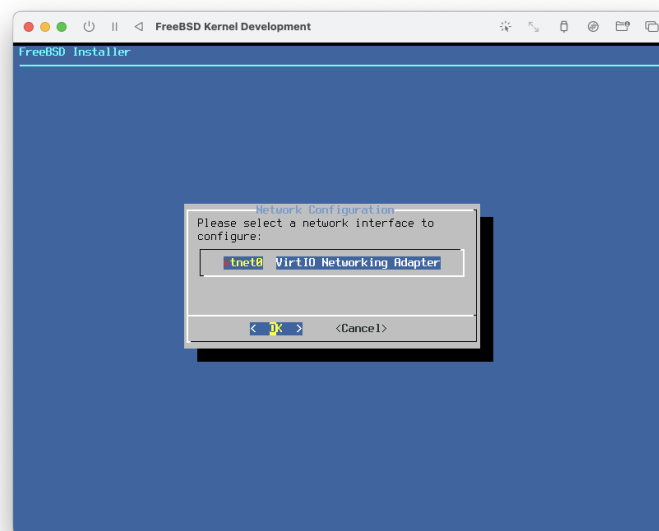


Figure 22: There is only one network device

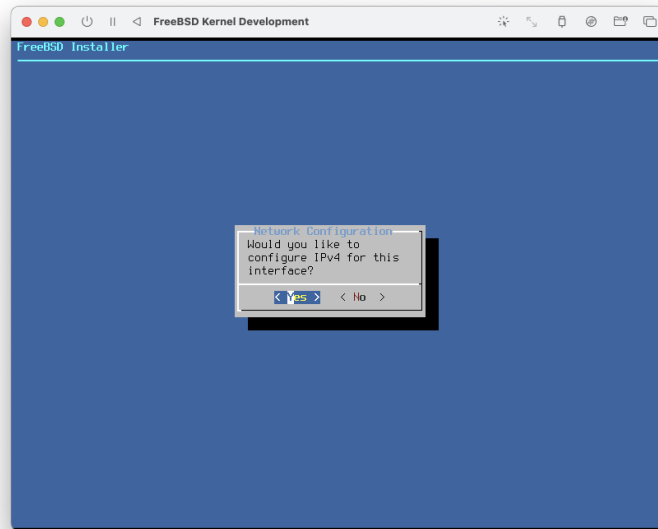


Figure 23: Use IPv4

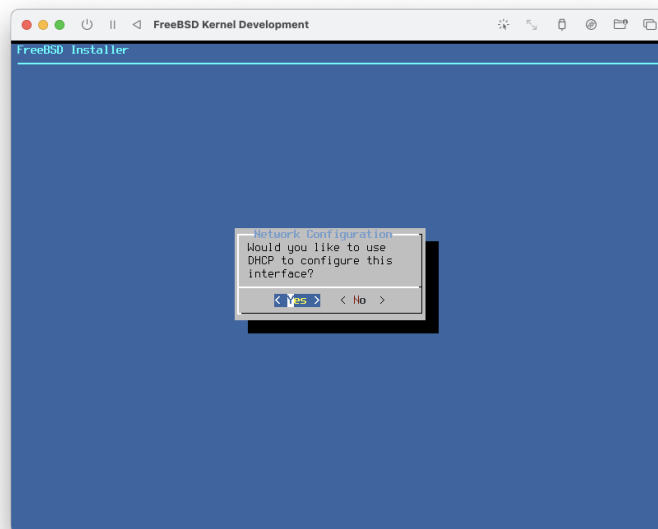


Figure 24: Use DHCP for IPv4

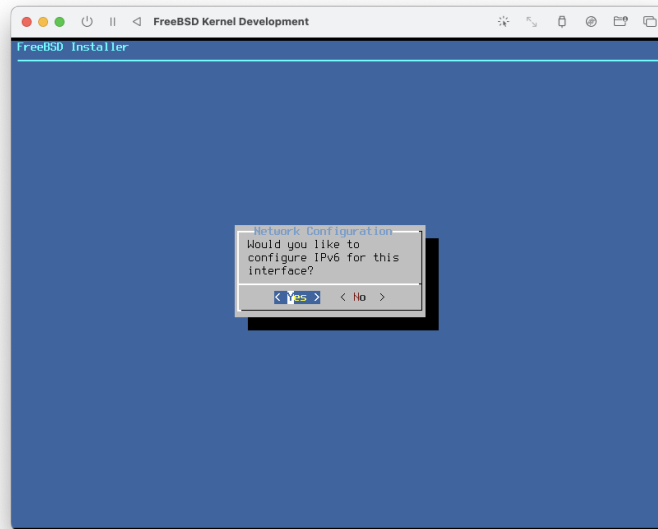


Figure 25: Do not configure IPv6

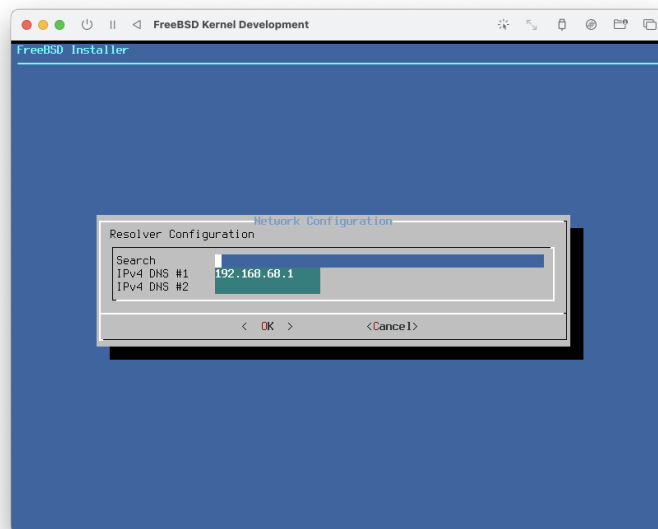


Figure 26: Accept the default DNS resolver settings

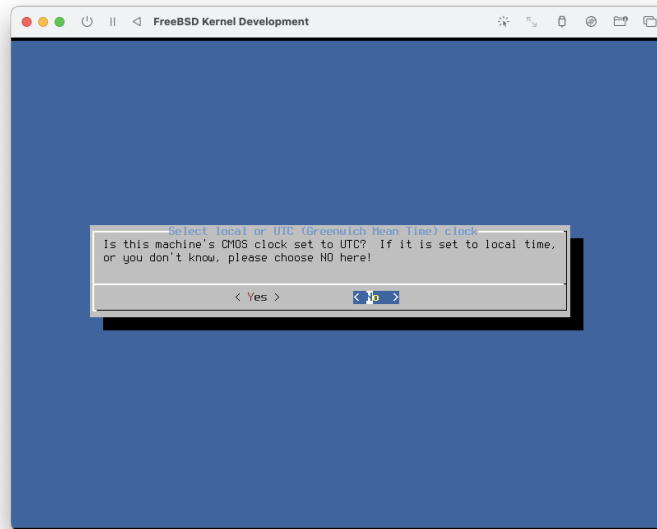


Figure 27: Start setting the clock, select NO

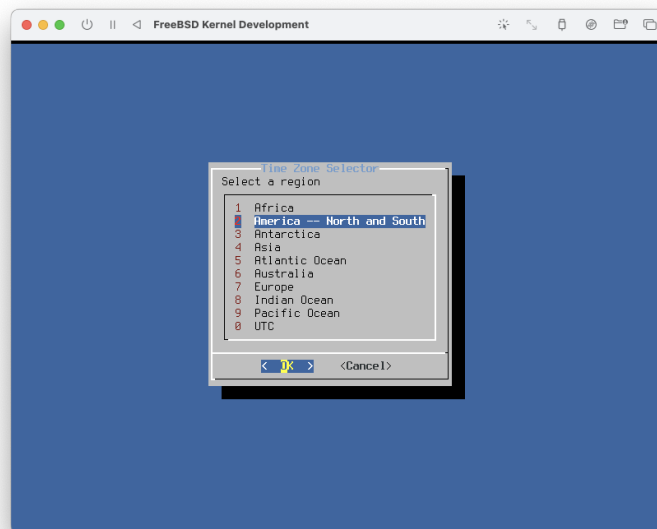


Figure 28: We're setting this up in America

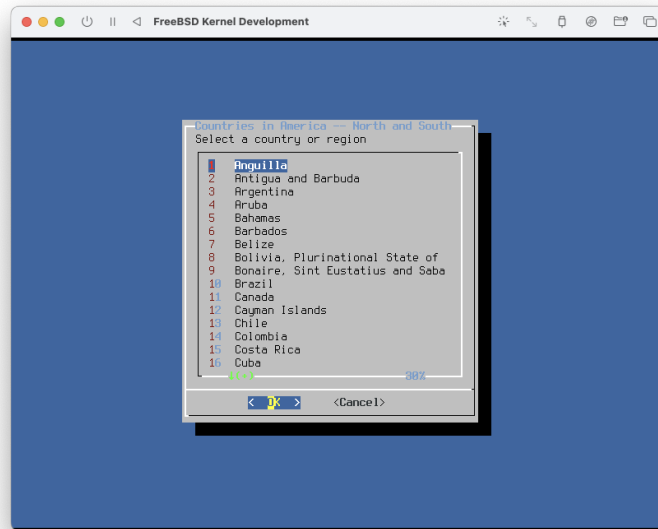


Figure 29: Scroll down to the correct country

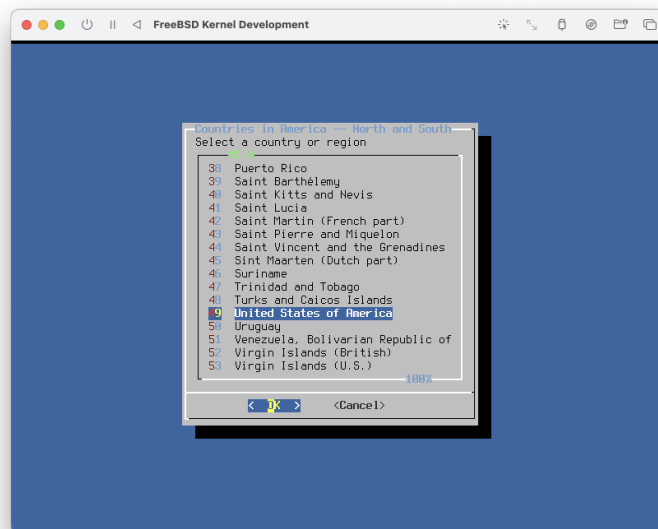


Figure 30: Select United States of America



