1. Option 1 would be best. A non-ideal multimeter would have a small resistance and therefore as the current passes through the ammeter in Option 2, it will decrease in magnitude. This means the voltage reading in the voltmeter will not be as accurate.

2. I chose 100 ohms, 440 ohms, 2700 ohms, and 27000 ohms for the load resistances. These values were small enough to allow for good reading in the multimeters, but still large enough to actually contribute to varying voltage and current readings. To further analyze this, we can look at Ohm's law where R=V/I. This relationship implies that large resistance would result in small currents, assuming the voltage from the source is constant. Very small resistances would result in very large current readings. I wanted something in between so that the readings were reasonable.

3. Voltmeters are set up in parallel to the source because they have infinite resistance (if ideal). Therefore, no current flows through the voltmeter. The resistance in the ammeter is relevant, yet small. The ammeter is not ideal, therefore it would have some resistance leading to uncertainty in measurements.

4. According to my plots, there is a steady relationship between V and I. However, at some point near I_{max}, the relationship no longer holds and V drops to zero. Similarly, V_∞ is only achieved when I_{max} is zero. Given the accuracy of the readings from the multimeters, I would say the output resistance is pretty small, which is good for accuracy. For example, when the power supply was set to 6.5V, the voltmeter read 6.498V, which is very close to the set value.

In [1]:
```python
#import libraries
import numpy as np
from scipy.optimize import curve_fit
import matplotlib.pyplot as plt
%matplotlib inline
```

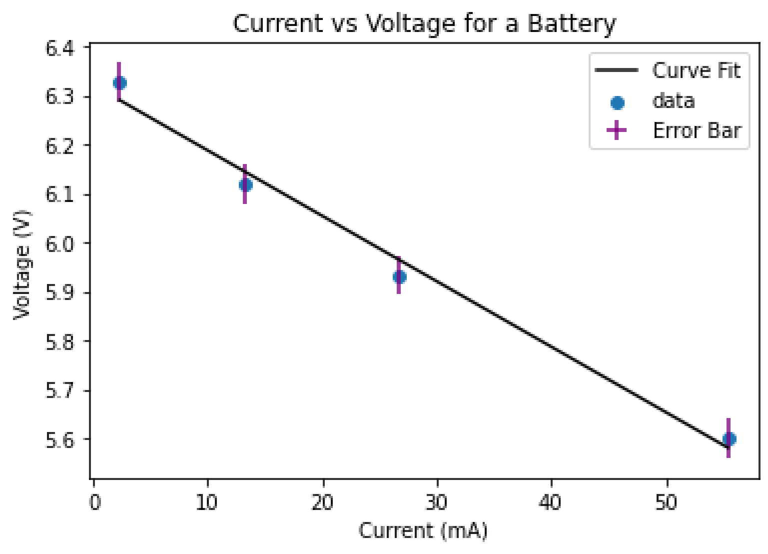
In [2]:
```python
#import battery data
Rl_b, V_b, I_b, Verr_b, Ierr_b = np.loadtxt("wiring_battery.csv", skiprows = 1, delimiter = ',', unpack = True)
```

In [3]:
```python
#define a linear model function
def f(x, m, b):
    return (m*x+b)
```

In [4]:
```python
# store p_opt and p_cov from the linear fit function
p_opt_b, p_cov_b = curve_fit(f, I_b, V_b, p0 = (-1,-1), sigma = Verr_b, absolute_sigma = True)
#store the optimal slope
m_opt_b = p_opt_b[0]
#store the optimal b value
b_opt_b = p_opt_b[1]
```

In [5]:
```python
#plot V vs I
plt.scatter(I_b, V_b, label = "data")

#plot errorbars
plt.errorbar(I_b, V_b, xerr = Ierr_b, yerr = Verr_b, ls = "none", color = 'purple', label = "Error Bar")

#plot the curve fit
plt.plot(I_b, f(I_b,m_opt_b, b_opt_b), color = "black", label = "Curve Fit")

#set title and axis
plt.title("Current vs Voltage for a Battery")
plt.xlabel("Current (mA)")
plt.ylabel("Voltage (V)")

#show legend
plt.legend(loc = "upper right")
```

