1)

```
# Create a Center of mass object for the MW, M31 and M33
# below is an example of using the class for MW
MW_COM = CenterOfMass("MW_000.txt", 2)


# below gives you an example of calling the class's functions
# MW:   store the position and velocity COM
MW_COM_p = MW_COM.COM_P(0.1)
print("Milky Way: ")
print(MW_COM_p)
MW_COM_v = MW_COM.COM_V(MW_COM_p[0], MW_COM_p[1], MW_COM_p[2])
print(MW_COM_v)

# now write your own code to answer questions
M31_COM = CenterOfMass("M31_000.txt", 2)
M33_COM = CenterOfMass("M33_000.txt", 2)

print("M31: ")
M31_COM_p = M31_COM.COM_P(0.1)
print(M31_COM_p)
M31_COM_v = M31_COM.COM_V(M31_COM_p[0], M31_COM_p[1], M31_COM_p[2])
print(M31_COM_v)

print("M33: ")
M33_COM_p = M33_COM.COM_P(0.1)
print(M33_COM_p)
M33_COM_v = M33_COM.COM_V(M33_COM_p[0], M33_COM_p[1], M33_COM_p[2])
print(M33_COM_v)
```

```
In [63]: runfile('C:/Users/krist/ASTR400B/Homework4/CenterOfMass.py', wdir='C:/Users/krist/
ASTR400B/Homework4')
Reloaded modules: ReadFile
Milky Way:
(<Quantity -2. kpc>, <Quantity 2.89 kpc>, <Quantity -1.45 kpc>)
[ 0.8   6.16 -1.35] km / s
M31:
(<Quantity -377.66 kpc>, <Quantity 611.43 kpc>, <Quantity -284.64 kpc>)
[ 72.85 -72.14  49.  ] km / s
M33:
(<Quantity -476.22 kpc>, <Quantity 491.44 kpc>, <Quantity -412.4 kpc>)
[ 44.42 101.78 142.23] km / s
```

2)

```
# Q2
x_sep = MW_COM_p[0] - M31_COM_p[0] # x separation between MW and M31
y_sep = MW_COM_p[1] - M31_COM_p[1] # y separation between MW and M31
z_sep = MW_COM_p[2] - M31_COM_p[2] # z separation between MW and M31
MW_M31Separation = np.round(np.sqrt(x_sep**2+y_sep**2+z_sep**2), 3) # magnitute of total separation

print(MW_M31Separation)

vx_diff = MW_COM_v[0] - M31_COM_v[0] # vx difference between MW and M31
vy_diff = MW_COM_v[1] - M31_COM_v[1] # vy difference between MW and M31
vz_diff = MW_COM_v[2] - M31_COM_v[2] # vz difference between MW and M31
MW_M31Velocity = np.round(np.sqrt(vx_diff**2+vy_diff**2+vz_diff**2), 3) # magnitute of total veloci

print(MW_M31Velocity)
```

```
In [67]: runfile('C:/Users/krist/ASTR400B/Homework4/CenterOfMass.py', wdir='C:/Users/krist/
ASTR400B/Homework4')
Reloaded modules: ReadFile
769.18 kpc
117.717 km / s
```

3)

```
# Q3
x2_sep = M33_COM_p[0] - M31_COM_p[0] # x separation between M33 and M31
y2_sep = M33_COM_p[1] - M31_COM_p[1] # y separation between M33 and M31
z2_sep = M33_COM_p[2] - M31_COM_p[2] # z separation between M33 and M31
M33_M31Separation = np.round(np.sqrt(x2_sep**2+y2_sep**2+z2_sep**2), 3) # magnitute of total separa

print(M33_M31Separation)

vx2_diff = M33_COM_v[0] - M31_COM_v[0] # vx difference between M33 and M31
vy2_diff = M33_COM_v[1] - M31_COM_v[1] # vy difference between M33 and M31
vz2_diff = M33_COM_v[2] - M31_COM_v[2] # vz difference between M33 and M31
M33_M31Velocity = np.round(np.sqrt(vx2_diff**2+vy2_diff**2+vz2_diff**2), 3) # magnitute of total ve

print(M33_M31Velocity)
```

```
In [68]: runfile('C:/Users/krist/ASTR400B/Homework4/CenterOfMass.py', wdir='C:/Users/krist/
ASTR400B/Homework4')
Reloaded modules: ReadFile
201.083 kpc
199.37 km / s
```

4)

The iterative process to calculate the center of mass is important because, as the Milky Way and M31 begin merging, the stars that are far from the center of one galaxy will be greatly affected by the gravity of the other galaxy, so using them to calculate a center of mass will make the result more inaccurate.