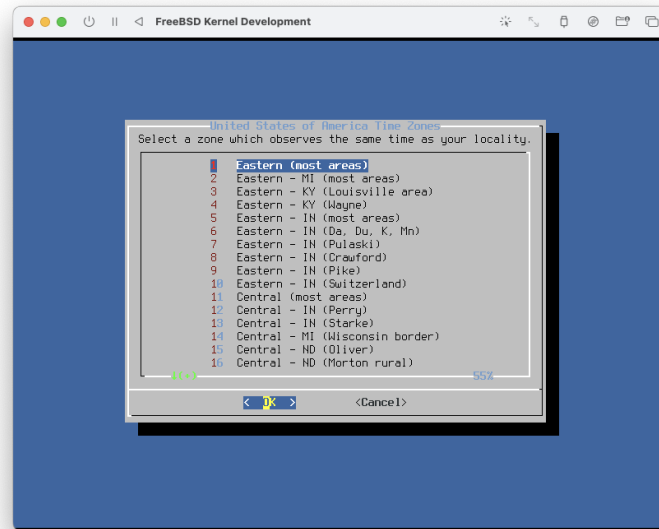


Figure 31: We are in the Eastern timezone

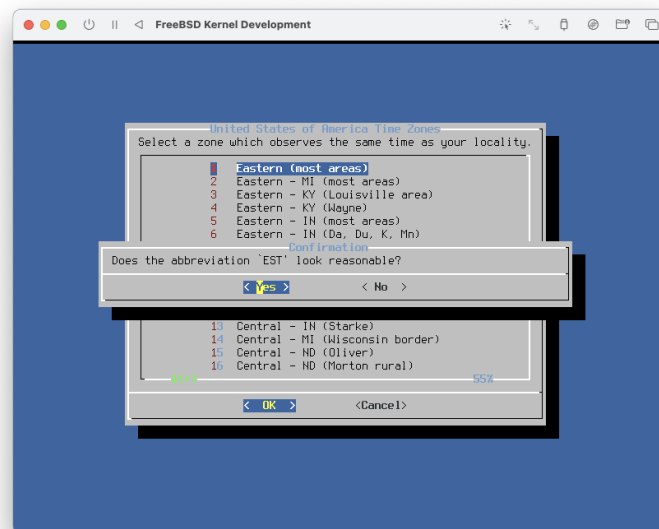


Figure 32: Accept EST

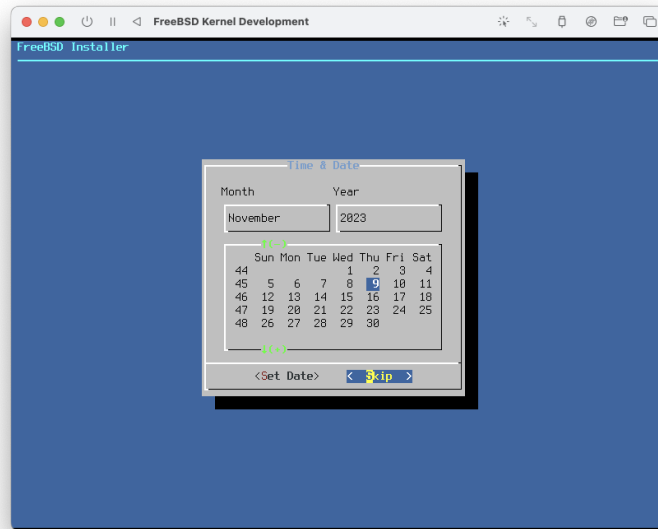


Figure 33: Skip setting the date (ntp will handle this on first boot)

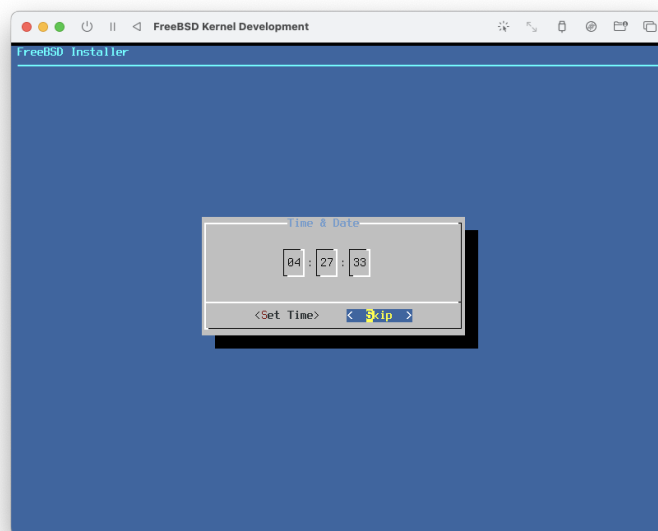


Figure 34: Skip setting the time (ntp will handle this on first boot)

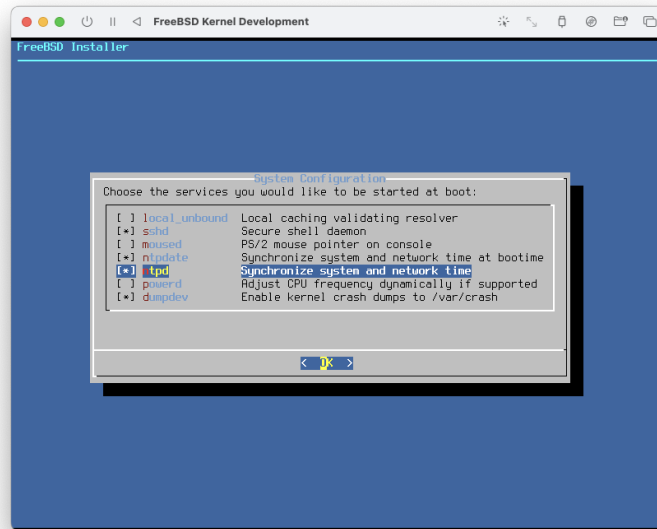


Figure 35: Select both ntpdate and ntpd

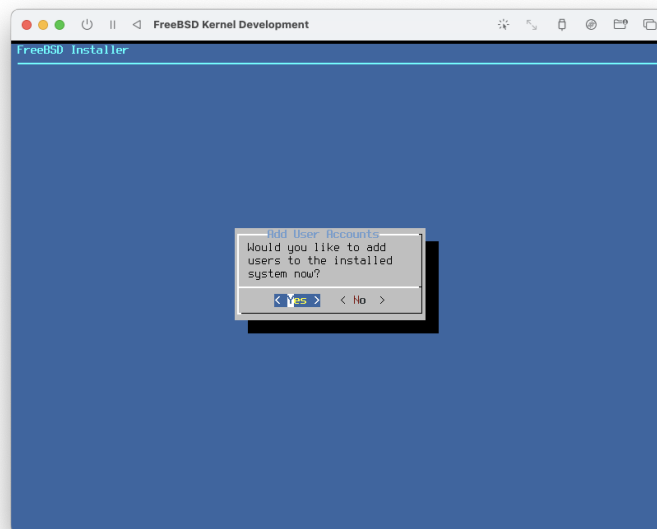


Figure 36: Add a user

```
FreeBSD Kernel Development
FreeBSD Installer
=====
Add Users

Username: alice
Full name: Alice the Test User
Uid (Leave empty for default):
Login group [alice]:
Login group is alice. Invite alice into other groups? [Y]: wheel
Login class [default]:
Shell (sh csh tcsh nologin) [sh]:
Home directory [/home/alice]:
Home directory permissions (Leave empty for default):
Use password-based authentication? [yes]:
Use an empty password? (yes/no) [no]:
Use a random password? (yes/no) [no]:
Enter password:
Enter password again:
Lock out the account after creation? [no]:
Username      : alice
Password      : *****
Full Name     : Alice the Test User
Uid           : 1001
Class         :
Groups        : alice wheel
Home          : /home/alice
Home Mode     :
Shell         : /bin/sh
Locked        : no
OK? (yes/no): yes
adduser: INFO: Successfully added (alice) to the user database.
Add another user? (yes/no): no
```