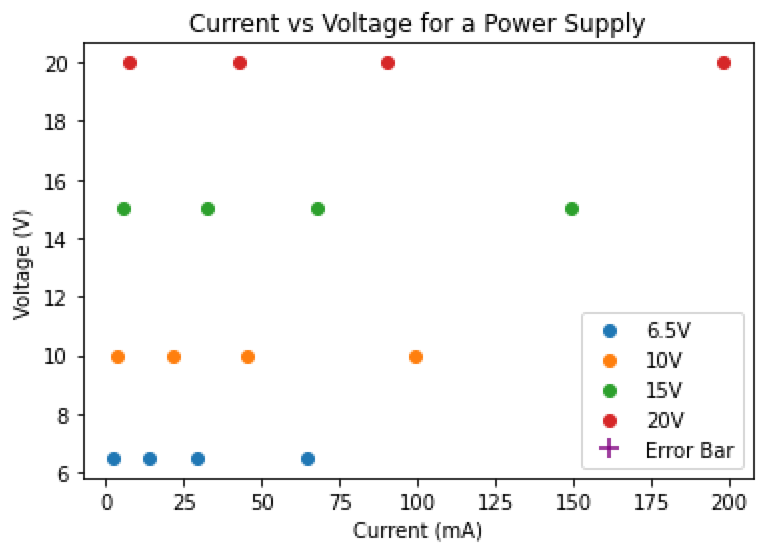
Out[5]:
```
<matplotlib.legend.Legend at 0x21b0c88e8b0>
```



In [6]:
```python
#import the data supply data for 6.5V, 10V, 15V and 20V power supply

Rl_ps, V_ps, I_ps, Verr_ps, Ierr_ps = np.loadtxt("wiring_ps.csv", skiprows = 1, delimiter = ',', unpack = True)

Rl_ps10, V_ps10, I_ps10, Verr_ps10, Ierr_ps10 = np.loadtxt("wiring_ps10.csv", skiprows = 1, delimiter = ',', unpack = True)

Rl_ps15, V_ps15, I_ps15, Verr_ps15, Ierr_ps15 = np.loadtxt("wiring_ps15.csv", skiprows = 1, delimiter = ',', unpack = True)

Rl_ps20, V_ps20, I_ps20, Verr_ps20, Ierr_ps20 = np.loadtxt("wiring_ps20.csv", skiprows = 1, delimiter = ',', unpack = True)
```

In [7]:
```python
#plot power supply data
plt.scatter(I_ps, V_ps, label = "6.5V")
plt.scatter(I_ps10, V_ps10, label = "10V")
plt.scatter(I_ps15, V_ps15, label = "15V")
plt.scatter(I_ps20, V_ps20, label = "20V")

#plot error bars
plt.errorbar(I_ps, V_ps, xerr = Ierr_ps, yerr = Verr_ps, ls = "none", color = 'purple', label = "Error Bar")
plt.errorbar(I_ps10, V_ps10, xerr = Ierr_ps10, yerr = Verr_ps10, ls = "none", color = 'purple')
plt.errorbar(I_ps15, V_ps15, xerr = Ierr_ps15, yerr = Verr_ps15, ls = "none", color = 'purple')
plt.errorbar(I_ps20, V_ps20, xerr = Ierr_ps20, yerr = Verr_ps20, ls = "none", color = 'purple')

#set title and axis
plt.title("Current vs Voltage for a Power Supply")
plt.xlabel("Current (mA)")
plt.ylabel("Voltage (V)")

#show legend
plt.legend(loc = "lower right")
```

Out[7]:
```
<matplotlib.legend.Legend at 0x21b0c963430>
```



In [8]:
```python
#print resistances for battery and power supply
print("Rb =", -1*m_opt_b)
print("Rps =", 0)
```

```
Rb = 0.013357856011585161
Rps = 0
```

In [9]:
```python
#define reduced chi squared function
def chi(N, n, yi, xi, sigma_i, m, b):
    v = N-n
    ye = f(xi, m, b)
    chi = np.sum(((yi-ye)**2)/(sigma_i**2))
    chi = chi/v
    return chi
```

In [10]:
```python
#battery reduced chi squared
chib = chi(4, 2, V_b, I_b, Verr_b, m_opt_b, b_opt_b)
chib
```

Out[10]:
```
1.040184790897989
```

In [11]:
```python
#6.5V power supply reduced chi squared
chi_ps = chi(4, 2, V_ps, I_ps, Verr_ps, 0, V_ps)
chi_ps
```

Out[11]:
```
0.0
```

In [12]:
```python
#10V power supply reduced chi squared
chi_ps10 = chi(4, 2, V_ps10, I_ps10, Verr_ps10, 0, V_ps10)
chi_ps10
```

Out[12]:
```
0.0
```

In [13]:
```python
#15V power supply reduced chi squared
chi_ps15 = chi(4, 2, V_ps15, I_ps15, Verr_ps15, 0, V_ps15)
chi_ps15
```

Out[13]:
```
0.0
```

In [14]:
```python
#20V power supply reduced chi squared
chi_ps20 = chi(4, 2, V_ps20, I_ps20, Verr_ps20, 0, V_ps20)
chi_ps20
```

Out[14]:
```
0.0
```

In [ ]: