Solutions to Problem Set 1

1. The bar graph meter consists of a column of 50 light emitting diodes (LEDs) that span the range of 0-10 V. At 0 V no LEDs are lit, and at 10 V the entire column of LEDs are lit. At voltages in between the LEDs between 0 and a displacement proportional to the voltage are lit. The length of the column of LEDs is 250 mm. We can determine the sensitivity of the meter in two ways: (1) the number of lit LEDs per unit voltage or (2) the length of the lit column of LEDs per unit voltage. Thus, we can determine the sensitivity of the meter by either dividing the number of LEDs by the full-scale voltage or the length of the LED column by the full-scale voltage.

$$\text{Sensitivity} = \frac{50\,\text{LEDs}}{10\text{ V}} = 5\text{ LEDs/Volt} \quad \text{or} \quad \text{Sensitivity} = \frac{250\,\text{mm}}{10\text{ V}} = 25\text{ mm/Volt}$$

The precision of the instrument will be determined by the smallest voltage difference that can be measured with this device. Since the smallest voltage difference will be measured when the LED at the top of the column changes state from off to lit or from lit to off, a voltage change of

$$\Delta V = \frac{10\text{ V}}{50} = 0.2\text{ V}$$

will be required for this state change. The accuracy of the meter is listed as within one percent of the reading on the specification sheet, so the precision will be 0.2 V ± 0.1 V for a full-scale reading of 10 V. If we take the worst-case, then the precision is 0.3 V.

The resolution of the instrument is the smallest change in voltage that can be detected which is again determined by the change of state of an LED. Thus, in this case the precision and the resolution will be the same. Very often in a situation such as this we will not indicate the error associated with determining the resolution as we did in the case of determining the precision.

As the data sheet points out, this type of instrument is used as a quasi-analog meter that is very large and can be read at a distance. It's precision and resolution is approximately the same as a commercial analog meter with a pointer, since these usually have a resolution of 2 percent of the full-scale reading. Analog meters are useful for getting an idea of the size of the quantity being measured when actual numbers are not as important. They also are valuable when the variable being measured is rapidly varying over time, and a digital meter would have the numbers changing so quickly that it would be difficult to read. A medical application for such a meter (it is a little large for most medical applications) could be to display quantities such as the heart rate or blood pressure that vary over time so that a clinician could get a rough idea of their value by glancing at the meter. A digital readout would be necessary to get the actual value of the heart rate or blood pressure. Often this is difficult since the heart rate and blood pressure can vary with each heart beat, and the digital meter might be showing a different number with each heart beat thereby making it difficult for the clinician to quickly and easily determine average values. The analog meter, on the other hand, presents a column of light that is proportional in length to the quantity being measured and can be quickly read.

3. We must compare the signal and the noise at the same place in the amplifier, either the input or the output. The signal at the amplifier's output will be

$$V_o = 90\ \mu\text{V x } 10^3 = 90\ \text{mV}$$

So the signal to noise ratio is

$$S:N = \frac{90\ \text{mV}}{3\ \text{mV}} = 30$$

It is the usual convention to present this in decibels. Because this is a voltage ratio, this will be

$$S:N = 20\log_{10}(30) = 29.5\ \text{dB}$$