Figure 37: Add a user, example is Alice, use your own login

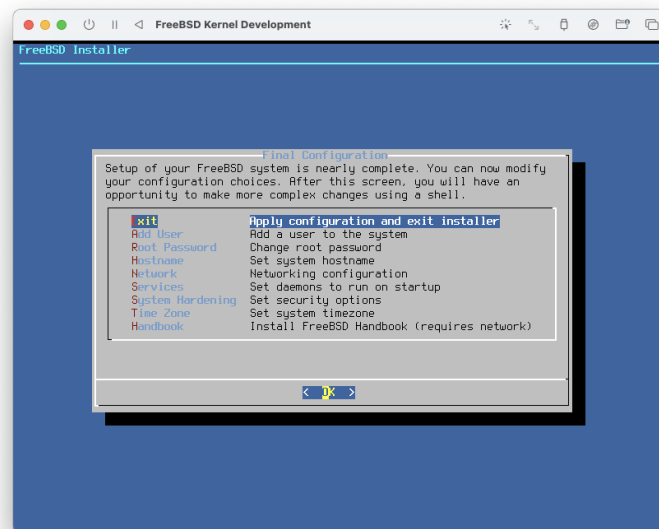


Figure 38: Nearly done, we can Exit

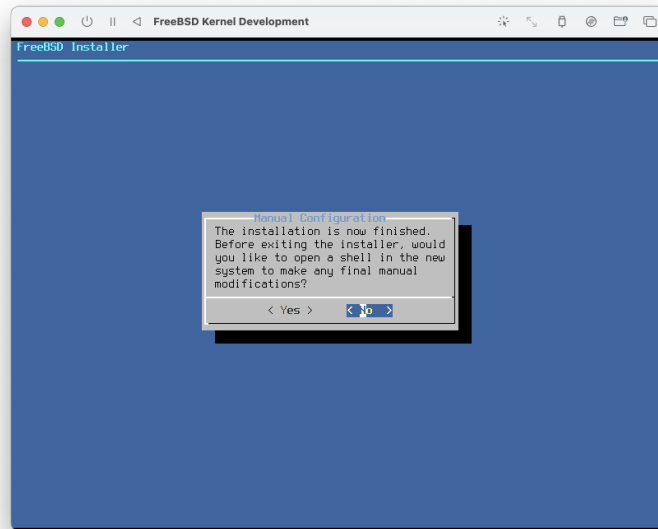


Figure 39: No need for manual modifications, select NO

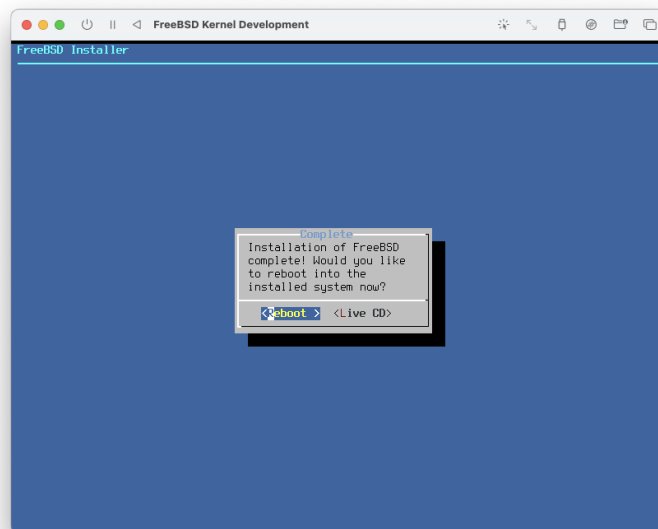


Figure 40: Reboot the system

```
FreeBSD Kernel Development

Starting ums0 mouse.
add host 127.0.0.1: gateway lo0 fib 0: route already in table
add host ::1: gateway lo0 fib 0: route already in table
add net fe80:: gateway ::1
add net ff02:: gateway ::1
add net ::ffff:0.0.0.0: gateway ::1
add net ::0.0.0.0: gateway ::1
Updating /var/run/os-release done.
Updating motd:
Clearing /tmp (X related).
Creating and/or trimming log files.
Starting syslogd.
Setting date via ntp.
 9 Nov 04:34:03 ntpdate[937]: step time server 128.199.243.248 offset -17999.906041 sec
No core dumps found.
Security policy loaded: MRC/ntpd (mac_ntpd)
Starting ntpd.
Mounting late filesystems:
Configuring vt: blanktime.
Generating RSA host key.
3072 SHA256:6bJezgY+mahULyakoFeH4oYBVJ0/FrkBLHdHk8XezEs root@kernel-dev (RSA)
Generating ECDSA host key.
256 SHA256:Td78u0m9r/JI1VgBJ+ZK1XFrGai+yLN20JtJCb11Ro root@kernel-dev (ECDSA)
Generating ED25519 host key.
256 SHA256:0gudt55NrPqm25uU4F0ubcDXKYX7PMKdbuIm+nD1SRw root@kernel-dev (ED25519)
Performing sanity check on sshd configuration.
Starting sshd.
Starting sendmail_submit.
Starting sendmail_msp_queue.
Starting cron.
Starting background file system checks in 60 seconds.

Thu Nov  9 04:34:04 EST 2023

FreeBSD/arm64 (kernel-dev) (ttyv0)

login: 
```

Figure 41: Normal boot to the login prompt.

```
FreeBSD Kernel Development

256 SHA256:0gudt55NrPqm25uU4F0ubcDXKYX7PMKdbuIm+nD1SRw root@kernel-dev (ED25519)
Performing sanity check on sshd configuration.
Starting sshd.
Starting sendmail_submit.
Starting sendmail_msp_queue.
Starting cron.
Starting background file system checks in 60 seconds.

Thu Nov  9 04:34:04 EST 2023

FreeBSD/arm64 (kernel-dev) (ttyv0)

login: root
Password:
Nov  9 04:34:11 kernel-dev login[1101]: ROOT LOGIN (root) ON ttyv0
FreeBSD 13.2-RELEASE releng/13.2-n254617-52secfda597 GENERIC

Welcome to FreeBSD!

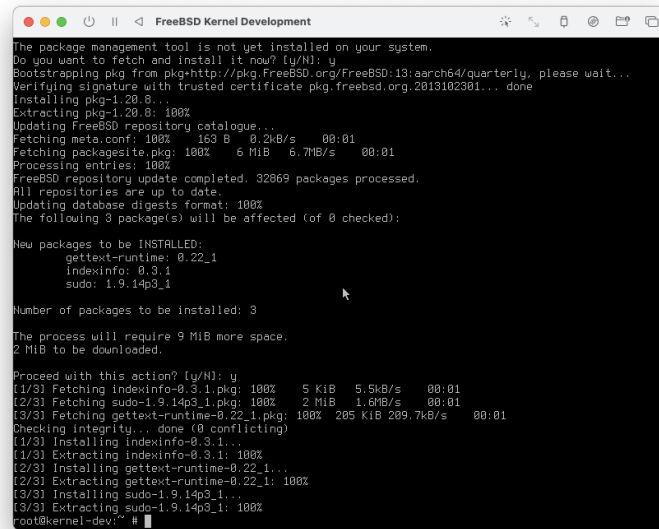
Release Notes, Errata: https://www.FreeBSD.org/releases/
Security Advisories:  https://www.FreeBSD.org/security/
FreeBSD Handbook:    https://www.FreeBSD.org/handbook/
FreeBSD FAQ:         https://www.FreeBSD.org/faq/
Questions List:      https://www.FreeBSD.org/lists/questions/
FreeBSD Forums:      https://forums.FreeBSD.org/

Documents installed with the system are in the /usr/local/share/doc/freebsd/
directory, or can be installed later with: pkg install en-freebsd-doc
For other languages, replace "en" with a language code like de or fr.

Show the version of FreeBSD installed: freebsd-version ; uname -a
Please include that output and any error messages when posting questions.
Introduction to manual pages: man man
FreeBSD directory layout:   man hier

To change this login announcement, see motd(5).
root@kernel-dev:~# 
```

Figure 42: Login to the system as the root user



```
FreeBSD Kernel Development

The package management tool is not yet installed on your system.
Do you want to fetch and install it now? [y/N]: y
Bootstrapping pkg from pkg+http://pkg.FreeBSD.org/FreeBSD:13:aarch64/quarterly, please wait...
Verifying signature with trusted certificate pkg.freebsd.org.2013102301... done
Installing pkg-1.20.8...
Extracting pkg-1.20.8: 100%
Updating FreeBSD repository catalogue...
Fetching meta.conf: 100% 163 B 0.2kB/s 00:01
Fetching packagesite.pkg: 100% 6 MiB 6.7MB/s 00:01
Processing entries: 100%
FreeBSD repository update completed. 32869 packages processed.
All repositories are up to date.
Updating database digests format: 100%
The following 3 package(s) will be affected (of 0 checked):

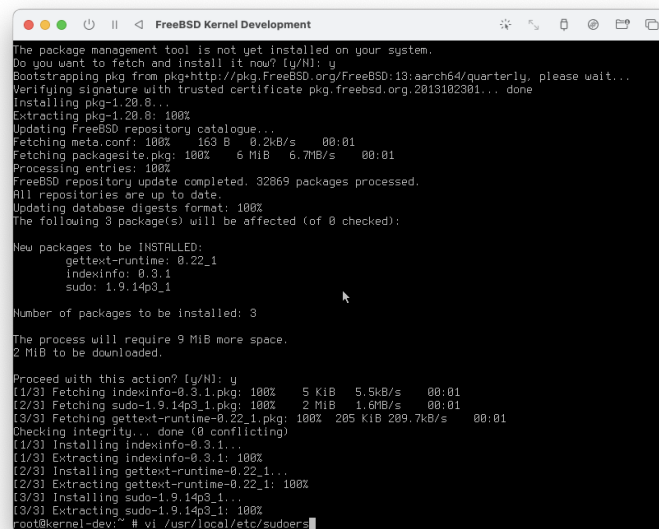
New packages to be INSTALLED:
    gettext-runtime: 0.22_1
    indexinfo: 0.3.1
    sudo: 1.9.14p3_1

Number of packages to be installed: 3

The process will require 9 MiB more space.
2 MiB to be downloaded.

Proceed with this action? [y/N]: y
[1/3] Fetching indexinfo-0.3.1.pkg: 100% 5 KiB 5.5kB/s 00:01
[2/3] Fetching sudo-1.9.14p3_1.pkg: 100% 2 MiB 1.6MB/s 00:01
[3/3] Fetching gettext-runtime-0.22.1.pkg: 100% 205 KiB 209.7kB/s 00:01
Checking integrity... done (0 conflicting)
[1/3] Installing indexinfo-0.3.1...
[1/3] Extracting indexinfo-0.3.1: 100%
[2/3] Installing gettext-runtime-0.22.1...
[2/3] Extracting gettext-runtime-0.22.1: 100%
[3/3] Installing sudo-1.9.14p3_1...
[3/3] Extracting sudo-1.9.14p3_1: 100%
root@kernel-dev:~ #
```

Figure 43: Use the pkg command to install sudo



```
FreeBSD Kernel Development

The package management tool is not yet installed on your system.
Do you want to fetch and install it now? [y/N]: y
Bootstrapping pkg from pkg+http://pkg.FreeBSD.org/FreeBSD:13:aarch64/quarterly, please wait...
Verifying signature with trusted certificate pkg.freebsd.org.2013102301... done
Installing pkg-1.20.8...
Extracting pkg-1.20.8: 100%
Updating FreeBSD repository catalogue...
Fetching meta.conf: 100% 163 B 0.2kB/s 00:01
Fetching packagesite.pkg: 100% 6 MiB 6.7MB/s 00:01
Processing entries: 100%
FreeBSD repository update completed. 32869 packages processed.
All repositories are up to date.
Updating database digests format: 100%
The following 3 package(s) will be affected (of 0 checked):

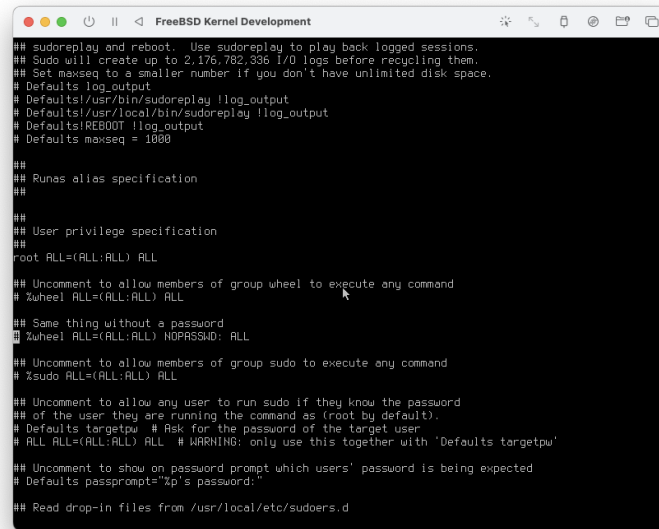
New packages to be INSTALLED:
    gettext-runtime: 0.22_1
    indexinfo: 0.3.1
    sudo: 1.9.14p3_1

Number of packages to be installed: 3

The process will require 9 MiB more space.
2 MiB to be downloaded.

Proceed with this action? [y/N]: y
[1/3] Fetching indexinfo-0.3.1.pkg: 100% 5 KiB 5.5kB/s 00:01
[2/3] Fetching sudo-1.9.14p3_1.pkg: 100% 2 MiB 1.6MB/s 00:01
[3/3] Fetching gettext-runtime-0.22.1.pkg: 100% 205 KiB 209.7kB/s 00:01
Checking integrity... done (0 conflicting)
[1/3] Installing indexinfo-0.3.1...
[1/3] Extracting indexinfo-0.3.1: 100%
[2/3] Installing gettext-runtime-0.22.1...
[2/3] Extracting gettext-runtime-0.22.1: 100%
[3/3] Installing sudo-1.9.14p3_1...
[3/3] Extracting sudo-1.9.14p3_1: 100%
root@kernel-dev:~ # vi /usr/local/etc/sudoers
```

Figure 44: Edit the sudoers file with vi



```
## sudoreplay and reboot. Use sudoreplay to play back logged sessions.
## Sudo will create up to 2,176,782,336 I/O logs before recycling them.
## Set maxseq to a smaller number if you don't have unlimited disk space.
# Defaults log_output
# Defaults!usr/bin/sudoreplay !log_output
# Defaults!usr/local/bin/sudoreplay !log_output
# Defaults!REBOOT !log_output
# Defaults maxseq = 1000

##
## Runas alias specification
##

##
## User privilege specification
##
root ALL=(ALL:ALL) ALL

## Uncomment to allow members of group wheel to execute any command
# %wheel ALL=(ALL:ALL) ALL

## Same thing without a password
# %wheel ALL=(ALL:ALL) NOPASSWD: ALL

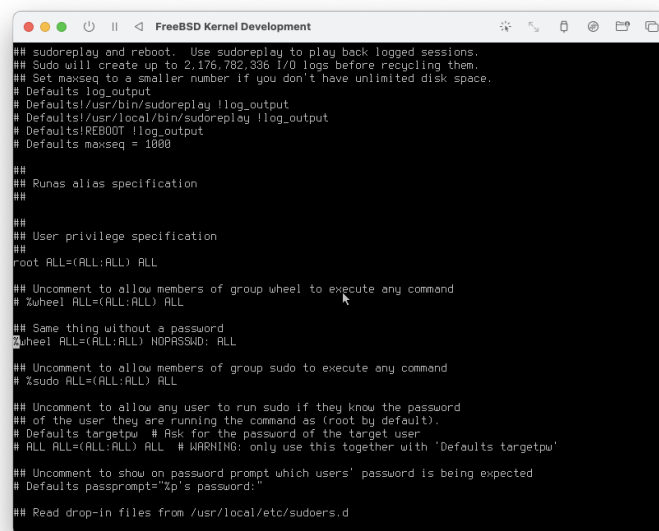
## Uncomment to allow members of group sudo to execute any command
# %sudo ALL=(ALL:ALL) ALL

## Uncomment to allow any user to run sudo if they know the password
## of the user they are running the command as (root by default).
# Defaults targetpw # Ask for the password of the target user
# ALL ALL=(ALL:ALL) ALL # WARNING: only use this together with 'Defaults targetpw'

## Uncomment to show on password prompt which users' password is being expected
# Defaults passprompt="%p's password:"

## Read drop-in files from /usr/local/etc/sudoers.d
```

Figure 45: Go to the line to uncomment where wheel users can use sudo without a password.



```
## sudoreplay and reboot. Use sudoreplay to play back logged sessions.
## Sudo will create up to 2,176,782,336 I/O logs before recycling them.
## Set maxseq to a smaller number if you don't have unlimited disk space.
# Defaults log_output
# Defaults!usr/bin/sudoreplay !log_output
# Defaults!usr/local/bin/sudoreplay !log_output
# Defaults!REBOOT !log_output
# Defaults maxseq = 1000

##
## Runas alias specification
##

##
## User privilege specification
##
root ALL=(ALL:ALL) ALL

## Uncomment to allow members of group wheel to execute any command
# %wheel ALL=(ALL:ALL) ALL

## Same thing without a password
# %wheel ALL=(ALL:ALL) NOPASSWD: ALL

## Uncomment to allow members of group sudo to execute any command
# %sudo ALL=(ALL:ALL) ALL

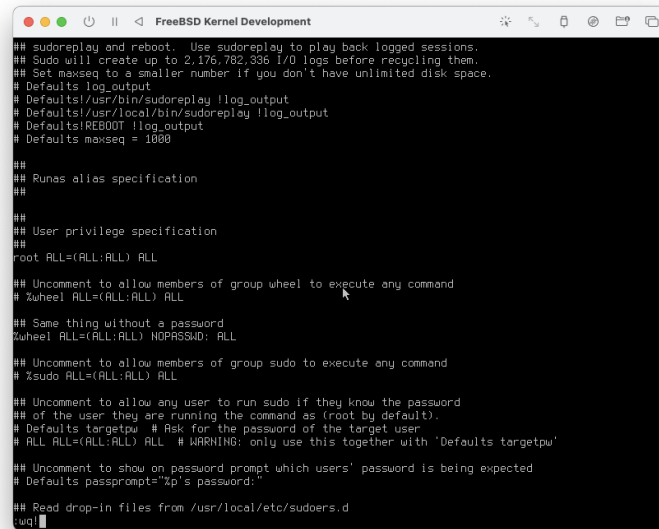
## Uncomment to allow any user to run sudo if they know the password
## of the user they are running the command as (root by default).
# Defaults targetpw # Ask for the password of the target user
# ALL ALL=(ALL:ALL) ALL # WARNING: only use this together with 'Defaults targetpw'

## Uncomment to show on password prompt which users' password is being expected
# Defaults passprompt="%p's password:"

## Read drop-in files from /usr/local/etc/sudoers.d
```

Figure 46: Remove the comment (#) character





```
## sudoreplay and reboot. Use sudoreplay to play back logged sessions.
## Sudo will create up to 2,176,782,336 I/O logs before recycling them.
## Set maxseq to a smaller number if you don't have unlimited disk space.
## Defaults log_output
## Defaults!usr/bin/sudoreplay !log_output
## Defaults!usr/local/bin/sudoreplay !log_output
## Defaults!REBOOT !log_output
## Defaults maxseq = 1000

##
## Runs alias specification
##

##
## User privilege specification
##
root ALL=(ALL:ALL) ALL

## Uncomment to allow members of group wheel to execute any command
# %wheel ALL=(ALL:ALL) ALL

## Same thing without a password
%wheel ALL=(ALL:ALL) NOPASSWD: ALL

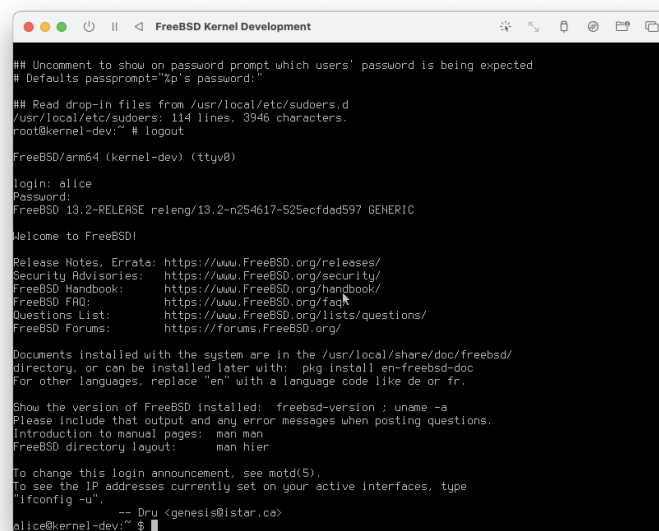
## Uncomment to allow members of group sudo to execute any command
# %sudo ALL=(ALL:ALL) ALL

## Uncomment to allow any user to run sudo if they know the password
## of the user they are running the command as (root by default).
# Defaults targetpw # Ask for the password of the target user
# ALL ALL=(ALL:ALL) ALL # WARNING: only use this together with 'Defaults targetpw'

## Uncomment to show on password prompt which users' password is being expected
# Defaults passprompt="%p's password:"

## Read drop-in files from /usr/local/etc/sudoers.d
:wp!
```

Figure 47: Save and quit vi with the :wq! command sequence



```
## Uncomment to show on password prompt which users' password is being expected
# Defaults passprompt="%p's password:"

## Read drop-in files from /usr/local/etc/sudoers.d
/usr/local/etc/sudoers: 114 lines, 3946 characters.
root@kernel-dev:~ # logout

FreeBSD/arm64 (kernel-dev) (ttyv0)

login: alice
Password:
FreeBSD 13.2-RELEASE releng/13.2-n254617-525ecfdad597 GENERIC

Welcome to FreeBSD!

Release Notes, Errata: https://www.FreeBSD.org/releases/
Security Advisories: https://www.FreeBSD.org/security/
FreeBSD Handbook: https://www.FreeBSD.org/handbook/
FreeBSD FAQ: https://www.FreeBSD.org/faq/
Questions List: https://www.FreeBSD.org/lists/questions/
FreeBSD Forums: https://forums.FreeBSD.org/

Documents installed with the system are in the /usr/local/share/doc/freebsd/
directory, or can be installed later with: pkg install en-freebsd-doc
For other languages, replace "en" with a language code like de or fr.

Show the version of FreeBSD installed: freebsd-version ; uname -a
Please include that output and any error messages when posting questions.
Introduction to manual pages: man man
FreeBSD directory layout: man hier

To change this login announcement, see motd(5).
To see the IP addresses currently set on your active interfaces, type
"ifconfig -u".
-- Dru <genesis@istar.ca>
alice@kernel-dev:~ $
```

Figure 48: Log into the system as a normal user

```
FreeBSD Kernel Development

## Uncomment to show on password prompt which users' password is being expected
# Defaults passprompt="%p's password:"

## Read drop-in files from /usr/local/etc/sudoers.d
/usr/local/etc/sudoers: 114 lines, 3946 characters.
root@kernel-dev:~ # logout

FreeBSD/arm64 (kernel-dev) (ttyv0)

login: alice
Password:
FreeBSD 13.2-RELEASE releng/13.2-n254617-525ecfdad597 GENERIC

Welcome to FreeBSD!

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FreeBSD FAQ: https://www.FreeBSD.org/faq
Questions List: https://www.FreeBSD.org/lists/questions/
FreeBSD Forums: https://forums.FreeBSD.org/

Documents installed with the system are in the /usr/local/share/doc/freebsd/
directory, or can be installed later with: pkg install en-freebsd-doc
For other languages, replace "en" with a language code like de or fr.

Show the version of FreeBSD installed: freebsd-version ; uname -a
Please include that output and any error messages when posting questions.
Introduction to manual pages: man man
FreeBSD directory layout: man hier

To change this login announcement, see motd(5).
To see the IP addresses currently set on your active interfaces, type
"ifconfig -u".
-- Dru <genesis@star.ca>
alice@kernel-dev:~ $ sudo shutdown -p now
```

Figure 49: Issue a shutdown with sudo as a normal user

```
FreeBSD Kernel Development

For other languages, replace "en" with a language code like de or fr.

Show the version of FreeBSD installed: freebsd-version ; uname -a
Please include that output and any error messages when posting questions.
Introduction to manual pages: man man
FreeBSD directory layout: man hier

To change this login announcement, see motd(5).
To see the IP addresses currently set on your active interfaces, type
"ifconfig -u".
-- Dru <genesis@star.ca>
alice@kernel-dev:~ $ sudo shutdown -p now
Shutdown NOW!
shutdown: [pid 1171]
alice@kernel-dev:~ $
*** FINAL System shutdown message from alice@kernel-dev ***

System going down IMMEDIATELY

Nov  9 04:38:02 kernel-dev shutdown[1171]: power-down by alice:
Stopping sshd.
Waiting for PID(s): 1050.
Stopping cron.
Waiting for PID(s): 1086.
Stopping ntpd.
Waiting for PID(s): 985.
Stopping devd.
Waiting for PID(s): 731.
Writing entropy file: .
Writing early boot entropy file: .
Terminated
Nov  9 04:38:03 kernel-dev syslogd: exiting on signal 15
Waiting (max 60 seconds) for system process 'vnlru' to stop... done
Waiting (max 60 seconds) for system process 'syncer' to stop...
Syncing disks, vnodes remaining... 0 0
```

Figure 50: System starts shutting down

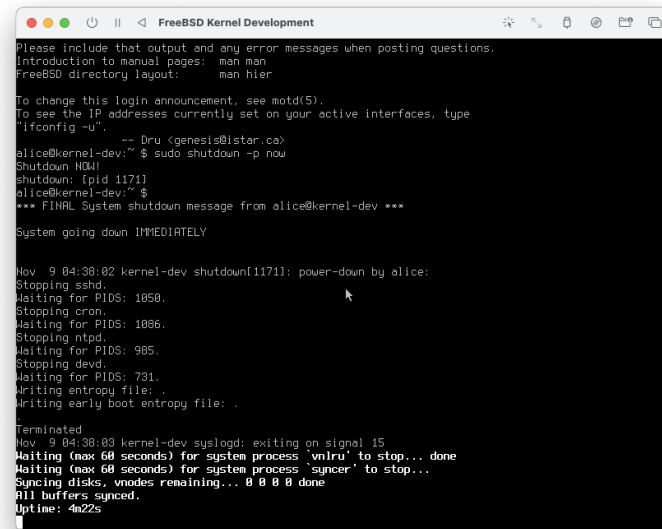


Figure 51: System shutdown complete, VM powers off

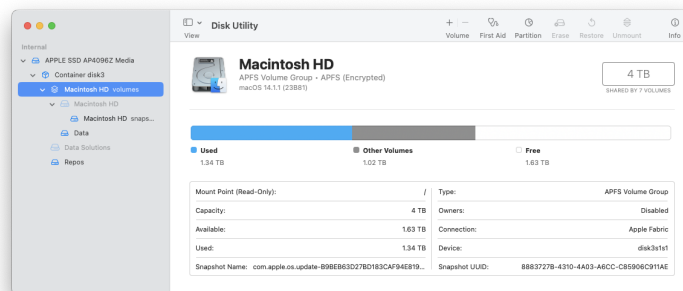


Figure 52: Open Disk Utility and Select the Macintosh Volume

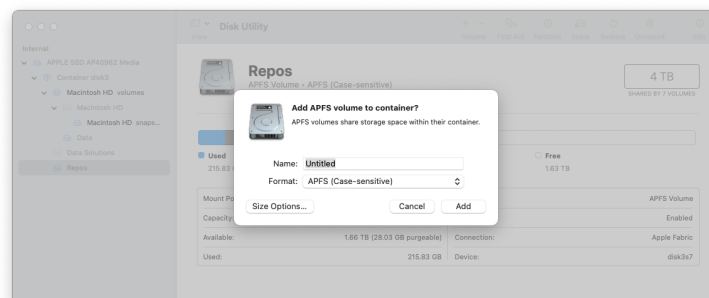


Figure 53: Add a new, case sensitive, volume

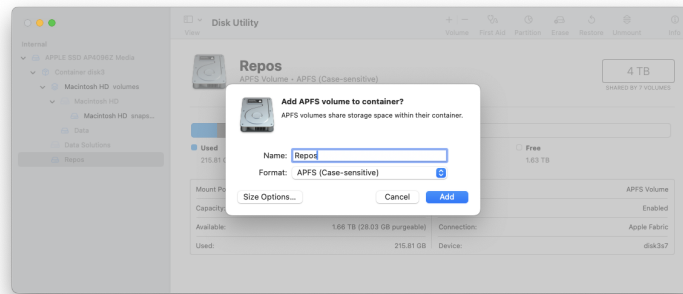


Figure 54: Give the volume a useful name

```
ifconfig
vtnet0: flags=1008843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST,LOWER_UP> metric 0 mtu 1500
options=80028<VLAN_MTU,JUMBO_MTU,LINKSTATE>
ether f6:d6:33:68:f7:0d
inet 192.168.68.2 netmask 0xffffffff broadcast 192.168.68.255
media: Ethernet autoselect (10Gbase-T <full-duplex>)
status: active
nd6 options=29<PERFORMNUD,IFDISABLED,AUTO_LINKLOCAL>
lo0: flags=1008049<UP,LOOPBACK,RUNNING,MULTICAST,LOWER_UP> metric 0 mtu 16384
options=680003<RXCSUM,TXCSUM,LINKSTATE,RXCSUM_IPV6,TXCSUM_IPV6>
inet 127.0.0.1 netmask 0xff000000
inet6 ::1 prefixlen 128
inet6 fe80::1%lo0 prefixlen 64 scopeid 0x2
groups: lo
nd6 options=21<PERFORMNUD,AUTO_LINKLOCAL>
```

Figure 55: Check the virtual machine's IP address

```
cat /etc/exports
/Volumes/Repos -alldirs -maproot=0:0
```

Figure 56: Setting up the exports

```
> sudo nfsd start
> sudo nfsd status
Password:
nfsd service is enabled
nfsd is running (pid 704, 8 threads)
```

Figure 57: Start NFS daemon

```

> sudo mount -v -t nfs 192.168.68.1:/Volumes/Repos/Yale/freebsd-src /usr/src
> df /usr/src
Filesystem                                1K-blocks      Used    Avail Capacity  Mounted on
192.168.68.1:/Volumes/Repos/Yale/freebsd-src 3902665360 2305897348 1596768012    59%    /usr/src
> ls /usr/src
ls /usr/src
CONTRIBUTING.md bin sbin
COPYRIGHT cddl secure
LOCKS contrib share
MAINTAINERS crypto stand
Makefile etc sys
Makefile.inc1 gnu targets
Makefile.libcompat include tests
Makefile.sys.inc kerberos5 tools
ObsoleteFiles.inc lib usr.bin
README.md libexec usr.sbin
RELNOTES release
UPDATING rescue

```

Figure 58: Mount the source volume

Finally we mount the Repos volume into the virtual machine.  
You can now build a new kernel.

```

> cd /usr/src
> sudo make -j 8 buildworld >& /tmp/bw.out

Check the output log in /tmp/bw.out

> sudo make -j 8 buildkernel >& /tmp/bk.out

Check the kernel build log in /tmp/bk.out

```

Figure 59: Build the world and the kernel